Achieving eHealth interoperability
Via peer-to-peer communication
Using JXTA Technology

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--Yan Hu
“In the name of Allah, most Gracious, most Compassionate”

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ABSTRACT

eHealth is an emerging area that boost up with advancement in Information and Communication Technology (ICT). Due to variety of eHealth solutions developed by different IT firms with no proper shared standards, interoperability issue is then raised.

Blekinge County healthcare organizations use two different systems MAGNA CURA and SYStem Cross. The two systems work well in their own scope. But these systems often need to communicate and coordinate for exchange of patients’ information which leads to the problem of interoperability.

The aim of this research study is to provide fast and reliable peer-to-peer solution for exchange of patient information so as to achieve interoperability among healthcare organizations. This proposed solution is tested as a middleware between MAGNA CURA and SYStem Cross currently used by Blekinge County healthcare organizations.

A qualitative approach including in-depth literature review and a semi-structured face-to-face interview has been used for understanding the context of research problem. We have tested our approach through an executable prototype. The prototype is implemented using JXTA platform.

We have learned that Blekinge healthcare is decentralized and heterogenous in nature. For such kind of environment, peer-to-peer communication approach is suggested. According to the test result, the suggested syntactic level interoperability between the two mentioned systems has been achieved.

Keywords: eHealth, syntactic interoperability, peer-to-peer communication, JXTA technology
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INTRODUCTION

With the rapid development in technology, world is undergoing a digital revolution in the area of Information and Communication Technologies (ICT) [1]. ICT tools are used to find, study, analyze, exchange and present information faster and more accurate [2]. ICT changes the environment we live in, the style of living, the way of thinking and so on. It becomes the driving force for globalization and changes all the aspect of human life [3]. It has enabled organizations and societies to access, adapt, apply and produce information. One of the applications of ICT in healthcare is eHealth, which aims to offer better health services. eHealth is an emerging field in the age of medical informatics, public health and business. It refers to all health services and information delivered by using ICT [4]. eHealth makes it possible for the care providers to have fast and easy access to patient information and connect patient to care providers for home treatment, appointment and seeking of help in case emergency. It breaks the barriers among health service providers from different member states (EU states), so they can work more closely together and make it easy for patient to carry out medical treatment abroad [5]. Many eHealth technologies such as Electronic Transfer of Prescription (ET), Computerized Patient Record (CPR), Electronic Health Record (EHR) and Telemedicine are widely used and delivered tangible benefits [6].

In Europe and US, the current major investment is to develop Electronic Health Record (EHR) to support the professionals to work with complex health care, and provide accounts to simplify managing clinical work [7]. According to the report of US Medical Management Association and Healthcare Information and Management System Society, only 31% of doctors and 19% of hospitals are using Electronic Health Records (EHRs) because system and equipment are not interoperable. Interoperability of systems or components is their ability to successfully exchange information and use that information for determined task [8]. Sweden has a decentralized health care, with 20 county councils and 290 municipal councils. The main responsibilities include the suitable medical services, provision needs of development, quality assurance and finance all care activities. In the county councils, governments more or less hire services of private health care providers. According to the local policy, the county council must provide all residents health and medical services at a high-level. Health and healthcare planning must be based on public health needs. The Swedish health care confronts some challenges like some other countries; interoperability is one of the big issues [9].

Blekinge County has two main hospitals and several healthcare centers using electronic health record (EHR). Hospitals use SYStem Cross while municipality healthcare centers use MAGNA CURA. These two systems are different in technology and medicinal
terminologies. The hospitals are interoperable with each other but they are not interoperable with municipality healthcare centers. Since healthcare organizations are decentralized, the exchange of patient information needs mostly peer to peer communication. Some advantages make peer to peer networking more effective than client-server model in the existing Internet applications, such as enhanced load balancing, dynamic information repositories, redundancy and fault tolerance, content-based addressing and improved searches [10].

Our thesis work will highlight the current research in eHealth interoperability, existing gap and proposed solution to fill this gap. Interview with relevant people who are working in healthcare is conducted after literature review. We focus on current working systems and the problem in communication. After analyses of interview result, we design a prototype to test our research finding. This prototype is based on atomistic P2P communication model with JXTA technology. At the end, we validate our research findings through runnable prototype and derive conclusion.
1 BACKGROUND

Patient’s medical record is a common and widely used mean of documenting and exchange of patient diagnosis, prescription, treatment and other related activities. This record is not only important for the care continuation of individual’s health but also a key source for education, research and planning to handle any appalling situation. It is an integral part of healthcare [11].

The main objective of health and medical care services is to build up a healthy community and healthcare on equal terms. Efficient and effective healthcare not simply useful for the health, security and well-being of citizen but also provide confidence and ability to manage with the primary needs of society [12]. Like all other aspect of human life, healthcare also relies on the use of different technologies, among which Information and Communication Technology (ICT) plays significant role in facilitating, storing, communicating, processing and transmission of information in digital format. According to Sweden’s National eHealth Strategy, the role of ICT was limited in healthcare compared to other sectors. ICT tools used in hospitals and other healthcare units were using for a small fraction of task.

Modern ICT can provide various tools and solutions to store, organize, coordinate and exchange healthcare information and perform other clinical research much more effectively. The use of advance ICT tool and solution will enable all patients to receive satisfactory, safe and in-time healthcare. Also it provide an easy access to comprehensive healthcare information, check their own health status and able to keep an eye on who and when have had access to their personal information. Also modern ICT enable care professional to devote more time to patient and adapt care provision to individual needs [13]. Authorities and healthcare providers will be able to ensure patient’s safety and quality concerns, as well as to plan resource distribution and issue early warning about disastrous situation [12].

The use of different ICT tools and solutions in healthcare introduce a new business called eHealth. It is described as “an emerging filed in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development but also a state-of-mind, a ways of thinking, an attitude and a commitment for networked, global thinking to improve healthcare locally, regionally and worldwide by using information and communication technology” [4].

European Union’s Sixth Research and Development Framework Program (FP6), states that the basic purpose of eHealth is research and development on advanced ICT-based eHealth systems, services focusing on integrated health information systems, intelligent environment for health professional and online health services for patients and citizen [14]. eHealth
enable systems to exchange, process and store patient health information digitally that may used for different purposes like care continuation, research and education, considering information integrity and privacy at any cost.

In compliance to FP6, several eHealth projects were initiated like MYHEART, CLINICIP, AMICA, ARTEMIS and DICOMS [14]. MYHEART is for early diagnosis and prevention of cardio vascular diseases through biomedical sensor embed in clothes. CLINICIP uses biosensor for constant monitoring of glucose level in blood and decision made by adaptive control algorithm. AMICA uses patient medical information and other evidence for improving medical decision and preventing medical error. ARTEMIS is a semantic Web Service-based P2P framework for interoperability of medical information. DICOMS provides immediate assistance to medical specialist remotely at the spot of accident or other disaster through a web-portal [14].

According to National Strategy for eHealth Sweden [12], the use of eHealth solutions and services would enable citizens to have all-time access to their health information as well as healthcare professionals. The healthcare professionals will have quick and easy access to interoperable eHealth solutions, in-time status checkup for patient history and other related tasks.

The Swedish strategy focuses on six action areas:

- Every eHealth tool and solution must act in accordance with existing laws and regulatory framework.
- There should be a common information structure nationwide and patient data should be stored electronically.
- There should be a common technical infrastructure nationwide that ensure secure exchange of information among all stockholders.
- Facilitating interoperable and supportive ICT systems in healthcare to overcome the present gap of inoperability among different healthcare systems.
- Facilitating access of information across organizational boundaries by all care providers to improve individual health, check the efficacy of previous care and make future decision.
- Enabling citizen to have all the time, easy and secure access to his personal health information and easy contact to his care provider anytime from anywhere.

Healthcare interoperability is highly required for exchange of patient data among different systems in such a way that clinical or operational meaning of the data is preserved [9].

Making systems and components interoperable will speed up information retrieval, processing and delivery among healthcare givers and receivers. It will not only result in
efficient care for individual’s health, but also the information will be used for research purpose, diagnoses, treatment and prevention of new disease [11].

According to [8], shifting on new technology is quite expensive and time-consuming because of immaturity of market, health sector is not ready to invest since there is no guarantee of interoperability.

In accordance to European Union Commission action plan for European health, “each member state should identify and outline interoperability standards for health data message and electronic health record”, Sweden publishes a National Strategy for eHealth in 2006[14]. In this report, cooperation and interoperability among all different healthcare centers were the main focus.

The National Strategy for eHealth in Sweden, provides several guidelines to overcome technical as well as semantic interoperability problem in the form of e-prescription, use of different health standards like Health Level (HL-7), developing Clinical Document Architecture (CDA).
2 Problem Definition

Knowledge sharing among different organizations becomes significant especially when some services are crossing outside their own organization, such as healthcare. In healthcare, it becomes more critical for patient treatment. However, there are some problems on knowledge sharing in eHealth, such as the interoperability problem. It prevents two applications to communicate and exchange data accurately, effectively, and consistently [15]. Different organizations or individuals (care providers) provide similar or related services for the same group of people (care receivers). Services and applications in different organizations are different in concepts, models, vocabulary and so on. Even the ICT solutions supplied by different suppliers are different in terms of technology, structure, and design. All these dissimilarities lead to the problem of sharing knowledge which is referred as interoperability problem [16].

Modern ICT tools and solutions provide organizations and associations with a more convenient way to deliver and exchange information. According to [17], ICT has been widely used in the health care for different purposes and all healthcare applications are purely based on ICT which provides care for the citizen through various healthcare providers. Efforts like ODBC (Open Database Connectivity) and use of Web-services have been made to solve syntactic interoperability problem. Since health care involves the exchange of clinical information, which contains too much complex issues. Some international standardization efforts have been made, for example: HL7, GEHR, CEN/ISO 13606, openEHR and CPRS. Different companies and researchers are working to overcome the interoperability problem, but more challenges have been resulted [9].

Blekinge County Council also provides citizens free and convenient healthcare services by using ICT tools and solution. Several ICT based tools are used in various healthcare centers and hospitals, but they are still facing with the problem of coordination and exchange valuable patient information due to the absence of appropriate interoperability ICT platform [9]. Several gaps and solutions are proposed for achieving eHealth interoperability, but none of them have been implemented and approved.

Our main motivation of thesis work is to research, implement and test an appropriate approach for achieving interoperability among different healthcare centers in Blekinge County. The solution will help healthcare centers to provide better and more convenient service to the citizens especially elderly people. Our solution will be based on P2P communication model.
2.1 Research Questions
We formulate the following questions which guide us to achieve our aims and objectives.

Q1. Why the proposed peer-to-peer communication approach is feasible to achieve eHealth interoperability?

Q2. How could interoperability among diverse health systems be achieved in the county of Blekinge?

To answer our first research question, we perform literature review and conduct interviews from healthcare professionals. We present a detail description about eHealth interoperability, different approaches toward achieving interoperability, and challenges in achieving interoperability in Blekinge County Council. We also describe motivation for proposing Peer-to-Peer model to achieve eHealth interoperability.

For answering our second research question, we design a prototype on the base of previous research and interviews findings. We propose atomistic P2P which also known as pure P2P communication model for our implementation because health is a critical issue. Since there is a need of communication protocol to provide a safe transmission, JXTA technology which also supports XML language is used in this prototype.

2.2 Goals and Measures for the Study
ICT based tools are being used widely in healthcare domain for communication, exchange, storage and other activities regarding patient health. However interoperability is a major constraint especially for heterogeneous systems. The problem is more critical in case of emergency, to access in-time and right patient medical information. We assume that Blekinge citizens will gain greater benefits by using interoperability solution in future. This will lead to safer and more convenient health care services in different healthcare centers and hospitals.

The main goal of the study is to cover current interoperability gaps with our proposed solution via P2P communication model. In order to achieve the goal, there are some processes.

- To find the need for interoperability among different healthcare systems.
- To know what have been done till now for eHealth interoperability.
- To find the gaps in the current study/solution.
- To design a prototype based on P2P communication.

Our study will make it possible for healthcare centers to exchange patient information in real time, and health authorities can provide better services for the citizens in Blekinge.
3 RESEARCH METHODOLOGY

Research methodology is a plan or strategy to conduct a research work in a scientific way and link methods to outcome [18]. It defines how to develop research activity and what measurement should be used to advance the research. It helps author to achieve research goal [18]. Our thesis work is based on qualitative research methodology which uses deductive scientific approach. Qualitative study is useful to identify a specific approach for collection of data and the steps involved to analyze it. Data collection methods need active participation of the participants. These methods are in the form of open-ended observation, interviews, documents and so on. At the start stage, we need literature review to get a deep understanding of eHealth interoperability and to get ideas from others’ work on achieving interoperability. Besides literature review, we also use data collection method like interview with professionals from healthcare domain to understand the existing systems (MAGNA CURA and SYStem Cross) and what problems they are facing due to interoperability. On the basis of the knowledge gained through literature review, interview and informal discussions, we develop a prototype and test it by communicating and exchanging the patient data. In the end, the result is analyzed to reach the conclusion of our study.
Figure 1 Research Process
3.1 Literature Review
According to Dawson [15], literature survey is the first step to any research work performed in two phases called literature search and literature review. It is required since it justifies the importance of a research topic and identifies gaps in the past and current research. It also provides a starting point for other researchers to know how much our research work has contributed to the solution of a particular problem and the relevant literatures. Literature search is a “systematic process of gathering publish to available information relevant to subject” [14]. It means that any research materials we look for must be well recognized by research community and have valuable contributions to the research problem. To search for the past and current research and any type of supporting materials, we formulated the following key words specifically and checked it up in the well-known databases.

The key words are: eHealth interoperability, implementing interoperability in eHealth, P2P communication in eHealth interoperability, communication and exchange of patient information in eHealth, Clinic Documents Architecture.

We searched the publications through the online databases which are provided by the library of Blekinge Institute of Technology (BTH). We searched ACM Digital Library, CiteSeerX, Google Scholar, IEEE Xplore, SinceDierect, SpringerLink, Compendex-Inspect and so on. All these databases are the most authoritative in the field of computer science and technique. They are reliable, updated, and well recognized.

“Literature review represents your written understanding, critical evaluation, conceptualization and presentation of the material you have obtained.”[15] Literature review is the first phase of research that helps researcher to limit the scope of research topic, to convey its importance to reader, to share results of others’ relevant work and to cover the gaps through the gained knowledge [14].

We reviewed the searched literature zealously and critically to have the basic idea of eHealth interoperability, peer-to-peer communication, contributions and gaps in the existing research and guidelines to cover these gaps.

3.2 Informal discussion
We were also engaged in face-to-face informal discussion with senior PhD students and professionals who have working experience in eHealth projects. We received a positive feedback from those students and especially from the professionals. It helped us to understand research problem.

3.3 Interview
Interview is a useful method for data collection with better response rate and closer judgment of people’s experience, opinion, desire and feelings [18]. To support and implement literature study for research problem, we felt the need to have more detail understanding of
the existing eHealth systems (SYSTEM Cross and MAGNA CURA) and significance in achieving interoperability. We used a semi-structured interview with both open-ended and close-ended. The interviewees were selected carefully by assuming that they were aware of the importance of eHealth interoperability, challenges to achieve eHealth interoperability and the government policies for eHealth.

3.4 Prototype

Prototyping is a technique that has been widely used in systems development and research. Prototype refers to the process of developing a system or a product by showing the feasibility of a solution to a problem. Prototype is generally operated by their developer and those who are aware of its underlying technology [19].

In our study, we designed a prototype for achieving interoperability between different healthcare systems in Blekinge. Based on the results of literature review and informal discussions, we find that JXTA may be a suitable development platform for P2P communication. JXTA is a P2P-based collaborative approach to deal with sharing services. It is used for the different P2P systems to solve interoperability problems. JXTA is independent on operating system, network transmission technology and programming languages. It can be used in cross-platform. After the development, we tested the domo with different patient data to validate our qualitative study.
4 THEORETICAL WORK

This chapter describes in detail terms and concepts, related work about research topic, challenges and issue as well as implementation detail of the proposed solution. To explore the importance, need and suggestion for proposed solution, interview is followed in the empirical part and then research finding will be tested through prototype in the later chapter.

4.1 eHealth Services and Functions

eHealth provide a number of services to the citizens, healthcare professionals and administrations. Some of them are:

- ePrescription.
- Electronic Health Record
- Patient Identification
- Telemedicine services
- Monitoring
- Communication/Accessibility

4.1.1 ePrescription

According to S.Chu[20], “ePrescription is the electronic transmission of prescription of pharmaceutical products from legally and professionally qualified/registered healthcare practitioners to registered pharmacies (or dispensing system)”. This prescription contains different information like diagnosed health problem, specific medicine prescribed, amount and dosage as well as some other relevant care information.

ePrescription provides numbers of benefits identified by[21] like safe and secure access to the right prescription by the pharmacist without waiting for customer at pharmacy. Also it is useful for clinical staff in decisions making and workflow process.

4.1.2 Electronic Health Record

Electronic Healthcare Record (EHR) also called as Electronic Patient Record refers to digitally stored information. This information includes blood group, medical history, checkups, laboratory tests and diagnostic image reports and so on about individual’s health.[22] These records are stored in different formats like relational database table, structured or unstructured formats and even in digitized hardcopies which result in some interoperability problems.

4.1.3 Patient Identification

According to Massachusetts General Hospital (MGH) safety guidelines [23], it is very important to identify a patient before providing treatment. Without a proper and immediate patient identification, it is a hard and challenging job for clinicians to provide in-time and
right care in emergency cases. According to MGH two identifiers Patient’s name and Medical Record number would be used for inpatient. While for outpatient identification any two of the patient’s name, medical record number, social security number, date of birth or facial recognition are used.

4.1.4 Telemedicine Service
Telemedicine are exchange of medical information by means of telecommunication technologies for remote consulting, medical procedures or examinations [24]. As described by the author of [21], the interaction for Telemedicine often take place between hospitals or clinics, advancement in recent technological solution also allow patient and care providers to coordinate anywhere all the time. Even medical practitioner can attend emergencies while sitting in their homes. So the modern telemedicine give the vision of anytime and anywhere access to care.

4.1.5 Monitoring
This kind of services are mostly focused on elderly people with security alarm that sense and monitor temperature, pulse, blood pressure, glucose level constantly. They compare with preset values and send alarm when values are abnormal. If the user presses manually press button, care provider will reach for care. Information about visit is stored in handheld computers, then transfer to information system [14].

4.1.6 Accessibility
Health personals in elderly home care regularly need contact with both elderly people at home and municipality healthcare. Main hospital and even patient need to contact care providers for appointment, consultation, prescription renewal. So the system should provide accessibility and communication for information exchange [14].

4.2 eHealth Interoperability
As identified and described by[9][17][20][11], for the patient and different care providers, it is difficult to get some benefits by using the eHealth services due to the lack of interoperability among ICT tools and solutions. Literature study shows that interoperability is a blazing issue of today’s research. A lot of investment has been made to cope with these issues. So first we describe what interoperability is.

eHealth interoperability refers to “communicating and exchanging patient data accurately, securely, effectively and consistently with different information systems, software applications and networks in such a way that clinical or operational purpose and meaning of the data are preserved and unaltered”[9].
Asuman Dogac et al. describe interoperability as the ability of different ICT systems and applications to communicate and exchange information safely, accurately and consistently as well as use the exchanged information effectively. According to (Brown and Reynolds, 2000) [25], interoperability on a specific task is said to exist between two applications. It means that one application can receive data from the other and perform the desired task in an appropriate and adequate manner without the need of any extra operator involvement. The following keys make two systems interoperable.

- The system should be able to communicate.
- The data received by the receiving end is sufficient to perform the task; the meaning attached to data remains unaltered.
- The task is performed to be satisfied with the user of the receiving system.

This definition identifies two layers of interoperability [9].

1. Syntactical interoperability
2. Semantic Interoperability.

### 4.2.1 Syntactical Interoperability

Syntactical interoperability is an application level interoperability that allowing multiple applications with different implementation languages, execution platforms and interfaces to communicate and cooperate for data exchange [4]. So syntactic interoperability only commit the exchange of data.

To overcome with syntactic interoperability problem, different approaches and standards have been made like Open Database Connectivity (ODBC), message queues, interface engine, Web services based on SOAP (Simple object Access Protocol), XML, UDDI (Universal, Description, Discovery and Integration) and SQL standard [22].

### 4.2.2 Semantic Interoperability

The word semantic refers to the meaning and use of data (Wood, 1975). A word has different meaning in different context. For example, the value ‘20’ carries different meaning when use in temperature database and person’s age database. One can identify its meaning based on the schema information from database. Moreover, for complete semantic interoperability, not only the schema information is sufficient but also social and cultural perspective [26].

According to Asuman Dogac et al., Semantic interoperability means that document is interpretable and the content is understandable. Semantic interoperability helps integrate data from different sources through semantic mediation. Semantic mediation is smart data discovery and integration system using knowledge based query system, which allows integrating disparate data resources. He further elaborates that semantic mediation convert healthcare message defined in one standard to another.
Rong Chen [11] describes that for semantic interoperability not only the structure of record should be shared but also the definitions of clinical meaning (reference terminologies and ontologies) should be definite. According to ISO/TR 20514[11], the prerequisites for Electronic Health Record from interoperability informational perspective are:

- Standardized reference model.
- Standardized interface model
- Standardized set of domain-specific concept model
- Standardized terminologies associated with controlled vocabularies.

Several efforts and standardization have been made to achieve semantic interoperability. MREx, a Medical Record Exchanger based on the latest technology “Semantic Web” were designed to help healthcare providers immediate and real time access to the right information about patient health. This kind of information stored in distributed environment with different schemata. A virtual record is created from patient EMR at different sites [27]. Other approaches like openEHR, HL-7, SNOMED CT were also introduced to achieve interoperability.

### 4.3 Challenges in eHealth interoperability

The authors [9] have identified the following different interoperability challenges.

#### 4.3.1 Interfacing

Since interoperability among healthcare organizations is needed for exchanging information, the first problem is the interfacing problem. Interfacing is the boundary or layer at which interaction between two systems occur.

#### 4.3.2 Integration

Combining several diverse applications into a relation for collaboration as a single entity refer to integration. This requires implementation of different standards and communication platforms.

#### 4.3.3 Accessibility

Accessibility means that who has the right to access for patient information and at which level. There should be certain levels of accessibility like a patient can only view his record while doctor or nurse can have access to view and update his record after treatment. To cope with this challenge, a proper authentication mechanism need to be applied and certain level of accessibility should be defined.

#### 4.3.4 Security and Privacy

Personal information should be kept private, and even may not be shared with any authority without the consensus of patient. For information security and privacy, healthcare provider
should follow HIPAA (Health Insurance Portability and Accountability Act) rules, authentication procedure by allowing only authorized users also should be done.

### 4.4 Achieving eHealth Interoperability

Numbers of approaches and standards have been designed and developed at international level for achieving interoperability among healthcare organization.

#### 4.4.1 Health Level Seven (HL-7)

HL-7 is one of the leading and earlier standards for the exchange of clinical and administrative data among health information system by ANSI-accredited Standard Development Organization (SDO) [24]. HL-7 is used for Clinical and Document Architecture (CDA). It incorporate (HIPAA act.1996) to manage universal patient record. HL-7 uses several measures for security, privacy, integrity and availability of patient record. It has different versions like HL-7 v2, HL-7 v3. HL-7 v3 is based on reference information model (RIM) and use Extensible Markup Language (XML) [28].

#### 4.4.2 GEHR/openEHR

Good European Health Record (GEHR) was an EU initiative as a research project (1992), but later turned as Good Electronic Health Record with participation from Australia. It is maintained by ‘openEHR Foundation’. GEHR/openEHR introduces the concept of ‘archetype’. To model the structure of EHR, two-level methodology is used. In the first level Generic reference model for healthcare domain is developed which contain only few classes (role, act, entity, and participation). While in the 2nd level, healthcare application specific-concepts (blood pressure, lab reports and so on) are modeled as archetypes [11].

#### 4.4.3 CEN/ISO 13606

A EU standard from CEN TC/251(Standardization body that design standards for interoperability between independent health systems) was intended to be the first fully implementable EHR standard. Some parts of this standard were implemented in various projects of countries like Denmark, UK, Netherlands, Sweden and Norway. But it fails to be fully implemented due to much weakness which makes it no marketplace. The CEN pre-standard (CEN ENV 13606:2000) is a message based standard. An information model is defined for exchange of EHR called extended architecture because of extension of perrleased standard CEN ENV 12265: 1997). CEN 13606 use several machine-readable terms that can be used for structuring EHR contents. Also it focuses on the interfaces relevant for communication between EHR systems [21]. In 2001 it was revised by adopting openEHR archetype methodology and released with the new name EHRcom.
4.4.4 Digital Imaging and Communication in Medicine (DICOM)
DICOM is a de facto standard which is available since 1993 for medical image communication developed by medical industry and professional organization under the supervision of National Electrical Manufacturers Association. It defines data structure and services for the vendor-independent exchange of medical images and related information [21]. It uses binary encoding with hierarchical lists of data element. This data element identified by numerical tags and application-level network protocols. Web Access to DICOM Persistent Objects (WADO) service is needed in order to view DICOM Structured Reporting document in HTML format (WADO retrieve DICOM objects like images, waveforms and reports via HTTP or HTTPS from a Web Server). A number of commercial implementation supporting WADO is available. Typical user cases for DICOM images within a Web-based EHR references to DICOM images sent by e-mail or made available through web browser. This aims at image and report distribution both within and between health care enterprises.

4.4.5 SNOMED CT
Standard for Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT) developed by American Pathologist and English National Health Services is the more comprehensive clinical terminology used as reference terminology. A collaborative body among 12 countries (Spanish, Denmark, Sweden and so on) called International Health Terminology Standards Development Organization (IHTSDO) has been established to maintain and develop the content of SNOMED CT[11].

4.4.6 openEHR
openEHR design specification is based on Reference Model (RM), Archetype Model (AM) and Template Model (TM). RM model is a super set of CEN EN/ISO 13606 part-1 which consist of data types, data structures and EHR model. The classes of EHR model are the building block of AM and provide semantic of data. There are many entries in RM like observation, evaluation, instruction and action with building clinical meaning. “The AM provides constraining mechanism over RM classes and is the design specification for archetypes.” At last the TM provide grouping of several archetypes and further constrain to meet local requirements [11].
4.4.7 The Clinical Patient Records System
A web-based Clinical Patient Records System (CPRS) [28] based on HL-7 v3 were developed with Microsoft technology C#.NET and ASP.NET. C#.NET and ASP.NET can be deployed on any version of Window server running IIS 6.0 or higher. CPRS also require SQLXML v3.0 and Microsoft Internet Explorer Web Control (MIEWC) to be installed on application server. The main objective of CPRS was to facilitate the caregivers a safe and secure web-based interface to browse, search, edit and maintain Universal Patient Record (UPR) of their patients. The use of web-services enables CPRS to read clinical codes from external clinical references. There are four subsystems in CPRS. “CDA Tree” displays UPR clickable tree form, “CPA Properties” allow editing and rendering of UPR node, “CDA Document” covert XML view of UPR into a paper based clinical document view and the last subsystem “Data Connect subsystem” is responsible for handling data [30].

4.4.8 The Standard Taiwan Electronic Medical Record Template
To achieve the functional and semantic interoperability, Taiwan Association of Medical Information and Department of Health established a research project to develop EHR template or TMT with the following guidelines.

- Transferable to international medical information standards.
- Having minimal impact on the existing healthcare system.
- Easy to implement and deploy.
- Compliant with Taiwan’s current laws and regulations.
Now TMT became the EHR template for functional and semantic interoperability. To work and integrate easily into the existing health environment, samples from the existing paper-based forms used by medical professionals were taken. Process of standardization became the building block of EHR. Each TMT form is represented by a single and specific XML schema to describe its structure, contents as well as semantics. While creating patient’s EHR using TMT, it create sheet from TMT forms. A sheet is an instance of a TMT form[31].

**4.5 Swedish strategy toward Interoperability**

As pointed out by the author of [11], nearly all the counties and municipalities are using Electronic Health Record (EHR) in their Hospitals and primary care centers. However only in Stockholm region, 25 different EHR systems are in use. Different vendors use different information models and terminologies for recording clinical data. It is nearly impossible to get consistent data from central database for further use and analysis. Thus interoperability is a very important problem, and many efforts have been made to resolve the problem.

**4.5.1 The Julius Project**

The Julius project was a Swedish initiative (2001) with two aims [11].
• Enabling the clinicians to define which data is required to be recorded for clinical studies and which is for ordinary documentations.

• The template for data entry and presentation should possibly used in combination with the existing EHR systems.

A template based on supplementary electronic health record system named Julius were developed into implementation and tested in 3 health care centers in Stockholm. The result showed that adding supplementary functionality to the EHR is efficient for enabling the clinician in control of system. Julius has three subsystems.

• Concept Data Service (CDS): It is the first place for clinician to design a template where data items relevant to clinical concept are defined. These data items are used to record health information [32].

• Template Data Service (TDS): This system is used to compose new template or edit old ones. These templates are then used by PDS for recording data.

Figure 5 CDS [32]

Figure 6 CDS [32]
• **Patient Data Services (PDS):** This system used for storing and managing patient data. It uses the TDS template definitions and transforms into web forms which are used for data entry.

![Patient Data Services (PDS)](image)

**Figure 7 PDS [32]**

4.5.2 The Cambio Cosmic EHR System

Cambio Cosmic is an EHR System from Cambio Healthcare in Sweden which uses a system engine called Cambio Spider. The system has been developed in three different layers: presentation layer, business logic layer, and storage layer. Cambio Spider is based on application servers like IBM WebSphere, BEA Weblogic, and Sybase Enterprise Application Server that lies in the middle [33]. Cosmic is in accordance with European Healthcare Information System Architecture. It has been used in several EU countries like Sweden, Denmark, and UK [11].

![System Architecture of Cambio Cosmic]([image](image))

**Figure 8 system architecture of cambio cosmic [33]**
4.6 Peer-to-peer paradigm

According to Yeager and Joseph [34], Peer-to-Peer (P2P) has no specific definition but used in different context. “Generally P2P describe an environment where computers connect each other in a distributed environment that does not use a centralized control point to route or connect data traffic”. It refers to “a class of systems and applications that utilize distributed resources to perform a function in decentralized manner”. Intel P2P community defines it “the sharing of computer resources and services by direct exchange between systems” [35]. Peer-to-Peer computing was introduced in 2001, with the Napster’s support for sharing music file over the web. However it became a main focus in distributed and collaborative computing (web & ad-hock networks) both by industry and academia. In today’s globalization age, distributed computing is an emerging trend, so P2P is the ultimate solution and gaining more and more attention in research, product development and investment circles. P2P networking offer unique advantages making it a more effective in alternative to several client-server e-commerce applications. It became mature into a secure and reliable technology. P2P network distribute information among members of node instead of focusing on a single server. P2P networks are largely useful in application scenarios like personal, commercial, public and military environments [36].

P2P computing is useful for internet applications that need high scalability and availability [35]. There are several application based on peer-to-peer technology such as Gnutella, OBEX, Jet Send, Napster, Bitorent, Limware and so on.

In contrast to traditional client-server, each node in P2P has equal status. Each node not only acts as a server providing services to other nodes, but also enjoys the services provided by other nodes [10].

<table>
<thead>
<tr>
<th>A server based network</th>
<th>A peer-to-peer based network</th>
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Figure 9 Client-Server mode and Peer-to-Peer mode [37]
The strength of P2P mode is reducing the dependence and decentralizing control to the server [30]. Some P2P model even does not need a server. The user can connect to other users without server. Users under P2P model have more initiative and operability than the traditional client-server mode.

Some important features of Peer-to-Peer computing are [9]

- P2P system is self-organization and non-centralized, each node (peer) is autonomous and dynamic.
- Each node plays the role of both client and server in the P2P system.
- The functions and responsibilities of each node is the same, the interaction between them is direct and right.
- There is no centralized mechanism in pure P2P system.
- Peers are formed dynamically in an ad-hoc manner and removal of nodes has no significant impact on the network.

4.6.1 The advantages of P2P model
This new architecture has many potential advantages to be discovered [30]:

- **Non-centralized**: The network resources and services distributed among all nodes, the transmission of information and achieving services are direct between the nodes without the involvement of intermediate links and servers, this avoid a possible bottleneck. This basic characteristic brings the advantage of scalability, robustness and so on.

- **Scalability**: In the P2P network, with the user's accession, not only the demand for services increase, overall system resources and service capacities are also expanded synchronously. It always can meet user’s needs more easily. In theory its scalability can be considered almost infinite. In the P2P network, the more resources available, the faster download speeds.

- **Robustness**: P2P architecture is high fault-tolerance and inherently resistant to attack. As services are scattered among the various nodes, some destruction of nodes or network has little effect on the other parts. P2P network can automatically adjust the overall topology of other nodes to keep connectivity in the case of some nodes failure. P2P networks are usually self-organization, and allow nodes to join and leave freely.

- **Cost-effective**: Performance advantages of P2P have been an important reason for its widespread concern. With the development of hardware technology, personal computers computing and storage capacity, network bandwidth grows based on the Moore's theorem. P2P architecture can effectively use the large number of spread ordinary nodes on Internet, distributing computing tasks or stored data to all nodes. Some of the idle computing powers or storage spaces are used to achieve high-performance computing and mass storage.
- **Privacy protection:** In the P2P network, information transmission is scattered among various nodes without going through a particular link. It greatly reduces the possibility of leakage and eaves-dropping the user's privacy information. In addition, solve the Internet privacy issues main relay on the technical method of secondary transit. In the traditional anonymous communication systems, the realization of this mechanism is dependent on certain server node. In P2P, all participants can provide secondary transit functions, thus greatly increasing the flexibility and reliability of anonymous communications so it provide users better privacy protection.

- **Load balancing:** In the P2P network environment, each node is both a server and a client. It reduces the requirements of the computing power, storage capacity of the server in the traditional C / S structure. Also resources are distributed across multiple nodes, this makes a better implementation of entire network load balancing.

Current research suggests that P2P can be used in many fields, such as sharing of CPU cycles and timely information transmission, components of interoperability and data sharing.

### 4.7 P2P communication model

There are three architectural model of P2P like atomistic, User-centric and Data Centric. In atomistic P2P model there is no central administration and each peer equally acted as server and clients. User Centric is mediated by a central server which has a directory with a permanent unique user Id for each node, so that any peer may able to access target peer by login into the server and connect to the directory listing peer. The 3rd form of P2P model is Data Centric (DCP2P). It is similar in structure to User centric but instead of listing individual peers; DCP2P maintains an index over all available and registered resources [38].

Atomistic P2P model is also known as pure P2P model, since all the nodes in the network work as true peer, without a central server involved. Each user access network randomly, and with a group of its neighbor nodes structure a logical covered network through a point-to-point connection. Contents querying and content sharing among nodes broadcast directly through the adjacent relay nodes, each node will record the search path, in order to prevent the search loop happened. Atomistic P2P network structure solves the issue of network architecture centralization, with better scalability and fault tolerance [38].

We propose Atomistic P2P model for our health scenario because health is a critical issue to avoid the evolvement for central authority. The following Figure shows Atomistic P2P model.
4.8 JXTA Technology
Peer-to-Peer communication can be achieved by using JXTA technology, “An open source Java based network programming and computing platform for modern distributed computing, especially for P2P networking”. It designed by ‘SUN Microsystems’ to solve the current problems of distributed computing like interoperability, ubiquity and portability and so on. Peers in JXTA set up virtual or Ad-hoc network where each peer in the network cooperate and use resources directly behind firewall or network address translations (NATs) and even on different network [39][40].

Several P2P applications like Napster, Gnutella, Kazza, and Bitorent are popular for file sharing. Microsoft also use P2P technology in Windows Messenger, but all these functions and technologies are proprietary. JXTA is an open source framework and provide generalized vehicle for security problems as well as file sharing [34]. JXTA were designed to meet the following objectives [40][34].

- **Interoperability**: Enable one peer to discover and communicate easily with others, participate in community activities with different P2P implementations and offer services seamlessly across different systems and communities.

- **Platform independence**: Numbers of P2P applications offer services by using API which is specific to certain platform. Developers are forced to choose among a number of API, use certain protocols by targeting a specific user. Making two different P2P communities interoperable, the developer has to duplicate the same service, or make a bridge between the two which is impractical and inefficient. JXTA is independent on any platform, programming language and developing environment.

- **Ubiquity**: JXTA is designed to be implemented on every device from sensor, PDA to mainframe.

4.9 JXTA architecture
There are 3 layers in JXTA architecture, shown as below [40]. The bottom layer is core layer; it deals with the “initialization of the peer, message routing and other bottom layer
mechanisms”*. The middle layer is the service layer, which provides access to the interface of JXTA protocols perform tasks like file sharing, searching and indexing. The top is application layer; it accesses the JXTA network and its services through the development of applications. In addition, there are some secure factors involved in these three layers, but manifestation changes in different layer.

Figure 11 JXTA architecture [40]

4.10 JXTA Concepts/Terms

- **Identifiers:** JXTA use 128-bit unique identifier (UUID) for each entity. Locally this identifier is unique and can easily generate, but globally there is no guarantee whether this identifier is remain unique during runtime.

- **Advertisements:** It is an XML structured documents which describe and publish the existence of peers, groups, pipes or services. The primary use of advertisement it to hold specific information about peers like name, ID and other run time [41][36]

There are 6 basics types of advertisement.

1) Peer advertisement.
2) Peer group advertisement
3) Pipe advertisement.
4) Service advertisement.
5) Content advertisement.
6) Endpoint advertisement.

- **Peer:** It is an entity that can understand all the required protocols. A peer does not require all the six protocols. Peer even performs if it does not support any protocol.

- **Peer group:** It is a virtual entity that speaks to the set of group protocols. Peer group is a collection of cooperating peers which provide a command set of services. There is no specific rule when and how a peer joins to a group. No membership is required. A peer
can belong to more than one group. JXTA specification only state how peers should be discovered by using peer discovery protocol.

- **Pipes:** Pipes are communication channels for sending and receiving messages. They are unidirectional (in-pipes and out-pipes) and asynchronous. Their endpoint can be moved among peers and dynamically bound through Pipe Binding Protocol. Point-to-Point Pipe connects exactly two peers, sender and receiver. While a Propagate Pipe connect multiple end point together. JXTA do not specify how the message exchanges through pipes. Any uncast or multicast mechanism can be used.

- **Messages:** Message is basic unit of communication designed as ‘datagram’, it contains an envelope and a stack of protocols. Envelope contain header, source endpoint, destination endpoint (mapped to physical address). The protocol stack contain variable numbers of bytes, one or more credentials, sender and receiver identification and so on. Message is sent to endpoint as reliable datagram, addressed through URL.

### 4.11 JXTA protocols

JXTA technology composed of a set of open XML interoperable protocols. It is defined by one or more messages, exchanged among members who participate in the protocol. The message have a predetermined format that may include some anonymous. TCP/IP connects internet nodes, but JXTA technology interconnects peer nodes. JXTA is also a platform independent like TCP/IP and can use features of TCP/IP. JXTA does not rely on a single transport protocol as TCP/IP, but use the features provides by transport protocols. JXTA define the following six kinds of basic protocols [36][40][42].

- **Peer Discovery Protocol (PDP):** PDP is one of the core protocols of JXTA technology used by peers to discover any publish resources (peer, peer group, pipe etc.). It is compulsory represented as advertisements. PDP is based on ‘Rendezvous peers’ a special peer which have the ability to catch or discover advertisement. It forward request to other peer and to bridge them between network segments even using different protocols.

- **Peer Resolver Protocol (PRP):** PRP protocol is used to send a general query message from one peer to other peers, and receive the query results. It is a basic query response protocol. Query messages contain unique ID which matches the response message ID. When a peer is found through the PDP, the query message can be sent to the peer.

- **Peer Information Protocol (PIP):** User through the PIP knows other peer’s state, up-time, load capacity and so on. JXTA implements peer monitoring and peer account function through PIP, which is essential for high serviceability systems.

- **Peer Membership Protocol (PMP):** Peers can build up a peer group, join or leave from a peer group by PMP protocol. Peer group forms a logical boundary with a common
interest. Also one peer can belong to more than one group. PMP can join or withdraw from a peer group found by PDP.

- **Pipe Binding Protocol (PBP):** It is simply said that PBP will bind operating pipeline of peer group members to the actual transport protocol. Pipe is above the physical network transmission protocol such as TCP/IP, which is the virtual channel of communication between Peers. A peer can set up one or more endpoints of pipes by PBP.

- **Peer Endpoint Protocol (PEP):** PEP is the routing protocol of JXTA used to find the route to the other peers. It defines a set of demand query messages, helps peer deliver the message to the specified peer through the routing services. PEP route differently with TCP/IP transport protocol and ignore any fire wall presence of logical network, build on IP Network Address Translator (NAT).

### 4.12 JXTA Discovery Mechanism

JXTA do not mandate any specific discovery mechanism, it may be completely centralized, decentralized and hybrid. JXTA version 1.0 gives the following discovery mechanism [36].

- **LAN-based discovery:** Peers are discovered via local broadcast over the subsets.

- **Discovery through invitation:** Invitation is broadcast, any peer that receives the invitation (either in-band or out-of-band) use the information contained in the invitation for discovering remote peer.

- **Cascaded discovery:** When a peer discovers another peer, it views the horizon of the second peer with its permission. In this way, peer discovers new peer, peer group and services.

- **Discovery via rendezvous points:** Since rendezvous peer keep information about its attached peer, any peer that are going to discover other peers or services, connect through pipe to the rendezvous peer. It knows about all the peers attached to rendezvous peer in this way.

### 4.13 JXTA Security Consideration

JXTA is independent on any specific security approach. JXTA version 1.0 came-up with a comprehensive set of security primitives to support security solutions for the services provided by JXTA. JXTA community considers security model based on the existing technologies without compromising their rational and strong expected security. It provides the following security primitives [36]:

- A simple crypto library supports hash functions (MD5), symmetric encryption algorithm (RC4) and asymmetric crypto algorithms (Diffie-Hellman, RSA).

- An authentication framework is based on PAM (Pluggable Authentication Module).

- A simple password-based login plan can be plugged into PAM.
• A simple access-control mechanism based on peer groups, where each member of the group is granted access to any data offered by another peer. However nonmember has no access.

• A transport security mechanism use Transport Layer Security, with the exception that unidirectional pipe does not allow any handshake, crypto strength negotiation or two-way authentication on a single pipe.

• The demonstration services called InstantP2P and Content Management Service (CMS) also make use of added security features provided by the underlying Java platform.
5  **EMPIRICAL WORK**

According to [43], empirical work is to gain information or knowledge through observation, experience or experiment. It is a fundamental concept about scientific method or empiricism that all evidences should be based on observations. Empirical work complements our theoretical views. Data in empirical study is collected through different methods such as interviews, questionnaires, case studies, observations and diaries. These are used to draw conclusion [43].

5.1  **Interview**

Interview is a method of exploring and describing the basic theme of studying the subject matter. According to (McNamara, 1999), “interview help in getting the story behind a participant’s experiences” [44]. The interviewer can pay particular attention to the information around the topic. The main thing to consider before going to interview is to “have better understating regarding the interviewee’s perspective”. This will help in getting useful information. Interviews are mostly used in qualitative research work [9]. Our focus group is eHealth professionals with better understanding and knowledge about the interoperability problems, needs of interoperability and its impact on healthcare.

5.1.1  **Purpose of interview**

The purpose of interviews is to gain knowledge about the work of existing systems and problems during communication. The main investigating topic of interview is interoperability among different healthcare centers in Blekinge County.

5.1.2  **Interview Planning**

For interview, we searched for contacts of the relevant personals, then wrote brief emails about the objective of interview and requested for appointment. Three interviews were conducted based on the availability and suitability of interviewees. Two of the interviews in Ronneby from Ulf Danielsson (IT-Adminstrator, Ronneby Muncipility) and Anne Maire (Senior Nurse, Vidablick Ronneby). The third interview was conducted from Jakobson (Deputy System Administrator, LANDSTINGET Karlskrona). All interviews were conducted in decent manner with full cooperation of interviewees.

5.1.3  **Interview Design**

We formulated a semi-structured interview including 30 open-ended questions in the beginning, and reduced them to 12 later on. The reason for this reduction was that some of those questions were already answered through literature or during the interviews form pervious research. Questions were designed in a way to help author for overseeing the vision
of the professional about their working experience in the relevant domain. They were asked both in formal and informal mode. The whole session was mainly focused on the interoperability problem and challenges during the communication of systems.

5.1.4 Interviewee selection

We contacted several healthcare individuals both in Ronneby and Kalrskrona Municipality. The following available people were interviewed.

**Olf Danielsson:** He is a medical IT administrator of healthcare center Vidablick. He works for many years in Ronneby Komune. He is now responsible for providing IT support of healthcare services for patients coming from hospitals to municipality healthcare centers.

**Anne Marie:** She is a senior nurse who works for last 20 years at Vidablick Ronneby. She uses MAGNACURA system to manage healthcare services and record, for elderly and handicapped people leaving in Vidablick.

**Jacobson:** He is Deputy System Administrator working for the last 7 years with SYStem Cross. He is dealing with the technical problem of SYStem Cross community and testing updated solution provided by the SYStem Cross developer team.

5.1.5 Data Collection

Data from interviews was recorded by noting the important hints and recording with the permission of interviewees. The recorded data was properly drafted for analysis, as well as used for prototype development. Anne Marie and Jacobson helped us for collecting more valuable information by sharing their experience and views about eHealth interoperability, problems and suggestions. Ulf Danielson also talked about vision of National Strategy of eHealth Sweden [12][13].

5.2 Interview Analysis

The main objective of this interview is to study interoperability problem between SYStem Cross and MAGNA CURA, solutions to overcome this problem and discuss our proposed design. The same questions were asked to all the three interviewees in order to know different opinions about the same topic.

5.2.1 The problem

According to the response to Question 2 and 3 (problems in system communication) from Ulf Danielson and Anne Marie, health care centers like Vidablick, Ågårdsbo, Olsgården, Ålycke and Björkliden use MAGNA CURA for healthcare management of elderly and handicapped citizen. These systems are interoperable to communicate and collaborate with each other. However, they are unable to communicate directly to SYStem Cross. There is a need for communication and collaboration between SYStem Cross and MAGNA CURA, when an elderly or handicapped patient is referred to vårdentals or hospitals for medical
checkup or emergency. The doctors and nurses at vårdcentrals or hospitals need their records from health centers, because patient data is not centralized. Similarly when patients are discharged, nurses at hospitals publish their treatment history into the Journal on SYStem Cross. However this journal is not accessible at health centers like Vidablick and Ågårdsbo where nurses also need the patient treatment history for further care. So the main purpose of communication is to exchange patient treatment summary and read some new health relevant information.

5.2.2 Solutions
According to the response to Question 4(Solution like OVK and telephonic conversation for information sharing about patient health) from Ulf Danielson, Jacobson and Anna Marie, there is no such solution to communicate with MAGNA CURA and SYStem Cross directly. Since some information is important and required both by doctors and nurses, an alternate solution called OVK program is used. OVK is a separate program which is used only to document patient information on both sides by nurses. If a patient goes to a hospital, nurse at a healthcare center will write a reference note including current status of the patient and some other health relevant information. Doctors or nurses at hospital or vårdcentral access and read information from OVK. Also at the time of discharge, nurses at hospital write note about the treatment which he or she got at hospital and some further medication in OVK. This information is then accessed by nurses at healthcare center and copied into MAGNA CURA.

According to Anne Marie, they also make telephone conversation for consulting the doctors about treatment advice if patients become abnormal in health condition.

According to the response to Question 4 from Anna Marie, though OVK have solved the problem of information exchange, but information documented in the OVK are not reliable. According to her experience, sometimes message is strange and difficult to understand. So they call concerned person for clarification. However sometimes due to the absence of concerned person, they have to wait till the right person is available. This results in treatment delay, since they can’t take the risk of wrong treatment or medication.

According to the response to Question 4 from Jacobson, there are some problems with OVK. They are going to replace OVK with a new program called PRATOR which is still under development and will be in function from next year.

According to Ulf Danielson and Anna Marie, Ronneby Komune has made an agreement with LINDSTINGET Karlskrona for access to SYStem Cross so that nurses can read patient’s journal from SYStem Cross and publish information. This accessibility will be possible in next year.
5.2.3 Middleware concept
From the response to Question 5 (about our proposed solution as middleware) from Anne Marie, any solutions that would provide direct communication between SYStem Cross and MAGNA CURA will be better. Even in case of access to SYStem Cross, they have to keep patients’ information in MAGNA CURA and publish to journal.
According to Ulf Danielson and Jacobson, implementing middleware between MAGNA CURA and SYStem Cross is an interesting idea, but it depends on the successful implementation and recommendation by decision makers. At syntactic level it should be possible, but at semantic level it needs too much work. Healthcare organizations have not yet implemented health standards, therefore semantic interoperability will be the major issue.

5.2.4 Information Accessibility
According to Ulf Danielson and Jacobson, privacy and information security is the most critical issue. People are more curious about their personal health information. Both SYStem Cross and MAGNA CURA have strict accessibility rules. Only authorized person have the right to access patient information with the consent of patient.

5.2.5 Centralized vs. Peer-to-Peer Communication
According to Jacobson, SYStem Cross is centralized with records of all the patients throughout the Blekinge region. He further elaborates that there is one main server in Karlskrona and clients at vårdcentrals. Doctors and nurses at healthcare centers access SYStem Cross through client terminals and record information. In response to the question about the case of server crash, he told us that they use two main servers, active server and passive server. If active server crash because of technical problems, passive server take over the control and normalize the situation. However in case of link failure and server load due to enormous requests, there may be a problem with centralized approach.
According to Ulf Danielson, MAGNA CURA is not centralized, but every healthcare center keeps its own record. MAGNA CURA and SYStem Cross do not share resources due to heterogeneity, therefore Peer-to-Peer will be a good solution.
6 PROTOTYPE DESIGN

In this chapter, we focus on the prototype design which is based on the P2P communication to achieve interoperability between different healthcare systems. There are two main phases in this development, systems interface simulation and communication establishment. Section 6.1 introduces the framework of the whole P2P work group. Section 6.2 describes the two systems ‘SYStem Cross’ and ‘MAGNA CURA’ interface simulation. Section 6.3 is about how these two systems communicate with each other on the JXTA platform.

6.1 The communication model

6.1.1 Basic framework
In order to clarify the scope of the prototype implementation, we design a basic framework of the whole P2P workgroup communication model shown as Figure 12.
In this model, every healthcare center is defined as a peer. Every system is connected to the Internet. They can communicate very well each other with their own systems, but among different systems, they cannot communicate. Our main work is to make different systems can share patients’ data. The following list the minimal basic operations.

- Share their own database to the P2P platform in every fixed time, in our case, share their database to jxta.org.
- When one system needs to find some information of their patients, they send the request. And then if the other system has the information, they will receive the detail soon.

6.1.2 Scenario for the prototype design

For the prototype design, we assume these situations

- When patients go to healthcare centers, the nurses or doctors will keep patient records in their own database. The database administers of both system will broadcast these information every fixed time to JXTA communication platform.
- When the nurse at Ronneby Vidablick needs to do some medicine physical therapy, she may need some medicine information of the senior citizens from Karlskrona Hospital. So she inputs the personal number of the citizen in the third P2P communication program as a request, and then she can receive the information from the hospital’s database.
- When the doctor in Karlskrona Hospital needs the physical therapy information from Ronneby Vidablick, he does the same processes to get the patient data from Vidablick’s database.

Figure 13 describes the scenario of the two different systems which share the patient information.
6.2 System interface simulation
On this phase, we design the interface of both 'MAGNA CURA' and 'SYStem Cross' to show the basic operations to input the data and management of their own database. We use .NET platform to develop because object oriented technique is more efficient and has reusability.

6.2.1 MAGNA CURA

Figure 14 Login in interface
According to this system simulation, we define two databases; one is database from the skatteverket, which means if the nurse input the patient’s personal number, his basic information will be called from the national citizen database. Then the nurse will input some
issues done for the patient in the blank of ‘Ärenden’ and at the same time store this into their own database. And this is the other database which we define.

6.2.2 SYStem Cross

![Figure 17 Doctor’s login in interface](image1.png)

![Figure 18 Doctor’s reception management interface](image2.png)
In this system, four databases are defined, not only the database from the skatteverket. The second database of this system is a login-in database which is storage of all doctors’ information and their login-in information. The third database is book data which shows all reception information of all patients. The fourth one is the patients’ database which contains medical information of each patient such as symptom and medicine information.

### 6.3 System P2P communications

#### 6.3.1 JXTA platform development

According to “JXTA JXSE Programmers Guide 2.5” [45], we build our JATX communication platform as following steps.

- Build up JXTA data exchange architecture which is called Pipe advertisement based on XML.
- Build JXTA group, in this case it is automatically built in Peer Group Net.
- Set up JXTA data send mechanism. First, we get the basic information from the database, then the Adv/ send message is created in the JXTA based data architecture. In the end, broadcast the created Adv/ send message.
- Set up JXTA data receive mechanism. In the beginning of this step, query data is got, then query is sent and waiting for response. At last, Resolution is done if the query message is received.
6.3.2 P2P communication establishment
In the beginning of the communication, each system broadcasts their database in the third party system. In our case, all data in our peer group is sent to JXTA.org.

![Figure 20 Send data from SYStem Cross](image)

![Figure 21 Send data from MAGNA CURA](image)

When the nurse who uses MAGNA CURA wants some medicine information from the SYStem Cross side, she just inputs the personal number of the elderly citizen. After some minutes, the information of that citizen is shown on the screen. As the same to the doctor of SYStem Cross, he inputs the personal number of the patient, the therapy records from the Vidablick is also received.
Figure 22 Search information from other system

Figure 23 Receive data in the **SYSstem Cross** side
Figure 24 Receive data in MAGNA CURA side

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<tr>
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<tr>
<td>Civil</td>
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<tr>
<td>Vitamin C 500mg</td>
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7 DISCUSSION AND VALIDITY ASSESSMENT

7.1 Discussion

eHealth is a broad concept and domain that has been widely researched, however new problems arise which lead to further research. Interoperability is one of such problems which arise among healthcare organizations when need to communicate for sharing of patient’s health information. Through research study, we learned that there were different challenges in achieving eHealth interoperability like integration, interfacing and so on. These challenges occur because healthcare organizations use different health management system. We studied many solutions and recommendations like use of same health standard and efficient use of latest ICT technology.

We also found that Blekinge healthcare used two different information systems SYStem Cross and MAGNA CURA. Interoperability issue occurs between these two systems in some cases, because healthcare is decentralized. They have not yet implemented the proposed eHealth interoperability standards. Healthcare providers are aware of the importance of interoperability problem, and willing for a solution that directly communicates the two systems without shifting on new technology. Our proposed solution will help healthcare organizations in Blekinge to exchange patient information in an efficient and reliable way. Since we have not considered deeply with security relevant issues in our prototype, we are not sure whether our solution has the risk of sharing health information.

7.1 Validity Assessment

Assessment of any research work carries two main objectives which help to learn and summarize what has been learned. Validity of assessment is the suitability, reliability and accuracy of assessment [46]. Guba and Lincoln (1981) stated that any research which has to be considered a valuable research must have aspects like “truth value, applicability, consistency, neutrality”. They proposed that criteria in qualitative research for ensuring the “trustworthiness” of research findings are: creditability, transferability, dependability and conformability.

7.1.1 Credibility

According to William M.K. Trochim, the result of qualitative research should be realistic and believable in the perspective of research participants [47]. To reach maximum credibility, we firstly discussed the topic with seniors and supervisor to know if the topic is trustworthy. From the literature we found that many researches had been done, but it is still going on, new challenges are discovering time to time.
Though we were expected to implement the proposed peer-to-peer solution, in order to validate the previous research findings, we decided to investigate the problem further. It is necessary for us to know in both technical and user perspective, and to ensure whether proposed solution will benefit or not. Therefore face-to-face interviews were conducted. From analyzing interview results, authors got what was expected. During the last phase of our research plan, we implemented the proposed solution and tested by sample data. Due to time limit we were unable to perform a demo-based survey which would further make the research findings more credible.

7.1.2 Transferability
Another criterion of qualitative research is the transferability of research results. It refers to how much qualitative results can be generalized or transferred to other contexts or settings [47].
This research study primarily aimed at achieving eHealth interoperability among the healthcare organizations in Blekinge County. They use two main information management systems MAGNA CURA and SYSTEM Cross for health management services which work in distributed environment. However the proposed solution can be deployed and implemented throughout decentralized healthcare sector of Sweden. However, the most important thing to be conscious about is that healthcare is a very complex domain. We tried to implement JXTA platform for Peer-to-Peer communication among different systems at syntactic level. However at semantic level, the real challenge is there. So we were not confident of how eHealth interoperability via p2p communication would be achieved. Because of the results analysis of interview, it was found that eHealth had not yet adopted the health standard like HL-7, SONMEC CT as proposed by National Strategy of eHealth Sweden[17][13].

7.1.3 Dependability
According to Trochim[47], changes usually occur in research setting which affect result. Dependability emphasizes researcher to be responsible for ever-changing context within which research occur. The research is bound to describe the changes that happen during the setting and how these changes affected the study of the research.
In the beginning of the research we thought that we would try to attain interoperability via peer-to-peer communication using Health Level 7(HL-7) standard an SONMED CT for semantic interoperability. After literature study, it was observed that healthcare was a more complex domain, involving a large number of complicated data types. Also during the interviews, we found that no health standard had yet been implemented in healthcare which makes it difficult to work at semantic interoperability level. So we shifted to work only at syntactic level. This shift raised validity threat of our proposed technology. Also during
interview analysis we found that the relevant persons had different view about Peer-to-Peer approach. **SYstem Cross** community who has centralized environment seems reluctant to work with the new approach while the **MAGNA CURA** community was pleased with Peer-to-Peer approach. The only common thing in the research was the implementation of middleware that would resolve the interoperability problem. Thus validity results will be 50, 50.

### 7.1.4 Conformability

The fourth validity criterion for qualitative research is called conformability which refers to the degree. A result could be confirmed or agreed upon by others. Conformability means that the outcome of any research is the result of participant’s bias, inspiration and motivation rather than researcher.

We deeply studied the research problem and the proposed solution, and then tested through prototype. After successful implementation, the idea was shared with the participants, their view and suggestion which were considered. Participants were informed about the importance of proposed implementation. Questions about different concerns like security, privacy and availability of peers were answered. Also pros and cons of the existing solutions as well as different eHealth services which would be provided by our proposed solution were highlighted.

The prototype was planned to present but due to resource limitation, it was not showed. Also due to time limitation, survey was not conducted. However, by face to face interview, we tried to achieve maximum user satisfaction.
8 EPILOGUE

8.1 Conclusion

The main goal of the study is to cover current interoperability gaps through proposed solution via P2P communication. To support the main goal of our study, an extensive literature was reviewed and face-to-face interviews were conducted with the participants for further elaborating the importance of research problem. From our research findings we concluded that eHealth interoperability is a big challenge not only in Sweden, but also worldwide. A lot of research has been done to solve interoperability both at syntactical and semantic level.

During study we found that Blekinge healthcare centers uses two different systems called MAGNA CURA and SYStem Cross. Both systems are interoperable on their own but do not interoperate with each other. The two systems need to communicate with each other for exchange of record when a patient is referred to or discharged from hospitals. Due to interoperability problem between two systems, they rely on alternate solution like using OVK and telephone. A solution in the form of middleware is suggested.

The research findings also showed that as the scope of eHealth expands, more municipality healthcare centers would join the existing distributed eHealth environment for sharing useful medical information. Therefore, P2P communications would be the ultimate solution. This is the answer of our first research question.

However from literature review as well as results of current and previous interviews, there are many concerns about P2P such as free riding, information security and so on. We also studied many solutions that provide P2P communication but these are either proprietary or they do not provide eHealth information security. JXTA is the most important technology which is newly developed with a set of XML support and open source protocols. This study finds that it can be used to avoid these concerns.

To test and validate the research finding from the literature and interview, a P2P based prototype was developed with the use of JXTA technology. First we analyzed the database of both two systems to find out the basic data for data sharing, and then we designed a prototype based on the case of SYStem Cross and MAGNA CURA. We tested prototype by making a group of 3 peers, and then patients’ information from other peer was successfully received. In this way, we are able to achieve eHealth interoperability in Blekinge at syntactic level. This is also the answer of our research question 2. However validation of our proposed solution should be done through the real data and a survey on the targeted population for approval is needed. JXTA is independent on any system, programming language and so on,
our solution is a kind of data/information transmitting tool. As a result, the idea of achieving eHealth interoperability via Peer-to-Peer communication using JXTA technology can also be used outside of Blekinge. It is a quick and effective way to share patient data without changing anything of current systems. However our prototype is developed based on the interview results, so we don't think it can be directly used outside. It must be modified according to the different environments.

8.2 Recommendations
Literature study showed that a numbers of solutions and recommendations have been proposed to overcome interoperability at both syntactic and semantic level in healthcare. National Strategy of eHealth Sweden provides a clear guideline for future interoperability. However we sadly state that the job of implementing health standard is still pending and individuals are less aware of the use of Peer-to-Peer approach.

After analysis of research findings, we suggest the following recommendations that will be helpful for individual facing with interoperability problem and making effort for it.

- The concept of middleware that will permanently solve interoperability problem and provide direct communication.
- Achieving eHealth interoperability without using common health standard like HL-7 and SONMED CT will be merely a dream.
- With the passage of time, the scope of eHealth will expand by joining more and more health centers in a decentralized manner, so Peer-to-Peer will be the ultimate solution.
- Keeping in view different features of JXTA such as interoperability, information security and ubiquity, it would be the most useful technology.

8.3 Future Work
We had a very broad research plan and high expectation when we started our work. We wished a demo-based survey after successful achievement of syntactic interoperability. To achieve eHealth interoperability fully in Blekinge requires a long study period. Due to several constraints like time limitation, shortening in programming and research skills, difficulty in appointments and language communication, it is not just that a master thesis could work out. There were several issues in P2P which were not focused on, such as quality of service, packet losses and recovery as well as user authenticity. We would like researchers to perform quantitative study by conducting experiments through real data in Blekinge. The most challenging task is semantic interoperability since healthcare is a much more complex area that needs a lot of efforts.
REFERENCES


of Technical Interoperability Solutions in eHealth.”


Appendix A

Interview with IT Administrator

Q.1 What system do your health care centers use?
Ans: We use both systems i.e MAGNA CURA and SYSteam Cross. MAGNA CURA is a program that is used by healthcare centers like Vidablik for managing health record and other useful health information regarding elderly and disabled care, Whereas SYSteam Cross is used for General Medical treatment to every citizen living in Blekinge County. Nurses at Vidablick some time need to have access to SYSteam Cross.

Q.2 When/why do you need to communicate with other systems (whom)? What contents do you need to communicate with others?
Ans: Vidablick Nurses may need to communicate with SYSteam Cross, when an elder patient being treated at one of the two hospital (Karlskrona and Karlsham) and refer to elderly health center for care continuity Or when elder patient got some serious health problem that need to refer to hospital then Doctor or Nurse at hospital would like to know his/her treatment record (Patient Summery).

Q.3 What is the problem while you communicate with others system like SYSteam Cross and what solution have been made?
Ans: Interoperability; since both system intended for different jobs and totally different in all aspect i.e different companies, different technologies etc.
Solution to this problem is OVK, A program which work as third party for information exchange. At the time of discharging a patient, doctor or nurse at hospital write a note about the illness, treatment given and medication if needed for care continuity. Similarly, if an elder patient at Vidablick got serious illness and need to refer to hospital for treatment, nurse at Vidablick write a note about patient condition, any medicine he/she was using, what happened with the patient, how long he/she were affected with that problem. The information from OVK are then documented and stored in database.
Q.4 Are you satisfied with those solutions for communication problem? If not then what you propose?

Ans: Yes, we are also working on giving access to Vidablick nurses for access to **SYStem Cross** from next year.

Q.5 Do you prefer a solution in such a way that it doesn’t affect your system but it only plays as a middle man between your request and the receiver system, so would you like to implement it?

Ans: Yes, though we are working on solution that will be installed by next year which will enable Nurse to have access to **SYStem Cross**. but solution that would directly communicate both systems without any effect will be good.

Q.6 Why both hospital and healthcare don’t use the same system?

Ans: Because MAGNA CURA deals with elderly patient and **SYStem Cross** for general health.

Q.7 How you keep the treatment record for further care prescription in your system?. Which tool and DBMS **MAGNA CURA** use?)

Ans: We keep patient record in database. We use SQL Server.

Q.8 When a patient is discharged from hospital and refer to local healthcare for care continuity, how his prescription record is exchanged?( use some portable medium to carry information exchange or it take place online).

Ans: Using **OVK**. The Nurses at Hospital write a summary report of the patient and any further medication. The nurses then access to **OVK** are checking for summery. The record is then updated in **MAGNA CURA**.

Q.9 Do you update your patient record each time he take care of you till the specified treatment period?

Ans: Yes. When a nurse at Vidablick provides any medication to elderly patient, they would update his/her record.

Q.10 According to National strategy of Health, to make systems interoperable, specific health standards need to be implemented, so do you know that any such standard is implemented?

Ans: Not now but in future this could be implemented.
Q.11 How patient information is protected?
Ans: Information can be protected by restricted access. Every professional login with his/her own rights. Only doctor and nurses can access to patient history. Only doctor can make prescription, pharmacy can only request for prescription.

Q.12 According to National strategy of health focus is on National database for patient’s health record. Would you prefer the centralized data sharing or Peer-to-Peer?
Ans: Since healthcare providers like Vidablick and hospitals use different systems and data is decentralized. For such decentralized data sharing P2P is the best alternative.
Appendix-B

Interview with Vidablick Nurse Ronneby Municipality

Q.1  What system your healthcares centers use?
Ans:  We use MAGNA CURA for rehabilitation of handicapped and care of elder people.

Q.2  When/why do you need to communicate with other systems (whom)? What contents do you need to communicate with others?
Ans:  Since we use MAGNA CURA, so we keep journal regarding patient health. If an elder patient feels ill, we evaluate his health condition and then document that information which will be required to exchange with the doctor.

Q.3  What is the problem while you communicate with others system like SYStem Cross and what solution have been made?
Ans:  There are two problems. First problem is that we have no access to SYStem Cross. 2nd problem is that MAGNA CURA didn’t communicate with SYStem Cross because both are totally different.
To exchange information regarding patient health, we use a program called OVK in which we write the patient health status and any other relevant information. Also we communicate through telephone to exchange patient’s health information.

Q.4  Are you satisfied with those solutions for communication problem? If not then what you propose?
Ans:  These are not so useful though we can’t avoid their importance, but it will be better if either we use Single system in all kind of healthcare or MAGNA CURA directly communicates with SYStem Cross. Some time when I access OVK for the patient summery, the information seems strange to me and I didn’t understand what the doctor means, so I need to talk to that doctor through telephone and some time it take time to find the doctor available which result in treatment delay. This problem became sever if patient need that medication and proper information are getting delayed.

Q.5  Do you prefer a solution in such a way that it doesn’t affect your system but it only plays as a middle man between your request and the receiver system, so would you like to implement it?
Ans:  Yes it will be quite interesting and it is our dream that we can access patient record from SYStem Cross through MAGNA CURA instead of using OVK.
Q.6 Why both hospital and healthcare don’t use the same system?
Ans: **MAGNA CURA** deal with elderly and disabled patient. **SYStem Cross** is used by hospitals and medical care center through the Blekinge County.

Q.7 How you keep the treatment record for further care in your system?
Ans: When we receive patient summary through **OVK**, we store these information in **MAGNA CURA** to maintain patient history using database.

Q.8 When a patient is discharged from hospital and refers to local healthcare for care continuity, how his prescription record is exchanged?
Ans: Through **OVK** and telephonic conversation. Medical report of the discharge patient from **OVK** is accessed and then wrote to **MAGNACURA**.

Q.9 Do you update your patient record each time he take care of you till the specified treatment period?
Ans: Yes of course this kind of information became the patient history which the doctor would need at the time of checkup.

Q.10 According to National strategy of Health, to make systems interoperable, specific health standards need to be implemented, so do you know that any such standard is implemented?
Ans: No this is still the problem.

Q.11 How patient information is protected?
Ans: Only authorized personal have access.

Q.12 According to National strategy of health focus is on National database for patient’s health record. Would you prefer the centralized data sharing or Peer-to-Peer?
Ans: Peer to Peer will be good.
Appendix-C
Interview with Depty System Administrator SYStem Cross

Q.1 What system your healthcares centers use?
Ans: SYStem Cross. This system is used for providing healthcare to general public.

Q.2 When/why do you need to communicate with other systems (whom)? What contents do you need to communicate with others?
Ans: When an elderly ill patient come to hospital then the doctor at Karlskrona hospital would need his/her record.

Q.3 What is the problem while you communicate with others system like MAGNA CURA and what solution have been made?
Ans: I am not sure we need to communicate with MAGNA CURA. There is a problem to the Nurses at Vidablick that they might have problem in accessing SYStem Cross but by next year we are solving that problem and Nurse will have access to SYStem Cross.

Q.4 Are you satisfied with those solutions for communication problem? If not then what you propose?
Ans: There were some problem with OVK as pointed by the nurse and we are going to remove OVK by another program called Prator. So i think this program will solve it. How this program work, I don’t know. But this program which is developed by same company that developed SYStem cross and this program will talk to MAGNACURA.

Q.5 Do you prefer a solution in such a way that it doesn’t affect your system but it only plays as a middle man between your request and the receiver system, so would you like to implement it?
Ans: I am not sure, we are already working on solution that will be installed by next year which will enable nurse to have access to SYStem Cross, but solution that would directly communicate both systems without any effect will be good.

Q.6 Why both hospital and healthcare don’t use the same system?
Ans: Since SYStem Cross started in 1997 as a very simple healthcare program with only limited facilities, however it’s no growing more and more by including more and more services. So at the movement MAGNA CURA work at his own place and SYStem Cross working on its own place, but in the future may be SYStem Cross
also provide the same services as MAGNA CURA, however SYStem Cross still under development.

Q.7 How you keep the treatment record for further care prescription in your system?. Which tool and DBMS MAGNA CURA use?
Ans: We keep patient record on the main server. We use SQL Server.

Q.8 When a patient is discharged from hospital and refer to local healthcare for care continuity, how his prescription record is exchanged
Ans: In two ways. For SYStem Cross, when a patient is discharged from hospital or referred to hospital from vardcentral, information regarding patient health are write to the Journal and the Doctors/Nurses at both side access an read this journal.

Q.9 Do you update your patient record each time he take care of you till the specified treatment period?
Ans: Yes ofcourse, all the time the nurse provide treatment to the patient, the information are recorded in the system which at the time of discharge printed in the form of summary report.

Q.10 According to National strategy of Health, to make systems interoperable, specific health standards need to be implemented, so do you know that any such standard is implemented?
Ans: This has to be implemented in future. I have read about it but they are not practially in use.

Q.11 How patient information are protected?
Ans: There are strict rule regarding the access to patient information. Only doctor and nures have access to patient history. Nurse can only view the prescription and upate histroy when treatment is given. She cann’t precribed by her/him self. Only docotr can make prescription. If any research institution need to access, it is done through pateint concenses.

Q.12 According to National strategy of health focus is on National database for patient’s health record. Would you prefer the centralized data sharing or Peer-to-Peer?
Ans: Regarding SYStem Cross, we have centralized structure i.e clinet-sever. The main server is here at Lindstinget karslkrona and all the other systems at different primary healthcare act as client. However MAGNA CURA is working differently. So for us as SYStem Cross team, we don’t think P2P will be better and it will not work with
**SYstem Cross** because **SYstem Cross** is very old program. We have a very huge server that store all patient infromation registered at **SYstem Cross** and one passive server. If the active server failed to survive, the passive server take over the control. If is it possible with **MAGNA CURA** side, then it may be. Although P2P have useful result regarding load balance on the server, linke failure to the centeral server and so on but information security is the main issue.