# *Computer-Supported Cooperative Work in Tele Home Care - Architecture Design, Implementation and Evaluation*

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*This Master's Thesis is carried out as a part of the education at the University of Agder and is therefore approved as a part of this education. However, this does not imply that the University answers for the methods that are used or the conclusions that are drawn.*

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**Abstract**

With the development of healthcare service and computer networks, the healthcare providers are focusing on how to implant new technologies into health sections. These instant messaging techniques can lead healthcare service more efficienct than before. It is necessary to design and construct a cooperative work platform for patients and healthcare providers. They are able to communicate with each other, share information or documents and access into health records. This project will concentrate on the system design, implementation and evaluation to achieve a better performance platform. The underlying data repository will encompass distributed system aspects and data warehousing approach to promote the functions of this healthcare system. This platform will be deployed to the tele home care service and in-depth study on the healthcare services. Some of the innovations will be included in system design. The target of this project is to design the architecture of collaborative workspace for healthcare personnel and implement a prototype with useful functions. The evaluation will be conducted to validate the efficiency of proposed distributed database for patient records. In addition, it will be more flexible and less data redundant. Meanwhile, a demo system will be deployed in order to show and define the implemented functions.

**Keywords**: computer-supported cooperative work, distributed system, healthcare, tele home care

# Preface

This report is the result of the MSc ICT Master Thesis, IKT509, at the Faculty of Engineering and Science, University of Agder in Grimstad, Norway. The research started at 5 Jan, 2012 and ended on 31 May, 2012. This project appertains to eHealth domain, and the main subject is the eHealth system design that implements a system prototype that performs a role of information platform in hospitals or clinics. The report subject is Computer-supported Cooperative Work in Tele Home Care – Architecture Design, Implementation and Evaluation. My supervisors are Rune Fensli and Dafferianto Trinugroho. Professor Fensli has medical treatment system background and knowledge in eHealth domain. Dafferianto is a PhD student in faculty Information and Communication Technology, and concentrate in Health Informatics research. The theoretical sources used in this project are from IEEE guideline and professional papers. With the development of eHealth system, it will enhance the healthcare service quality and reduce cost for caring patients. In summary, the eHealth information software design and research will promote healthcare services. This project is able to largely generate the contribution for healthcare services development in the future.

Jinlun Liu

Grimstad, May 2012

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# List of Abbreviations

| | |
|---|---|
| CSCW | Computer-Supported Cooperative Work |
| EHR | Electronic Health Records |
| NHN | National Health Network |
| ICT | Information and Communication Technology |
| PC | Personal Computer |
| B/S | Browser/Server |
| IT | Information Technology |
| UML | Unified Modelling Language |
| CPU | Central Processing Unit |
| HL7 | Health Level 7 |
| FMS | Flash Media Server |
| RTMP | Real Time Messaging Protocol |
| FLV | Flash Video |
| OEPR | Oral Electronic Patient Records |
| EJB | Enterprise JavaBean |
| CORBA | Common Object Request Broker Architecture |
| J2EE | Java Platform, Enterprise Edition |
| PaPeHR | Personal electronic Health Record |
| ECG | Electrocardiography |
| CDA | Clinical Document Architecture |
| HIS | Health Information System |
| RIM | Reference Information Model |
| HDF | HL7 Development Framework |
| TCP/IP | Transmission Control Protocol/Internet Protocol |
| NHIN | Nationwide Health Information Network |
| CDC | Centre for Disease Control |
| SOA | Service-Oriented Architecture |
| BAN | Body Area Network |
| GPRS | General Packet Radio Service |
| RIA | Rich Internet Application |
| RPC | Remote Procedure Calls |
| AMF | Action Message Format |
| IDE | Integrated Development Environment |
| GUI | Graphic User Interface |
| EER | Enhanced Entity-Relationship |
| ER | Entity-Relationship |
| LAN | Local Area Network |

# Chapter 1

# Introduction

With the progress of medical techniques and development of network, people are able to have a better and more prompt healthcare environment compared with before. It is necessary to provide a platform for patients and healthcare providers to communicate with each other, share information or documents, and access into Electronic Health Records (EHR). Nowadays, many researchers have been concerned on a system conception named Computer-Supported Cooperative Work (CSCW) which can be used for supporting healthcare services. CSCW is a scientific field that motivates and validates group work design. It is an identifiable research field focusing on understanding characteristics of interdependent group work with the objective of designing adequate computer-based technology to support such cooperative work. In other hand, home care and community based health services are becoming an increasingly important part of the healthcare services continuum.

There are many reasons for the situations described above. For instance, patients are leaving hospital sooner and need some additional care at home while they recover. Treating patients at home is less expensive than treating them in the hospital. Many patients prefer to stay in their homes as long as possible before moving onto a higher level of healthcare service, e.g. nursing home, hospice. Tele home care is an emerging field that will benefit home care providers and their patients. It is defined as, the use of communications and information technology to deliver health services and exchange health information to and from the home (or community) when distance separates the participants. Tele home care does not replace in person home care visits, but is used primarily to augment current services.

## 1.1 Thesis Headline Definition

The goal of this research is to enhance the quality of service in tele home care domain by using CSCW. A web-based collaborative workspace for healthcare system will be designed and implemented in this project. It is enabling real-time and offline remote collaboration between different actors within the healthcare sector. The underlying data repository will encompass distributed system aspects and will use data warehousing approach to promote flexibility and reduce data redundancy in the system. Performance evaluation and verification on some use cases will be conducted. In addition, a demo of implementation will be deployed in order to show defined functions.

With the CSCW architecture design and evaluation, it is able to define and choose a better system structure. According to this research, it is available to reflect on how previous CSCW research inform the designs and improve it with other advanced technologies at opportune time. Besides, healthcare providers are able to choose different CSCW structure depends on the distinct actual situations.

Patients are capable of obtaining much higher and more efficiency level healthcare services from providers according to this architecture.

## 1.2 Background and Motivation

Rapid advances in computer and network technologies made healthcare collaborative system ubiquitous. Especially the appearance of the concept in CSCW enlarges the development space of healthcare techniques. CSCW research has been interested in healthcare including online diagnosis, EHR examination and clinical collaborative works. The term of CSCW was first coined by Irene Greif and Paul M. Cashman in 1984, at a workshop attended by individuals interested in using technology to support people in their work [1]. Although many prior CSCW researches and technologies have focused on clinical and hospital applications, it is possible to have more distinct directions and spaces of evolvement. For instance, the network topology optimization based on National Health Network (NHN), local clinical system access of EHR, high security level document sharing via collaborative system and etc. Hence, it is an opportune time to reflect on how previous CSCW research can inform the design of current technologies that support collaboration in healthcare. Meanwhile, it is possible to define an agenda for research into how information techniques can support new forms of collaboration, such as clinician-patient collaboration [2].

Most developed countries are facing important overall problems regarding healthcare services. These challenges turn tele home care into one of the fastest growing domain of healthcare provision. The tele home care is defined as a two-way interactive audio-visual communication between healthcare providers and patient in his/her place of residence [3]. With more advanced Information and Communication Technology (ICT), tele home care can add more roles into information channels, such as home nurse and family members. That will cause the communication channels into three or more. A noted challenge is to use CSCW incorporate with tele home care. This would allow healthcare organizations to better handle the services with more diversified.

The main motivation is that if healthcare systems are designed with collaborative perspective in tele home care, there is a requirement of system flexibility and well organized data transmitting and storage. Based on this discussion, the architecture design will focus on network topology, server setting, Personal Computer (PC) healthcare system implementation and database application. However, scientific design of the effective in tele home care solutions is still rare. With the growth of user requirements and services complexity, increasingly demands for related research and practical implementation become more significant than before. Performance evaluation and verification on some use cases are necessarily evolved. With corporation of CSCW and tele home care, the service work will be more efficiency and quality in clinic or hospital can be significantly improved.

## 1.3 Problem Statement

The health informatics deals with the resources, devices and methods required to optimize the acquisition, storage, retrieval and use of information in healthcare. Health informatics tools include not only computers but also clinical guidelines, formal medical terminologies, and information communication systems. In essence, health informatics is targeted at information processing of large sets of health data [4]. As such, health informatics is deeply rooted in tele home care. Therefore, some of new problems will be aroused in health informatics realm.

- Data storage growth

As the population grows, the amounts of digital data usage also will be increased. Business everywhere is facing the day to day of dealing with volumes of digital assets. From small business to large enterprise, the growth of Internet has resulted the high requirement and challenge to manage, store and archive digital data. The same situation is in EHR and clinical related data. There is no surprise that human beings will face to the high pressure storage of all information. Analysts for the computer storage industry estimate that the growth of storage used to sustain business process is 75% to 100% per year. At the same time, the amount of budget money available to retain the needed skills for managing the installations and for improving the data process techniques. It means that people who build the maintain and process the data in large ware housing environments must individually learn how to manage 50 to 100 times more data over next seven years than currently manage [5]. Therefore, it is essential to dig out a method to manage those data and information. As a part of the digital data, EHR storage and processing becomes a problem that we have to deal with.

- Server processing pressure

Web and network applications play an important role in our daily life. The server processing cost and pressure problem is another issue that we need to solve. The rapid development of global information, various types of B/S (Browser/Server) system is unceasingly becoming the first choice of healthcare providers. Meanwhile, along with the expansion of quality demands, the applications seek for higher performance. Servers need to deal with patients or healthcare providers request for data processing every day. With the enlargement of client traffic, the server may always confront with the risk of crash down. These performance issues reflect on memory, network interface and processor of the server. Following the problems illustrated above, the architecture design process will consider about this issue deeply and give a better scenario.

- Better system modelling

As we know, a system design is a procedure of problem solving and planning for a system solution. During the design processes, designer should consider the modelling of the system, user requirements research, compatibility, scalability, reliability and etc [6]. We may already have existing system based on CSCW, but only focused on one or two aspects of usage. The target of this project is to establish a platform with more functions and higher integration.

System modelling is the interdisciplinary study of the use of models to conceptualize and construct systems in Information Technology (IT) development. A common type of systems modelling is function modelling, with specific techniques such as Unified Modelling Language (UML). It aimed for a precise and abstract way of specifying the informational and time characteristics of a data processing problem, and wanted to create a notation that should enable the analyst to organize the problem around any piece of hardware. Their efforts was not so much focussed on independent systems analysis, but on creating abstract specification and invariant basis for designing different alternative implementations using different hardware components.

- System analysis accuracy

System analysis in the field of electrical engineering characterizes electrical systems and their properties. It can be used to represent almost anything from population growth to audio speakers, electrical engineers often use it because of its direct relevance to many areas of their discipline, most notably signal processing and communication systems. With the organization of system functions, it is possible to analyze each function and how it communicates with the users. The development of a computer-based information system includes a systems analysis phase which produces or enhances the data model which itself is a precursor to creating or enhancing a database. There are a number of different approaches to system analysis. However, what is the health informatics system want is a more accuracy system analysis. In order to that, it will increase the efficiency and flexibility of the system.

- Friendly system implementation

After system modelling and system analysis, another significant issue is the system implementation. In computer science, an implementation is realization of a technical specification or an algorithm as a program, software component, or other computer system through programming and deployment. Many implementations may exist for a given specification or standard. For example, web browsers contain implementations of World Wide Web consortium-recommended specifications, and software development tools contain implementations of programming languages. Certainly, for implementing this system, it needs software development tools, programming languages and development environment. Hospitals and clinics need more friendly system to take care of patients. The conception of friendly includes user interface, user satisfaction, powerful functions and etc. What we are looking for is a system with high performance evaluation and verification on use cases.

In general, the problems statements described above include different aspects in software, network and infrastructure. The aim of this project is to establish a platform for real-time communication between healthcare providers and patients. The channels it provides can be a conference call, a message and an email. It is able to frame a platform for users to share documents easily and conveniently. The system should with a friendly interface for healthcare providers to access to an EHR. Cooperating with CSCW, tele home care services should avoid or reduce the high-capacity data storage and heavy server processing pressure in the future.

## 1.4 Contribution to Knowledge

The project will develop a CSCW based platform for tele home care. The CSCW will integrate the web-based collaborative workspace and to be a comprehensive healthcare system. The workspace is enabling real-time and offline remote collaboration between different actors in healthcare sector. The system architecture is a patient centric infrastructure which designed for patient information management at the point of care service and enhanced collaborative working of multi-disciplinary healthcare providers. Focusing on the point of care aspects, it is not difficult to find out some of the major issues identified by different surveys, exploratory and future work studies. The healthcare service platform needs to solve the problems such as lack of appropriate and timely information, lack of proper communication channels, and in consistent communication among healthcare providers [7]. To summarize from the process and problems of the project need to solved, we can list the contribution that this project can lead to. The following content will illustrate the contribution to knowledge of this project.

- A prototype of healthcare service platform

One of the targets of this project is to implement a prototype of platform in healthcare service domain which combines the concepts of CSCW and tele home care. The entire process of system development will strictly follow the software development procedure. After system testing, the prototype will be deployed onto the real server. The main contribution is the prototype of system, which can be a reference or expanded in future work.

- Advanced performance of infrastructures

Repository for data storage and server performance is the focus of this project. Distributed system and data warehousing approach are used to promote flexibility and reduce data redundancy. With the growth of EHR data, the data searching time cost increased as well. It is possible to experiment to explore the growth rate of searching time by using data central or distribute database. It will be advanced if all the machines can provide more efficiency and fast services to patients and healthcare providers.

- Selection of database centralized or distributed

A centralized database is a database located and maintained in one location, opposite to distributed database. One main advantage in data central structure is that all data is located in one place. It's simple and management readily. The disadvantage is that data bottleneck may occur. A distributed database in which storage devices are not all attached to a common Central Processing Unit (CPU). It may stored in different computers located in the same physical location, or may be dispersed over a network of interconnected computers. The problem of the choice of database centralized or distributed in storing EHR will be solve in this project. A specific curve diagram will be produced by experiment base on the platform described above. The horizontal axis is the information storage, and vertical axis is the searching time cost. A cross point produced by different curves which is the cut-off point in choosing centralized or distributed database for EHR.

## 1.5 Research Approach

The methodology that used in this study is mainly based on architecture design, implementation and evaluation. CSCW as a research discipline was formed lack of peer-to-peer collaboration and coordination. Therefore, from CSCW perspective work, it needs more complete collaborative works based on medical informatics. With the main argument described before, the following content shows the research approach in this project.

The architecture network topology is based on NHN. Besides, it will follow closely with the requirement of high security mechanism, network feasibility and flexibility. The innovation points in the design are imported from the conception of distributed database and server. Then, a web-based healthcare collaborative workspace will be implemented in this project. This application provides video communication, document sharing, message contacting services to healthcare providers and patients. In addition, there will be an EHR searching engine function embedded into the workspace. Healthcare providers are able to use the engine to check patient previous records. A virtual database used for store EHR is devised by following Health Level 7 (HL7) standard documentation. HL7 is an all-volunteer, non-profit organization involved in development of international informatics interoperability standards. It supports clinical practise and management, delivery, and the evaluation of health services. Furthermore, the evaluation experiment will base on this platform. The aim is to explore the different curves on data searching time cost with information storage increasing between distributed database and data centralized.

The implementation process follows the standard of waterfall software development procedure. Java programming language technology is used to create both client and server side application. While the server-side implementation is widely accepted, but the browser-based client-side applications have been less successful because the file sizes are large and the installation is cumbersome. Flex is a great solution for Java developers. In this project, the main development platform is MyEclipse, with flex builder plug-in installed. The flex builder is responsible for MXML files, which are the code for system interface. MyEclipse is the container of Java code. After compiling these two types of files, we can obtain SWF and class files. On the other hand, it uses Tomcat as develop server and Flash Media Server (FMS) for media data streaming serve in server part. Flash Media Server is a hub. Flash based applications connect to the hub using Real Time Messaging Protocol (RTMP). The RTMP is initially a propriety protocol developed by Macromedia for streaming audio, video and data over the Internet, between flash player and server. The server can send and receive data to and from the connected users with live web Flash Video (FLV) player installed or the video published. The database will use MySQL. It is worth to notice that, the EHR data in database will not use real data but creating digital string. Evaluation between different architects will experiment on different machines.

## 1.6 Structure of Thesis

This chapter gives an introduction, motivation and list out the problems. Then it illustrates the contribution to knowledge and research approach on performance evaluation and verification. Besides, relative technologies used in this workspace and curve exploring are included in the text. The rest of chapters in this dissertation are as following.

Chapter 2 describes the state of the art about the technologies and analysis of CSCW cooperating with healthcare services. It involves medical system based on CSCW, web-based diagnosis support in healthcare and CSCW in telemedicine. Data warehousing and distribute system technologies are included. Furthermore, the chapter also provides the relative documents on standards and protocols.

Chapter 3 demonstrates the architecture design which we supposed to combine CSCW with tele home care sector. It contains system network topology diagram, distribute database and server conception and database mapping mechanism.

Chapter 4 discusses the healthcare collaborative workspace implementation processes, tools and results. The virtual EHR database construction, principle and code of EHR searching engine are also presented in this chapter.

Chapter 5 shows the performance evaluation between data centralized and data distributed structure.

The experiment will be deployed on real machine because of the simulation in real environment. The finally curve is the result of this experiment. And it is able to coordinate the cross point on the curve diagram.

Chapter 6 gives a discussion on selection of data central and distributed structure. It will present the advantage and disadvantage in each scenario. Furthermore, this discussion chapter will illustrate not only about the currently usage but also about the future work based on this project and prototype.

Chapter 7 which is the last section will present the conclusion of this Master thesis work and suggest the future work. After the whole work, it is possible to give a future prospect about CSCW combine with tele home care. There is no doubt that, the work will enhance the quality of electronic healthcare services in the future.

# Chapter 2

# State of the Art

Many investigations have studied the CSCW based healthcare services, including remote medical services, medical record management, patient-to-healthcare providers' tele-conference and etc. E.J Gomez designed a telemedicine system for medical imaging diagnosis based on CSCW distributed architecture [8]. Kurt Sandkuhl and Anders Carstensen presented web-based coordination support in care planning [9]. It starts from a case of study in the area of healthcare, and introduces a web-based coordination support application. Beyond the archive: thinking CSCW into EHRs for home care published by three scholars from University of Aarhus of Denmark [10]. Computer supported cooperative work for telemedicine presented by Wenhua Huang et al. [11]. Most of the studies considered combining CSCW with healthcare services. This section will describe the state of the art specific for the CSCW in healthcare service domain and other relative documentation.

## 2.1 Medical System Based on CSCW

Telemedicine is changing the classical form of health care delivery, by providing efficient solutions to an increasing number of new situations, one of which benefits from CSCW. In E.J Gomez's paper [8], it presents the design and development of a telemedicine system for remote computer-supported cooperative medical imaging diagnosis. The novel component of system is a new CSCW distributed architecture, consists of a collaborative toolkit to add audio conferencing, telephoning, window sharing, user's coordination and application synchronization facilities, to either existing or new medical imaging diagnosis applications.

In comparison with existing CSCW products, which are mainly based on centralized architectures, the distributed toolkit is designed dedicatedly for telemedicine applications: to allow different levels of sharing between participants, improving user feedback in highly interactive user interfaces, and optimizing the required communication bandwidth. The telemedicine CSCW system has been applied to build a cooperative medical imaging diagnosis application. For example, two doctors located in different hospitals. They need to achieve a cooperative diagnosis on hemodynamic studies using cardiac angiography images. The design of the graphical user interface for this kind of telemedicine CSCW systems can be used for them to work together online [8].

## 2.2 CSCW for Telemedicine

The CSCW based cooperative medical diagnosis environment has an extensive application in the modern healthcare organizations. Xiaolin Lu presents the design and development of a CSCW based remote cooperative oral medical diagnosis system [12]. The system is designed to provide a dynamic environment for oral healthcare professionals to access patient's information and increase the capacities of the patient consultation. It provides interactive medical service and medical record management. The system also provides a cooperative oral medical imaging diagnosis environment that allows doctors located in different hospitals to achieve a cooperative diagnosis through the oral images tool, telemedicine, the Oral Electronic Patient Records (OEPR) and video conferencing. The system framework, system architecture design, system integration and some key technical issues are investigated and described in the paper. The system can be applied as a cooperative environmental for hospitals and dentists to provide the remote oral medical service and improve synergies between the oral medical professionals and the healthcare organizations. Fig. 2.1 describes the system framework of the remote cooperative medical diagnosis system.

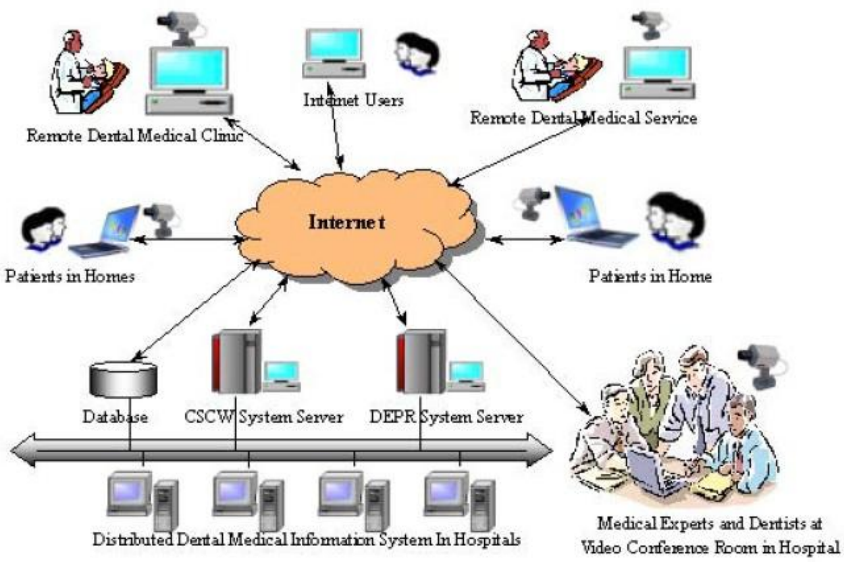


Figure 2.1: Framework of the remote cooperative medical diagnosis system [12]

The system provides doctors consultation and basic patient information to the long-distance medical service. Different documents can be shared such as treatment list, diagnosis list, and medical images materials. Patients can stay at home and doctors in hospital or clinics communicate with the system via camera and microphone.

The middleware of CSCW, OEPR, oral images data, and multimedia Enterprise JavaBean (EJB) offers distributed transaction processing. Many host computers can join to offer the many services. Compared with other distributed technology, such as Common Object Request Broker Architecture (CORBA) technology, the system structure of EJB has hidden the lower detail, such as distributed application, the events management, the target management, multi-thread management and connoting pool management etc. Distributed computing enable users operate in any time, any place, and obtain business logic and data processing in remote server. The distributed systems enable the databases and services in the same or different computers. The database uses JBBC to communicate with EJB (back-end server). The system front-end uses the back-end server to provide service. The front-end client communicates with back end EJB.

Fig. 2.2 shows the main architecture of the system based on Java Platform, Enterprise Edition (J2EE). The J2EE is a widely used platform for server programming in the Java programming language. The Java platform (Enterprise Edition) differs from the Java Standard Edition Platform (Java SE) in that it adds libraries which provide functionality to deploy fault-tolerant, distributed, multi-tier Java software, based largely on modular components running on an application server.

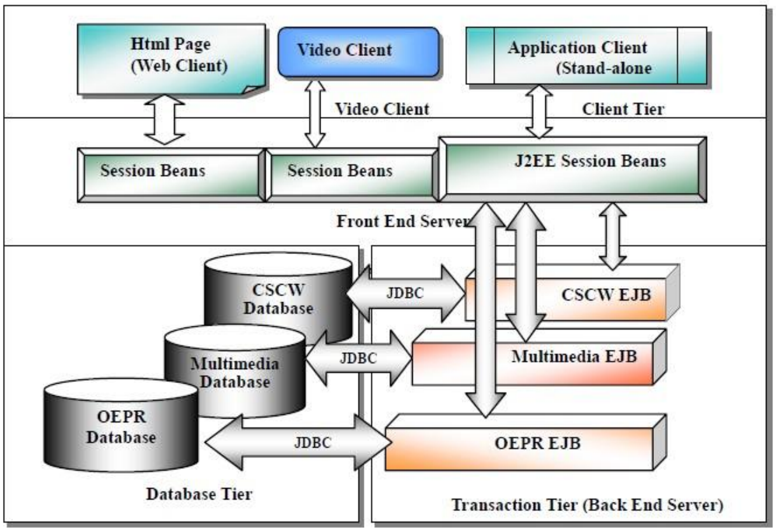


Figure 2.2: System architecture based on J2EE [12]

## 2.3 Patient Administered Personal EHR Architecture

It is certain that the patient's access to his/her own medical records and treatment information in the future will play an important role in healthcare service sector. Shared access to EHR will thus be significant for obtaining electronic collaboration, both the patient and also for the healthcare professionals [13]. With Patient administered Personal electronic Health Record (PaPeHR) solution, there is a lack of scientific publications describing how the patient can be able to manage the required tasks. The architecture is designed to separate EHR database into three, such as vital signs database, PaPeHR database and core-EHR database. The Fig. 2.3 describes the principles of this architecture.

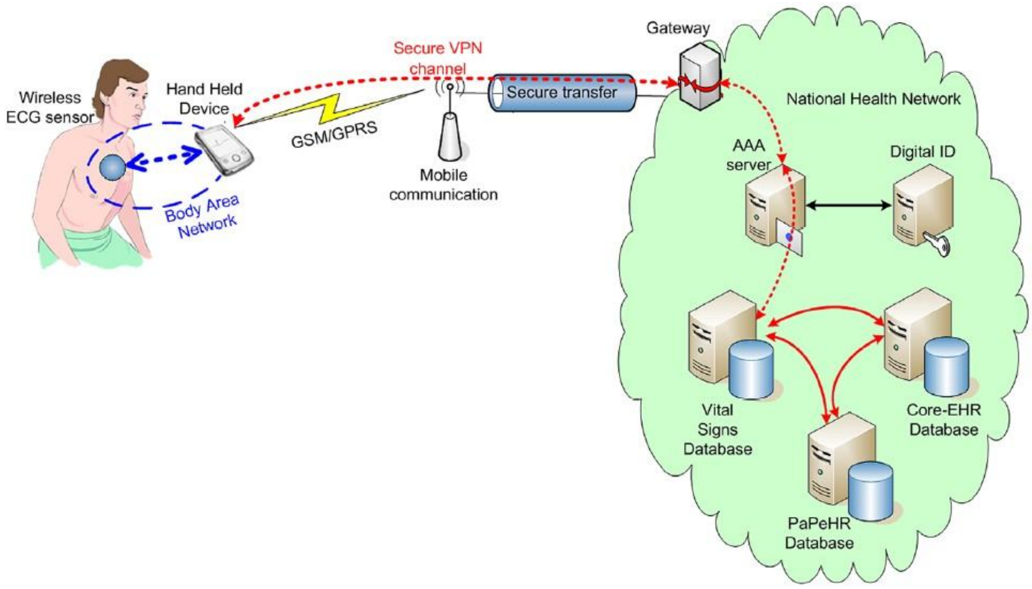


Figure 2.3: Architecture of patient administered EHR [13]

The Electrocardiography (ECG) wireless sensor collects patient vital data and transmits via secure transfer. The files send to gateway at edge of NHN, where a data server can poll for the transmitted files, thus the files can be stored in a vital signs database, which is directly linked to the patient's PaPeHR database and also to the core-EHR database. The main structure based on user access. The access can be defined as denied, read only, permissions to write etc. This architecture can be improved and completed in future work. The CSCW in tele home care architecture in this dissertation will be based on this with some improvements.

## 2.4 Distributed Information System

In healthcare information system, patient data can be stored in a distributed environment allowing healthcare providers at different locations to share and access easily a variety of EHR. Such EHR will become an essential source of information for future healthcare providers and rapidly take over the role of the paper-based medical records. Therefore, a reliable, secure, and efficient data storage infrastructure is critical to future healthcare systems. However, there are several technical challenges including reliability, security, and adequate online performance that make the design and implementation of such distributed data storage difficult [14]. For this main idea, the CSCW in tele home care architecture can import the structure from it. Fig. 2.4 shows a distributed information system structure. Distinct division of labour between the servers, such as database server, file server, storage server and tape lib. Secured data transmit via network and send to corresponding server to handle with.

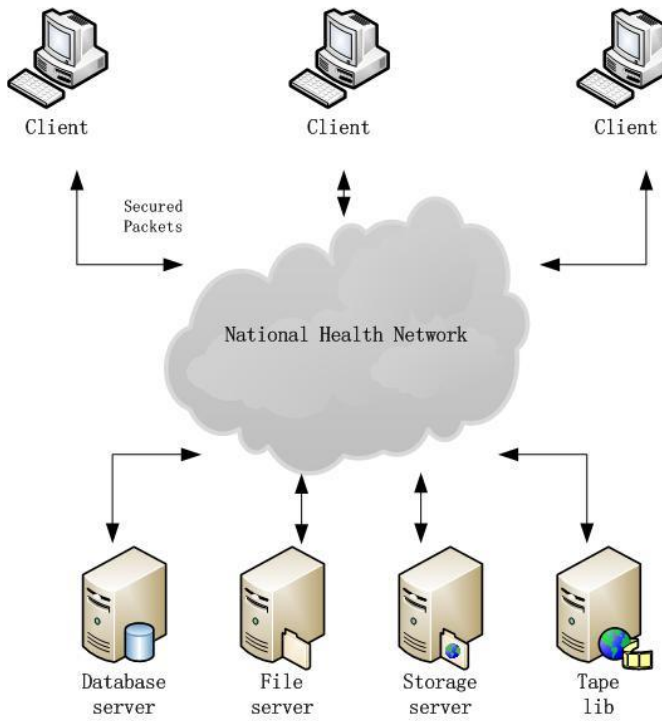


Figure 2.4: A distributed information system structure [14]

Considering that an EHR system is connected to multiple clients to share information, the server pressure will be increased during the access section. Each of the clients represents an authorized healthcare provider such as doctors, radiologists, cardiologist, pathologist, dentist, neurologist, etc. Any client can access, modify, add or delete information in the shared storages. Since NHN runs over the Internet, clients and storage servers can be located in any geographical location allowing true patient data sharing among healthcare providers. Distributed server is a promote method to solve the problem of high pressure in server. The previous server can be separated into several and located in different locations. It’s certain that more server machine will raise the budget. However, it can increase the flexibility, maintainability and reduce access pressure of the server.

## 2.5 Data Mapping Engine

Data mapping is the process of creating data element mapping between two distinct data models. Since distributed databases help reduce database high storage pressure, we need a mapping database to direct to specific element. Hence, the data mapping engine concept will be introduced into architecture. HL7 Clinical Document Architecture (CDA) is a renowned exchange standard. Presently, there are many studies regarding CDA to resolve the problems of healthcare information sharing. The data mapping engine processes the mapping between Health Information System (HIS) items and CDA items. Each CDA item is mapped to HIS item and the data is extracted from HIS for CDA generation. Fig. 2.5 illustrates the mapping process. The data is extracted from database and save it as a string format. The mapping engine will receive and parse this string.

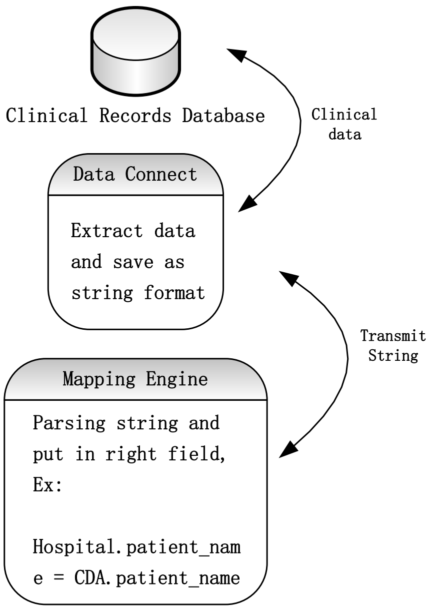


Figure 2.5: Mapping procedure [15]

In corresponding CSCW in tele home care architecture, it supposes to build a mapping database to save specific data location information. In mapping database, it only stores patient basic data and the address of distribute database, which stores the complete information. When we search an EHR of a patient, the system will a request to mapping database. After found the data location, the system sends a message to distributed database to acquire the EHR data and send back result. The same principle as CDA, the prototype is the EHR searching platform in this project. All the experiments will base on this platform and produce a curve result finally.

## 2.6 HL7 Standard Specification and Application

Hospitals and other healthcare provider organizations typically have many different systems used for everything from billing records to patient tracking. All these systems communicate with each other. HL7 is a specific flexible standards, guidelines and methodologies to regulate the communication among these systems. HL7 develops conceptual standards, document standards, application standards and messaging standards. Messaging standards are particularly important because they define how information is packaged and communicated from one party to another. Such standards set the language, structure and data types required for seamless integration from one system to another [16].

### 2.6.1 HL7 Specification

The Reference Information Model (RIM) and HL7 Development Framework (HDF) are the basis of HL7 messaging standard development process. RIM is the representation of the HL7 clinical data and life cycle of messages or group of messages. HDF is a project to specify the processes and methodology used by all the HL7 committees for project initiation, requirements analysis, standard design, implementation, standard approval process, etc. HL7 specification document is established on RIM and HDF which published by HL7 international community.

HL7 service is developed to work under regular operating system and its socket communication based on Transmission Control Protocol/Internet Protocol (TCP/IP). File based communication where files are transferred to dedicated directories. According to HL7 standard, messages are composed out of segments which are delimited by defined terminators. In this project, the healthcare collaborative workspace will transmit message, which regulated by using HL7. For instance, the message to request a specific EHR, the acknowledgment of the request and the message send result backwards to system, etc. The following code is a general acknowledgment message based on HL7 standard [17]:

```
MSH|^~\&|EB^EB^GUID||DPS^DPS^GUID||199601061000||ACK^A02|
C7E7-85-11-A5-004005|P|2.3|AL|NE
MSA|AA|000002
```

In this message, MSH represents message header segment and MSA is message acknowledgment segment. Check from HL7 specification standard document, the distinct notations in this message have different meanings. The corresponding symbol and meaning is presented in the following table 2.1. The system will parse the string of this message in this mechanism.

Table 2.1: HL7 message standard notation resolution

<table>
<tr><th>Notation</th><th>Element Name</th><th>Element Meaning</th></tr>
<tr><td>|</td><td>Field separator</td><td>Hardcoded</td></tr>
<tr><td>^~\&</td><td>Encoding characters</td><td>Hardcoded</td></tr>
<tr><td>EB</td><td>Namespace ID</td><td>Sending application name</td></tr>
<tr><td>GUID</td><td>Universal ID type</td><td>Hardcoded</td></tr>
<tr><td>DPS</td><td>Namespace ID</td><td>Message application name</td></tr>
<tr><td>199601061000</td><td>Date/Time of message</td><td>Hardcoded</td></tr>
<tr><td>ACK</td><td>Message type</td><td>General Acknowledgement</td></tr>
<tr><td>A02</td><td>Trigger event</td><td>Trigger event of acknowledged message</td></tr>
<tr><td>C7E7-85-11-A5-004005</td><td>Message control ID</td><td>Hardcoded</td></tr>
<tr><td>P</td><td>Processing ID</td><td>Hardcoded</td></tr>
<tr><td>2.3</td><td>Version ID</td><td>Hardcoded</td></tr>
<tr><td>AL</td><td>Accept acknowledgement type</td><td>Always</td></tr>
<tr><td>NE</td><td>Application acknowledgement type</td><td>Never</td></tr>
<tr><td>AA</td><td>Acknowledgement code</td><td>Application Accept</td></tr>
<tr><td>000002</td><td>Message control ID</td><td>Hardcoded</td></tr>
</table>

According to the HL7 standard, it can parse the message above. This message is send from EB to DPS, and time is 6th January, 1996 at 10 o'clock. The message is to give DPS that EB's acknowledgment in standard version 2.3. This is an example of message in HL7 standard. There are many different types of messages such as patient identification segment, diagnosis segment, procedures segment and etc. In this project, the request and acknowledgment of messages will obey the HL7 standard.

### 2.6.2 HL7 EHR System Functional Model and Standard

The HL7 EHR system functional model and standard documents key functions of EHR systems to enable consistent expression of system functionality. The functions are organised in two methods: as a hierarchy within the broad headings of care delivery and infrastructure functions; and as a list of functions that are deemed essential or desirable within four common care settings. The purpose of this is to understand the dependencies of functions upon each and to distinguish the key functions each system should perform to satisfactorily address the clinical and business needs within care settings. The Dickinson's published document HL7 EHR system functional model and standard described the methods discussed above and also describes the impact of the standard on related work occurring within and outside the HL7 community, and an overview of future plans for development of this standard. [18]

To achieve healthcare community consensus at the outset, the functions are described at a high level. The model is built in user-oriented language. The document is intended for a broad readership. Future work on this Dickinson's standard document will incorporate conformance criteria based on the functions included within this baseline and extend functionality to lower levels. There is a model prototype of key capabilities in EHR. We can follow the specific subjects to establish a virtual EHR database to accomplish the experiment. In addition, it is also useful and valuable for the work of public EHR in Norway in the future.

# Chapter 3

# Architecture Design

Healthcare service is among the most complex and highly collaborative domains of work practice. Most researches with CSCW in healthcare domain include access into patient EHR, collaborative clinical technologies, remote diagnosis and etc. In this section, it will illustrate a specific architecture design scenario of CSCW used in tele home care. The scenario will focus on architecture network topology and advanced communication technology. It discusses with system structure, database technology and user authentication mechanism. Although many prior studies and technologies have focused on these clinical settings, the aim of this project is to give an all-round architecture scenario and describe it in detail.

Currently, there is a significant challenges related to the growing proportion of elders and chronic patients in Norway or even the world. Healthcare systems are looking for new methods for collaboration in information technologies to address those challenges. However, with the CSCW widely used, new problems will produce. High capacity of data storage and server processing pressure in the future is an essential topic that we need to solve. The first section describes the architecture network topology, configuration with machines such as servers, client computers and databases. Then, the following content is the communication technologies description base on CSCW platform. The system structure such as distributed server, distributed database and data warehousing are the innovations in this project. The design description will also describe the user authentication, authorization mechanism in this scenario. For instance, it will give a solution for doctor accessing patient EHR data.

## 3.1 User Requirement Analysis

The requirements based on workspace environment are from several aspects just as interactivity, security, effectiveness and etc. When designing a scenario model, it is necessary to define user requirements first. These requirements state what the customers actually want it to do. The development and evaluation of a CSCW in tele home care needs to take numerous considerations in order to satisfy the different user requirements. Some of the important aspects are discussed below.

### 3.1.1 Simplicity and Performance

The system simplicity does not mean less functionality and complexity. It means the system should be simple enough to accommodate component development and being implemented efficiency. For instance, while developers want to add a new component into the existing system, it should available to embed without disturb to other components. On the other hand, system performance is also significant. It includes the set of roles, skills, activities, tools and deliverables applied at every phase of system life cycle. A system with well performance has several objectives:

- Increasing business revenue by ensuring the system can process transactions within the requisite timeframe.
- Eliminate system failure requiring scrapping and writing off the system development effort due to performance objective failure.
- Eliminate late system deployment due to performance issues.
- Eliminate avoidable system rework due to performance issues.
- Eliminate avoidable system tuning efforts.
- Avoid additional and unnecessary hardware acquisition costs.
- Reduce increased software maintenance costs due to performance problems in production.
- Reduce increased software maintenance costs due to software impacted by ad hoc performance fixes.
- Reduce additional operational overhead for handling system issues due to performance problems [19].

One of the aspects that user mostly concern is the performance of the system. The CSCW architecture with well performance design will reduce and even avoid unnecessary troubles. In one words, the system should be lightweight.

### 3.1.2 Scalability and Fault-Tolerant

In electronics industry (including hardware, communication and software), scalability is the ability of a system, network, or process, to handle growing amount of work in the graceful manner or its ability to be accommodate that growth. In software system level, the scalability always describes the database and the functions of the system design. A number of different approaches enable databases to grow to very large size while supporting an ever-increasing rate of transactions per second. It is often advised to focus system design on function scalability rather than on capacity. It is typically cheaper to add a new node to a system in order to achieve improved performance than to partake in performance tuning to improve the capacity that each node can handle. The importance of the scalability decides the development of the system and the market in the future. A system with better scalability has more competitive strength.

### 3.1.3 Interactivity

In information science field, communication and industrial design, there is debate over the meaning of interactivity. In the science view of interactivity, there are three levels such as non-interactive, reactive and interactive. Most of information systems need to reach interactive level, and the same with collaborative workspace. It means the workspace should have the ability to provide a range of services with involvement of user interaction. Hence, CSCW in tele home care should obtain high interactivity between patients and healthcare providers.

The user interaction needs to be consistent and compatible with users' values. It should be performed with minimal cognitive effort of the user. For example, patients can select the service they want such as video conferencing online. The system should provide a platform for users after user push the chatting button. Doctors can access patient EHR, the platform should able to supply an interface for database. Furthermore, if the system has a hand-free interface (an interface that the users can operate the system without hands) such as speech recognition, may make the system more applicable and acceptable [20].

### 3.1.4 Real-time Services

Real-time is the ability that a system enables publication of communication among the users. The CSCW can offer a platform for users to have real-time communication. It can conveniently transmit the media data such as video and voice. In addition, it should have the function which can rapidly transmit the vital data gathered by mobile sensors without delay. It also needs emergency recognition function for emergency prediction, protection and response. Meanwhile, it is necessary to consider about offline application with message send. If a user is offline, the system should enable to store the messages from other users and display them when the user is online. Though the massages are not real-time, however, a complete computer system should with a well organized message mechanism.

### 3.1.5 Security

Security is the level of protection against danger, damage, loss and crime of a system. And it as a form of protection is structures and processes that provide or improve security as a condition. Some of the user information and personal medical data have to be protected and forbidden to be disclosed to anyone. The deployment of appropriate security and privacy solutions mainly focus on data transmission and storage. Considered the personal medical data of privacy, the system should have a complete security mechanism to encrypt the data.

For example, as we all know, the computer virus especially Trojan virus spread rapidly and growing exponentially. Most of the viruses bring the damage to personal computer and even server machine. And for the personal information, some Trojan can break the program and embezzle the data which is private. Because of this situation, the system should have its own data encryption algorithm and add fire wall in the network. The security mechanism will be in average level in this project. However, it is a real important aspect to computer systems. And with the development of collaborative workspace, the developers should consider about this and fix the system with high level security mechanism. In CSCW, we need to consider about the solution that if a patient with EHR move from one hospital to another. Doctor requires a well organized authentication and authorization mechanism to access the EHR data in a distributed database [21].

## 3.2 Scenario of CSCW in Tele Home Care

The macro-structure is an essential part in architecture design. It is similar to a construction of a building. The engineer will draw a blueprint for the building, with details like height, width, materials and etc. The same principle with the design CSCW in tele home care, we suppose to give an overview in this section. This part discusses the scenario of CSCW architecture including user requirement use case, and network distribution by using diagrams and text illustration. In normal circumstance, system requirement decides the functions and environment. And most requirements are from clients. Requirements described in this project based on the patients and healthcare providers. Most of information gathered from papers, website and journal materials, which are useful in collaborative workspace development.

### 3.2.1 Overview of the Architecture

Healthcare organizations are characterized by high level of complexity operations and practises. CSCW Architecture built in tele home care sector is designed. This would allow healthcare organizations to better handle the services to patients. Many tools and hardware involved in the design, such as server machine, firewall, client machine, database and etc. The entire architecture is based on Nationwide Health Information Network (NHIN). It is an initiative for exchange of healthcare information being developed under encouraging by national healthcare organizations. The government of Norway presents National Health Plan for Norway (2007-2010) [22]. This document discusses the healthcare services in Norway today, and suggests policies that are intended to result in a better health service. A better health service means prevention and facilitating the participation of patients and their relatives. The NHIN should with following characteristic:

- Cohesion and interaction
- Democracy and legitimacy
- Proximity and security
- Stringer patient role
- Professionalism and quality
- Work and health

Fig. 3.1 describes the main CSCW architecture in tele home care base on NHIN. Each hospital and smart house is regarded as a node in the architecture. There are many hospitals and smart houses will connect to NHIN, constructed as a huge healthcare service oriented network. NHIN plays as a role of switch. It is responsible for the information exchange between the different elements. The message transmitting mechanism is based on HL7 standard which is the most popular used healthcare information standard.

Each hospital has several client machines, connected by service oriented bus. Meanwhile, all the EHR data will store into PaPeHR database. The vital signs database collects patient real time vital parameters. With secure transfer and information exchange by server, the branch network aggregates to NHIN. It is similar in each smart house, but with less clients and more intelligent devices.

Centre for Disease Control (CDC) is the information accumulative platform. The main database in CDC is the core EHR database. Lack of accessing to updated information is a challenge for healthcare providers in Norway. In order to provide healthcare providers that need to access to the patient's medication information fast, core EHR database is the best solution. Moreover, there is a mapping database provides mapping services to users. With the numbers of data and healthcare information growth, all EHRs store into one database will cost a lot of time when searching a specific record. However, if we select to use distribute database structure, it needs a record navigation. The data mapping can solve this problem. Hence, we establish a mapping database in CDC to operate request into right direction. In addition, CDC server is in a distributed system structure. In order to reduce server pressure, the previous server will departed into three servers. File server, storage server, real-time information server compose to server platform of CDC.

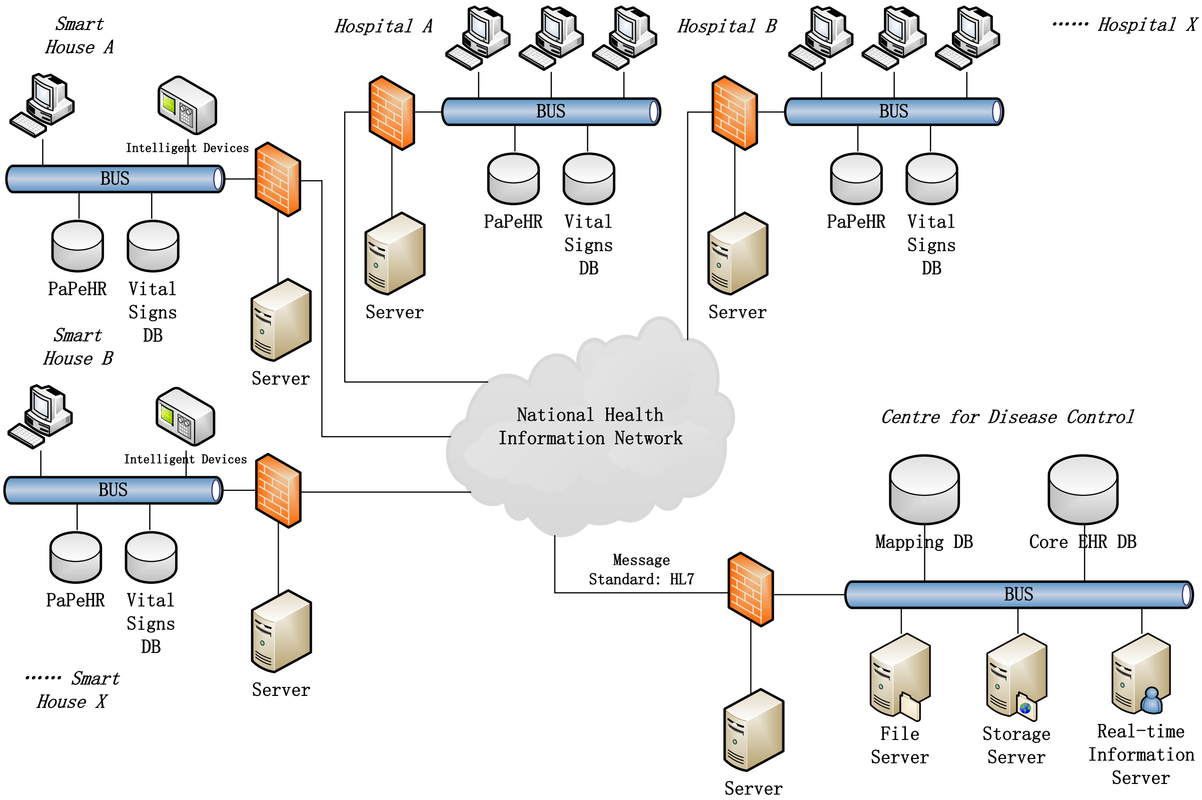


Figure 3.1: Main CSCW architecture in tele home care

### 3.2.2 Distributed Database System

Distributed database is a database in which storage devices are not all attached in one computer. The database may locate in different physical locations. Fig. 3.2 describes the distributed EHR database architecture. Mapping database records other EHR database location, such as IP address and port number. Next level database is the specific patient EHR database, which connect with PaPeHR and vital signs databases. According to this architecture, it will solve the problem of high EHR storage pressure of data centralized. It will be more flexibility and scalability to the system architecture in tele home care section.

However, the distributed database architecture highly relies on network bandwidth and CPU speed. During the process of the searching engine sending a request to mapping database and get result, the message will transmit across the network with triple times. The advantages of distributed database are increase reliability and availability, reflects organizational structure, improve performance and etc. Conversely, it also has disadvantages. It may arouse the problems such as complexity, economics, and difficult to maintain integrity.

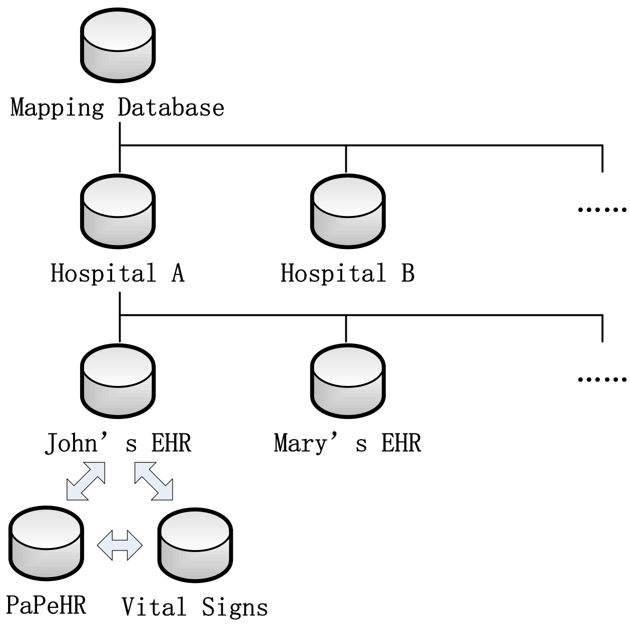


Figure 3.2: Distributed EHR database architecture

### 3.2.3 EHR Database Mapping

Data mapping is the process of creating data element mappings between two distinct data models. To date, data mapping is a great solution for exchanging data between different health institutes. It significantly improves the problem of database distributed. In this CSCW architecture, EHR database mapping is the most important section to distributed EHR storage. Fig. 3.3 describes the two possible different types of message transmitting process. They are three-way and four-way structures.

The three-way model is presented in the left diagram. While healthcare providers need to search a specific patient's EHR, searching engine will send a request to mapping application. The mapping server parses the message and found the item location from mapping database. Then it redirects the request to the location just discovered. The target server receives the message, parses it and digs the data from PaPeHR database. Finally send back the result to the searching engine. In addition, the request is according to a function named search with PID, item, date and source IP address parameters.

The figure on the right is the four-way model. Searching engine send the request to mapping engine. Mapping engine will send back the data source address and port number to searching engine. According to the IP address and port number, the searching engine will send the request to EHR storage server and ask for result. Finally, after data search from distributed EHR database, server will send back the result.

Different structure has its own advantages and disadvantages. Three-way structure will cost less time than four-way. But the problem is that the entire architecture highly relies on the mapping server. For instance, if the mapping server breaks down, it will seriously affect data search process. Four-way model can reduce this type of dependence. However, it will have four times message transmit during network. It may arouse network traffic jam. Besides, if the CSCW use four-way model, we should consider about access authority problem. After EHR server receives the request, the first and significant process is verified if the user has permission to search the data. It means each distributed

EHR server should have an authorization of the searching engines. But in three-way model, the authorization will be accomplished by mapping server.

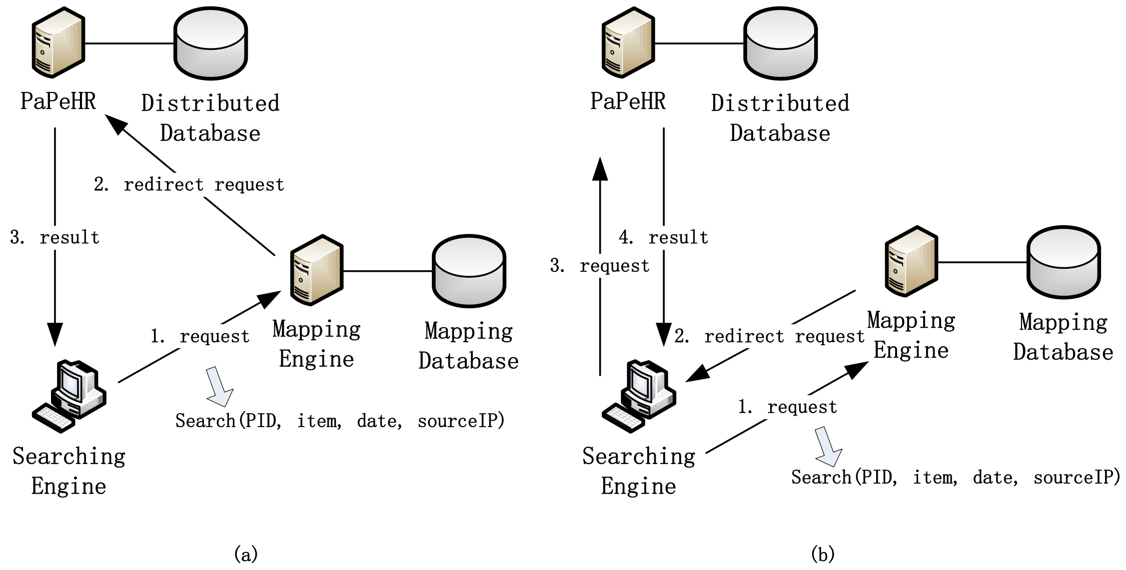


Figure 3.3: (a) three-way EHR searching model; (b) four-way EHR searching model

Because of the request message will be redirected by the mapping engine. Hence, the entire application highly relies on network bandwidth and conditions. As a result, distributed database is able to realize its advantage only in the case that much more data storage. Data centralized structure does not have mapping process. Therefore, the searching time consume is only a bilateral message send. Message sent across the network twice, but triple times in distributed database system.

### 3.2.4 EHR Data Warehousing

In essence, the data warehousing concept was intended to provide an architectural model for the flow of data from operational systems to decision support environment. The EHR in CSCW is able to use data warehousing technology to be well organized. A new type of data model, multidimensional data model, emerged that has since made inroads on the relational model when the objective is to analyze data, rather than to perform on-line transactions.

Multidimensional data models are designed expressly to support data analysis [23]. The EHR is the type of data that need searching, analyzing and management. If we import the advanced storage technology into CSCW, it will make the system with more efficiency. A cube is a truly multidimensional data structure for capturing and analyzing data. It suggests three dimensions and consists of uniquely identifiable cells at each of the dimension’s intersections. Hence, we suppose to store all EHR data into one cube. This cube can be divided into many smaller cubes, which stores EHR data of each patient. The smaller cube can also be divided into different items.

Under normal circumstances, database use two-dimension table to store data. An example schema instance for EHR typical storage structure is shown in Table 3.1 to 3.5. The first main schema holds the other items key number. No. 2234 is the key of patient John. The detail of this patient can be shown in a sub schema. The same principle acts in date record. No. 207 presents the date of March 1st,

2009. No. 853 of health information item is the record of "You are in healthy condition". In result management, No. 2475 means the record of "Continue taking medicine". This structure is similar to a star. It has one dimension table for each dimension.

Table 3.1: Main schema of EHR example

| **PID** | **HealthInformation_ID** | **ResultManagement_ID** | **Date_ID** |
|---|---|---|---|
| 2234 | 853 | 2475 | 207 |
| 2234 | 855 | 2476 | 208 |
| 2235 | 855 | 2477 | 209 |

Table 3.2: Patient schema

| **PID** | **Name** | **Details** |
|---|---|---|
| 2234 | John | …… |
| 2235 | Mary | …… |

Table 3.3: Date schema

| **Date_ID** | **Day** | **Month** | **Year** |
|---|---|---|---|
| 207 | March 1st, 2009 | March 2009 | 2009 |
| 208 | March 13th, 2009 | March 2009 | 2009 |
| 209 | March 15th, 2009 | March 2009 | 2009 |

Table 3.4: Health information schema

| **HealthInformation_ID** | **Record** |
|---|---|
| 853 | You are in healthy condition |
| 855 | Sub-health |

Table 3.5: Result management schema

| **ReaultManagement_ID** | **Record** |
|---|---|
| 2475 | Continue taking medicine |
| 2476 | You need a surgery |
| 2477 | Proper diet |

It seems that typical structure has the problem of much tables and data separation. It makes difficult to organize and analyze the data. Therefore, we import the multidimensional database from data warehousing technology. If we use the cube to store EHR data, it is easier to check the data structure. Fig. 3.4 shows the same EHR data storage example as above. The main cube stores the patients' EHR data with three dimensions, such as name, year and item. We dig out one of the sub cube. It has three dimensions with month and sub items in health information. One of dimension of the final cube is sub items of key data, which is the sub item of health information. According to this structure, the data will has less redundancy and much easier to organize.

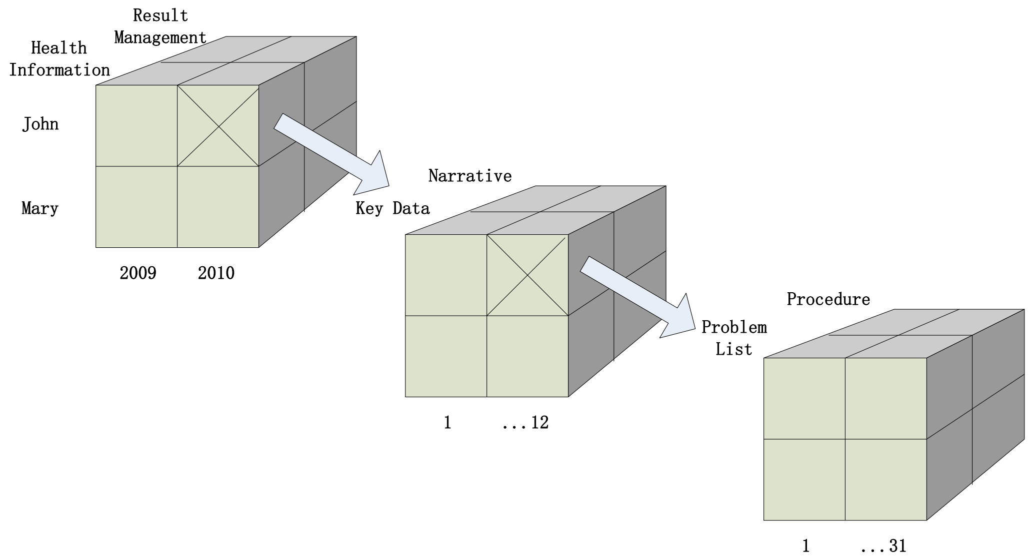


Figure 3.4: Multidimensional database structure

### 3.2.5 Distributed Server Architecture

The distributed server system is constantly evolving during the last decade. It is the one of the most important issues in CSCW technologies. The reason for the distributed server architecture is the availability of reducing server pressure during customer traffic peak and enhancing the flexibility of the entire structure. Architectures based on networked servers have been further developed these years. In these architectures, the control of the simulation relies on interconnected server. Client computers are assigned to the server in this system. The centralized server will handle all the requests and acknowledgments messages. With the increasing of customer traffic, the server is confronted with high data management pressure situation. Each thread running on server deals with each client connection. The increasing of threads may arouse the risk of server crash.

CSCW can be defined as such a computer system, which support a group of clients to participate in a common task and provide with interfaces to access shared environment. The architecture of CSCW in tele home care can not only provide an external environment, which offers resource searching, group decision support, multi-part communication and other services for patients or healthcare providers, but also implement application communication by solving problems resulting from the different architectures. Besides, the CSCW provides a cooperative work environment for the geographically distributed people, and supports the cooperative work between cooperative members, who are temporally separate and spatially distributed while with the different tasks [24].

Therefore, in this CSCW architecture which used in tele home care, the centralized server will be separated into several parts. It is the distributed server architecture. The main server is used for obtaining and parsing client requests. The file server used for storing the files which clients uploaded. Storage server is the machine that for operating web information, data exchanging and recording network configurations. The real-time information such as video stream, voice stream and real-time messages are handled by real-time information server. It charges for real-time data exchange. According to this structure, each server will carry out their own duties and distributed data into different machines.

This distributed server architecture used in tele home care sector will definitely solve the problem of high server pressure and more flexibility. One of the servers crashed but the entire system can still running. It also easily has error checking to each server. However, it also has its own disadvantages. Server distributed means that it requires more machines support. It will increase the operating and maintenance cost. Hence, healthcare providers should discretely choose the architecture. It depends on the user requirement and numbers of clients.

### 3.2.6 Healthcare Service-Oriented Bus

The increasing for a good healthcare quality has brought ICT to a significant role in healthcare domain. The objective of healthcare service by using IT science is to reduce formal healthcare providers work and give further services to chronic patients or elders. However, what the healthcare providers and patients required is a flexible service and integration environment. One of the solutions is to modify the present service structure. Hence, it is available to add a logical integration platform into CSCW architecture. The platform should integrating various devices and services by adopting the service-oriented bus to provide interoperability, modularity, and reusability of different service components.

Service-Oriented Architecture (SOA) provides a way for customer of services, such as web-based applications. The SOA implementations rely on a mesh of software services. The services comprise un-associated, loosely coupled units of functionality that have no calls to each other. In real life, most of web services approach is straightforward and simpler to be deployed by using point-to-point structure. But with increase of applications, more points will be added into the environment. If one point is down, it may affect the entire system. On the other hand, a centralized service bus approach seems an excellent method to avoid the point down problem. Fig. 3.5 depicts the general comparison of the two SOA approaches.

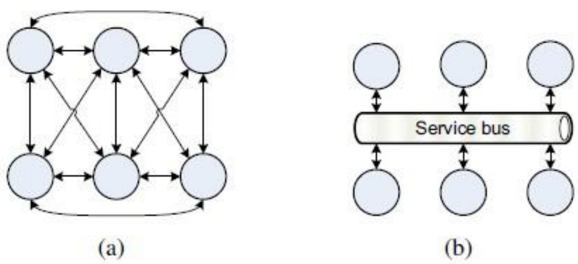


Figure 3.5: (a) Point-to-point approach; (b) Service bus approach [25]

In CSCW architecture, all the service channels are replaced to service bus. It will provide a better centralized mechanism for integrating various devices and services in hospitals or smart houses. The devices such as client machines, server machine and intelligent devices are connected to the service bus. However, this may brought to us new problems. The service bus approach is more complicated than point-to-point. In implementation section, integration of different devices and services need well organized interfaces. Since the healthcare services in hospitals or smart houses will produce large number of messages and data streams, the service bus needs to uniform the interface by using standards. Hence, this will become an essential problem in the future.

### 3.2.7 Vital Signs Network Structure

The healthcare is facing major challenges in the near future as costs are rapidly increasing worldwide due to aging population and widespread chronic diseases. Remote monitoring of vital signs is an important technique to ensure the health and life quality of a patient. In this CSCW architecture scenario, vital signs network is an essential part. It may make the healthcare providers easier to obtain patient health conditions and give remote diagnosis. In this structure, it includes body area network (BAN), vital sensors, wireless communication and a gateway to collect the data. The network also connected to service bus. All the data collected by gateway stored into vital signs database.

Fig. 3.6 shows the vital signs network structure in CSCW. Different sensors collect different vital signs. The types of vital signs may include body temperature, pulse rate, blood pressure, respiratory rate and etc. The wireless communication transferred in secure channel by using General Packet Radio Service (GPRS). The receiving device obtains the data and sends it to a gateway. The gateway will handle the vital signs and redirect it to right position in vital signs database. This sub-architecture in CSCW may be located in hospital or smart house. According to this, it will make healthcare service more efficiency and with higher quality.

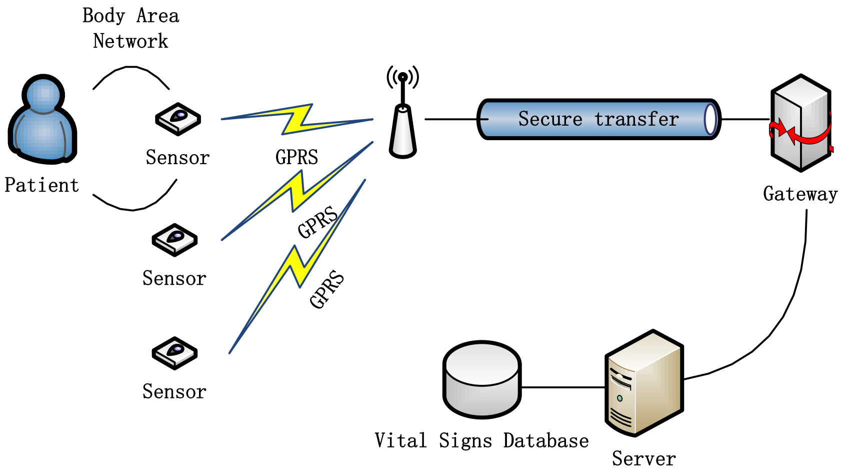


Figure 3.6: Vital signs network structure

## 3.3 Related Technologies and Tools

Several related technologies and tools developed within CSCW architecture. The web-based platform in this CSCW is a Rich Internet Application (RIA), which uses a rich client deployment model. FMS in platform used for handle the video and audio data stream on server. BAN technology is responsible for collecting vital signs data. These are relative important technologies and tools in CSCW architecture in this project. In this section, it will illustrate the objects above to give some introduction before implementation section.

### 3.3.1 Rich Internet Application Technology

RIAs are web applications that have some of the characteristics of desktop applications, typically delivered by way of an Ajax framework, proprietary web browser plug-ins, advanced JavaScript compiler technology, or independently via sandboxes or virtual machines. Examples of RIA frameworks that require browser extensions include Adobe Flash, Java/Java FX and Microsoft Silverlight. The collaborative workspace in CSCW architecture is a RIA based on web browser.

The applications used RIA technology can improve security mechanism, but the extensions themselves remain subject to vulnerabilities and access is often much greater than that of native web applications. For security purposes, most RIAs run their client portions within a special isolated area of the client desktop called a sandbox. The sandbox limits visibility and access to the file-system and to the operating system on the client to the application server on the other side of the connection. This approach allows the client system to handle local activities, calculations, reformatting and so forth, thereby lowering the amount and frequency of client-server traffic, especially versus client-server implementations built around so-called thin clients [26]. Hence, it is no doubt that the development trend of software is RIA. It is an excellent choice to use RIA in CSCW architecture.

### 3.3.2 Flash Media Server

Flash Media Server is a hub. Flash based applications connect to the hub using RTMP [27]. The RTMP is initially a propriety protocol developed by Macromedia for streaming audio, video and data over the Internet, between flash player and server. The server can send and receive data to and from the connected users with live web FLV player installed or the video published. Connected clients can make Remote Procedure Calls (RPC) on the server-side and the server can call methods on specific clients. Standard ActionScript objects are transported across the net connection using the Action Message Format (AMF) which is handled transparently by the server and flash client.

The server also allows users to receive and publish net streams. When viewing a net stream the user can either create their own to view a remotely stored FLV or the server can instantiate a net stream and play a video on it, the latter method means that every user will be at the same point in the video when they subscribe to it as they are all viewing the same stream.

In CSCW architecture, FMS is treated as a data stream convertor running on server machine. It easily helps the web-based platform to communicate by video and audio. Healthcare providers and patients are able to use video conference to have remote diagnosis, medical treatment and etc. It is certain that enhance the quality of healthcare services via FMS in CSCW.

### 3.3.3 Body Area Network

This section gives an overview of BAN, which used in CSCW architecture and how the technology is employed. BAN is an interdisciplinary field of study. There is a lot of technology out there, which allows for inexpensive and continuous monitoring of the patient. Home telemedicine and e-health is a medium with potential to transcend social, economic, healthcare and geographical barriers. These barriers are placed all around us in society today. Development of new technology is rapidly moving forward, which gives new opportunities and new ways to provide healthcare. These barriers are bound to fall in tomorrow's society of health care. Interaction between different types of technology provided by different manufactures is not well developed within the research field of BAN [28].

BAN can be used to extend health care service outside the hospital. Developers of EHR have been around for many years [29]. Still there are not many hospitals in the world which have a paperless workflow related to patient care and health service. When the data format protocols have been selected, as standards within hospitals, then many of them data format protocols will also be defined for homecare medical use with BAN. For advanced CSCW in tele home care sector, it is necessary to deposit BAN into the architecture.

The technology of BAN has been developed with invasive and non-invasive sensors technology like for instance heart sensor, blood pressure sensor, glucose sensor, ECG sensor, motion sensor etc. Vital parameters are transmitted to a receiver device or a personal gateway by wireless communication. The most significant three elements in this network are intelligent sensors, wireless communication and receiver device. Accordingly, healthcare providers can collect useful information. Therefore, in healthcare sector, BAN is an essential section in CSCW.

## 3.4 Test Strategy and Hypothesis

Based on CSCW architecture design in tele home care sector, a demo will be implemented to measure the curve diagrams with the properties of time cost and information capacity. Our intent is to compare the performance of CSCW with traditional database centralized storage system and distributed database system described above. As discussed previously, EHR searching engine send a request to detect relative record. What we need to gain is the time consumption from request send to result back. It is available to depict the curve diagram and to find the cross point between two different curves.

Fig. 3.7 describes the curve diagram hypothesis of this experiment. The time cost of searching patient EHR may from database searching, program process time and network transmitting. The Database centralized structure has request and result messages only, so that twice across the network. However, distributed database has a mapping mechanism. Searching engine sends request to mapping server first. Then, mapping server will parse the request, find relative record address and redirect the request to the destination. Finally, the server which obtains the request will search the record in database and send result back to searching engine. Therefore, when the entire structure will less data storage, data centralized will cost less time than distributed. However, with the growth of the data, the distributed database structure will show the advantages that it has. The segregation of the data will reduce the searching time in database. The curve of data distributed will grow slower than data centralized.

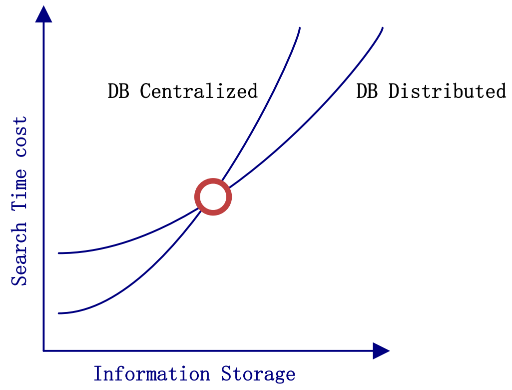


Figure 3.7: Experiment hypothesis

The experiment will execute on the web-based platform which implemented after architecture design. The entire comparison will separated into several parts. The system performance evaluation will be described specifically in Chapter 5. And reasons by analogy, the information storage will with exponential growth. Finally, we may discover an approximate cross point to find the best situation to use different database structure.

# Chapter 4

# Implementation

In this implementation chapter, it will give a system implementation description. It consists of system development environment, web-based collaborative workspace, mapping server application, EHR searching application program implement specification, database implementation and system test. The system test is an essential procedure in system design and investigation conducted to provide stakeholders with information about the quality of the product or service under test. In this project, it will use "black box" software testing method and give a result of the test. Each section described above will be illustrated by using text and relative class diagrams. With the association of the diagrams, it will describe the entire system more clearly. Some of essential code will be attached in appendix.

## 4.1 Development Environment

In computer program and software product development, the environment is the set of processes and programming tools used to create the program or software products. The term may sometimes also imply the physical environment. A development environment is one in which the processes and tools are coordinated to provide developers an orderly interface to and convenient view of the development process (or at least the processes of writing code, testing it, and packaging it for use). An example of an Integrated Development Environment (IDE) product is Eclipse. The term computer-assisted software environment is generally used to describe a set of tools and practices that facilitate management of a software development project.

In this project, Java programming language technology are used to create both client and server side application. The server-side implementation is widely accepted, but the browser-based client-side applications are less successful. Because the files size are large and the installation is cumbersome. Flex is a great solution for java developers. The main development platform for this solution is MyEclipse, with flex builder plug-in installed. Flex builder is responsible for MXML files, which are the files for system interface. MyEclipse is the container of java code. After compile these two types of files, it can obtain the SWF and class files. On the other hand, in server part, it uses Tomcat as develop server and FMS for media data streaming service. The database will use MySQL for data storing.

EHR searching engine will be embedded into the workspace. Application on mapping server and processing server are two executable jar file of Java. One is implemented to do the mapping work, and another is for EHR searching. We will use hibernate which is a Java framework technology for data storage to establish the EHR entity. According to this technology, the program will construct tables and relative mapping in database automatically. It will reduce so many works on data input and table construction.

## 4.2 Web-based Collaborative Workspace

With the progress of medical techniques and development of network, people can have a better and more prompt healthcare environment compared before. It is significant to provide a platform to patients and healthcare providers to communicate with each other and share information or documents. Besides, many researchers have concerned on electronic health records (EHR) and the system which used for supporting it. The collaborative workspace is a system that can be used for entering patients' EHR data and provides an interface for patients contact with their healthcare providers more conveniently. The workspace integrates information sharing, data interaction and video conferencing. Especially to notice that, it is based on web which is more in line with current computer technology development trend. The concept of web-based information system is not new. However, it is certain that people will focus on the system with more function based on accessing EHR, health materials and instant messaging in the future.

The web-based collaborative workspace for healthcare personnel is an application that running on browser via Internet. This workspace is an information system which is a part of CSCW architecture. It provides a platform for patients and healthcare providers to communicate with each other. Meanwhile, there are several aspects which can be used to describe this information system. First of all, it is the data interaction. It is better to develop an efficient data transmitting platform in healthcare domain. Physicians can easily access real-time patient's relevant information via EHR database. Patients can obtain their vital data to grasp their own health status. The information of patient vital parameters are heart beaten rate, blood pressure etc. They are collected by mobile sensors and read by the system. The second conception is the real-time information. All the data which users want to share is real-time. It is used for doctors comprehend patient's status synchronized. Then, another aspect is the media scalability. In acute situation, it is better to negotiate with doctor by video and voice, and acquire the patient data simultaneously. The workspace techniques can support the different standard of media, including text, pictures, voice, video, etc. The last one is the web-based. The application will be embed into website. Users can log into the system by easily clicking the web browser.

The design of web-based collaborative workspace is depicted in Fig. 4.1. The users are the subscribers to this workspace. All the users play a role of the candidates. One or more users in each domain can be as validated members when they communicating or sharing data through the workspace. The validated members are in one group which organized by administrator (healthcare specialist). The users in each group, as a super class in this scenario can operate the sources that provided via collaborative workspace.

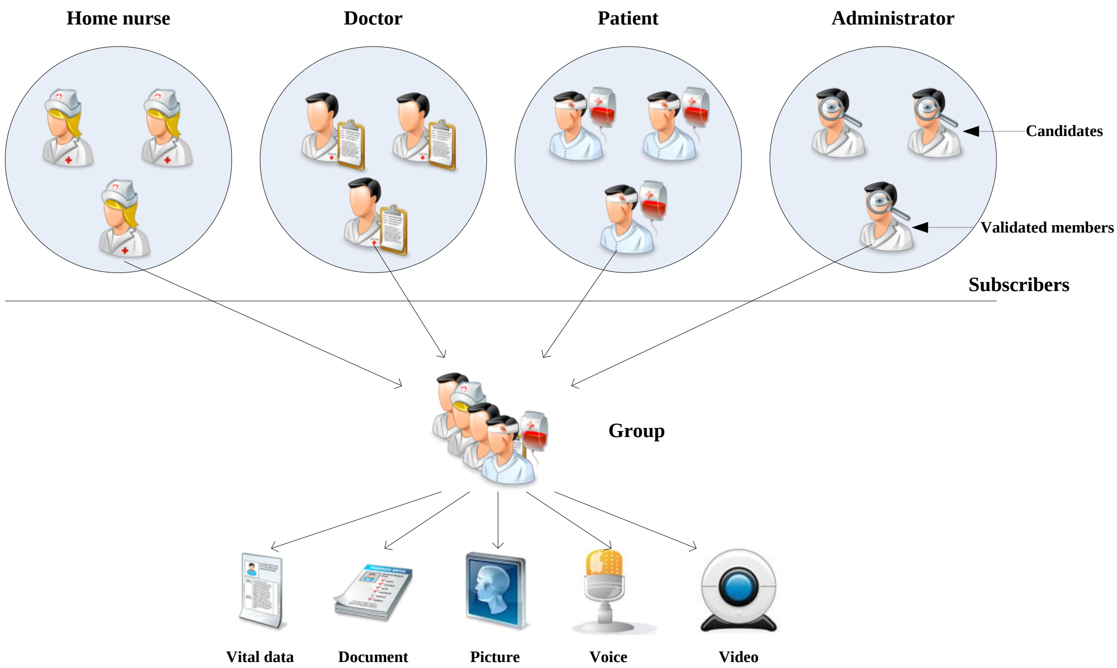


Figure 4.1: Design of collaborative workspace

Users can access into workspace by entering username and password, or with other methods with higher security mechanism (will not included in this study). The application runs via web browser and server, across Internet and connected to database. It needs video camera and microphone with computer or cell-phone by wired or wireless transmission. It is worth to mention that, in this project, the server will install an application which is FMS. It is used for video data and voice data transmission. According to these, the workspace is able to achieve goal with running on the web, sharing real-time data, video, voice and text documents. EHR search engine is also embedded in this workspace. The experiment and other implementation will be based on this platform. In short, this healthcare collaborative workspace is a corner stone of this CSCW architecture. Fig.4.2 shows the screenshot of real time CSCW prototype in this implementation. According to this platform, users can communicate by video conference, message, share documents and files. From the menu, we can see that doctor can use the EHR search engine to acquire specific patient records during remote diagnosis.

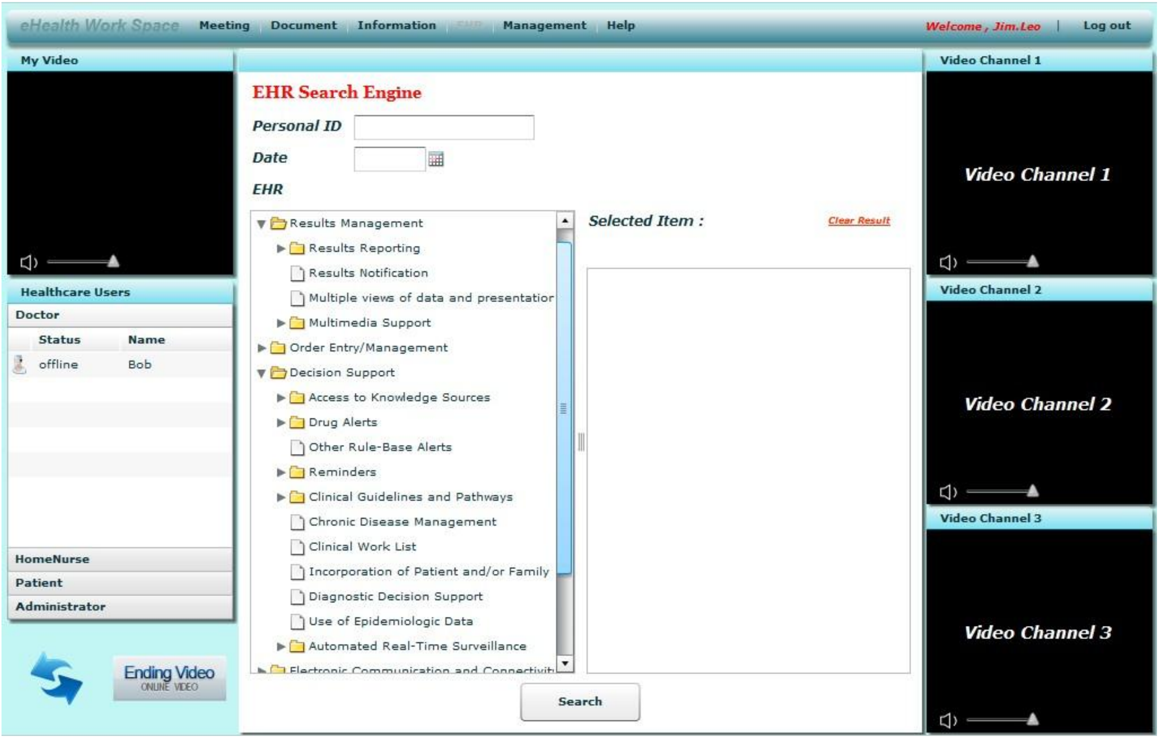


Figure 4.2: CSCW prototype implementation screenshot

## 4.3 Mapping Server Application

Mapping server is a significant element in CSCW architecture. It responsible for receiving user EHR searching request, find mapping address and port number, redirect request or send data resource address to searching engine. Mapping mechanism is essential to distributed database system. It acts as a role of commander. But first of all, it is better to illustrate from single database system.

As we know, database is a large, integrate collection of data. It can store objects, relationship, association and entities. Single database management system includes benefits such as recovery from crashes, concurrent access, data integrity, security and quick application development. However, independent database system may also arouse some problems. With the progress of the data quantity, a database will be in high storage pressure. System will cost much more time on data searching than before. Therefore, distributed database comes to solve this problem. In distributed database, data is stored in several different locations. Each management by system can run automatically. The location of data is unknown to client. It means data in distributed database is independent. A mapping is used for associating clients and data. In distributed database system, it is worth to notice some important aspects for distributed query processing, such as fragmentation, replication, parallelism and transparency. In CSCW, the using of distributed database is accordance with these principles.

### 4.3.1 Functional Description

There are three distinct types of processes for EHR data search query. The original process is a bilateral communication between client and EHR monitor server. Client send query message in HL7 standard with personal ID, date and EHR item. The EHR monitor server will parse the message, search specific result and send back. The second one is three-way process. Mapping server will be used which is the main implementation part in this section. Mapping server will act as a broker in the structure. As a broker, it charges for receiving message, parses it and redirects to EHR searching monitor. Four-way structure has the same principle to three-way. However, the only difference is sending back the location address and port number to client. Then client will send query again to this location.

We may find some different issues for the mapping server implementation. For instance, the problems that how to construct the message, send the message, parse the query message, the situation that one person has the not only one EHR record in different location and also connection exception. The methods to solve these issues will be presented in following sections.

- How to construct a query message?

Following HL7 standard, in searching client, there is a class named message constructor which is responsible for organizing query or other messages. In HL7, it is normally that one message constructed by message header and message body. Hence, it is more conveniently to generate message by using a specific method. Different types of message bodies have its related message body generator. The methods that used for generating message header and body return to a string ‘a’ and string ‘b’. The query message is a string, which composites by string ‘a’ plus string ‘b’. The required elements to query message are personal ID, date of record and item of record. According to these elements, EHR searching monitor can search specific data for client.

- How to send the message?

The back control procedure is implemented by Java. In Java, we always use socket programming to solve network communication issues. The socket class implements client sockets. A socket is an endpoint for communication between two machines. The actual work of the socket is performed by an instance of the “SocketImpl” class. An application, by changing the socket factory that creates the socket implementation, can configure itself to create sockets appropriate to the local firewall.

In searching engine, it exist writing and reading socket. Write socket is used for send message stream to mapping engine. The read socket is used for monitoring the result. The same situation is in mapping server. Only difference is that read socket in mapping server is never closed, but searching engine will close the read socket after getting result. The socket acts as a channel to communicate with others. Some of the important specific socket code will be attached in Appendix B.

- How to parse the query message?

Received message is difficult to parse with different format. However, HL7 standard can solve this problem. In HL7, the message string is constructed by different elements separated by vertical lines. After the application receiving the message, it is possible to divide the elements into an array of string.

Since we already know the element sequence because of HL7, it is easily to dig out the useful information from the array.

- The problem of one record in different location

In mapping server database, the key to seek records location is personal ID. But the problem may be aroused when one patient has different records in distinct locations. Meanwhile, N locations situation requires EHR searching engine to send N times query to these locations. To solve this issue, we have to organise mapping database properly.

Each patient can not in same hospital in one time. It is possible to record a period with one location. The period means the time from begin till to end. The time record should accurate to second. In mapping server database, there is a table to record patient personal information such as ID and username. The ID of table is the key data to connect other tables. The table of mapping attributes stores location IP address, port number, ID of patient and time period. In mapping time table, it stores begin and end time. When the client searches the mapping location, the correct location is with the attribute of time in this period.

- How to solve the machine connection reset exception

When we use the four-way structure, mapping server will send the location record back to client. The client needs to establish another socket communication with EHR monitor server. Meanwhile, it may arouse an exception named connection reset. This problem is endemic in socket communication. On the other hand, this exception could not be thrown, or the whole connection will be broken. However, there is a method to solve this issue. We could not use two socket connections together, but it is possible to close one connection before another start. Therefore, shut down socket connection and other stream ports before another communication begin is the best way to solve connection reset exception.

### 4.3.2 Implementation Description

The application on mapping server is implemented by Java, with socket, Graphic User Interface (GUI), and other related back-end coding. It is a visualized, executable program which listens to client, receives request and finds related location. Then it will send back the address in four-way structure and redirect request to EHR monitor in three-way structure. Fig. 4.3 is the screen shot of mapping server application. Realizing the importance of displaying message transmission process, there is a screen to display the information.

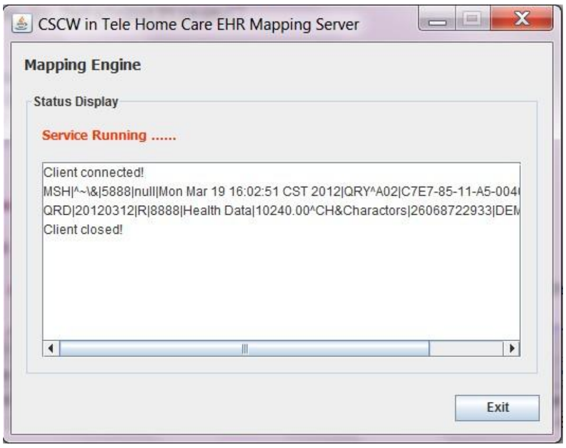


Figure 4.3: Screenshot of EHR mapping server application

The main class in this application is "MappingEngine.java". We suppose to give three-way structure application as an example. Because the principle between three-way and four-way is similar, so it is unnecessary to repeat it again. The mapping engine application uses thread to control entire service procedure. Two of the most important functions are "run ()" and "redirection ()". In the first function, it is the function that implements interface "Runnable". It listens to client request without break. Hence, the program should in an infinite loop. After acquire location address, it invokes the second function "redirection ()". The main code is presented below.

```
……
while(bConnected) {
        String str = dis.readUTF();
        System.out.println(str);
        display.setText(display.getText()+"\n"+str);
        String[] array = str.split("\\|");
        String source_IP = s.getInetAddress().toString().substring(1);
        String dir_IP = getMappingAddress(array[17]);
        int port = getPort(array[17]);
        record(source_IP, array[17], array[12], array[15]);
        redirection(str, dir_IP, port,source_IP);
        }
……
finally {
        try {
                if(dis != null) dis.close();
                if(s != null) s.close();
        } catch (IOException e1) {
                e1.printStackTrace();
        }
……
```

The variable "dis" is data input stream, it can invoke "readUTF ()" function to obtain request message. When a client sends a request message, the application parses it and gets location by using necessary element in message. Then mapping engine will record this message and redirect it to target machine. The main code of function "redirection ()" described as following content.

```
……
try {
        Socket socket = new Socket(target_address, target_port);
        OutputStream os = socket.getOutputStream();
        DataOutputStream dos = new DataOutputStream(os);
        String send = str+"|"+source_IP;
        dos.writeUTF(send);
        dos.close();
} catch (UnknownHostException e) {
        System.out.println("Error, can not find host");
} catch (IOException e) {
        System.out.println("Connect refused");
}
……
```

This function establishes a new socket communication to target machine, adds source client machine IP address and resends the request. Meanwhile, the application has relatively complete error control mechanism. The exceptions are from different fields such as could not find target machine and failed connect to target. According to this application, mapping server acts as a broker to clients. It provides record mappings service and acts as an essential part in distributed database system.

## 4.4 EHR Searching Application

The EHR searching service is provided by EHR searching monitor application. The largest bright spot in this application is the well organization of database. We import Hibernate technology, which is the most popular Java framework for data storage. It is free framework that is distributed under the Lesser General Public License.

Hibernate is an object-relational mapping library for the Java language, providing a framework for mapping an object-oriented domain model to a traditional relational database. It solves object-relational impedance mismatch problems by replacing direct persistence-related database accesses with high-level object handling functions. Hibernate primary feature is mapping from Java classes to database tables (and from Java data types to SQL data types). Hibernate also provides data query and retrieval facilities. Hibernate generates the SQL calls and attempts to relieve the developer from manual result set handling and object conversion and keep the application portable to all supported SQL databases with little performance overhead [30]. Hence, it can conveniently use Hibernate to query data and establish data model.

### 4.4.1 Functional Description

The EHR searching monitor is responsible for monitoring requests from mapping server or client directly. The principle of sending, receiving, parsing message is same with mapping server monitor, such as socket communication, thread and related classes. The difference is EHR searching monitor need to search specific record from database according to some important elements from query message. Therefore, we concentrate on how to organize the EHR model and how to send back the result to source location.

- How to organize the EHR model?

The Hibernate uses mapping to organize data model. Mapping Java classes to database tables is accomplished through the configuration of an XML file or by using Java Annotations. Java annotation is a special case in Java programming language, where annotations can be used as a special form of syntactic metadata in the source code. Classes, methods, variables, parameters and packages may be annotated. The annotations can be embedded in class file generated by the compiler and may be retained by the Java virtual machine and thus influence the run-time behaviour of an application.

In EHR model, one record contains several sub items such as health information data, patient support, results management and etc. Each sub item also includes several subjects. For instance, health information has key data, narrative, capture of identifiers and etc. Therefore, we may use the hibernate annotation to set different subjects to with relationships. Each attribute in class maps to one column in database. The key value which is used to associate other attributes adds an annotation tag named "OneToMany". Finally, EHR for each person becomes an entity which can conveniently managed by Hibernate.

- How to send result to client?

When mapping server redirects the request to EHR searching monitor, it will add the client IP address and port number to the tail of message. After receiving request message and acquiring records, EHR searching monitor will send the result to machine according to IP address and port number which attached on message tail.

### 4.4.2 Implementation Description

The application of EHR searching monitor is implemented by Java, with Hibernate and database. It is also a type of visualization, executable program, which monitoring to client or mapping server, receiving request and finding related record. Fig. 4.4 is the screenshot of EHR searching monitor. Similar to mapping server application, the screen displays the status and message in the services. Administrator can click the exit button to abort the application.

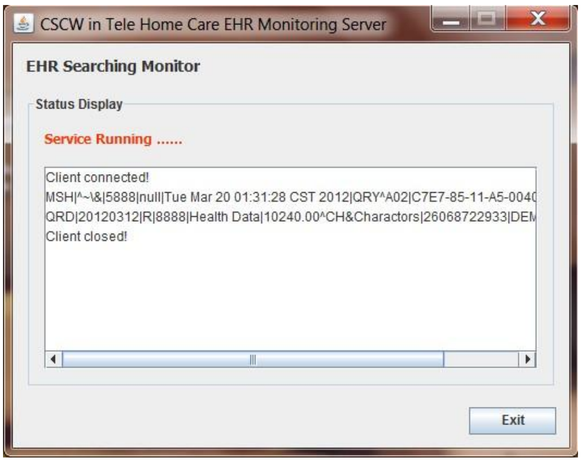


Figure 4.4: Screenshot of EHR searching monitor application

The main class of this application is “EHRMonitor.java”. The same as before, we use three-way structure as an example. The application listens to the request from mapping server. The communication methods are similar to mapping server. It also uses socket programming with read, write functions. The difference is that there is an extension function named “getResult ()” responsible for searching records. This function has with three variables such as personal ID, date and item. It related to another class named “EHRSearch.java”. This class is a core to the entire application. With corresponding attributes, it is able to acquire specific EHR and return to a string which is the result that client needs. The main code is presented below.

```
……
        String result = null;
        Session session = sf.openSession();
        session.beginTransaction();
        Query q = session.createQuery("select resultsReporting from ResultsReporting
resultsReporting where resultsReporting.resultsManagement.ehr.patient.personalID=? and
resultsReporting.resultsManagement.ehr.date = ?");
        q.setString(0, PID);
        q.setString(1, date);
        List<ResultsReporting> list = (List<ResultsReporting>)q.list();

        for(ResultsReporting resultsReporting:list) {
                result = resultsReporting.getLaboratory();
                System.out.println(resultsReporting.getLaboratory());
                break;
        }
        session.getTransaction().commit();
        session.close();
……
```

Session is a special class in Hibernate. It is intelligent with storing and fetching object entity. The long string after the code “session.createQuery” is a HQL command. It guides the session to get the result from database. After result obtained, it will be stored into a container “List”. Then it returns the result to EHR searching monitor. The monitor sends back result to source client finally. Some of the important code of EHR searching monitor will be attached in Appendix C.

## 4.5 Database Design

Database design is the process of producing a detailed data model of a database. The process of doing a database design generally consists of a number of steps which will be carried out by designer. This process has two steps. First of all, it is to determine the relationship between the different data elements. Second is to superimpose a logical structure upon the data on the basis of these relationships [31]. In this system, we suppose to use Enhanced Entity-Relationship (EER) Model to describe the database design. In computer science, the EER model is the high level or conceptual data model incorporating to original Entity-Relationship (ER) models and ER diagrams.

Mapping server application contains three significant model elements such as patient, mapping attributes and mapping time. The model of patient is the main subject in this ER models. It is specified by key value id and patient personal ID. It related to more than one mapping attributes and mapping time. In mapping attributes, it includes mapping address, mapping port number and mapping time. The column patient id is the mark to model patient. The mapping time is related to a time zone which patient live in hospital or clinics. It used to avoid different records in different locations. Fig. 4.5 shows the ER diagram of mapping database design. The line with circle and triangle in each side presents one to more relationship. For instance, one patient may have many mapping attributes and mapping time. Each mapping time may relate to many mapping attributes.

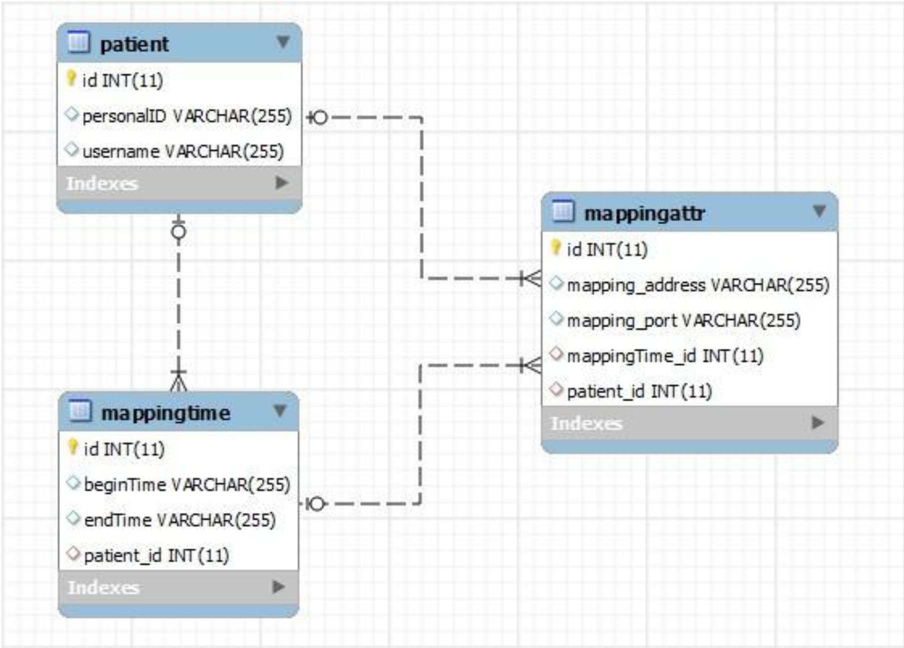


Figure 4.5: Mapping application database design ER diagram

On the other hand, the database EHR design is the most essential part in this system. EHR model consists by approximately 35 sub models. Each sub model has its own key value and attributes. In this part, we use decision support which is a sub item of EHR as an example. A patient model is an entity. An entity may be defined as an object which is recognized as being capable of an independent existence and which can be uniquely identified. An entity is an abstraction from the complexities of some domain. When we speak of an entity we normally speak of some aspect of the real world which can be distinguished from other aspects of the real life [32]. The main code of class “DecisionSupport.java” is presented as below.

```
……
@Entity
public class DecisionSupport {
        private int id;
        private String otherRule_BaseAlerts;
……
        private String useOfEpidemiologicData;
        private EHR ehr;
        @Id
        @GeneratedValue
        public int getId() {
                return id;
        }
        public void setId(int id) {
```

```
                this.id = id;
        }
……
        public void setUseOfEpidemiologicData(String useOfEpidemiologicData) {
                this.useOfEpidemiologicData = useOfEpidemiologicData;
        }

        @ManyToOne(fetch=FetchType.EAGER)
        public EHR getEhr() {
                return ehr;
        }
        public void setEhr(EHR ehr) {
                this.ehr = ehr;
        }
}
……
```

In the code, there is a note which is “@Entity” on the top of class. That is the annotation note in Hibernate. It presents this class is an entity. In this class, it includes several attributes such as id, other rules and etc. It also contains an EHR entity as a private attribute. In the following code, there are two notes which are “@id” and “@GeneratedValue”. That means the attribute id is the unique key value of this entity. Finally, at the end of function getter and setter, the note “@ManyToOne” presents EHR entity has many entity of decision support. Besides, after “@ManyToOne” note, there is a fetch type note. The fetch type is eager. That means, when system fetch an entity from database, all the attributes of this entity will be selected.

There is another problem that how to organize these entities. In Hibernate, a configuration xml file named “hibernate.cfg.xml” is used for operating entities. We use decision support entity again. In this xml file, it includes the function of communicating with database and data mapping mechanism. In decision support part, it has a mapping related to all the entities which has relationship with decision support entity. The code below clearly displays the mapping mechanism of decision support entity.

```
……
<!-- 4. Decision Support -->
        <mapping class="no.uia.ehr.ds.DecisionSupport"/>
        <mapping class="no.uia.ehr.ds.entity.AccessToKnowledgeSources"/>
        <mapping class="no.uia.ehr.ds.entity.AutomatedReal_TimeSurveillance"/>
        <mapping class="no.uia.ehr.ds.entity.ClinicalGuidelinesAndPathways"/>
        <mapping class="no.uia.ehr.ds.entity.DrugAlerts"/>
……
```

After checking the code, we use an ER diagram to show the relationship of decision support entity and its related entities. Fig. 4.6 describes the ER diagram of it. One patient can has many EHR records. An EHR can have several decision support records. Each decision support model can have different sub items such as drug alerts, access knowledge sources and etc. The relationship to these sub items is one-to-many.

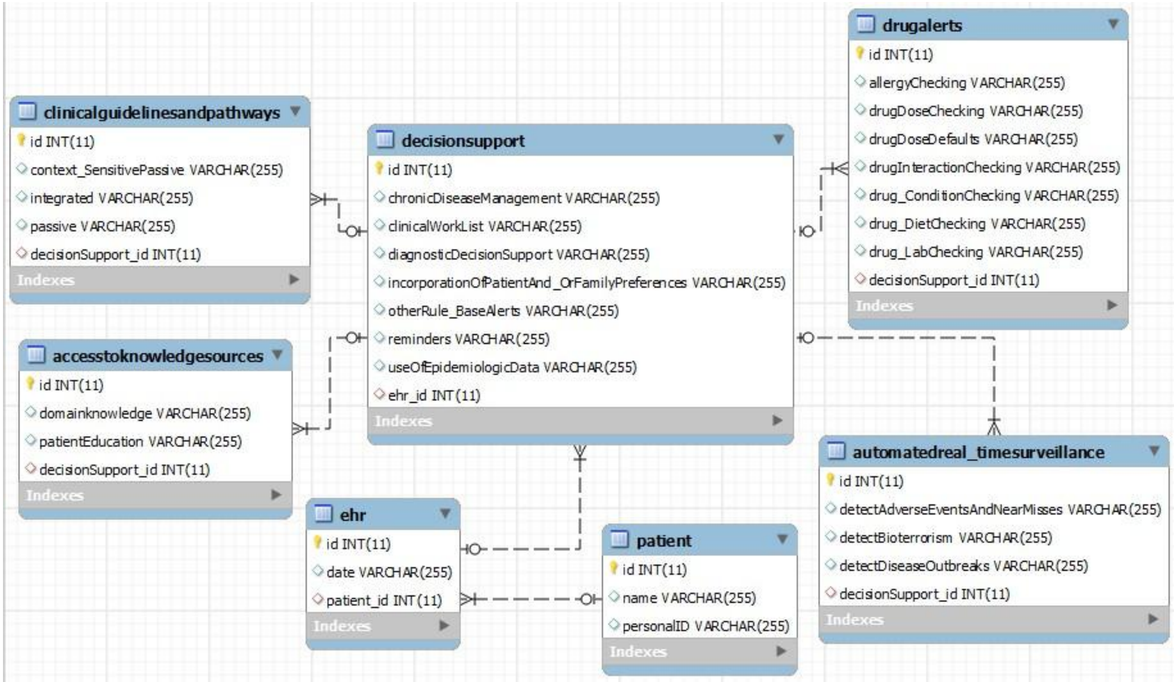


Figure 4.6: Decision support entity ER diagram

This is an instance of EHR entities. There are 8 main entities of EHR. Each main entity has several sub entities. According to Hibernate and Java program, it could produce that table in database automatically. It is easily to check relationships among different entities. In addition, database schema “ehr” is the data container of EHR searching monitor application. Schema “map” is the data container of mapping server application. Once the relationships and dependencies amongst the various pieces of information have been determined, it is possible to arrange the data into a logical structure which can then be mapped into the storage objects supported by the system. It is certain that this database design is efficiency, clear and flexible. Developers can do modification on it conveniently in the further system development in this system architecture.

## 4.6 System Validation Test

System validation test is an essential step after the system prototype implementation. It is an investigation conducted to provide stakeholders with information about the quality of the product or service under test. It can also provide an objective, independent view of the software to allow the business to appreciate and understand the risks of software implementation. Test techniques include, but are not limited to, the process of executing a program or application with the intent of finding software bugs (errors or other defects). There are several testing methods can be selected in this project. Software testing methods are traditionally divided into white- and black-box testing. These two approaches are used to describe the point of view that a test engineer takes when designing test cases [33]. In this project, it will use black-box testing on workspace.

Black-box testing treats the software as a "black box"—without any knowledge of internal implementation. This method of test can be applied to all levels of software testing: unit, integration, system and acceptance. It typically comprises most if not all testing at higher levels, but can also dominate unit testing as well [34]. In this project, the validation test section will treat the workspace as a black box. With corresponding input and output, the system validation test will check whether the system can work in right executing processes and if there are system bugs existing.

For this system, the validation tests are conducted as two-way, three-way and four-way message processing. In different types of tests, a query message is send to validate if the client can receive the right record result. The query message from client is sent to search a record with specific personal ID, date and item from EHR database. The specific test process and test results are showing in Table 4.1. The test sends the same query message. The massage queries the record which related personal ID is “26068722933”. The date is “20120314” and item is “key data”. The main purpose of this test is to verify whether the each function of this system works properly. According to this table, it is easy to see the validation test result of the system. Finally, we can see that all types of system can work properly. Next step, it is able to use these systems to do the evaluation experiment.

Table 4.1: System validation test result

<table>
<tr><th></th><th>Two-way Structure</th><th>Three-way Structure</th><th>Four-way Structure</th></tr>
<tr><td>Validation Query Message</td><td colspan="3">MSH|^~\&|5888|127.0.0.1|Sat Mar 24 23:00:24 CST 2012|QRY^A02|C7E7-85-11-A5-004005|P|2.3|AL|NE|<br>QRD|20120314|R|8888|Key Data|10240.00^CH&Charactors|26068722933|DEM</td></tr>
<tr><td>Client Connect</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Mapping Server Received</td><td>None</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Mapping Server Redirection</td><td>None</td><td colspan="2">MSH|^~\&|5888|127.0.0.1|Sat Mar 24 23:06:12 CST 2012|QRY^A02|C7E7-85-11-A5-004005|P|2.3|AL|NE|<br>QRD|20120312|R|8888|Key Data|10240.00^CH&Charactors|26068722933|DEM|127.0.0.1</td></tr>
<tr><td>EHR Monitor Message send</td><td colspan="3">MSH|^~\&|8888|127.0.0.1|Sat Mar 24 23:06:31 CST 2012|ACK^A02|C7E7-85-11-A5-004005|P|2.3|AL|NE|<br>MSA|AA|record</td></tr>
<tr><td>Result Received</td><td>Yes</td><td>Yes</td><td>Yes</td></tr>
<tr><td>Result</td><td>record</td><td>record</td><td>record</td></tr>
<tr><td>Test Result</td><td>Correct</td><td>Correct</td><td>Correct</td></tr>
</table>

# Chapter 5

# Performance Evaluations

In software engineering, performance testing is a general testing performed to judge whether the system performs in terms of responsive under particular workload. It can be comprehend as an investigation or validation system attributes, such as flexibility, scalability and resource usage. In this chapter, the performance evaluation is based on a load test which is one of software performance testing type. Load testing is the simplest form of performance testing. The load can be expected concurrent data transmitting within different set duration. This test will give out the response time in distinct data configuration and structure. This part has two sections. First, there will be a methodology description of this evaluation, such as experiment tools, environment and rules. Then it will give the consequence of test by using tables and curve diagrams.

## 5.1 Test Methodology

System performance in this CSCW architecture depends on the time consumption of EHR searching from specific database. The CSCW will be configured into a real network environment. There are three machines which performed as searching client, mapping server and EHR server. Searching client is response to send query message to acquire a specific record from EHR database. Mapping server is the machine which used for storing data mapping location. EHR server is the records source. An assumption of performance evaluation is given in test and hypothesis section. As illustrated above, the test executed in this environment by collecting time measurement of sending real query message in different system structure. There is an inner timer in this system to calculate the time from message send out to result get back. That means the time includes system operating time, network transmitting time and data searching time. Hence, machine property and network statues largely determine the system performance.

In order to enhance the accuracy of test result, this evaluation should be restricted by several standardized rules in environment and hardware:

- The entire evaluation processing should in one test environment.
- Each record query message should be same.
- To solve the problem of micro difference in time measurement, we suppose to use nano time.
- The evaluation will obey the measurement standard.

The following photo shows the evaluation environment. Machines in photo from left to right are EHR record server, mapping server and searching client. These machines are connected in a Local

Area Network (LAN), which linked by a switch. That means we treat the network statues is in best condition. The machines operating system is Microsoft Windows 7.

Figure 5.1: Evaluation environment

The specific configuration on these three machines is in the following tables. The attributes are IP address, subnet mask, default gateway, port number.

Table 5.1: Evaluation test machine configuration

| | **Searching client** | **Mapping server** | **EHR record server** |
|---|---|---|---|
| **IP Address** | 172.25.35.15 | 172.25.5.15 | 172.25.25.15 |
| **Subnet Mask** | 255.255.0.0 | 255.255.0.0 | 255.255.0.0 |
| **Default gateway** | 172.25.35.1 | 172.25.5.1 | 172.25.25.1 |
| **Port number** | 8888 | 5888 | 7777 |

In order to make the evaluation with more standardization, it is necessary to make a rule for experiment. We suppose to make several parameters for the test. N is the most important parameter which presents EHR data quantity in two-way database (data central). N' is data quantity in three and four-way structure. P presents the number of patients. In distributed database structure, the number of database is k. The parameter d means average record of each patient. The formula presents the relationship of N, N’ and P is:

$$d=N/P$$
$$N'=N/k$$

There will be two evaluation tests with dynamic parameters d and k. The first test concerns on dynamic increasing of EHR records. Second one is with dynamic k. P is a static parameter in these two test which equals to 1000. The following table presents the strategy of performance evaluation. The target is to measure the time of query a record process. After comparing the time, it is able to summarize the system performance. Meanwhile, each item in two tests will be measured to 20 times. The result is obtained after removing unreasonable outcome and calculating average consequence.

Table 5.2: Performance evaluation strategy

| | | | | |
|---|---|---|---|---|
| N = Data quantity of storage<br>N’ = Data quantity in distributed database<br>P = Number of patient<br>k = Number of database<br>d = Average record of each patient | | | N’ = N/k<br>d = N/P | |
| **Test 1** | | | k = 10, △ d = 5 | |
| d = 1 | d = 5 | d = 10 | …… | d = 50 |
| N = 1000 | N = 5000 | N = 10000 | …… | N = 50000 |
| P = 1000 | P = 1000 | P = 1000 | …… | P = 1000 |
| N’ = 100 | N’ = 500 | N’ = 1000 | …… | N’ = 5000 |
| **Test 2** | | | k = 25, △ d = 5 | |
| d = 1 | d = 5 | d = 10 | …… | d = 50 |
| N = 1000 | N = 5000 | N = 10000 | …… | N = 50000 |
| P = 1000 | P = 1000 | P = 1000 | …… | P = 1000 |
| N’ = 40 | N’ = 200 | N’ = 400 | …… | N’ = 2000 |
| **Test 3** | | | k = 50, △ d = 5 | |
| d = 1 | d = 5 | d = 10 | …… | d = 50 |

| | | | | |
|---|---|---|---|---|
| N = 1000 | N = 5000 | N = 10000 | …… | N = 50000 |
| P = 1000 | P = 1000 | P = 1000 | …… | P = 1000 |
| N’ = 20 | N’ = 100 | N’ = 200 | …… | N’ = 1000 |
| **Test 4** | | k = 75, △ d = 5 | | |
| d = 1 | d = 5 | d = 10 | …… | d = 50 |
| N = 1000 | N = 5000 | N = 10000 | …… | N = 50000 |
| P = 1000 | P = 1000 | P = 1000 | …… | P = 1000 |
| N’ = 13 | N’ = 66 | N’ = 133 | …… | N’ = 666 |
| **Test 5** | | k = 100, △ d = 5 | | |
| d = 1 | d = 5 | d = 10 | …… | d = 50 |
| N = 1000 | N = 5000 | N = 10000 | …… | N = 50000 |
| P = 1000 | P = 1000 | P = 1000 | …… | P = 1000 |
| N’ = 10 | N’ = 50 | N’ = 100 | …… | N’ = 500 |

The following figures are sequence diagrams. The diagrams present different message flow in different evaluation structures. Fig. 5.2 is the two-way structure experiment. The client sends a query message with personal id, date time and specific record item to EHR server. Then, after searching from database, the server will send the result back. This is the basic message flow in data central topology. Fig. 5.3 presents three-way structure message flow. Client will forward a query message with same parameters as two-way to mapping server. Mapping server will define the location of record and redirect the query to EHR server. Finally, EHR server dispatches the result back to client. Fig. 5.4 shows the message flow of four-way structure. Client sends the query to mapping server. Mapping server will respond with location IP address and port number. The client will send the query message again to new location of EHR server. The server will transmit back result at the end.

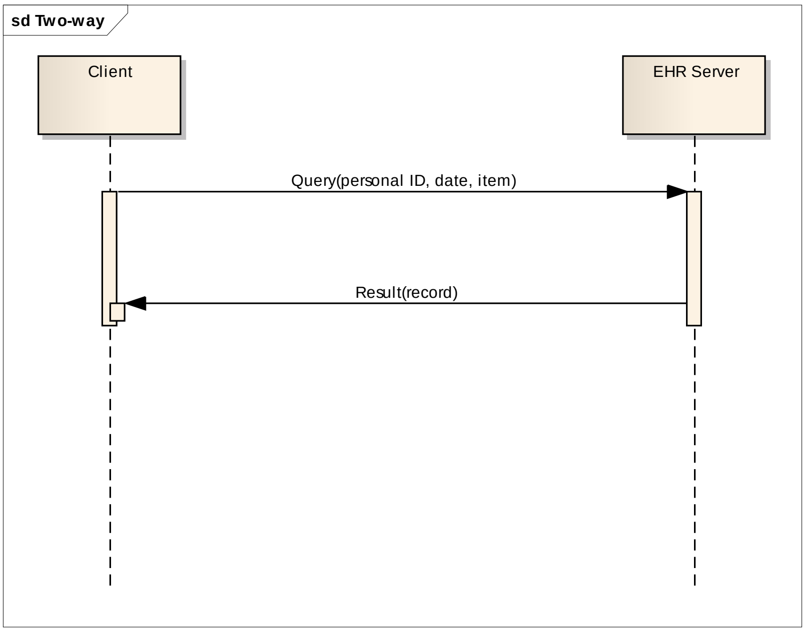


Figure 5.2: Two-way structure message flow

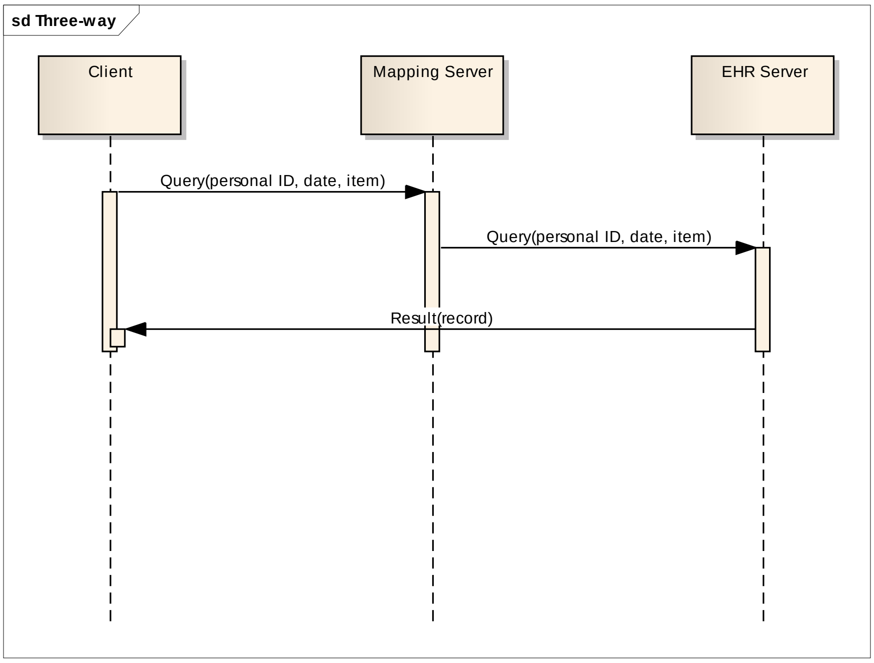


Figure 5.3: Three-way structure message flow

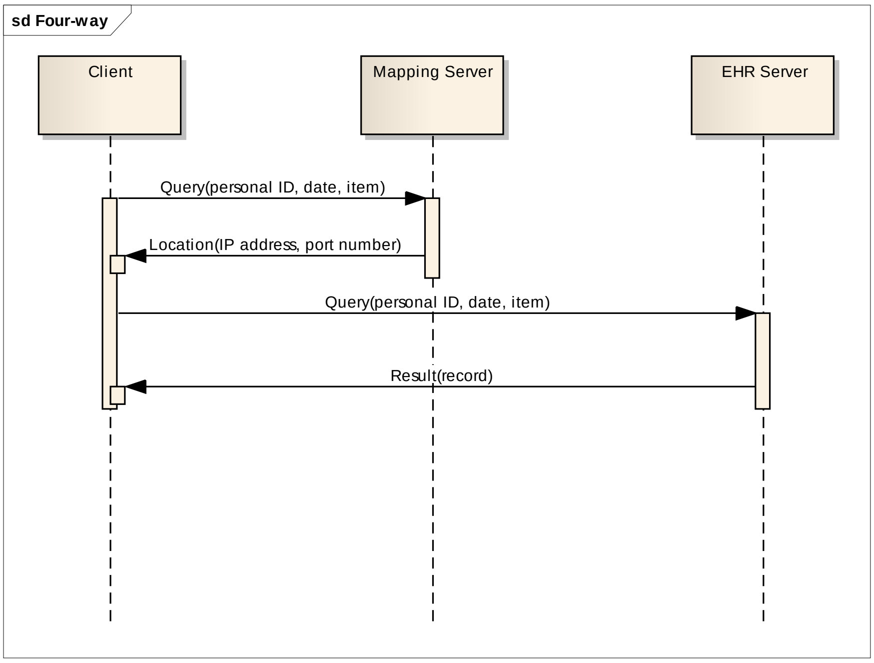


Figure 5.4: Four-way structure message flow

Each test includes the experiments on data central structure, three-way distributed structure and four-way distributed structure. The aim of this evaluation is to confirm that distributed database based CSCW is more flexible and efficiency than database centralized one. After the time measurement, it is able to draw a curve diagram to show the performance intuitively.

## 5.2 Evaluation Configuration

In this section, it will describe about evaluation hardware configuration. Machine setting and configuration will highly affect evaluation result during experiment. For instance, the time of processing of a server machine with 1G physical memory will more than 2G machines. The factors that will affect evaluation are CPU, physical memory, network traffic, operating system, system model and etc. What we should concern is to conduct the experiment in the same situation. Fig. 5.5 shows the connection of machines. The switch is connected by searching client, mapping server and EHR server. The three machines can communicated with each other. That means each machine can send and receive message.

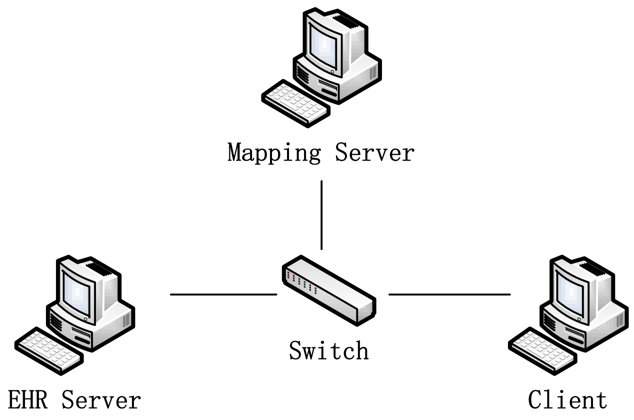


Figure 5.5: Evaluation configuration

Table 5.3 shows the specific configuration of three machines.

Table 5.3: Specific machine configuration

| | **Client** | **Mapping Server** | **EHR Server** |
|---|---|---|---|
| **Operating system** | Windows 7 Professional 32-bit (6.1, Build 7601) | Windows 7 Professional 32-bit (6.1, Build 7601) | Windows 7 Professional 32-bit (6.1, Build 7601) |
| **System manufacturer** | Hewlett-Packard | Dell Inc. | Hewlett-Packard |
| **System model** | HP Compaq dc 7600 Convertible Minitower | Precision WorkStation 390 | HP Compaq dc 7600 Convertible Minitower |
| **BIOS** | Hewlett-Packard 786 D1 Vo1.03 | Phoenix ROM BIOS PLUS Version 1.10 2.3.0 | Default System OS |
| **Processor** | Intel (R) Pentium (R) 4 CPU 3.00 Hz, 3000Mhz 1 Core(s), 2 Logical Processors | Intel (R) Core (TM) 2 CPU 6600@ 2.4GHz (2 CPUs) ~ 2.4GHz | Intel (R) Pentium (R) 4 CPU 3.00 Hz, 3000Mhz 1 Core(s), 2 Logical Processors |
| **Memory** | 1024M RAM | 2048M RAM | 1024M RAM |

Different configuration will lead to distinct experiment results. Across this research, three of curve diagram can be indicated by experiment results. The limitation of the evaluation is that EHRs in database are virtual records, network environment is smooth and machines are normal machines. However, the main tendency and curve direction will not be affected. The evaluation results and curve diagrams will be given in next section.

## 5.3 Experimental Result

By following the strategy illustrated above, the experiment can be executed on different structure systems. That means distinct experiment environment will lead different evaluation results. The test is separated into three sections, such as k = 10, 25, 50, 75 and 100. During distinct parameter configurations, it is able to obtain three result forms. The field in each form is the average value. This section will discuss about each test, with combination of test result and related curve diagram.

The first test is with the 10 distributed databases environment experiment. This test also involves two, three and four-way structure results. With experimental operation in each environment, the table 5.4 shows the result of first test. According to the result table, the curve shows in Fig. 5.6. From the curve, it is obvious that two-way structure cost less time than others at the beginning. With the increase of information storage, the time grows exponentially, but other two are slowly. Four-way structure always have one more network transmitting than three-way. Hence, the time consumption is more than three-way in same situation. Another character in this curve is the cross point of the curves. When the information is around 10000, the distributed database system is better than data centralized structure. Meanwhile, we should notice that, different results come from distinct experiment environment. Therefore, it is worth to consider about real network environment when you are choosing whether use distributed system or not.

Table 5.4: Evaluation result (k=10)

| **Evaluation 1** | | | |
|---|---|---|---|
| | **Two-way (ns)** | **Three-way (ns)** | **Four-way (ns)** |
| **d=1, N=1000, N'=100** | 1017768827 | 1064848499 | 1154750567 |
| **d=5, N=5000, N'=500** | 1099370617 | 1142242886 | 1210724892 |
| **d=10, N=10000, N'=1000** | 1262324784 | 1160167447 | 1215710733 |
| **d=15, N=15000, N'=1500** | 1342939568 | 1188746759 | 1225206054 |
| **d=20, N=20000, N'=2000** | 1473262498 | 1209464863 | 1241016932 |
| **d=25, N=25000, N'=2500** | 1572973830 | 1235285740 | 1242221250 |
| **d=30, N=30000, N'=3000** | 1997668942 | 1240718986 | 1247956256 |

| | | | |
|---|---|---|---|
| **d=35, N=35000, N'=3500** | 2212080357 | 1248974088 | 1257259256 |
| **d=40, N=40000, N'=4000** | 2594611151 | 1253392557 | 1265619599 |
| **d=45, N=45000, N'=4500** | 2725499804 | 1266412916 | 1306225385 |
| **d=50, N=50000, N'=5000** | 2942513689 | 1274626610 | 1322977967 |

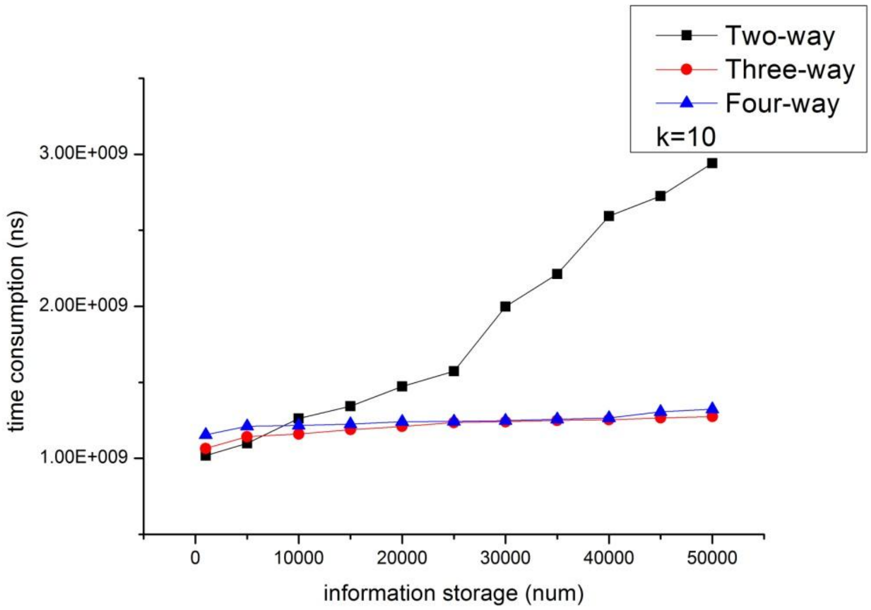


Figure 5.6: Evaluation result curve (k=10)

Table 5.5 describes the test result with 25 distributed databases based structure. The two-way curve is same compare to the first test. The differences are in other two curves. With the increase of database, less information will be stored in each container. The three and four-way curve will increase more slowly than before. This conclusion shows that, the quantity of database can affect distributed system performance. More data containers will reflect three and four-way structure advantages. Fig. 5.7 is the curve diagram of this test.

Table 5.5: Evaluation result (k=25)

| **Evaluation 2** | | | |
|---|---|---|---|
| | **Two-way (ns)** | **Three-way (ns)** | **Four-way (ns)** |
| **d=1, N=1000, N'=20** | 1017768827 | 1018033207 | 1066904133 |
| **d=5, N=5000, N'=100** | 1099370617 | 1099268003 | 1082658279 |

| | | | |
|---|---|---|---|
| **d=10, N=10000, N'=200** | 1262324784 | 1125839582 | 1142536837 |
| **d=15, N=15000, N'=300** | 1342939568 | 1158676353 | 1218718781 |
| **d=20, N=20000, N'=400** | 1473262498 | 1170232642 | 1188315910 |
| **d=25, N=25000, N'=500** | 1572973830 | 1160167447 | 1215710733 |
| **d=30, N=30000, N'=600** | 1997668942 | 1170961339 | 1221068426 |
| **d=35, N=35000, N'=700** | 2212080357 | 1189771011 | 1234923120 |
| **d=40, N=40000, N'=800** | 2594611151 | 1199647899 | 1228163277 |
| **d=45, N=45000, N'=900** | 2725499804 | 1194534336 | 1237529755 |
| **d=50, N=50000, N'=1000** | 2942513689 | 1209464863 | 1241016932 |

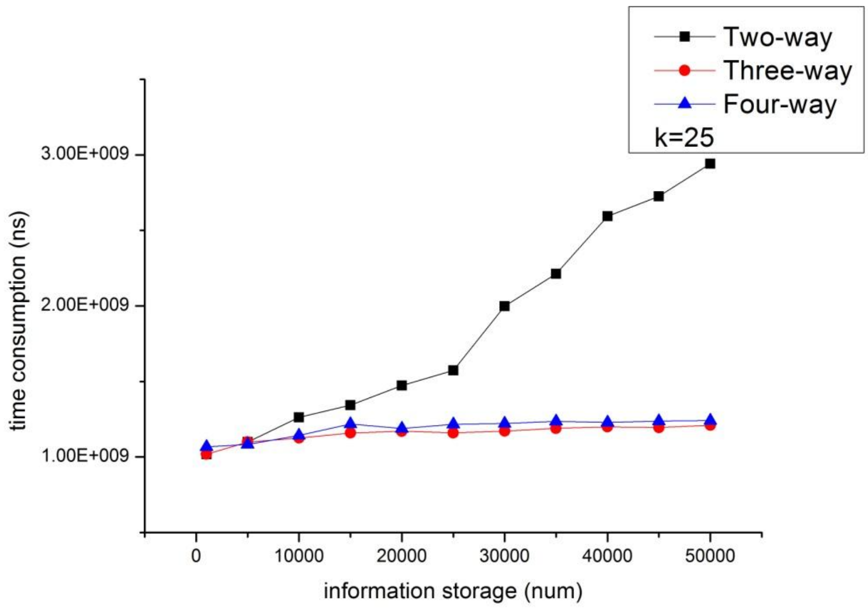


Figure 5.7: Evaluation result curve (k=25)

The third test is the 50 database based environment experiment. The same test principle as before, we measure the time consumption among these three system structures. Table 5.6 shows the average result of this test. It is clear that, with more databases, the distributed system will have better performance. Besides, with the increase of the information, the curves tend to stabilized if more databases are set into the system. Fig. 5.8 shows the curve in this evaluation.

Table 5.6: Evaluation result (k=50)

| **Evaluation 3** | | | |
|---|---|---|---|
| | **Two-way (ns)** | **Three-way (ns)** | **Four-way (ns)** |
| **d=1, N=1000, N'=20** | 1017768827 | 1034147454 | 1043429808 |
| **d=5, N=5000, N'=100** | 1099370617 | 1064848499 | 1077360276 |
| **d=10, N=10000, N'=200** | 1262324784 | 1099268003 | 1082658279 |
| **d=15, N=15000, N'=300** | 1342939568 | 1111096250 | 1120724469 |
| **d=20, N=20000, N'=400** | 1473262498 | 1125839582 | 1142536837 |
| **d=25, N=25000, N'=500** | 1572973830 | 1142242886 | 1210724892 |
| **d=30, N=30000, N'=600** | 1997668942 | 1158676353 | 1218718781 |
| **d=35, N=35000, N'=700** | 2212080357 | 1160954082 | 1209492980 |
| **d=40, N=40000, N'=800** | 2594611151 | 1170232642 | 1188315910 |
| **d=45, N=45000, N'=900** | 2725499804 | 1174837134 | 1196745567 |
| **d=50, N=50000, N'=1000** | 2942513689 | 1160167447 | 1215710733 |

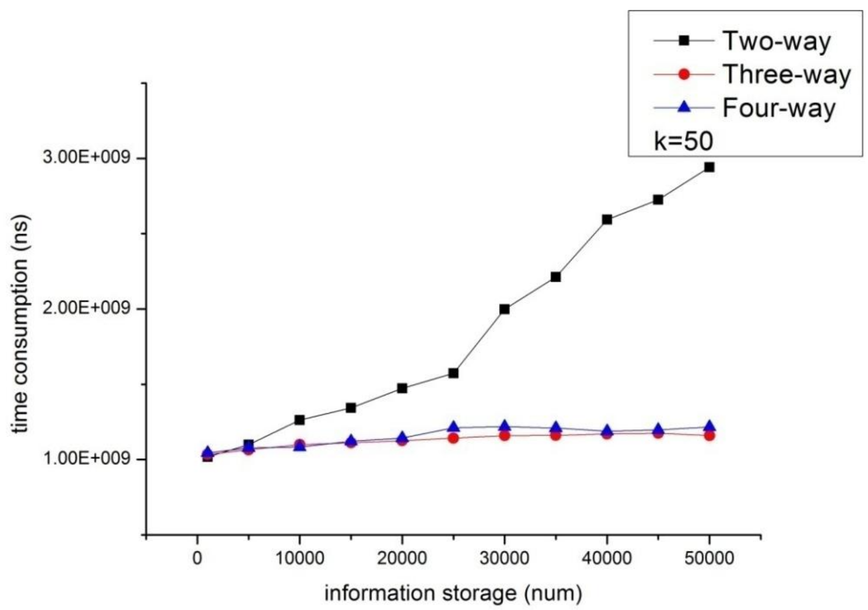


Figure 5.8: Evaluation result curve (k=50)

The following evaluation is on 75 databases based distributed system. We use the same measurement method as before. It is able to obtain two lower time cost curve than before. The search times are close even the information increase doubling. Table 5.7 shows the average result of this test. Fig. 5.9 presents the curve diagram.

Table 5.7: Evaluation result (k=75)

| **Evaluation 4** | | | |
|---|---|---|---|
| | **Two-way (ns)** | **Three-way (ns)** | **Four-way (ns)** |
| **d=1, N=1000, N'=20** | 1017768827 | 1030198904 | 1056891299 |
| **d=5, N=5000, N'=100** | 1099370617 | 1051280646 | 1068425244 |
| **d=10, N=10000, N'=200** | 1262324784 | 1074814452 | 1081972213 |
| **d=15, N=15000, N'=300** | 1342939568 | 1099268003 | 1082658279 |
| **d=20, N=20000, N'=400** | 1473262498 | 1100452393 | 1125526403 |
| **d=25, N=25000, N'=500** | 1572973830 | 1115193406 | 1132403796 |
| **d=30, N=30000, N'=600** | 1997668942 | 1125839582 | 1142536837 |
| **d=35, N=35000, N'=700** | 2212080357 | 1142011812 | 1167130288 |
| **d=40, N=40000, N'=800** | 2594611151 | 1142351044 | 1186797942 |
| **d=45, N=45000, N'=900** | 2725499804 | 1158676353 | 1218718781 |
| **d=50, N=50000, N'=1000** | 2942513689 | 1183313465 | 1238515512 |

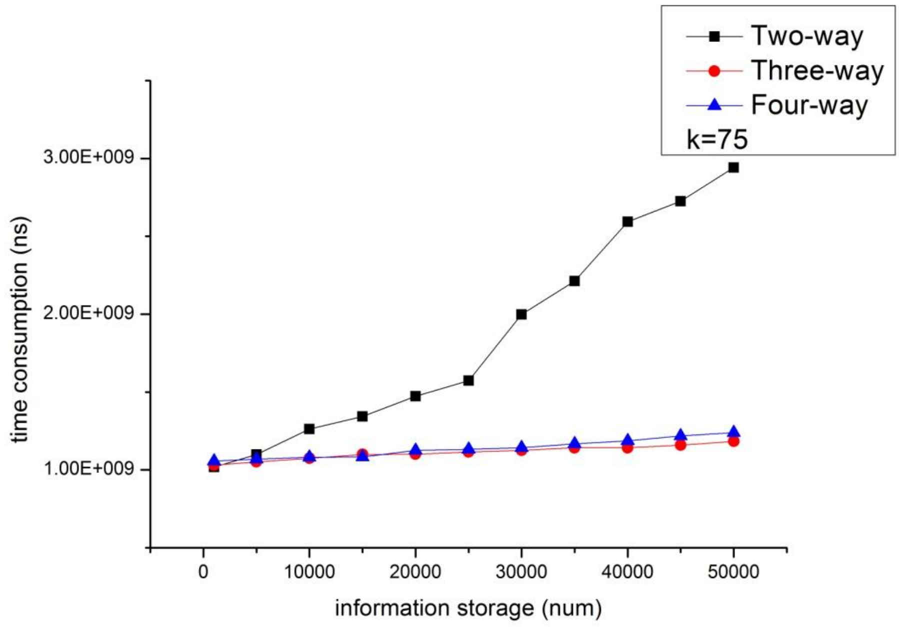


Figure 5.9: Evaluation result curve (k=75)

The last experiment is the test of k equals to 100. The following results and curve indicated that more databases will lead a better performance. The time cost even lower and tend to flat. Meanwhile, after five different evaluation tests, we can conclude several advantages of distributed database system. Table 5.8 shows the test result and Fig. 5.10 is the curve diagram related to the results.

Table 5.8: Evaluation result (k=100)

| **Evaluation 5** | | | |
|---|---|---|---|
| | **Two-way (ns)** | **Three-way (ns)** | **Four-way (ns)** |
| **d=1, N=1000, N'=20** | 1017768827 | 1030198904 | 1056891299 |
| **d=5, N=5000, N'=100** | 1099370617 | 1051280646 | 1068425244 |
| **d=10, N=10000, N'=200** | 1262324784 | 1074814452 | 1081972213 |
| **d=15, N=15000, N'=300** | 1342939568 | 1099268003 | 1082658279 |
| **d=20, N=20000, N'=400** | 1473262498 | 1100452393 | 1125526403 |
| **d=25, N=25000, N'=500** | 1572973830 | 1115193406 | 1132403796 |
| **d=30, N=30000, N'=600** | 1997668942 | 1125839582 | 1142536837 |
| **d=35, N=35000, N'=700** | 2212080357 | 1142011812 | 1167130288 |

| | | | |
|---|---|---|---|
| **d=40, N=40000, N'=800** | 2594611151 | 1142351044 | 1186797942 |
| **d=45, N=45000, N'=900** | 2725499804 | 1158676353 | 1218718781 |
| **d=50, N=50000, N'=1000** | 2942513689 | 1183313465 | 1238515512 |

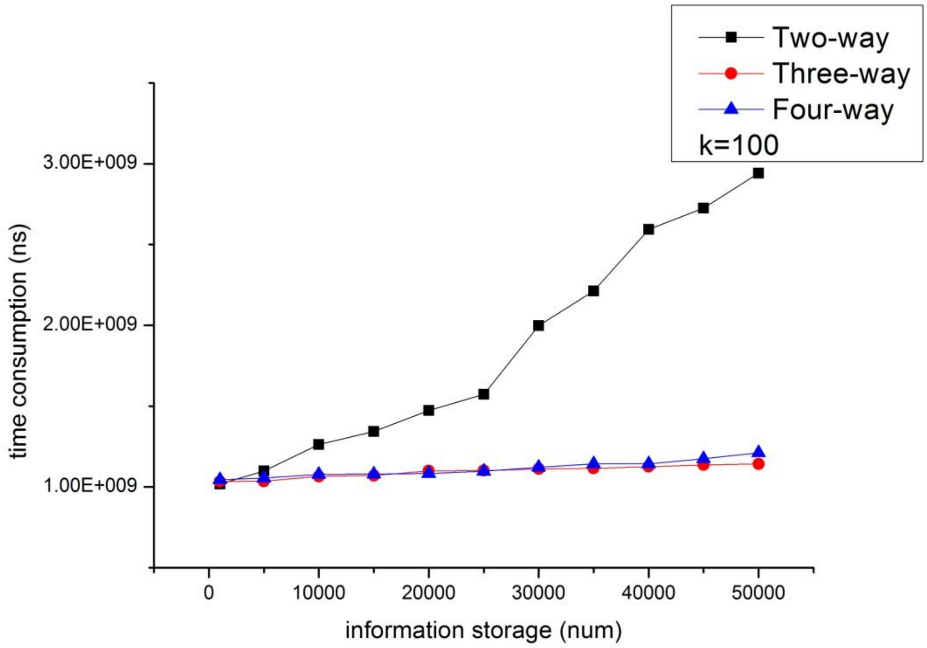


Figure 5.10: Evaluation result curve (k=75)

From the result tables and curves, it is obviously that with the increase of information, record search time will also grow. With more and more databases add into system, distributed database system will lead lower search time consumption and better performance. The time consumption will in the sections of machine processing, network traffic and database searching. The most time-consuming item is the record database searching.

# Chapter 6

# Discussions

## 6.1 Comparison between Proposed System and Previous Works

Different with previous scenarios, the proposed CSCW design provides an efficient medical information transmission procedure. This scenario adds the conceptions of distributed databases, distributed server and advanced database organization. Besides, service-oriented bus and body sensor networks are the attached items to this architecture. Compare with previous design or products, this system is more flexible and efficient. It also includes some characteristics such as web-based systems, based on RTMP video stream transmitting protocol and HL7 health message standard.

Reviewing from existing healthcare research works within CSCW section, the products focus on one or some of themes which illustrated above. The previous studies concern more about the field of healthcare. However, the system should be a role of CSCW in understanding the patient-hospital relationships. It should not only concern about functional support but even more comprehensive. That means it can concentrate on communications, remote diagnosis or documentation and etc. Therefore, new scenarios should largely focus on relationship between systems and users.

The proposed CSCW system is a web-based collaborative workspace. The common basis for communication is important in any collaborative systems. All of the patients and end-users prefer the ideas of remote communication and sharing data, documents with clinicians. The proposed solution has been solved these problems. The users only need a browser and a flash player for applying the services of this system. In addition, the solution also concerns on the system performance, flexibility and reliability. Distributed database systems for EHR storage can reduce the congestions occur due to centralized databases. Distributed server structure is the way to avoid server crashes when the network is crowded by more clients. After the evaluations, it is obvious that the proposed scenario will show its preferable strength with the increasing of healthcare records over healthcare domains.

## 6.2 The Restriction of Deployment in Real Environment

Distributed database and server systems will surely arouse some potential problems. To understand the challenges to use of proposed system in real environment, it is necessary to discuss about the restrictions in design, implementation, evaluation and deployment. They are the key points that should be concerned in the future works. In this section, it will illustrate some of the issues during development procedures.

Balancing an appropriate amount of functionality with simplicity of use can be a challenge for any interactive collaboration system but particularly arises in systems that have highly varied users [35]. Therefore, the functionality in design of CSCW should cover a much larger scope. Despite this scenario has been included sufficient functions, but it also could be expanded. For example, it can add more privacy and security diagnosis, audio communication and etc.

In implementation part, it is worth to notice that the system is a prototype. A prototype is an early sample or model built to test a concept or process or to act as a thing to be replicated or learned from. Most of important functions have been accomplished. Some details and flaws may exist. However, the proposed system is a platform that can be used for experimenting and testing. Besides, other developers can implement a similar healthcare service system by improving this prototype or design their own systems by using this system directly.

In addition, the CSCW architecture in this project is based on web. It is a RIA application based on Browser/Server architecture. It means the system can be deployed in smart house, patient private house, clinics or hospitals. By using the web, users can easily log into a browser and use the system without installing any plugin into their own computer. During the system design procedures, developer should consider all the situations that the system may face to. Hence, there are some restrictions during the implementation and data collecting processes. The following context illustrates the restrictions of this system in this project.

- The workspace will be implemented as a prototype. Some of the functions will be not realized. The aim of this project is to have a prototype design and implementation, and presents a better scenario to architecture design.

- The system test data will not from real users, because of some restrictions. The testing data are generated by the developer by using a loop program.

- The flash based application has problems running on iPad-1. But it is supported by higher version of iPad. It is also possible to use other technologies to implement the workspace. Because the specific design is the most important key to software.

Evaluation part in this project acts as a comparison between data central system and distributed data system architecture. The database structure follows EHR functional model. Records in the database are generated by loop programs. This means that there is not real experimental data in this evaluation, but virtual records. However, the reality of the records is not the key to the database. Therefore it is not critical even though the experimental data is inserted.

# Chapter 7

# Conclusions and Future Prospect

## 7.1 Conclusions

In conclusion, we have described the CSCW in tele home care architecture design specification. The prototype system is implemented based on the scenario. This solution integrates distributed database, distributed server, service-oriented bus and vital signs network. In addition, the evaluation between data central and data distributed structure provides system performance from time measurement in system processing. From this study, we can conclude that the CSCW in tele home care architecture has enormous potential empowering patients, allowing patient and healthcare provider communication, remote diagnosis and EHR search.

In most medical services that patients received, they need an efficient and independent system for remote diagnosis, document sharing and etc. Therefore, design of an efficient, timely and auto treatment information system can lead to lowered stress levels for healthcare providers and improved health outcomes. The proposed scenario of CSCW in tele home care demonstrates to enhance tele home care service quality and user satisfaction. This research also concentrates on system performance and development sections.

During the evaluation procedures, it can conclude that the factors affecting on CSCW performance are machine performance, network traffic and quantity of information storage. Future development can improve any of these aspects. Compared with different system structures, distributed database CSCW is more flexible and easier to maintenance. Because the database storing with less quantity of information. It is easier for administrator to manage the records and data. More databases will lead system to have better performance. From the evaluation curves, we can see that with the increasing of database number, the system will have better performance. However, more storage container means more budgets and maintenance consumption. Therefore, under the permission of budget and excellent network environment, it is better to use distributed database structure in CSCW. The CSCW with distributed server and distributed database can lead to a high quality service in healthcare. It will be more flexible, efficient and reliable. In addition, database storage structure could be an item to enhance CSCW performance in the future work. For example, the technology of data storage can be data warehousing or even three dimensional database in further development. The solution is specifically developed for the healthcare domain to supply better services for patients.

## 7.2 Future Prospect

The idea of web-based healthcare service system is developing now. It has been around in the technical community for a long time. The distributed system also has been used in real life. In fact, the significant goal of remote healthcare service is the development with strong social and economic motivations. There is no doubt that, the CSCW in tele home care has a bright future. It will surely enhance the quality and efficiency of healthcare services.

In the future work, this prototype system can be treated as a corner stone. Future projects can extend the functions and interfaces developed in this thesis. The related functions such as video conferencing with sharing medical records, document sharing and accessing to patient EHR database can be further modified in further projects. It is a reference platform which helps to accelerate the development of medical devices with seamless connectivity and data aggregation capabilities. The future work may produce a system with more functions and higher security mechanism. Besides, data warehousing and data mining can be considered into EHR storage. In summary, the CSCW architecture scenario and related system will become an important instrument for tele home care section in the near future.

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# Appendix A

# HL7 EHR System Model

1. **Health Information and Data**
    - 1.a Key data
        - 1.a.1 Problem list
        - 1.a.2 Procedure
        - 1.a.3 Diagnosis
        - 1.a.4 Medication list
        - 1.a.5 Allergies
        - 1.a.6 Demographics
        - 1.a.7 Diagnostic test results
        - 1.a.8 Radiology results
        - 1.a.9 Health maintenance
        - 1.a.10 Advance directives
        - 1.a.11 Disposition
        - 1,a.12 Level of service
    - 1.b Minimum datasets for nursing homes
        - 1.b.1 Defined MDS
        - 1.b.2 Expanded/Refined MDS
    - 1.c Narrative (Clinical and patient narrative)
        - 1.c.1 Free-text
        - 1.c.2 Template-based
        - 1.c.3 Deriving structure from unstructured text
        - 1.c.4 Natural language processing
        - 1.c.5 Structured and coded
            - 1.c.5.1 Signs and symptoms
            - 1.c.5.2 Diagnoses
            - 1.c.5.3 Procedures
            - 1.c.5.4 Level of service
        - 1.c.6 Treatment plan
            - 1.c.6.1 Single discipline
            - 1.c.6.2 Interdisciplinary
    - 1.d Patient acuity/severity of illness/risk adjustment
        - 1.d.1 Nursing workload
        - 1.d.2 Severity adjustment
    - 1.e Capture of identifiers
        - 1.e.1 People and roles
        - 1.e.2 Products/devices

1.e.3 Places (including directions)

**2. Results Management**

2.a Results reporting
- 2.a.1 Laboratory
- 2.a.2 Microbiology
- 2.a.3 Pathology
- 2.a.4 Radiology reports
- 2.a.5 Consults

2.b Results notification

2.c Multiple views of data and presentation

2.d Multimedia support
- 2.d.1 Images
- 2.d.2 Waveforms
- 2.d.3 Scanned documents
- 2.d.4 Pictures
- 2.d.5 Sounds

**3. Order Entry/Management**

3.a Computerized provider order entry
- 3.a.1 Electronic prescribing
- 3.a.2 Laboratory
- 3.a.3 Microbiology
- 3.a.4 Pathology
- 3.a.5 Xray
- 3.a.6 Ancillary
- 3.a.7 Nursing
- 3.a.8 Supplies
- 3.a.9 Consults

**4. Decision Support**

4.a Access to knowledge sources
- 4.a.1 Domain knowledge
- 4.a.2 Patient education

4.b Drug alerts
- 4.b.1 Drug dose defaults
- 4.b.2 Drug dose checking
- 4.b.3 Allergy checking
- 4.b.4 Drug interaction checking
- 4.b.5 Drug-lab checking
- 4.b.6 Drug-condition checking
- 4.b.7 Drug-diet checking

4.c Other rule-base alerts (e.g., significant lab trends, lab test because of drug)

4.d Reminders
- 4.d.1 Preventative services

4.e Clinical guidelines and pathways
- 4.e.1 Passive

- 4.e.2 Context-sensitive passive
- 4.e.3 Integrated

4.f Chronic disease management
4.g Clinical work list
4.h Incorporation of patient and/or family preferences
4.i Diagnostic decision support
4.j Use of epidemiologic data
4.k Automated real-time surveillance

- 4.k.1 Detect adverse events and near misses
- 4.k.2 Detect disease outbreaks
- 4.k.3 Detect bioterrorism

**5. Electronic Communication and Connectivity**

- 5.a Provider – provider
- 5.b Team coordination
- 5.c Patient – provider
- 5.d Medical devices
- 5.e Trading partners (external)
  - 5.e.1 Outside pharmacy
  - 5.e.2 Insurer
  - 5.e.3 Laboratory
  - 5.e.4 Radiology
- 5.f Integrated medical record
  - 5.f.1 Within setting
  - 5.f.2 Cross-setting
    - 5.f.2.1 Inpatient - outpatient
    - 5.f.2.2 Other cross-setting
  - 5.f.3 Cross-organizational

**6. Patient Support**

- 6.a Patient education
  - 6.a.1 Access to patient education materials
  - 6.a.2 Custom patient education
  - 6.a.3 Tracking
- 6.b Family and informal caregiver education
- 6.c Data entered by patient, family, and/or informal caregiver
  - 6.c.1 Home monitoring
  - 6.c.2 Questionnaires

**7. Administrative Processes**

- 7.a Scheduling management
  - 7.a.1 Appointments
  - 7.a.2 Admissions
  - 7.a.3 Surgery/procedure schedule
- 7.b Eligibility determination
  - 7.b.1 Insurance eligibility
  - 7.b.2 Clinical trial recruitment

        - 7.b.3 Drug recall
        - 7.b.4 Chronic disease management

**8. Reporting and Population Health Management**

- 8.a Patient safety and quality reporting
    - 8.a.1 Clinical dashboards
    - 8.a.2 External accountability reporting
    - 8.a.3 Ad hoc reporting
- 8.b Public health reporting
    - 8.b.1 Reportable diseases
    - 8.b.2 Immunization
- 8.c Deidentifying data
- 8.d Disease registries

# Appendix B

# Main Code in Mapping Server Application

```
……
/**
	 * Start mapping service
	 */
public void start() {
		try {
			ss = new ServerSocket(MAPPING_PORT_NUM);
			started = true;
		} catch (BindException e) {
			System.out.println("Port in use....");
			System.out.println("Please restart program");
			notice.setText("Port in use...Please restart program");
		} catch (IOException e) {
			e.printStackTrace();
		}

		try {
			while(started) {
				Socket s = ss.accept();
				Client c = new Client(s);
				System.out.println("Client connected!");
				if(display.getText().equals("")) {
					display.setText("Client connected!");
				} else {
					display.setText(display.getText()+"\nClient connected!");
				}
				new Thread(c).start();
				//dis.close();
			}
		} catch (IOException e) {
			e.printStackTrace();
		} finally {
			try {
				ss.close();
			} catch (IOException e) {
				e.printStackTrace();
			}
		}
	}
```

```
……
/**
        * Redirection the request
        */
            public static void redirection(String str, String target_address, int target_port,String
source_IP) {
                        try {
                                    Socket socket = new Socket(target_address, target_port);
                                    OutputStream os = socket.getOutputStream();
                                    DataOutputStream dos = new DataOutputStream(os);
                                    String send = str+"|"+source_IP;
                                    dos.writeUTF(send);
                                    dos.close();
                        } catch (UnknownHostException e) {
                                    System.out.println("Error, can not find host");
                        } catch (IOException e) {
                                    System.out.println("Connect refused");
                        }
            }

……
/**
        * Sub class running with thread
        */

class Client implements Runnable {
                        private Socket s;
                        private DataInputStream dis = null;
                        private boolean bConnected = false;

                        public Client(Socket s) {
                                    this.s = s;
                                    try {
                                                dis = new DataInputStream(s.getInputStream());
                                                bConnected = true;
                                    } catch (IOException e) {
                                                e.printStackTrace();
                                    }
                        }

                        public void run() {
                                    try {
                                                while(bConnected) {
                                                            String str = dis.readUTF();
                                                            System.out.println(str);
                                                            display.setText(display.getText()+"\n"+str);
                                                            String[] array = str.split("\\|");
                                                            String source_IP = s.getInetAddress().toString().substring(1);
                                                            String dir_IP = getMappingAddress(array[17]);
                                                            int port = getPort(array[17]);
                                                            record(source_IP, array[17], array[12], array[15]);
```

```
                        redirection(str, dir_IP, port,source_IP);
                    }
                } catch (EOFException e) {
                    System.out.println("Client closed!");
                    display.setText(display.getText()+"\nClient closed!");
                    System.out.println();
                } catch (IOException e) {
                    e.printStackTrace();
                } finally {
                    try {
                        if(dis != null) dis.close();
                        if(s != null) s.close();
                    } catch (IOException e1) {
                        e1.printStackTrace();
                    }
                }
            }

        }
    ......
/**
    * Main function in class
    */

public static void main(String args[]) {

        /*
         * Create and display the form
         */
        EventQueue.invokeLater(new Runnable() {
            public void run() {

                mappingEngine.setResizable(false);
                mappingEngine.setTitle("CSCW in Tele Home Care EHR Mapping Server");
                WindowCenter.center(mappingEngine);
                mappingEngine.setVisible(true);
            }
        });
        mappingEngine.start();
    }
```

# Appendix C

# Main code in EHR Searching Monitor Application

```
……
/**
	* Start mapping service
	*/

public void start() {
		try {
			ss = new ServerSocket(EHR_PORT_NUM);
			started = true;
		} catch (BindException e) {
			System.out.println("Port in use....");
			System.out.println("Please restart program");
			notice.setText("Port in use...Please restart program");
		} catch (IOException e) {
			e.printStackTrace();
		}

		try {
			while(started) {
				Socket s = ss.accept();
				Client c = new Client(s);
				System.out.println("Client connected!");
				if(display.getText().equals("")) {
					display.setText("Client connected!");
				} else {
					display.setText(display.getText()+"\nClient connected!");
				}
				new Thread(c).start();
				//dis.close();
			}
		} catch (IOException e) {
			e.printStackTrace();
		} finally {
			try {
				ss.close();
			} catch (IOException e) {
				e.printStackTrace();
			}
		}
```

```
    }

/**
    * Invoke class EHRSearch to acquire EHR result
    */

public static String getResult(String PID, String date, String item) {
            EHRSearch sear = new EHRSearch();
            String result = sear.searchEHR(PID, date, item);
            return result;
    }

/**
    * Send result back to source machine
    */

public static void sendResult(String source_IP, int source_port, String result) {
            try {
                    Socket socket = new Socket(source_IP, source_port);
                    OutputStream os = socket.getOutputStream();
                    DataOutputStream dos = new DataOutputStream(os);
                    MessageConstructor messageConstructor = new MessageConstructor();
                    String temp = messageConstructor.generateMSH(source_IP, source_port);
                    String ack = temp + messageConstructor.generateACK(result);
                    dos.writeUTF(ack);
                    dos.close();
            } catch (UnknownHostException e) {
                    System.out.println("Error, can not find host");
            } catch (IOException e) {
                    System.out.println("Connect refused");
            }
    }
……
/**
    * Sub class running with thread
    */

class Client implements Runnable {
            private Socket s;
            private DataInputStream dis = null;
            private boolean bConnected = false;

            public Client(Socket s) {
                    this.s = s;
                    try {
                            dis = new DataInputStream(s.getInputStream());
                            bConnected = true;
                    } catch (IOException e) {
                            e.printStackTrace();
                    }
            }
```

```
                public void run() {
                        try {
                                while(bConnected) {

                                        /*SaveEHR save = new SaveEHR();
                                        save.save();*/

                                        String str = dis.readUTF();
                                        System.out.println(str);
                                        display.setText(display.getText()+"\n"+str);
                                        String[] array = str.split("\\|");
                                        String result = getResult(array[17],array[12],array[15]);
                                        String source_IP = array[19];
                                        int source_port = Integer.parseInt(array[14]);
                                        sendResult(source_IP,source_port,result);

                                }
                        } catch (EOFException e) {
                                System.out.println("Client closed!");
                                display.setText(display.getText()+"\nClient closed!");
                                System.out.println();
                        } catch (IOException e) {
                                e.printStackTrace();
                        } finally {
                                try {
                                        if(dis != null) dis.close();
                                        if(s != null) s.close();
                                } catch (IOException e1) {
                                        e1.printStackTrace();
                                }
                        }
                }

        }

    ……
/**
      * Main function in class
      */

public static void main(String args[]) {

        /*
         * Create and display the form
         */
        EventQueue.invokeLater(new Runnable() {

            public void run() {

                eHRMonitor.setResizable(false);
                eHRMonitor.setTitle("CSCW in Tele Home Care EHR Monitoring Server");
                WindowCenter.center(eHRMonitor);
```

```
                    eHRMonitor.setVisible(true);
                }
            });
            eHRMonitor.start();
        }
        ……
/**
    * EHR search function in EHRSearch.java
    */

public String searchEHR(String PID, String date, String item) {

                    beforeClass();

                    String result = null;
                    Session session = sf.openSession();
                    session.beginTransaction();
                    Query q = session.createQuery("select resultsReporting from ResultsReporting
resultsReporting where resultsReporting.resultsManagement.ehr.patient.personalID=? and
resultsReporting.resultsManagement.ehr.date = ?");
                    q.setString(0, PID);
                    q.setString(1, date);
                    List<ResultsReporting> list = (List<ResultsReporting>)q.list();

                    for(ResultsReporting resultsReporting:list) {
                            result = resultsReporting.getLaboratory();
                            System.out.println(resultsReporting.getLaboratory());
                            break;
                    }
                    session.getTransaction().commit();
                    session.close();

                    afterClass();

                    return result;
            }
        ……
```