Abstract

The care of chronic disease has become a main challenge for healthcare institutions around the world. As the incidence and prevalence of chronic diseases continue to increase, traditional hospital-based healthcare is less able to meet the needs of every patient. Treating chronic disease heavily depends on the patient’s daily behaviors, so patient-centered healthcare is encouraged. To improve patients’ quality of life, moving the base of healthcare from hospital to home is imperative. Home-based chronic disease care involves many different healthcare organizations and healthcare providers. Therefore, interoperability is a key approach to provide efficient and convenient home-based healthcare services.

This thesis aims to reveal the interoperability issues in the current healthcare system and to point out an appropriate technical solution to overcome them. We start with collecting perspectives from both healthcare providers and healthcare recipients through interviews and online surveys to understand the situations and problems they face. In our research study, we mainly use two current techniques—peer-to-peer (P2P) networks and cloud computing—to design prototypes for sharing healthcare data, developing both a P2P-based solution and a cloud-based solution. Comparing these two techniques, we found the cloud-based solution covered most of the deficiencies in healthcare interoperability. Although there are different types of interoperability, such as pragmatic, semantic and syntactic, we explored alternative solutions specifically for syntactic interoperability.

To identify the state of the art and pinpoint the challenges and possible future directions for applying a cloud-based solution, we reviewed the literature on cloud-based eHealth solutions. We suggest that a hybrid cloud model, which contains access controls and techniques for securing data, would be a feasible solution for developing a citizen-centered, home-based healthcare system. Patients’ healthcare records in hospitals and other healthcare centers could be kept in private clouds, while patients’ daily self-management data could be published in a trusted public cloud.
Patients, as the owners of their health data, should then decide who can access their data and the conditions for sharing.

Finally, we propose an online virtual community for home-based chronic disease healthcare—a cloud-based, home healthcare platform. The requirements of the platform were mainly determined from the responses to an online questionnaire delivered to a target group of people. This platform integrates healthcare providers and recipients within the same platform. Through this shared platform, interoperability among different healthcare providers, as well as with healthcare recipients’ self-management regimens, could be achieved.
To my beloved Cheng
I would like express my sincere thanks to my Supervisor, Professor Guohua Bai, for leading me into the world of academia and giving me constant guidance and supports during my studies. I also would like to thank Dr. Stefan Johansson, Dr. Martin Fredriksson and Prof. Sara Eriksén for their feedbacks and suggestions to my research.

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Yan Hu

Karlskrona, Nov. 2014
Preface

This thesis consists of five publications, four of which are papers submitted, peer-reviewed and published in conference proceedings. Paper IV has been peer-reviewed and accepted by Health Informatics: An International Journal, and it will be published in the coming issue. All the publications have been written together with other colleagues from Blekinge Institute of Technology. The included papers have been modified to fit the thesis format, but the content is not changed.


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6.1 Introduction


1 Introduction

1.1 Background

The care of chronic disease has become a main challenge for healthcare institutions around the world. Chronic diseases now are the leading causes of death, according to WHO: “Chronic diseases brought about 63% of all deaths, over 36 million people died from chronic diseases in 2008, and nine million of them were under the age of 60” [1]. Living with a chronic disease has a significant impact not only on a person’s quality of life but also on their family and the current healthcare system. Elderly people living with more than one chronic disease face particular challenges, both medically and socially [2].

Patients who suffer from chronic diseases have to be monitored and receive regular checkups. This is very costly, time consuming and inconvenient for most patients, especially for aged people. At the same time, healthcare spending is continuously increasing due to the high occurrence rate of chronic diseases and lack of healthcare resources [3]. Meanwhile, most of the cases for chronic diseases do not need urgent medical diagnosis and treatments. Usually, lifestyle, diets and metabolism are the main factors that cause most common chronic diseases. Treating chronic diseases depends heavily on the patients’ daily behaviors. Therefore, most conditions of chronic diseases may be alleviated by changing daily behaviors, such as discontinuing the habits of smoking and drinking, implementing and regulating a healthy diet, or increasing physical exercise [4]. By changing chronic disease patients’ healthcare from hospital-based to home-based, it may save a lot of time and resources, and provide more efficient healthcare. The quality of the patients’ lives could be greatly improved by better care for chronic diseases.

Home-based healthcare could enable the care recipients to live independently at home. Healthcare providers could monitor the patients based on their shared daily health data, and provide some clinical suggestions, as well as giving feedback through reports of medical
examinations that the patients have undergone. In addition, for home-based healthcare, more people are encouraged to assist with the care, such as family members and other patients with the same symptoms. This patient-centered home-based healthcare will encourage healthcare recipients to care more about their health, and will provide long-term monitoring and healthcare by linking patients to the sharing of health information and by enabling chronic disease self-management activities [5].

Information Communication Technology (ICT) evolution has led to widespread use of wireless personal devices like smartphones, personal computers and other self-monitoring devices. This can provide a solution to help with home-based healthcare. Most of the daily health monitoring and basic treatments can be handled by healthcare recipients themselves at their homes [6]. There are already some commercial or research-based solutions for healthcare self-management. For instance, HealthVault [7], launched by Microsoft, is a web-based PHR system to store and manage health information. A lot of specific third-party applications, such as blood pressure management tools and medical image viewers, as well as hundreds of devices such as blood glucose meters and blood pressure monitors, cooperated with this platform to record health data.

The development of ICT has enabled people to enter a modern digital society. Our quality of life is promoted by the application of ICT in all fields. The use of modern ICT to support the healthcare services and medical informatics called eHealth. The World Health Organization (WHO) defines eHealth as “the cost-effective and secure use of information and communications technologies in support of health and health-related fields, including healthcare services, health surveillance, health education, knowledge and research.” [8] The goal of eHealth is to improve the cooperation and coordination of healthcare, so that improvements in the quality of care and reductions in the cost of care can be achieved at the same time. These obvious benefits have facilitated a rapid development of eHealth in recent years. Most eHealth applications researches around the world are listed below [9][10]:

- Electronic Medical Record (EMR)
Chronic disease care involves many healthcare organizations and healthcare providers. Different organizations usually use different healthcare information systems. In this situation, interoperability is a key issue in providing efficient and convenient healthcare services where multiple healthcare information systems are deployed. Both international and national solutions are needed to cover eHealth interoperability gap, as well as to facilitate the sharing of health data accurately and effectively among different healthcare information systems and applications [11]. eHealth interoperability is “the ability of health information systems to work together within and across organizational boundaries in order to advance the effective delivery of healthcare for individuals and communities”[12]. Due to the lack of interoperability among ICT tools and solutions used in healthcare, the healthcare recipients and different care providers sometimes find it difficult to obtain benefits by using the eHealth services [13]. Many studies show that interoperability is a blazing issue in today’s research [13][14].

1.2 Problem definition
Information sharing among different healthcare organizations becomes especially significant when some services are crossing outside one organization. The interoperability problem prevents two applications to communicate and exchange data accurately, effectively and consistently [15]. In the real world, different care providers provide similar or related health services for the same group of care recipients. Services and applications in different organizations are different in concepts, models,
vocabulary and so on. Moreover, ICT solutions supplied by different suppliers are also different in terms of technology, structure and design. All these dissimilarities lead to the problem of sharing healthcare data, which is referred to as an interoperability problem [16].

In Blekinge County, citizens are provided free and convenient healthcare services by using ICT tools and solutions. Several ICT-based tools are used in various healthcare centers and hospitals, but due to the absence of appropriate interoperability ICT platforms [17], they are still faced with the problem of coordinating and exchanging valuable patient information. The emergence of 1177 [18] helps most healthcare recipients to communicate with their providers without face-to-face visiting, but there are still several issues it cannot cover, and communication is lagged in some cases.

1.2.1 Research questions
The aim of this thesis is to discover the interoperability problems in current healthcare and find an appropriate technical solution to overcome the problems. The following research questions are formulated as a guide to achieve the research goals.

Q1. What are the main problems of interoperability in current healthcare?
Q2. What are the alternative solutions for healthcare interoperability problems, and in what contexts are they used?
Q3. How can cloud computing be used to achieve interoperability in home-based healthcare?

The research started with a common challenge in current healthcare—interoperability problems. In order to find the details of situations in healthcare interoperability, we collected the perspectives from healthcare providers and healthcare recipients, and defined the different levels of interoperability from others’ work. Based on the problems from Q1, we endeavoured to find all the alternative solutions, and compared the different contexts of the solutions that were feasible. The best solutions for achieving interoperability in home-based healthcare were found through Q2. By analyzing the results of Q1 and Q2, cloud computing was selected as the best technology. We then focused on the cloud computing and tried to come up with a reliable cloud platform to answer Q3.
1.3 Research methodology

Research methodology (RM) is a collective process of conducting research in a scientific way [19]. In this thesis, we use mixed research methodology containing both qualitative methods and quantitative methods. The methods we used included interview, online survey, literature review and prototyping.

Interview is a useful method for data collection, with a high response rate and closer judgment of people’s experience, opinion, desire and feelings [19]. We started with interviews of the healthcare providers and healthcare IT professionals to understand the current healthcare systems and the problems they are facing. We used a semi-structured interview with both open-ended and closed-ended questions. The interviewees were selected carefully on the assumption that they were aware of the importance and challenges of eHealth interoperability, as well as of the government policies for eHealth.

Survey is another method that we used to collect data directly from potential users. In this thesis, we used online survey as the main research method to obtain responses from healthcare recipients. The main advantages of online survey are their ease of access for the response group—which has difficulties in face-to-face discussions—their quick response and their low cost [20]. In the thesis, we applied online surveys twice. The first one aimed to analyze current problems and needs in chronic disease care, while the later one involved the collection of requirements for designing a cloud platform for home-based healthcare.

According to Dawson [21], literature review is the first step in any research work. 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 literature [19]. Literature review is a basic research method which is used through the whole research process of the thesis. It helps us to gain a deep insight into the defined problems and into others’ work, as well as to find possible solutions to problems in the real world. In this research, a systematic literature review was used to examine existing studies on
cloud-based eHealth solutions. It identifies the state of the art and pinpoints challenges and possible directions for applying cloud computing in eHealth.

Prototyping is the process of developing a system or a product by showing the feasibility of an idea. It is widely used in systems development and research [22]. Prototyping is an attractive method for complicated systems where there is no manual process or existing system to help determine the requirements, as well as no method for obtaining quick user feedback with regard to improvements [23]. There are three prototypes developed in this thesis; the first two prototypes were developed for the same scenarios with different technologies, P2P and cloud computing. These prototypes were used to compare these two technologies applied to eHealth interoperability problems in order to find out which was the most appropriate technology. Another prototype was used to clarify the requirements collected from the potential users, as well as for next step user evaluations. Table 1.1 lists different research methods used for answering research questions in this thesis.

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Table 1.1 Research methods and research questions

1.4 Related works

1.4.1 eHealth strategy

In 2010, European Union published an eHealth Action Plan 2012-2020 [24], which aimed to provide smarter, safer and more patient-centered health services. In accordance with this plan, Sweden has published a National Strategy for eHealth. The previous National Strategy for eHealth focused mostly on the development of ICT in the Swedish healthcare services. However, since then, there have been an increasing number of developmental needs to be coordinated across the entire sector. In order to bring cohesion and efficiency to all health and social care activities, new solutions must also reflect the needs of health authorities, including municipalities, county councils, private and third-sector practitioners.
From the recent National Strategy for eHealth [25], there are three main requirements that the eHealth domain must fulfill.

**Putting the individual needs first:** Modern healthcare must be based both on the individual’s need for high-quality care interventions and on a professional need for collaboration between different healthcare providers. More and more people nowadays are looking for individual solutions to their problems, taking their own initiatives and making active choices. This requires the healthcare providers to be able to offer services which are designed in accordance with the requirements and wishes of the individual, and use the Internet and social media as communication tools to a much greater degree than previously, in order to increase both accessibility and user-friendliness. The most important prerequisite of high-quality, accessible and secure healthcare and social services is efficient information exchange and cooperation between all providers. Authorized actors having access to the relevant information across organizational boundaries is the key to being able to create a coherent basis for making decisions about health and social care interventions.

**National coordination for healthcare services:** On the other hand, healthcare needs coordinated interventions from several different health authorities and practitioners. This increases the need of organizations and staff to have a fast, secure and simple way of being able to share comprehensible, reliable information. It must be possible for care staff to use technical tools as an aid and concrete support in their day-to-day work, support that clearly meets the needs of the organization as well. Apart from the secure and efficient exchange of information between various healthcare providers, healthcare recipients must also be able to access information that concerns them. This throws up major challenges, especially when the necessary information is not only to be exchanged between different service providers but also concerns individuals who are in need of interventions from healthcare services.

**Greater focus on e-issues, both nationally and internationally:** Good governance and quality monitoring in healthcare and social services are essential. An important monitoring instrument is accessible, structured and cohesive information that enables open and reliable comparisons. In this way, nowadays private companies and third-sector organizations play an increasingly important role as care practitioners. Moreover, the need for more in-depth and structured international exchanges of experiences is becoming clearer for all eHealth projects as national and international efforts increasingly coincide.
1.4.2 eHealth interoperability

According to the European Union eHealth Action Plan [24] and Swedish National Strategy for eHealth [25], on one hand, collaboration among different healthcare organizations at national and international levels is an imperative requirement to reduce costs and save resources. On the other hand, personal needs should be considered first of all when providing healthcare services. These two aspects will be the main trends of future healthcare. To realize these goals, interoperability is the key issue. An appropriate interoperability solution should be proposed to facilitate data sharing accurately and effectively among different healthcare organizations and between healthcare providers and healthcare recipients. In information systems research, there are several classifications of different levels of interoperability [26][27]. In the eHealth domain, the most used interoperability is syntactical interoperability and semantic interoperability [17].

Syntactical interoperability is a lower application-level interoperability, which makes multiple applications with different implementation of languages, execution platforms and interfaces, in order to communicate and exchange data. A lot of different approaches and methods have been made to overcome syntactical interoperability gaps, such as ODBC (Open Database Connectivity) [28], use of XML Web-services [29], Simple object Access Protocol (SOAP) [30] and SQL standards [31]. The syntactic interoperability allows successful data sharing, but it does not ensure that all systems can understand the shared data.

Semantic interoperability means that the data is exchangeable and the content is understandable by both sides. It is the actual meaning of the data that is exchanged. Semantic interoperability helps integrate data from different sources through semantic mediation, and is commonly achieved by informal agreements [32]. Rong Chen [33] mentioned that in the healthcare domain, to achieve semantic interoperability, not only should the structure of records be shared, but also the definitions of clinical meaning (reference terminologies and ontologies) should be established.

In order to achieve semantic interoperability, several efforts and standardizations have been made. Among all, Health Level Seven (HL7) International [34] is the main international healthcare informatics
interoperability standards organization. It is the seventh layer of the Open Systems Interconnection Reference model – the application layer. HL7 and its members provide a framework and related standards to exchange, integrate, share, and retrieve electronic health information. HL7 standards support clinical practices to manage, deliver, and evaluate healthcare services. HL7 is recognized as one of the most commonly used interoperability standards in the world [34]. Other widely deployed interoperability standards to overcome the eHealth semantic interoperability include the Standard for Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT) [35] and Digital Imaging and Communications in Medicine (DICOM) [36]. However, in a lot of cases, these standards are not based on real-life experiences and requirements, so the expectation of what can be achieved with these standards is too high [37]. For example, HL7 does not consider that different healthcare information systems have different clinical workflows and operational contexts [37]. The challenge of standardization highlights the interoperability.

1.4.3 Patient information sharing in Sweden

In Sweden, there is a national electronic service called National Patient Overview (Nationell Patientöversikt - NPÖ), which enables healthcare providers to share patient healthcare records with other healthcare providers through computer networks. The purposes of NPÖ are to facilitate cooperation among different healthcare providers in Sweden, as well as giving healthcare recipients access to their own healthcare information [38]. NPÖ does not replace the former patient record; it just makes the information available to more healthcare providers. If patients do not want certain information to appear in the NPÖ, they can block the records and decide who is allowed access to this blocked information. The shared information contains notes and summaries of care, visits and stays. Drugs which the patient was prescribed and the results of examinations and tests are also presented. All this information is shown from the last three years. For the convenience of patients’ movements, a patient can give consent to the so-called cohesive record. Cohesive record means that healthcare providers can share medical records with each other anywhere in Sweden [38].
To guarantee the privacy of patient health records, only healthcare providers with a relationship to the patient can access his or her information through NPÖ. Health providers must have valid e-service identifications to access the NPÖ. The patient is asked to agree before anyone is allowed to take note of the information. Every time when someone takes note of the information from a patient’s record, it will be automatically recorded. Therefore, it is possible to retrospectively track who has received the information, where and when it happened [38].

NPÖ assists cooperation among different healthcare providers at the national level. However, it is predominantly a solution for hospital-based healthcare, as the direct beneficiary of this service is the healthcare providers. When shifting to home-based chronic diseases care, NPÖ can provide few rights for healthcare recipients. Also, as home-based healthcare involves other parties like family members and other patients with the same symptoms, how to share data with these parties is another challenge. In addition, NPÖ is only used for sharing healthcare information in Sweden; when people go abroad, it is quite difficult for them to access their healthcare data.

1.4.4 Cloud computing

Nowadays, most elderly people have one or more chronic diseases. This high rate means that most of them need continuous but not urgent healthcare. In Sweden, people mainly visit hospitals or healthcare providers to receive healthcare. Besides visiting, sometimes they use the telephone or internet to commute with providers. When asked about communication troubles with healthcare providers, their answers were varied, but with the responses included troubles such as too long a waiting time, inconvenience for the patient to visit hospitals, and lack of cooperation between healthcare providers [39]. It is therefore more appropriate to adopt an efficient approach to trace and control the patients’ conditions via healthcare services, such as monitoring and recording physiological signals [40] in the home environment. To overcome these challenges, a possible innovation may involve a new eHealth approach developed by ICT.

The computing revolution has given rise to the concept of cloud
computing, which uses software, infrastructure and platform as services. According to the definition given by the U.S. National Institute of Standards and Technology [41], “cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction.”

Cloud computing is composed of five essential characteristics, three service models, and four deployment models (see Figure 1.1). Unlike traditional computing such as web hosting, cloud computing offers pay-as-you-go services, which gives users the opportunity to pay only for the resources they actually utilize, for a specific time period [42]. Cloud computing offers many advantages, such as economy of scale, availability, management, efficiency, consolidation, cost and energy savings, etc. This helps cloud users to better utilize computing resources and to minimize costs.

![Figure 1.1 Cloud computing overview model [41]](image)

Although there are different methods of classification for cloud computing, the cloud service is classified based on the service model “X as services”. The three layers are Infrastructure, Platform and Software, which depend on the type of service being offered.

Infrastructure as a Service (IaaS) is a cloud computing service model where hardware is delivered as off-premise, on-demand services. In this model, the service vendor owns the hardware or technology such as computing power, storage, operating systems, or other infrastructures. The
virtual hardware is created by the developer, and all the applications and services are developed based on the virtual hardware. Essentially, an IaaS vendor has created a hardware utility service where the user provisions virtual resources as required.

Platform as a Service (PaaS) provides an application platform, or middleware, as a service on which the developer can create customized solutions within the context of the development tools that the platform provides. These solutions are based on all different types of development languages, application frameworks and so on. It provides the tools and development environment for deploying applications with another vendor’s application.

Software as a Service (SaaS) comprises end-user applications delivered as a service rather than as traditional on-premises software. It offers user interaction with the software which is accessible via the Internet.

1.4.5 Cloud computing deployment models

From the view of a deployment model, cloud systems can be divided into four types: public cloud, community cloud, private cloud and hybrid cloud [41]. Each deployment model’s organizational structure and provisioning location differ from the others. There are differences in utilization style, security level and other characteristics offered by these four deployment models.

Public Cloud: The infrastructure or services of public cloud are open-provisioned for public use. As defined by NIST, “A public cloud is usually provided, managed, and operated by an enterprise, academic organization, government agency, or some combination of these. The cloud service providers make resources, such as computing capability, storage, application and other resources, available to the general customers through the connections of Internet” [41].

Public cloud services are widely used by many enterprises today. Famous service providers like Amazon, Google and Microsoft provide infrastructures and various applications as services. All these services can be accessed via the Internet by the customers. Other examples, like the dependent cloud service provider Dropbox, provide applications and storages which aggregate cloud infrastructure from Amazon.

Private Cloud: As a design, a private cloud owns the same features as a public cloud; meanwhile, it removes a number of objections including control over enterprise and customer data, worry about security, and issues relevant to regulatory compliance [43]. In accordance with the
definition of NIST, a private cloud is “the cloud infrastructure or services privately provisioned for exclusive using, managing and operating by a single organization. It is usually owned, managed, and operated by the organization, sometimes provided by a third party private cloud provider [41].”

Unlike public cloud services, a private cloud is hosted and protected by a corporate firewall. Thus it endows a private cloud with the same security level as the organization’s internal local area network, and the capacity to deliver an organization’s in-house cloud computing services remotely. In addition, the network is only accessible to a certain authorized group of users. A private cloud increases the possibility to achieve better security over cloud-based assets [44].

**Community Cloud:** In accordance with the definition of NIST, community cloud is “the cloud infrastructure or services provisioned for exclusive using, managing and operating by a specific community of organizations that have shared concerns. It is usually owned, managed, and operated by one or more organizations in that community, sometimes provided by a third party provider [41].”

In the model, several organizations which have the same policy and compliance considerations share a cloud infrastructure. The benefits of a shared non-public cloud are available for multiple independent entities without security and regulatory concerns [45]. Besides, cloud infrastructure has a better performance in cutting costs, since a larger group shares it than that which uses a private cloud.

**Hybrid Cloud:** An organization could build a cloud computing environment named “hybrid cloud,” where both internal and external cloud resources can be utilized and managed effectively. Hybrid cloud is defined by NIST as “the cloud infrastructure and services are a composition of two or more distinct cloud infrastructures and services which are different entities, but are combined together by techniques [41].”

Owing to the potential advantage, provided by the public cloud, of cost efficiency and scalability, the hybrid cloud model needs not host critical applications and data on a third party public cloud. Furthermore, a hybrid
cloud can deal with cloud bursting as well. For example, an existing private cloud may require a fallback option to support the peak load when it fails to deal with workload overflow. Thus, users can see through a transparent workload migration between public and private clouds.

1.4.6 Comparison of public, private, community and hybrid clouds

In the four deployment models, each model has its own advantages and drawbacks. In the healthcare domain, deploying a community cloud will bring problems, due to the fact that it involves multiple different organizations. Third party organizations and hospitals have different properties and duties by nature. They have their own different interests beyond a common shared mission and compliance. Accordingly, allocation of accountability and responsibility will be confusing when problems occur for either administration or management. Therefore, the community cloud deployment model will not be considered in our comparison. For the other three cloud deployment models, the comparison will be conducted through analyzing and comparing the following five factors: security and privacy, scalability and capability, customization, costs of setup and maintenance, and legal issues.

Security and Privacy: Security and privacy of healthcare data is one of the key factors in building the trust of patients. As a public cloud is hosted by a third party enterprise, so the health data will be stored in the servers, which are not fully trustable and are out of control of both the healthcare providers and the recipients. This will increase the potential for sensitive information leakage. The third party storage servers are often the targets of malicious attacks, which will be even worse due to the high value of the sensitive health information. Due to these facts, patients are probably not willing to let their entire health data be stored in public cloud servers. A private cloud is usually hosted by the organization in-house. The health data will be stored in the servers, which are operated by healthcare service providers. Although the disaster tolerance is not good as a public cloud, the threat of outside malicious attack will be far less. In addition, it is more flexible and reliable to implement fine-grained access control mechanisms to protect the privacy of health data. A hybrid cloud is the combination of a private cloud and a public cloud; it hosts sensitive data and workflow in its private cloud part, and can provide the same security and privacy guarantee as a private cloud.

Scalability and Capability: Another important reason for adopting cloud computing in health information sharing is the scalability and powerful
capabilities. Because of the benefits of distributed massive computer clusters, ubiquity and virtualization, a public cloud can provide high performance services with low requirements on user-end computer infrastructure. Compared with the economic reasons, the capability of the development platform is an important factor to adopt a public cloud [46]. Third party eHealth service providers can develop various services, such as historical health analysis, health data mining [47] and Clinical Decision Support System [46], on a public cloud platform. Theoretically, a private cloud can provide the same features as a public cloud. However, due to the private cloud’s own characteristics of smaller scale and limited access, it is unrealistic to make a private cloud function as a platform which needs to host various third party services [43]. This will cut down the potential value of massive health data. If a hybrid cloud hosts shared health information and insensitive services in its public cloud part, it can provide approximately the same scalability and capabilities as a public cloud.

**Customization:** Different legacy systems are used by different healthcare providers, and the deployed cloud model needs to be integrated into these systems without impacting the previous workflow. In addition, the specific requirements of security and privacy in healthcare data have high demands regarding authentication, authorization and traceability. Although public cloud providers deliver a set of various services, it is hardly to satisfy the special requirements from different healthcare providers. A private cloud provides the capability to customize services in accordance with particular demands. The hospital can modify the cloud system to be coordinated with other legacy systems, and can even move the legacy systems to a private cloud. A hybrid cloud has the ability to keep the capability of customization, while at the same time migrating appropriate services to the public cloud part. This makes a hybrid cloud even more flexible than a private cloud.

**Cost:** A public cloud offers a pay-per-usage charging model. Different parties only need to pay for the services they have used. The initial setup costs of hardware, software and bandwidth are covered by public cloud providers. Moreover, the lengthy time consumption and costly long-term maintenance, as well as the update of software and hardware, are no longer bottomless values. However, the legacy hardware has likely cut only a small piece of the total demand. The investment in new hardware and human resources will be very high. The costs of expansion, updates and long-term maintenance will be a burden to an organization which uses a private cloud. Although a hybrid cloud combines the capacity of a private cloud with the on-demand capacity of a public cloud, the investment cost of adopting a hybrid cloud is approximate to that of a
private cloud [48]. However, the migration of insensitive data and services to the public cloud part will reduce some of the burden as compared to a pure private cloud.

**Legal:** At present, a majority of big public cloud providers are from the US, so most data centers are located in the US. Because of the specialty of health data, it may cause some potential legal risks for other countries to deploy a public cloud in healthcare [49]. Different countries have different laws and regulations on managing patient data, and some nations do not allow sensitive health data to be transferred cross-border. Although big public cloud providers such as Amazon may offer options to allow customers to choose the regions for the storage of data, the choices of region are still limited. A private cloud will be hosted by healthcare organizations, so there will be no concern about the violation of laws or other regulations. As for a hybrid cloud, the sensitive data can be kept in the private cloud part while utilizing the public cloud part to process insensitive data.

Based on the analysis and comparison of the five key factors, it can be summarized that a public cloud is less appropriate than the other two clouds in security and privacy, customization and legal issues. A private cloud is less appropriate than the other two clouds in scalability and cost. By combing a private cloud with a public cloud, a hybrid cloud seems to be the most appropriate cloud deployment model for the objective of sharing health data. We use a quantitative score evaluation method [50] to compare these three cloud models, as shown in the radar chart below.

![Figure 1.2 Radar charts of clouds](image-url)
1.4.7 Cloud computing applied in eHealth

In order to examine existing research on cloud-based eHealth solutions, a literature review was conducted. The main goal was to identify the state of the art in this area and to pinpoint challenges and possible directions for researchers and application developers, based on the current literature.

From the review, we found that the research on cloud computing applied in eHealth started from 2010 [51]. We selected 44 research papers for final review. The topics discussed are quite broad in relation to the use of cloud computing in the eHealth domain. Generally, the topics can be classified into three categories. The following are the discussions of related articles from 2010 until early 2014.

1) Cloud-based eHealth framework design

Since one of the most significant advantages of cloud computing is its huge data storage capacity, six papers proposed cloud-based frameworks for healthcare data sharing. One of the pioneers in this area, Rolim et al. [51] designed a framework for data collection by using sensors attached to medical equipment; the collected data can be directly stored in a cloud, which can then be accessed by authorized medical staff. Some studies [52][53][54] proposed a national-level framework for eHealth based on cloud models. For example, Patra et al. [54] argued that on a national level, their cloud-based solution would provide a cost-effective way to deal with patient information for rural areas. By encouraging people in rural areas to upload their personal healthcare information to the health cloud, the care providers can provide them with more appropriate healthcare services, such as remote diagnosis, supervision and emergency calls.

Other studies related to this category of framework design are more specific as regards application areas, such as the design of a Virtual Research Environment by both Simth et al. [55] and Regola et al. [56], patients’ self-management by Martinovic et al. [57], transition or standardization of data stored in different EHR or PHR systems by Coats et al. [58] and Ekonomou et al. [59], and design of a secure EHR framework [60][61][62][63].

2) Applications of cloud computing
High accessibility, availability and reliability make cloud computing a better solution for healthcare interoperability problems. Papers in this category mostly applied cloud technology for healthcare data sharing, processing and management, and can be categorized based on three types of cloud platforms, namely public cloud, private cloud and hybrid cloud.

Six papers presented their eHealth applications by using or testing them in public clouds, such as Google App Engine [64], Windows Azure [65][66] and Amazon EC2 [67][68][69]. The application of Wooten et al. [67] provided patient-to-patient support and information sharing within the patient community. The solution proposed by Benharref et al. [66] used the mobile phones of seniors to send the patients’ data automatically to the cloud, and the patients themselves could decide with whom to share the data. Mohammed et al. [68] designed a Health Cloud Exchange (HCX) system which shares healthcare records between services and consumers, and includes some privacy controls.

For applications based on the private cloud, Bahga et al. [70] presented an achievement of semantic interoperability between different kinds of healthcare data, while DACRA [71] built a platform for interoperability on the syntax level. Vilaplana et al. [72] used queuing theory as the basic means by which to model the performance of an eHealth system based on the private cloud. Van Gorp et al. [73] applied virtualization techniques to allow patients to build their own lifelong PHRs. The PHR can then be shared with other stakeholders who are authorized and interested. Wu et al. [74] proposed an approach to EHR data schema composition with a broker-based access control. In order to reduce the cost of adopting EHRs, HP published a cloud-based platform called Fusion [75] for securely managing and sharing healthcare information on a large scale. Other studies also used the private cloud to integrate the EHR systems with other systems, like the healthcare billing system [76] and the national law system [77].

Gul et al. [78] and Chen et al. [79] proposed a shared EHR system based on a hybrid cloud. In the proposed application of Chen et al. [34], the patient’s medical data are stored both in a hospital’s private cloud and in the public healthcare cloud. A mechanism is set up to make sure that the owners of the medical records can decide when their records should be
protected in normal or emergency situations. Dixon et al. [80] implemented a community cloud-based exchange of clinical data between two disparate healthcare providers, which was mainly used in chronic disease healthcare.

3) Security or privacy control mechanisms

Healthcare data require protection for high security and privacy. Access control, an effective method to protect data, is widely used in many studies. Liu et al. [81] applied an identity based encryption (IBE) system in the access control of PHR; this identity-based cryptography system can reduce the complexity of key management. Attribute-based encryption (ABE) is one of the most preferable encryption schemes used in cloud computing. For example, Fakhrul et al. [82] implemented cipher text-policy ABE in a security manager module to make it act as an administrative person, ESPAC [83] and Narayan et al. [84] proposed a patient-centric ABE access control scheme, and Aljumah et al. [85] designed an emergency mobile access to PHR cloud-based ABE.

Three studies [86][87][88] combined ABE and IBE to identify access on different levels (normal and emergency); this combined approach can handle more complex situations than a single scheme. Role-based access control is based on ABE, which is an automatic procedure for authenticating healthcare user information and allocating the corresponding role to guarantee all associated operations. Tong et al. [89] introduced a cloud-based privacy-aware role-based access control model for controllability, traceability of data and authorized access to healthcare resources. Sharma et al. [90] developed an advanced role-based scheme, called “task-based control,” to determine whether access should be granted to a healthcare cloud.

Besides access control, several security protection techniques (trusted virtual domains [44], the watermarking method [91], secure index implementation [92], and secret-sharing schemes [93]) were also introduced to maintain the high security and privacy of healthcare clouds.
1.4.8 Cloud services for home-based healthcare

As shown above, there are many examples of how to adapt cloud computing technology to eHealth. For home-based healthcare, the main cloud service model is used as a platform for services, and applications of software as services are also widely used.

1) **Online software services**: Cloud computing services can support almost any type of medical software applications for healthcare organizations. They also provide real-time software updates as well as online maintenance. Different healthcare providers and recipients can customize different healthcare software applications based on their needs. The infrastructure formed by a large number of connected systems can be shared. This service greatly reduces the software license fees of providers and recipients. They pay for services only when they are in need of services. It also enables the improvement of the healthcare information technology standard. This service reduces the demand for hardware; a laptop equipped with a browser, or a smart phone, is sufficient for quick and efficient access to medical information.

2) **Data storage services**: Data storage services can help to build a healthcare information integration platform to integrate different healthcare providers. Thus, necessary medical information resources will be shared between healthcare providers and recipients. For example, when patients update their daily care data in the cloud, this data will be collected and stored. Care providers or their relatives can easily browse the health data if necessary. This ensures that home-based care can be as efficient as hospital-based care, because all the home care data is already stored.

3) **Computational Analysis Services**: The computation capacity provided by a cloud with mass data computing will improve the ability of large-scale medical data analysis, as well as the depth of medical data mining. Finding the association rules among mass data can not only provide some comprehensive and accurate decision supports for healthcare providers, but can also inspire healthcare recipients’ confidence to manage their own daily healthcare data. The improvements of medical data collation and processing will also benefit the doctors to provide a lot of scientific evidence for high-efficiency and high-quality diagnosis.
1.5 Contribution

The main contributions of the thesis are to identify the current problems of healthcare, especially interoperability problems, and then to determine a possible method to overcome the problems. In this thesis, cloud computing is selected as the technical solution to implement the scenarios based on its comparison with other technologies. The thesis includes five academic papers that have been published in or accepted to international conferences or journals. They are listed as follows.


The main structure of the thesis is shown in Figure 1.3. The first three papers begin with the research of interoperability problems in current healthcare. Paper I and Paper II are mainly based on the healthcare providers’ perspectives while Paper III is from healthcare recipients’ perspectives. Paper IV focuses on the cloud computing technology in eHealth, which is the main technology we have chosen to cover the interoperability problems. Paper V gathers the requirements of our cloud platform for achieving home-based healthcare interoperability.
In Paper I, a case study in Blekinge County healthcare organizations was conducted for understanding the contexts of eHealth interoperability issues. We interviewed healthcare system administrators and nurses in the county to discuss the interoperability problems between different healthcare systems, and potential solutions to overcome the problem. Based on the results and others’ studies, we defined two layers of interoperability in eHealth. Next, a peer-to-peer (P2P) model based on JXTA platform was implemented to solve the identified eHealth interoperability problems. The prototype could achieve the suggested syntactic level interoperability among healthcare organizations. The case study in this paper could answer RQ1 from the view of healthcare providers, and also presented a possible solution to address RQ2.

In Paper II, based on the case study in Paper I, we proposed a cloud computing solution for sharing healthcare information based on the Google App Engine (GAE). The paper also discussed the relationship between eHealth and cloud computing, as well as risks of applying cloud computing in the healthcare domain. The prototype from this paper could achieve interoperability not only among different healthcare centers, but also between healthcare providers and recipients, with high stability and availability. The end of this paper also mentioned advantages and disadvantages in using GAE (public cloud) for healthcare information sharing. It provides another possible solution to RQ2.
In Paper III, we firstly carried out a questionnaire to analyze current problems and needs in chronic disease care. The respondents of the questionnaire were healthcare recipients. We then compared possible technical solutions (P2P, SOAP, cloud computing) and proposed a cloud model for the identified problems. This model would help chronic patients self-record and control their daily care data, and communicate with other patients who have a similar situation. The proposed solution could also be used to integrate data from different healthcare providers for a cooperative work. The questionnaire results from this paper provided an answer to RQ1 from the perspective of healthcare recipients. Through the technical solutions compared in this paper, we partially found answers to RQ2.

In accordance with the research findings of RQ2, we conducted a systematic review of cloud computing in eHealth in Paper IV. We searched relevant articles, of which 44 papers met the criteria for inclusion. The studies identified three types of studied areas of cloud computing in eHealth, namely (1) cloud-based eHealth framework design (n=13), (2) applications of cloud computing (n=17), and (3) security or privacy control mechanisms of healthcare data in the cloud (n=14). Most of the studies in the review focused on concept proof designs. Only a very few studies have evaluated their research in the real world, which may indicate that the application of cloud computing in eHealth is still very immature. However, our presented review could pinpoint that a hybrid cloud platform with mixed access control and security protection mechanisms will be a main research area in future for developing citizen-centered home-based healthcare applications. This paper mainly addresses the answers to RQ3.

In Paper V, we conducted a questionnaire to gather the requirements of the online community for home-based healthcare and described them with user stories. Afterwards, a conceptual prototype was developed based on the requirements. The proposed virtual community involves healthcare providers, healthcare recipients and other people relevant to the home-based healthcare on one platform. It will solve the interoperability problems of current healthcare systems, as well as providing a technical solution for home-based healthcare. As a start in our practical development, this paper answers RQ2 from a different point of view, and
also provides answers to RQ3 in real-world scenarios. Table 1.2 shows the relationship between papers and research questions.

<table>
<thead>
<tr>
<th>Paper Number</th>
<th>Research Questions</th>
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<tr>
<td>Paper I</td>
<td>RQ1, RQ2</td>
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<td>Paper IV</td>
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<td>Paper V</td>
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Table 1.2 Relationship between papers and research questions

1.6 Conclusion

The main goal of the thesis was to find out the interoperability problems in current healthcare, and to provide an appropriate solution for the problems. To support the main goal of our study, an extensive literature review was performed, and face-to-face interviews and online surveys were conducted with the different kinds of participants in order to further elaborate the importance of the research problem. From our research findings, we concluded that eHealth interoperability is a big challenge not only in Sweden, but also worldwide. During study, we found that Blekinge healthcare centers use different systems. All systems are interoperable on their own but do not interoperate with each other. The lack of information sharing and of mobility of healthcare recipients leads to a waste of time and healthcare resources. Information sharing among different healthcare organizations and between healthcare providers and recipients becomes a considerable issue. In the eHealth domain, sharing information is an important consideration to fulfill the needs of public healthcare. Because of the development of ICT, the patient-centric healthcare model will be a future trend where patients are active participants in their own chronic disease healthcare. In this case, interoperability is also a key issue to consider for an efficient home-based healthcare.

To achieve interoperability among distributed and heterogeneous eHealth systems is not easy because it involves so many aspects, especially data security and individual privacy. Through our study, we found that cloud computing could meet most needs in covering healthcare interoperability problems. In our research, we mainly used two current techniques, peer-
to-peer (P2P) networking and cloud computing to design our prototypes and try to find a more appropriate solution. In accordance with our research, we used the same scenarios for developing prototypes of sharing healthcare data with a P2P-based solution and a cloud-based solution. Comparing these two techniques, one obvious advantage of cloud computing is that healthcare recipient can easily enroll in the sharing platform. Another advantage is that once the providers or recipients access the cloud, they can then decide which data can be shared and with whom it can be shared. In home-based healthcare, privacy and security are highly considered; the powerful management of cloud computing can provide different levels of access control for one piece of data. This guarantees the privacy of healthcare data. In the cloud, each piece of data can be managed by different security tools. This unique advantage of cloud computing has the potential to overcome the privacy and security challenges. However, P2P could not meet all the requirements. Scalability is another benefit of using cloud computing, as it can handle high traffic by easily adding more additional hardware infrastructure with no effect on the running service. Furthermore, one feature of cloud computing which can never be achieved through P2P is that various applications can be built on one cloud computing platform. All the data in the cloud storage can be obtained by these applications directly. This makes cloud computing a better technique for home-based healthcare. Mass data storage also makes possible daily data management of healthcare recipients in the cloud. A number of self-control decision support systems can be embedded in the cloud-based platform, which can help healthcare recipients have better self-management. By comparing these two main technical solutions, cloud computing is emerged as the more appropriate enabling solution.

Research on applying cloud computing technology to eHealth is in its early stages; most researchers have presented ideas without real-world case validation [94][95]. The obvious features of cloud computing technology provide more reasons to adopt cloud computing in sharing and managing health information. As a new technology, cloud computing has good performance in storing and accessing information. Almost all of the studies suggest that due to the huge amount of patient health data, especially in the case of daily care, the cloud’s big data storage service
provides a better way to store these data. The data can be shared among hospitals and third-party research institutions or other healthcare organizations, even on a national level. The huge data storage capacity of the cloud would help the development of big data mining in healthcare, as well as diagnosis and treatment. The pay-as-you-go mode of the cloud has significant economic strength, reducing cost for all healthcare organizations that would like to use cloud-based services. Some studies presented cloud-based patient-centric healthcare applications using the user-centric feature of cloud computing. Not only will this encourage healthcare recipients to be involved in their own healthcare, but also, the cloud-based healthcare platform will provide a technical solution as well as a social network. In addition, healthcare recipients’ participation constitutes an efficient healthcare education in terms of patients’ self-management.

High accessibility and availability of cloud computing could help the healthcare data stored in the cloud to be accessed at anytime and anywhere in the world. If healthcare recipients could make parts of their healthcare data in the public cloud open-access, which means that data can be “freely used, reused and redistributed by anyone – subject only, at most, to the requirement to attribute and sharelike [96],”, it could then be processed by remote services, such as medical systems in hospitals, clinical decision support systems and expert systems, or distributed to other medical personnel. The security and privacy gaps of healthcare data in the cloud could be solved by access control encryption schemes and security protection techniques. This would make it possible to move current server-client-based eHealth services to cloud-based eHealth services, and make a greater contribution to improving the current healthcare with the latest technologies. However, healthcare data contain sensitive information, and dealing with sensitive data in the cloud could potentially lead to legal issues. Besides, it is important to select cloud providers carefully to guarantee the confidentiality of healthcare data.

Based on our research, a hybrid cloud model which contains access controls and security protection techniques would be a reliable solution for developing a citizen-centered home-based healthcare system. The EHRs in the hospitals and data in other healthcare centers could be kept in
private clouds, while patients’ daily self-management data could be published in a trustable public cloud. Patients as the owners of their health data could decide who can access their data and the conditions for sharing.

We have proposed an idea of online virtual community for home-based chronic healthcare, a cloud-based home healthcare platform. The design idea comes from online social networks. The requirements of the community were mainly gathered from the questionnaires completed by the target group people. We used “user stories” of agile software development to describe the functional requirements and the non-functional requirements were briefly discussed as well. This platform puts healthcare recipients as the center, and integrates all the healthcare providers within the same platform. Through this shared platform, the interoperability among different healthcare providers as well as the self-management of healthcare recipients could be achieved.

1.7 Future work
In this thesis, the cloud-based home healthcare platform is mostly in the theoretical design stage, and the practical phase is just beginning with the early requirements collection. In the next step, we will present the prototype developed in Paper V to potential users to ask for feedback with regard to specification of the final requirements. We will then address the security and privacy control mechanism of the cloud-based platform. After all the preparation work is complete, the online virtual community for home-based chronic healthcare will be developed by using a hybrid cloud deployment model. When the implementation is finished, interviews and surveys of users and technical experts will be conducted for evaluation. The processes are shown in Figure 1.4.
As indicated in Figure 1.4 above, I plan to produce at least three papers to finish the whole research for my doctoral studies. After the research has been completed, I really hope that this idea and platform will attract some business companies, as well as local governments, to make use of them for home-based healthcare.
Abstract—eHealth is an emerging area that boosts up with advancement in Information and Communication Technology (ICT). Due to variety of eHealth solutions developed by different IT firms with no unified standards, interoperability issue has raised. In this paper, a case study in Blekinge County healthcare organizations has been conducted for understanding the contexts of eHealth interoperability issues. Then a peer-to-peer (P2P) model based on JXTA platform is implemented to solve the identified eHealth interoperability problems. According to the test result of the prototype, the suggested syntactic level interoperability among healthcare organizations has been achieved.

Keywords- eHealth, Interoperability, Peer-to-peer, JXTA
2.1 Introduction

With the rapid development in technology, world is undergoing a digital revolution in the area of Information and Communication Technologies (ICT) [97]. ICT tools are used to find, study, analyze, exchange and present information faster and more accurate. ICT has become the driving force for service organizations and citizens to access, adapt, apply and produce information interoperable [26]. One of the ICT applications in healthcare sectors is healthcare practice supported by electronic processes and communication, so called eHealth [98]. eHealth is an emerging field that covers medical informatics, public health and business that related to deliver health services and information by using ICT. eHealth makes it possible, for example, 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 organizations, so they can work more closely together. ICT can also help care receivers/citizens to have better control and self-management of their own health anywhere world around. Many eHealth technologies such as Electronic Transfer of Prescription (ET), Computerized Patient Record (CPR), Electronic Health Record (EHR) and Telemedicine are widely used and they have delivered tangible benefits [99].

In Europe, efforts have been made to develop Electronic Health Record (EHR) to support the professionals to work with complex health care, and to provide accounts to simplify managing clinical work [100]. However, a major problem is interoperability among different healthcare organizations. 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 [101].

In Sweden, responsibility for providing health care is decentralized to the county councils and municipal governments in some cases. In line with Swedish policy, every county council must provide residents health care at a high level, and work toward promoting good health for the entire population. Municipalities in Sweden are in charge of care for elderly
people in the home or in special accommodation. Municipalities also for provide support and services for people released from hospital care as well as for school health care. In order to improve access to health care, Sweden is actively involved in cooperation across the EU. This includes collaborating on specialized care, improving patient safety and enhancing patient influence. In the other hand, the challenges of accessibility, quality, efficiency and funding are confronted in Sweden as well as other EU countries [25].

In Blekinge County Sweden, there are two main hospitals and several healthcare centers using electronic health record (EHR) in their respective systems. Hospitals use SYStem Cross while municipality healthcare centers use MAGNA CURA. These two systems are built in different technology platform. The two hospitals are interoperable with each other but they are not interoperable with municipality healthcare centers. Since these healthcare organizations are decentralized (no one is obliged to share data with others), the exchange of patient information is a problem though it is very needed from citizens (patients) perspective [102].

2.2 eHealth Interoperability
A. What is eHealth Interoperability?

Healthcare interoperability is highly required among different systems in order to exchange of patient data [17]. Making systems and components interoperable will not be only a matter of speeding up information retrieval, processing and delivery among healthcare givers and hence resulting in an efficient care, it will also make the information accessible for research purpose, diagnoses, treatment and prevention of new disease [33]. According to Brown and Reynolds [31], 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. This definition identifies two layers of interoperability [17].

1) Syntactic interoperability
Syntactic 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. Syntactic interoperability only refers to the exchange of data.

2) Semantic Interoperability

Semantic interoperability means that document is interpretable and the content is understandable by the receiver side. 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.

B. Challenges in eHealth Interoperability

To achieve interoperability in eHealth area, some challenges should be faced [17].

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.

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.

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) 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, and authentication procedure by allowing only authorized users also should be done.

In this paper, we focus on solving syntactic interoperability among different healthcare organizations. The semantic interoperability needs high level of standard and ontology among healthcare organizations, and will not be discussed within this paper.

2.3 A Case Study in Blekinge County

To deep investigating the eHealth interoperability issues, we conducted a case study in Blekinge County, Sweden through interview.

A. 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.

B. Interview Planning

For interview, we searched for contacts of the relevant personals, then sent to them 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-Administrator, Ronneby Municipility) and Anne Maire (Senior Nurse, Vidablick Ronneby). The 3rd interview was conducted from Jakobson (Deputy System Administrator, LANDSTINGET Karlskrona). All interviews were conducted in decent manner with full cooperation of interviewees.

C. 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 from previous 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.

D. 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.

According to the response, health care centers in Blekinge 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 hospitals for medical checkup or emergency. So the main purpose of communication is to exchange patient treatment summary and read some new health relevant information.

2.4 Why Peer-To-Peer

A. What is P2P and JXTA?

Peer-to-Peer is a class of applications that takes advantage of resources – storage, cycles, content, human presence – available at the edges of the Internet [103]. To say it in a more clear way, P2P is a way to take advantage of previously unused resources.

According to Shirky, a problem can be solved by P2P, it must have two characters [104]:
• It treats variable connectivity and temporary network addresses as the norm.

• It gives the nodes at the edges of the network significant autonomy.

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 [105][106]. 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 six kinds of basic protocols such as Peer Discovery Protocol (PDP), Peer Resolver Protocol (PRP), Peer Information Protocol (PIP) and so on.

B. Why P2P?

P2P has some advantages that make it a powerful tool: Content and resources can be shared from both the center and the edge of the network. In client/server networking, content and resources are typically shared from only the center of the network.

A network of peers is easily scaled and more reliable than a single server. A single server is subject to a single point of failure or can be a bottleneck in times of high network utilization.

A network of peers can share its processor, consolidating computing resources for distributed computing tasks, rather than relying on a single computer, such as a supercomputer.

Shared resources of peer computers can be directly accessed. Rather than sharing a file stored on a central server, a peer can share the file directly from its local storage.
In this paper, we propose Atomistic P2P model for our health scenario because health is a critical issue to avoid the evolvement for central authority. Figure 2.1 shows Atomistic P2P model.

![Atomistic P2P model](image)

**Figure 2.1 Automatic P2P communication model**

### 2.5 Validation to The Proposed Solution - Prototype Design

In our study, we design a prototype for achieving interoperability between different healthcare systems in Blekinge County. 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 test the domo with different patient data to validate our qualitative study.

A. 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 2.2.
Figure 2.2 Basic framework of the P2P model

In this model, every healthcare center is defined as a peer. Every system is connected to the Internet. 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.

B. Scenario for the prototype design

For the prototype design, we assume these situations

- 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 2.3 describes the scenario of the two different systems which share the patient information.

![Figure 2.3 Share database between healthcare centers](image)

**C. Healthcare systems simulation**

We simulated the two mentioned healthcare systems ‘MAGNA CURA’ and ‘SYStem Cross’ to validate the proposed P2P solution. The interface of ’MAGNA CURA’ and ‘SYStem Cross’ are shown in Figure 2.4 and Figure 2.5.
According to “JXTA JXSE Programmers Guide 2.5” [107], we build our JATX communication platform as following steps.
1. Build up JXTA data exchange architecture which is called Pipe advertisement based on XML.

2. Build JXTA group, in this case it is automatically built in Peer Group Net.

3. Set up JXTA data sending 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.

4. 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.

E. P2P communication implementation

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 2.6 shows sending data from SYStem Cross.

Figure 2.6. Sending data from SYStem Cross
When the nurse who uses MAGNA CURA wants some medicine information from the SYStem Cross side, he/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/she inputs the personal number of the patient, the therapy records from the Vidablick is also received. Figure 2.7 shows receiving data in MAGNA CURA side.

![Figure 2.7 Receiving data in MAGNA CURA side](image)

In the equivalent situation, if healthcare providers in SYStem Cross need to access the data stored in MAGNA CURA side, in our proposed P2P model, it can be accessed easily in the same way. That’s so called Peer-to-Peer.

### 2.6 Conclusion and Future Work

The main goal of the study is to cover current interoperability gaps through proposed solution via P2P communication. 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. A P2P based prototype was developed with the use
of JXTA technology. 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 healthcare organizations at syntactic level.

However, validation of our proposed solution should be done through the real data and a survey on the targeted population for approval is needed. For the future work, we would like researchers to perform quantitative study by conducting experiments through real data in Blekinge healthcare organizations. Also, the more challenging task is semantic interoperability since eHealth is a much more complex area that needs a lot of efforts.
3 A Cloud Computing Solution for Sharing Healthcare Information

Abstract— in recent years, sharing healthcare information becomes one of essential requirements of e-health development. To cover this gap, different solutions are presented through different technologies. In this paper, we proposed a cloud computing solution for sharing healthcare information based on Google App Engine (GAE). With the experiment test results, we achieve interoperability among different healthcare centers and between healthcare providers and receivers with high stability and availability.

Key words- healthcare information, interoperability, cloud computing, GAE
3.1 Introduction

Along with the development of technology and civilization, citizens’ need for healthcare services has increased. Thanks to the medical care systems implemented in great extent of countries, people living in cities are healthier and live longer. With new requirements for healthcare services such as ageing population and increased mobility of people, e-health will develop on the trends related to “Monitoring”, “Communication/accessibility”, “Knowledge and decision making”, “Support for relatives and citizens’ social life” and “Cross-border or cross-regional care” [108].

Interoperability is one of big issue when we share healthcare information among healthcare centers and hospitals. There are two major issues which are created in interoperability in e-health are described respectively as “problems in communication among healthcare departments” and “problems in communication with different organizations” [109]. The importance of providing interoperability among different healthcare centers is significant.

Cloud Computing is a good approach that is based on delivering software, infrastructure and the whole computation platform as a service. Unlike traditional web hosting providers, cloud computing offers pay-as-you-go services. It means users only have to pay for the resources they use over time [42]. These services are offered over the Internet by large data and computing centers [110]. It is a good solution to integrate e-health services. From technical point of view, the main focus is to provide safe, fast, reliable and efficient healthcare information. Data persistence, durability and security as well as high computational power are of utmost importance to achieve the goal [42]. From medical point of view, cloud offers special channel to easily access electronic medical records. This ability of quick access to personal medical history can speed up treatment, help to avoid complications, and even saves lives. Cloud also can make it easy for the patients to locate and keep track of their own health record [111].

In this paper, we discuss cloud computing in healthcare domain in section 2. Cloud computing service providers are introduced in section 3. In section 4, we detail describe our cloud based solution with Google App
Engine (GAE) to share healthcare information. The experiment data analyses are discussed in section 5. Finally, we conclude our research findings and future work in section 6.

3.2 Cloud Computing in Healthcare

In order to avoid failures due to not fulfilling users’ needs, World Health Organization (WHO), in its 58th World Health Assembly, urged its members design long term strategies [112]. These strategies include establishing closer collaboration with other stakeholders, reaching communities and collaborating with local health organizations, establish centers for excellence, establish public health information systems on national level and develop an infrastructure for information and communication technologies. Standing in technical research, it is very hard to establish this kind of public health information system. Because all needs of infrastructure are huge and it is very hard to offer quick and easy accessing in general data center. However, it becomes possible by cloud computing technology. Cloud computing technology can unit many small infrastructures to be a large infrastructure. And it can manage infrastructure by itself and offer infrastructure as a service to organizations. Organizations only need to develop their application in cloud computing without concerning infrastructure. Meanwhile, cloud computing can offer quick and easy access to information by using their integrated infrastructure.

Standing in actual research, the technical, legal, economic and security details of cloud are not defined currently [113]. Cloud data can be stored and processed in the servers all over the world. Implementation of e-health on cloud computing is dependent upon the issues of privacy and ownership. Healthcare organizations have the ability to create policies for dealing with their data locally and on outsourced data center, but they cannot influence the way their data will be treated in cloud. In order to be completely adopted by healthcare organizations, cloud service providers must make sure that they fulfill the requirements of Health Insurance Portability and Accountability Act (HIPAA) [114].

The following risks should be address for successful implementation of e-Health in cloud [115].
Regulatory Risk: Regulatory risks are related to data encryption and prevention of unauthorized access, keeping privacy and confidentiality of data. These are the most important requirements of Health Insurance Portability and Accountability Acts (HIPAA), each of these should be fulfilled.

Intellectual Property Right Risk: Illegally using and exploiting the work of others come under this risk. In case of e-health the vendors want to own the software themselves, whereas the customer wants to own any content passing through the software. This problem could be solved by cross licensing and giving the right of ownership to each party based on what each party provides.

Liability Risk: Users always want some assurance from vendors regarding breaches of agreement especially in healthcare domain. If there are any breaches of agreement, the user should get the required compliance according to the applicable law. Similarly, it is also the responsibility of the user that who will not break the rules of agreement. The liability risk can be decreased if there is mutual understanding between the user and vendor.

A. Relationship between E-Health and Cloud Computing

In our research, we found that e-health and cloud computing have some relationships which we list them in Table 3.1.
Table 3.1 Relationship between E-Health And Cloud Computing

<table>
<thead>
<tr>
<th></th>
<th>E-health</th>
<th>Cloud Computing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure</td>
<td>Needs a huge infrastructure to establish different e-health service</td>
<td>A huge computing infrastructure which connect, access and distribute with huge numbers of small computing units</td>
</tr>
<tr>
<td>Storage</td>
<td>Needs access and store large data quickly and efficiently</td>
<td>Support user to access and store large data quickly and efficiently</td>
</tr>
<tr>
<td>Information</td>
<td>The service is distributing to every medical institutes; it needs information of medical institutes more integrating</td>
<td>Support user to integrate information from distributing branches</td>
</tr>
<tr>
<td>Development Tendency</td>
<td>Integrate different e-health services to be a platform</td>
<td>It support user to build platform in cloud</td>
</tr>
</tbody>
</table>

Table 3.1 shows that cloud computing can mostly meet the needs of eHealth. As compared to traditional solution of e-health, cloud computing can offer large infrastructure, quick access, and efficient storage and even offer integrated platform for e-health services. As we know, each cloud service model has different relationships between users and cloud providers [116], therefore sharing healthcare information in different cloud service, the solution should be different, as well as the requirements should also be different.

3.3 Cloud Computing Service Providers

According to our previous research, hospitals and healthcare centers have their own local database; patients’ data are stored in local database. In this case, we need a service as middleware to bridge among hospitals and healthcare centers. SaaS (software as service) is best choice to build sharing service [116]. SaaS is a web application which develops and runs
on PaaS (platform as service), it can be a middleware of information sharing among hospitals and healthcare centers.

Google, Microsoft and Amazon provide users to develop SaaS applications in their platforms. Google App Engine and Amazon EC2 can support to develop web service. Between GAE and EC2, we prefer to choose GAE. Google App is great for all types of applications like business, consumer, marketing, mobile, and website [117]. GAE is simple to learn, easy to develop and also easy to manage and storage. The free usage of GAE is more enhanced than free instance of EC2. Based above, we choose Google App Engine to be SaaS provider in our simulation. The main features of GAE are listed below.

- Highly Scalable: In high scalability, GAE manage and store infinite number of objects.

- Flexible Security and sharing: The OAuth 2.0 support the enhance security and add flexibility. The ACLs authenticate the individuals or groups, and share the data.

- Fast data access: GAE storage provides very quick and easy access to consumer data around the world and can give facility of hosting option in highly optimized data centers.

- High Reliable Storage: The data reliability of Google is high and SLA helps ensure that the data is available 100% when it is needed [117].

3.3 A Proposed Solution in Google App Engine (GAE)

The basic scenario in our research is actually taking help from our previous research paper “Achieving e-Health interoperability via peer-to-peer communication Using JXTA Technology” [118]. In that research we gave a very clear scenario which were required in county of Blekinge between hospital and healthcare center (care providers). In our prototype design, we mainly propose using cloud computing to bridge this interoperability gap between hospitals and healthcare centers (care providers). The basic structure of our solution is shown in Figure 3.1.
From Figure 3.1, we define three sources of healthcare information - hospital, healthcare center (care providers) and home. Based on combination with previous scenarios, we add source “home” into our scenario now. In this case, hospital and healthcare center (care providers) also want to directly access and get information from each other. The activity of home is uploading basic health information of the citizen to support healthcare planning and treatment. Also users are allowed to maintain their records at home. We use Google App Engine to simulate this scenario and discuss advantages and disadvantages of sharing healthcare information in cloud.

A. Simulation Environment

The simulation environment includes Google App Engine and three clients. Google App Engine is simulated as current healthcare information sharing platform. Three clients are simulated as hospital, healthcare center/care providers and home, which are the three sources of healthcare information and three users of healthcare, shown in Figure 3.2.
Figure 3.2 Simulation Environment

B. Prototype Structure

The prototype consists of two parts, client at local user and server in Google App Engine. Clients simulate as hospital and healthcare center. Clients send and share data through service. In our case, the clients are programmed in C#.net and the server is programmed in Java.

C. Simulation Results

In our simulation, it includes three parts: healthcare center and hospital share healthcare information between each other; online service shares healthcare information to healthcare center and hospital, and sharing picture file between healthcare center and hospital.

1) Sharing Healthcare Information between Hospitals and Healthcare Centers
Figure 3.3 Healthcare center – Data Sending

Figure 3.4 Hospital - Data Receive

Figure 3.3 and Figure 3.4 shows string data stores in healthcare center system can be shared to hospital system by using same personal number account. This part of simulation achieves data sharing from healthcare center to hospital. In the equivalent situation, if other healthcare providers need information from hospitals, they can also easily get it with the personal number. Figure 3.5 shows user can get data which stores in healthcare center system and share it to hospital system by login their
personal account through online interface at GAE. It means citizens can trace and check their healthcare plan by using online services.

2) Sharing Healthcare Information from Online Service to Healthcare Center and Hospital

Figure 3.5 Online Data Management for healthcare plan

Figure 3.6 Online Add New Data
Figure 3.7 Hospital and healthcare center receive data from online service

Figure 3.6 and Figure 3.7 show the data add in online service at GAE also can be shared to hospital and healthcare center. This simulation achieves the goal of users who stay at home can share their healthcare data to hospital and healthcare center.

3) Sharing picture file between healthcare center and hospital

Figure 3.8 shows picture sharing application in our prototype. Hospital and healthcare center use one data entity to share the picture. By using the sharing area, picture sharing can be achieved between hospital and healthcare center. In current version, we can distinguish picture source through pic source elements in list.
3.5 Results Analysis and Discussion

A. Data analysis

In our simulation, we use two application IDs to do the test. We can get detail and clear log files from GAE. The performance of GAE can be got when running the prototype through analyze log file.

In this part, we focus on analyzing log file of sharing picture file. Because sharing picture file has some flow as sharing string data. Binary stream of picture are stored and shared in the prototype. In other word, picture file is kind of string which is very long. Through analyzing log file of sharing pictures, we can get obviously performance of GAE handling long and large data.

In data sending test, latency and stability of operation request are two main items in this simulation. In the experiment, we send 14 jpg sample files to GAE. The size of samples is from 60KB to 1.7MB. We Table II show latency and response time of this 14 sending operation. From this table, we found that only size smaller than around 500KB can be sent to GAE.
Table 3.2 Latency and Stability of Sending Operation

<table>
<thead>
<tr>
<th>Type</th>
<th>Binary Length (char)</th>
<th>Size (KB)</th>
<th>Latency (ms)</th>
<th>Cpu_ms (ms)</th>
<th>Api_cpu_ms (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>jpg</td>
<td>88152</td>
<td>59.2</td>
<td>856</td>
<td>383</td>
<td>215</td>
</tr>
<tr>
<td>jpg</td>
<td>236588</td>
<td>138</td>
<td>1279</td>
<td>360</td>
<td>224</td>
</tr>
<tr>
<td>jpg</td>
<td>371032</td>
<td>153</td>
<td>568</td>
<td>525</td>
<td>233</td>
</tr>
<tr>
<td>jpg</td>
<td>326912</td>
<td>218</td>
<td>727</td>
<td>418</td>
<td>242</td>
</tr>
<tr>
<td>jpg</td>
<td>720216</td>
<td>279</td>
<td>818</td>
<td>523</td>
<td>252</td>
</tr>
<tr>
<td>jpg</td>
<td>929964</td>
<td>396</td>
<td>1716</td>
<td>1116</td>
<td>261</td>
</tr>
<tr>
<td>jpg</td>
<td>699904</td>
<td>482</td>
<td>1242</td>
<td>600</td>
<td>270</td>
</tr>
<tr>
<td>jpg</td>
<td>702464</td>
<td>502</td>
<td>1882</td>
<td>940</td>
<td>279</td>
</tr>
<tr>
<td>jpg</td>
<td>1185452</td>
<td>530</td>
<td>Error: Overflow</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>jpg</td>
<td>1033728</td>
<td>600</td>
<td>Error: Overflow</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>jpg</td>
<td>1413120</td>
<td>693</td>
<td>Error: Overflow</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>jpg</td>
<td>1440428</td>
<td>979</td>
<td>Error: Overflow</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>jpg</td>
<td>1784236</td>
<td>1280</td>
<td>Error: Overflow</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>jpg</td>
<td>3037868</td>
<td>1741</td>
<td>Error: Overflow</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
Cpu_ms means CPU milliseconds which refer to the number of milliseconds spent by a CPU - the one serve our app when executing the code in the app server. Api_cpu_ms is the number of milliseconds of CPU time spent executing API calls, such as requests to the database or memcache. Both these two parameters are the expression of the responsible time of the application. From Figure 3.9, when data size increase the api_cpu_ms increasing; and the increasing tendency of binary length is similar to cpu_ms. It shows GAE can handle data and store data into entity which stable in sending operation. But latency has no relationship between data size and binary length, which means latency in GAE, is unpredictable.

The aim of data receiving test is checking the latency and stability of receiving operation in different days. In our experiment, we take 5 records of receiving operation in log file which request at different three days. All of records request same size of data, shown in table III.
Table 3.3 Latency and Stability of Receiving Operation Regarding Date

<table>
<thead>
<tr>
<th>Date</th>
<th>Request Size of Data (KB)</th>
<th>Latency (ms)</th>
<th>Cpu ms (s)</th>
<th>Api cpu ms (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012/5/8</td>
<td>339</td>
<td>207</td>
<td>338</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/8</td>
<td>339</td>
<td>164</td>
<td>242</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/8</td>
<td>339</td>
<td>191</td>
<td>338</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/8</td>
<td>339</td>
<td>285</td>
<td>242</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/8</td>
<td>339</td>
<td>238</td>
<td>338</td>
<td>67</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>217</td>
<td>299.6</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/9</td>
<td>339</td>
<td>370</td>
<td>728</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/9</td>
<td>339</td>
<td>528</td>
<td>222</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/9</td>
<td>339</td>
<td>177</td>
<td>242</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/9</td>
<td>339</td>
<td>399</td>
<td>202</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/9</td>
<td>339</td>
<td>350</td>
<td>202</td>
<td>67</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>364.8</td>
<td>319.2</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/14</td>
<td>339</td>
<td>310</td>
<td>222</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/14</td>
<td>339</td>
<td>165</td>
<td>222</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/14</td>
<td>339</td>
<td>220</td>
<td>202</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/14</td>
<td>339</td>
<td>216</td>
<td>222</td>
<td>67</td>
</tr>
<tr>
<td>2012/5/14</td>
<td>339</td>
<td>209</td>
<td>378</td>
<td>67</td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td>224</td>
<td>249.2</td>
<td>67</td>
</tr>
</tbody>
</table>

From table III, the api_cpu_ms of receive operations in three days are the same. It means in these three days, GAE responds the receive operation using almost same time, GAE is stable. But latency of receive operation is also unpredictable.
B. Discussion

1) Advantages of healthcare information in GAE

Quick development: Google App Engine has developed framework that allow developers use java and python to develop applications which can run in GAE. It provides Google Web Toolkit to let developer build web application interface in GAE quickly and easily. Comparing with Hadoop, GAE don’t need to establish cloud computing environment. We can directly develop and run our e-health applications in GAE.

High Availability: Google provide 100% uptime of GAE, there is no schedule downtime in their plan. It means e-health application develop in GAE can run every seconds, 24 hours all year without disaster.

Large Data Table Storage: Google App Engine support large data storage. It can store less than 1 million long string data through special data type. String data type can store 500 characters and return only first 70 characters to its request. But special text data type can store and return unlimited characters. Most of the text healthcare data and smaller than 500KB health related picture files can be stored in GAE.

Application as Web Service: The applications running in cloud computing are typical web-services. It shows healthcare providers and receivers with applications do not need to establish special passage or access path to link each other. It increases system independence on each healthcare organization and home care.

Authorized Information: Google App Engine supports authorized information system by using entity data storage. Through simulation, server allows users register to their own account and store information. Clients can only gain access to authorized user’s information by using server account. This can ensure the security of the healthcare data sharing.

2) Disadvantage of healthcare information in GAE

Picture Sharing Limitation: According to our experiment results, the GAE upload maximum around 500KB of picture file, when picture file size increases than 500KB, it will not upload and give error message. While in
Google App Engine SDK, it doesn’t support file uploading directly, but it use the third party plug-in to complete this task and upload and download the picture file on website. The limitation of picture file is a big challenge for sharing healthcare data since some of healthcare information contains picture files. However, we just use a free GAE account to test our data and picture sharing function. It may be solved when using some paid GAE services.

Unpredictable Latency: From the results of data analysis, we can obviously know the latency in both sending and receiving operation are unpredictable, latency will change day by day.

Extra Consumption of resource in “First Request”: From the results of simulation, we find GAE need extra resource consumption when client first request to GAE. “First Request” means the user IP is first recorded into cookie in GAE. When first request happens, GAE will take longer time and use more CPU than a typical request for the application. And latency of first request is 10 times more than general requests.

3.6 Conclusion and Future Work
Information sharing among different healthcare organizations and between healthcare providers and receivers becomes considerable. In e-health domain, sharing information is one of important issue to fulfill the needs of public healthcare. To accomplish the needs of healthcare information sharing in e-health, cloud computing is a superior solution. Cloud computing is a new technology and have good performance in storing and accessing information. Our research mainly focus on the implementation of GAE as a SaaS cloud computing technique to share healthcare information. With the designed prototype, we could cover the current interoperability gap in e-health. The experiment results indicates that there are many strengths to use GAE based SaaS service to solve the problem such as quick development, high availability, large data table storage, application as web service and authorized information. In the other hand, obvious drawbacks like limitation of picture sharing and unpredictable latency are still challenges for widely using GAE to e-health development.
In our experiments, we just tested the data in a simulation environment, and a validation through the real data should be done in the future to get more accurate results and analyses. Surveys and interviews with targeted people are also an important part of future work. As is known to all, GAE is just a very small branch of cloud computing, we will try to use other cloud services to bridge the interoperability gap of e-health and find out the best cloud solution in the future.
4 A Cloud Model for Interoperable Home-based Chronic Diseases Healthcare

Abstract—traditional hospital based care cannot meet all the needs of chronic diseases care in home, especially for elderly people. A new approach applying eHealth that supports interoperable health care is required. To find a way to meet the new needs, we firstly carried out a questionnaire to analyze current problems and needs in chronic disease care. Then we compared possible technical solutions and proposed a cloud model for the identified problems. This model would help chronic patients self-record and control their daily care data, communicate with other patients who have the similar situation. The proposed solution could be also used to integrate data from different healthcare providers for a cooperative work, namely in this paper as Home-based Chronic Diseases Healthcare (HCDH).

Keywords—eHealth, home-based chronic disease healthcare, cloud, interoperability
4.1 Introduction
As a result of increased life expectancy and declining birth rate, the population of elderly is rising rapidly. Today there are around 810 million persons aged 60 or above in the world. The number will reach almost 2 billion by 2050 [119]. At the same time, chronic diseases have now become the leading causes of death [120]. It represents a huge global challenge for healthcare. Treating chronic diseases heavily depends on the patients daily behaviors. Living with a chronic disease has a significant impact not only on a person’s quality of life but also their family and the current healthcare system. Elderly people living with more than one chronic disease face particular challenges, both medically and socially. The quality of their life could be greatly improved by a better care of chronic diseases [2].

With the increasing of home based healthcare services in Europe, the problem of not being able to respond due to lack of personnel and nursing for homes is well reported [121]. Meanwhile, ICT evolution has led to use of wireless personal devices like smartphones, personal computers and other self-monitoring devices. This can provide with a solution to help home based healthcare. However, there is an interoperability problem with those technologies. To solve this interoperability problem, an eHealth approach based on cloud computing is proposed in this paper.

Sweden has published a new National Strategy for eHealth [25]. The focused problems have been shifted from the development of ICT in healthcare services to coordinated healthcare across the entire sectors to promote coherence and efficiency to all health and social care activities. There were three main requirements of eHealth areas in the National Strategy [25]; they are: (1) Putting the individual needs in the first place, (2) National coordination for healthcare services. (3) Greater focus on e-issues nationally and internationally.

To provide safe and efficient interoperable home based healthcare needs high performance ICT technologies. Because of the high demand of workload for uploading and sharing huge amount of patient dairy health data, traditional server-client computing system is no longer suitable. Cloud computing provides a better way to achieve the goal. According to
the definition of U.S. National Institute of Standards and Technology [41], “cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction.” The main features of cloud services are flexibility, interoperability, economy and security, which make it possible to use service in everyone’s daily life.

In this paper, we started with presenting challenges in chronic diseases healthcare, analyzed home-based care and healthcare information sharing demands based on our online questionnaires. Then we compared main eHealth interoperability techniques and found out cloud computing is the most suitable for HCDH. We proposed our cloud home care model, which is based on a PaaS (platform as services) and included some software services. The benefits of this model were discussed with user cases.

4.2 Challenges in Chronic Diseases Healthcare

Chronic diseases, such as cardiovascular disease, chronic obstructive pulmonary disease and diabetes, have become a main challenge to health sectors around the world. The incidence and prevalence of chronic diseases is continuing to increase [3]. Focusing on the features of chronic diseases care, traditional hospital based healthcare could not meet all the needs for chronic diseases care. There are some new challenges.

A. Lack of patients centered healthcare system

The traditional healthcare systems were designed for acute diseases [11]. That means most of the computer or mobile based healthcare systems were targeted for healthcare providers, either manage patients’ healthcare records, control pharmaceutical, or help for diagnoses. Although there are several home based healthcare systems in service now, few of them integrated with other systems [122].

B. Lack of cooperation among healthcare providers

The traditional responsibilities among healthcare providers are independent. However chronic diseases care needs efforts from all the evolved stakeholders, not only healthcare providers, but also receivers
themselves and their families. Chronic diseases care is normally home based. The care providers are diverse, so the communication and cooperation are even more significant [123]. On the other hand, because of the mobility of healthcare receivers, different nations and regions have different healthcare laws and guidelines. Sometimes it leads to a waste of time and resource due to poor collaboration. Overall the current chronic healthcare has gaps of waste, overlap, delay and lack of collaboration, of which mainly are interoperability problems.

C. Lack of Standards or guidelines for chronic diseases care

Although there are some international standards of healthcare like HL7 [34], or some national guidelines for primarily care [124], there is no standard specific for chronic diseases care. In some cases, the unclear responsibility of care badly reduces the quality of HCDH [123] [125].

D. Lack of educations for healthcare

Chronic diseases could be controlled by patients’ daily behaviors. One important part of home care is education, which means care providers should teach care receivers and their families the knowledge of their diseases. It will help chronic diseases patients manage and control themselves more efficiently. There are some education programs carrying out in developed countries [123], but most are regional. In developing countries, popularizing rate of chronic diseases healthcare education is lower [126]. Governments and organizations could pay more attention to the pervasive chronic diseases education. It is a strategy for improving chronic diseases care quality.

To overcome these challenges, a possible innovation might be from ICT, a new eHealth approach. Today patients who suffer chronic diseases have to be checked and monitored from time to time, and result in high cost, time consuming and inconvenient for patients [3]. Meanwhile, most of the cases for chronic diseases do not need urgent medical diagnosis and treatment. It is therefore more appropriate to adopt an efficient approach to trace and control the patients’ conditions via healthcare services such as physiological signals monitoring and recording [40] in the home environment.
4.3 Online Questionnaire Analysis
We conducted an online questionnaire of people aged 60 or above through some social media websites. The aims of this questionnaire are to know their current healthcare conditions, their views on home based healthcare and healthcare information sharing. In the end, we received 35 acceptable responses. Respondents are mainly elderly people from US and EU countries. There are 10 questions in it, which are listed in the following table.

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Answers</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Do you have any chronic diseases?</td>
<td>□ Yes □ No</td>
</tr>
<tr>
<td>2</td>
<td>What is your main way of receiving healthcare?</td>
<td>□ I visit Hospital or other healthcare center. □ Healthcare providers visit me in my home. □ Mixed, sometimes communicate by phone or internet.</td>
</tr>
<tr>
<td>3</td>
<td>Do you have any communication troubles with your current healthcare providers?</td>
<td>Open question</td>
</tr>
<tr>
<td>4</td>
<td>Do you have any home healthcare monitoring or testing devices?</td>
<td>□ Yes □ No</td>
</tr>
<tr>
<td>5</td>
<td>Would you like to self-manage some of your personal healthcare data?</td>
<td>□ Yes □ No □ I have no confidence to do it myself.</td>
</tr>
<tr>
<td>6</td>
<td>Would you like to share some of your daily health data to your authorized healthcare providers?</td>
<td>□ Yes □ No □ It depends</td>
</tr>
<tr>
<td>7</td>
<td>Would you like to share some of your daily health data to your relatives?</td>
<td>□ Yes □ No □ It depends</td>
</tr>
</tbody>
</table>
8 Would you like to share some of your daily health data to some research institution anonymously? □ Yes □ No □ It depends

9 Would you like to have an online community with same symptom chronic disease people? □ Yes □ No □ It depends

10 If there is one healthcare IT platform that integrate all the functions mentioned above (sharing some data securely, self-management, care receivers community etc.), would you like to try it? □ Yes □ No

The results show some today’s problems in receiving healthcare, as well as their wishes on sharing healthcare information with their healthcare providers and other chronic diseases patients with similar symptoms.

A. Common health conditions for elderly over 60

Among all the respondents, 85.71% elderly people have one or more chronic diseases. This high rate means most of them need continuous but not urgent healthcare. 31.43% people only visit hospitals or healthcare providers to receive healthcare. Besides visiting, 62.82% of people sometimes use the telephone or internet to commute with providers. When asking about communication troubles with healthcare providers, the answers are varied, but mainly responded with troubles as too long waiting time, inconvenient to visit hospitals and lack of cooperation between healthcare providers.
B. Views on home based healthcare

In our questionnaire, more than half elderly people have home healthcare monitoring or testing devices. Also from the high rate of telephone and internet to communicate, these people have already accepted ICT tools for their daily healthcare, and it is possible for them to have home based healthcare. The questionnaire also shows that 80% of people would like to self-manage some of their personal healthcare data. 11.43% people have no confidence to do it themselves. If care educations are conducted well, they are also willing to do self-management with their own data.
Figure 4.2 Answers of self-management

C. Views on healthcare data sharing

We asked four different kinds of possible sharing ways of their healthcare data. They are: (1) Share some daily health data to authorized healthcare providers. (2) Share some daily health data to relatives. (3) Share some daily health data to some research institution anonymously. (4) Have an online community other chronic diseases patients who have similar symptoms. All four kinds of sharing ways have more than half supports. One third chose “it depends” that means they are willing to sharing their healthcare data in some conditions or partly. To our surprise, communication with people who have same chronic diseases got the most support (88.57%). It requires that the new approach should not only effort on interpretability between healthcare providers and receivers, or among healthcare providers, but also among healthcare receivers.
The final question is if they are willing to have one healthcare IT platform that integrates all the functions mentioned. Nearly 90% participants would like to use it as their daily home based healthcare platform.

**4.4 Cloud Computing Service for eHealth**

The most significant challenge of home based healthcare for chronic diseases patients is interoperability. Interoperability among distributed and heterogeneous eHealth systems is complex because it involves data security and individual privacy. There are three main current techniques, cloud computing, peer-to-peer (P2P) network and Simple Object Access Protocol (SOAP) for achieving interoperability in eHealth.

We found that scalability is one of the benefits of using cloud computing, it can handle high traffic by easily adding more additional hardware infrastructure with no effect on the running service. This relies on large scale infrastructures and complex cloud systems while P2P and SOAP are lightweight and simpler to adapt in existing systems. Management is another primary benefit by using cloud computing compare with P2P and SOAP. The powerful management of cloud computing can provide different levels of access control for one piece of data. This guarantees the privacy of healthcare data. In the cloud, every piece of data can be managed by different security tools. P2P and SOAP both have been used for a long time, so there is no adopting cost. Furthermore, one feature of
cloud computing, which can never be achieved through P2P or SOAP, is various applications can be built on one cloud computing platform. All the data in the cloud storage can be obtained by these applications directly. This makes cloud a better technique for home based healthcare. Mass data storage also makes it possible for healthcare receivers’ daily data management in the cloud.

In HCDH, privacy, access control, data security and integration are main challenges. The unique advantages of cloud computing have the potential to overcome these challenges. Neither P2P nor SOAP could meet all the requirements of HCDH. According to our previous research [118][64], we used same scenarios for developing prototypes of sharing healthcare data with P2P based solution and cloud based solution. Comparing these two techniques, one obvious advantage of cloud is that healthcare receivers can easily enroll in the sharing platform. Another one is that once the providers or receivers access to the cloud, they can decide which data can be shared and to whom it can be shared. In addition, a number of self-control decision support systems can be embedded in the cloud based platform. It can help healthcare receivers have a better self-management.

Cloud computing is a new computing approach which uses software, infrastructure and platform as service handover. Unlike traditional computing such as web hosting, cloud computing offers pay-as-you-go services. It gives users the possibility to pay for the resources they actually use for a time period [42]. Cloud offers many advantages, such as economy of scale, availability, management, efficiency, consolidation, cost and energy saving. This helps cloud users better utilize the computing resources, as well as minimize the costs. Although there are different ways of classification of cloud computing, the cloud service is classified based on the service model “X as services”. These three layers are Infrastructure, Platform and Software, which are dependent on the type of services being offered [41] [127]. For HCDH, the main service model is platform as services, many applications of software as services are also widely used, such as:

1) Online software services: Cloud computing services can support almost any type of medical software applications for healthcare organizations. It also provides real-time software updates as well as online maintenance.
Different healthcare providers and receivers can customize different healthcare software applications based on their needs. The infrastructure formed by a large number of systems connected can be shared. This service greatly reduces the software license fees of providers and receivers. They pay for services only when they are in need of services. It also enables the healthcare information technology standard to be improved. This service reduces the demand for hardware, only a laptop equipped with a browser or a smart phone, can be used for quick access to medical information efficiently.

2) Data storage services: Data storage services could help to build healthcare information integration platform to integrate different healthcare providers. Thus, necessary medical information resources will be shared between healthcare providers and receivers. For example, when patients update their daily care data in the cloud, this data will be collected and stored. Care providers or their relatives can easily browse the health data if necessary. This ensures home based care can be as efficient as hospital based care because all the home care data is already stored.

3) Computational Analysis Services: The computation capacity provided by cloud with mass data computing will improve the ability of large scale medical data analysis, as well as the depth of medical data mining. Find the association rules among mass data can give some comprehensive and accurate decision supports not only for healthcare providers, but also inspire healthcare receivers’ confidence to manage their own daily healthcare data. The improvements of medical data collation and processing will also benefit the doctors to provide a lot of scientific evidence for high-efficiency and high-quality diagnosis.

4.5 Proposed Solution
Based on analyses of the online questionnaire, we list main needs of the HCDH cloud platform.

- Self daily behavior controlling plays an important role in chronic disease healthcare, which means the new proposed solution should support healthcare receivers to do some self-managements of their own cares.
- Personal health records can be shared with people who have the access rights to the platform, as well as the data sources can decide the level of sharing.

- Based on the healthcare receivers’ daily health information, the platform could automatically send reminders or alarms to the responsible healthcare stakeholders.

- Communities among healthcare receivers who have similar chronic diseases would be built so that they can help each other.

The proposed solution is based on a PaaS model and includes some software services. Figure 4.4 shows a cloud based platform for chronic disease healthcare, which can support healthcare data exchange, storage and processing. This proposed model could build a bridge for current gaps of HCDH, and help care receivers get more effective care as well as improve their life quality.

In this model, based on the data input to the cloud, computational analysis services can automatically process the data and send related requirements to the responsible care providers or care receivers themselves. All the input data can be stored and exchanged in the cloud. Authenticated users of the cloud, either care providers, or receivers at home could browse the remote healthcare records whenever they want. Some particular diseases’ online software services are embedded in the cloud. Chronic healthcare receivers could choose these services according to their own conditions. They could also exchange care experiences and establish a bond with other chronic disease patients who have similar symptoms.
4.6 User Cases
To explain how the different components work together in the proposed model, we demonstrate three user cases to describe actions of healthcare receivers, doctors and other healthcare providers, who are three main types of users of cloud based chronic diseases healthcare platform. In these cases, the actions drew with cloud sharps are performed in the cloud based platform.

User Case 1: From Doctors Perspective
Doctors will receive reminders of the patients’ appointment from the cloud before the patient visits. When meeting the patients, he or she will browse the relevant healthcare records stored in the cloud. Based on the records, the doctor will diagnose and treat the patient. After treatment, the doctor will update the personal healthcare records, as well as further care suggestions in the cloud. The cloud itself will decide the responsibilities of care and send the information to the responsible party.

User Case 2: From other Healthcare Providers Perspective

An authorized healthcare provider can also browse the relevant healthcare records when he or she is required to provide healthcare to the receivers. Then the provider will provide home cares and update the related healthcare records. The same as other cases, the cloud itself will send the
information of further care to the responsible party according to the input healthcare data.

User Case 3: From Healthcare Receivers Perspective

![Diagram of User Case 3](image)

Figure 4.7 User Case 3: From Healthcare Receivers Perspective

Healthcare receivers with chronic diseases use some self-monitoring devices to check their body parameters such as blood pressure and blood glucose. Then they update this data as daily healthcare information to the cloud. The cloud based platform stores the data and uses its embedded support decision systems to check the input data with the standard values. If the data is normal, it will send feedback to the receivers. Otherwise, the cloud will send the alarms to the responsible care providers based on different conditions automatically. Besides, healthcare receivers can also communicate with patients who have similar symptoms to share their care experiences and daily lives.

The action “Decide the responsibilities of care according to the input data” appears in all the three cases. It is a use of the strong data processing feature of cloud. The actions of browse and update personal healthcare information is a representation of data storage and exchange feature of cloud. Communicate with other patients is also benefit from the cloud’s powerful data storage and exchange capability.
4.7 Discussion
The proposed HCDH platform enables elderly an independent living at home and improves the quality of life even with chronic diseases. The services provided by cloud are ready to access at anytime and anywhere. It is designed to be available for 24/7 services which is crucial in some emergency circumstance in need of patient records.

Since Cloud computing ensures that healthcare receivers can receive healthcare services anywhere, care receivers can choose the services based on their different types of chronic diseases, and the needs of individual can be met more accurately. After patients’ electronic healthcare records and other related information are stored in the cloud, all authorized healthcare providers can browse the information for helping diagnose and treat care receivers cooperatively. Healthcare receivers as well as their relatives can immediately and easily browse their health record through the cloud to manage their own daily life. It also provides an online community for chronic diseases patients who have similar symptoms to share and learn each other.

In addition, the process of this home based healthcare will generate large samples of patient self-recording health data. Consider the huge number of patients, there is a big volume of data to be processed. If patients volunteer to share their daily health data to other healthcare research institutions or providers, it will benefit the research of chronic diseases and give more appropriate treatment to the patients.

Although cloud computing based model provides many advantages, privacy, security and trust are still challenges when it is used in the healthcare domain. Because healthcare information is very sensitive, data privacy control mechanism must be applied before the information is massively published in the cloud. Choosing secure cloud providers is another essential factor of successful cloud HCDH.

4.8 Conclusion
In this paper, we presented some challenges and problems in effective chronic diseases healthcare based on some literature review. An online questionnaire was carried out to know patients’ view of home based care
and healthcare information sharing. We found that a new home-based eHealth approach is urgently required to meet the needs. By comparing main technical solutions, cloud computing could be the most proper enabling solution. A cloud platform of HCDH is proposed, and we also explained the actions of doctors, other healthcare providers and healthcare receivers by user cases. This platform puts healthcare receivers as the center, and integrates all the healthcare providers within the same platform. Through this shared platform, the interoperability among different healthcare providers as well as the self-management of healthcare receivers can be achieved.
5 A Systematic Literature Review of Cloud Computing in eHealth

Abstract - Cloud computing in eHealth is an emerging area for only few years. There needs to identify the state of the art and pinpoint challenges and possible directions for researchers and applications developers. Based on this need, we have conducted a systematic review of cloud computing in eHealth. We searched ACM Digital Library, IEEE Xplore, Inspec, ISI Web of Science and Springer as well as relevant open-access journals for relevant articles. A total of 237 studies were first searched, of which 44 papers met the Include Criteria. The studies identified three types of studied areas about cloud computing in eHealth, namely (1) cloud-based eHealth framework design (n=13); (2) applications of cloud computing (n=17); and (3) security or privacy control mechanisms of healthcare data in the cloud (n=14). Most of the studies in the review were about designs and concept-proof. Only very few studies have evaluated their research in the real world, which may indicate that the application of cloud computing in eHealth is still very immature. However, our presented review could pinpoint that a hybrid cloud platform with mixed access control and security protection mechanisms will be a main research area for developing citizen centered home-based healthcare applications.

Key Words- Systematic review, eHealth, cloud computing, home-based healthcare
5.1 Introduction

This review examines existing researches on cloud-based eHealth solutions. The main goal is to identify the state of the art in this area and pinpoint challenges and possible directions for researchers and applications developers based on the current literatures. Though this study may not able to specify the benefits of using cloud technology in eHealth due to the progress in the area so far is made mostly in designs and concept-proof, not in real use context, we do, however, have identified some better ways of using cloud computing in eHealth.

eHealth is defined as “the cost-effective and secure use of information and communications technologies in support of health and health-related fields, including healthcare services, health surveillance, health education, knowledge and research”. [8] The goal of eHealth is to improve the cooperation and coordination of healthcare, in order to improve the quality of care and reduce the cost of care at the same time.

Cloud computing is a new technology which has emerged in the last five years. According to the definition by NIST, cloud computing is “a model can provide distributed, rapidly provisioned and configurable computing resources (such as servers, storage, applications, networks and other services), which are on-demand, rapid elastic and measured, to whom have network connections”. [41] Because of the obvious scalability, flexibility and availability at low cost of cloud services, there is a rapid trend of adopting cloud computing among enterprises or health-related areas in the last few years.

5.2 Methods

A systematic literature review requires a comprehensive and unbiased coverage of searched literatures. To maximize the coverage of our searched literatures, we started by identifying some of the most used alternative words/concepts and synonyms in the research questions [128]. We conducted first a manual search in the areas of related areas such as computer science and healthcare. The selected Databases are ACM Digital Library, IEEE Xplore, Inspec, ISI Web of Science and Springer. In order to cover more broad scope, open-access journals in the relevant areas were also included. We did not limit the publication year, since cloud
computing was proposed only in the last five years. After general study of the related areas, the language of the papers was limited to English. The following search string was used to search the above mentioned databases:

(Cloud)AND (eHealth OR "electronic health" OR e-health)

The search string could be modified slightly when searching in different databases, since they have different rules for search strings. Our first search by the search string in all the mentioned databases produced 237 articles. In order to focus on the most relevant literatures, we conducted a primary evaluation based on reading the abstracts of all selected articles. The evaluation is based on the criteria described in Table 5.1. The inclusion criteria are applied independently for each author to select the relevant articles. This evaluation selected 44 articles for our thorough study, and all are included in the reference list.

Table 5.1 Include and exclude criteria

<table>
<thead>
<tr>
<th>Include criteria</th>
<th>Exclude criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Directly or indirectly related to both eHealth and cloud technology.</td>
<td>- Irrelevant to study of the cloud or eHealth.</td>
</tr>
<tr>
<td>- Cloud-based eHealth frameworks design.</td>
<td>- Conceptual methods or cognitive introductions.</td>
</tr>
<tr>
<td>- Cloud computing solutions applied in healthcare.</td>
<td>- Review papers.</td>
</tr>
<tr>
<td>- Security and privacy mechanisms of healthcare data in cloud.</td>
<td>- Business analysis reports.</td>
</tr>
<tr>
<td>- Written in English</td>
<td>- Not written in English</td>
</tr>
</tbody>
</table>

The quality of each paper was assessed by two authors mainly based on the Jovell and Navarro-Rubio system for classification from score 9 to 1 [129]. Guidelines for performing systematic literature reviews in related subject area [130] were followed for technology related issues. After include/exclude criteria and quality assessment criteria, a chosen set of papers was available for the data extraction process. In order to avoid the bias of subjective preference, we applied the method by which one
researcher extracted the data and another checked the extraction. The Citation and Bibliography tool – Zotero – was used to manage all the extracted articles.

5.3 Results
After the steps of searching, evaluation and alternate reviews, 44 articles were finally selected from the total of 237 articles found from the first search. We believe the selected 44 articles can cover the basic view of the studied area of cloud computing in eHealth. Since both eHealth and cloud computing are emerging areas, the results of this study can offer the researchers up-to-date perspectives for their research.

We found 19 countries where research articles were published on eHealth cloud computing. The largest number of articles were produced in the USA (n=14), followed by EU countries (n=11). We found relatively few papers in this new area produced in developing countries such as China (n=3), India (n=2) and UAE (n=3) (see Table 5.2). All papers we searched were published after 2010, and this may indicate that research in cloud computing for healthcare is still an emerging area. Figure 5.1 shows the number of papers published across years in our searched results.

Table 5.2 Countries conducting cloud-based eHealth researches

<table>
<thead>
<tr>
<th>Country</th>
<th>No. of papers</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>14</td>
<td>[52],[56],[58],[62],[63],[67],[70],[74],[75],[77],[80],[86],[88],[90]</td>
</tr>
<tr>
<td>Canada</td>
<td>4</td>
<td>[68],[83],[84],[85]</td>
</tr>
<tr>
<td>Australia</td>
<td>3</td>
<td>[65],[89],[92]</td>
</tr>
<tr>
<td>UK</td>
<td>3</td>
<td>[55],[59],[71]</td>
</tr>
<tr>
<td>UAE</td>
<td>3</td>
<td>[53],[66],[78]</td>
</tr>
<tr>
<td>China</td>
<td>3</td>
<td>[79],[81],[91]</td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>[44],[93]</td>
</tr>
<tr>
<td>India</td>
<td>2</td>
<td>[54],[69]</td>
</tr>
<tr>
<td>France</td>
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<td>[87]</td>
</tr>
<tr>
<td>Croatia</td>
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<td>[57]</td>
</tr>
<tr>
<td>Italy</td>
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<td>[60]</td>
</tr>
<tr>
<td>Spain</td>
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</tr>
<tr>
<td>Sweden</td>
<td>1</td>
<td>[64]</td>
</tr>
<tr>
<td>Netherland</td>
<td>1</td>
<td>[73]</td>
</tr>
</tbody>
</table>
In the following, we present some important findings from our study. The topics discussed in the reviewed articles are quite broad in relation to the use of cloud computing in eHealth domain. Generally, the topics can be classified into three categories: 1) Cloud-based eHealth framework design (n=13); 2) Applications of cloud computing in eHealth (n=17); and 3) Security or privacy control mechanisms of healthcare data in cloud (n=14). The distribution of the above topics is shown in Figure 5.2.

Figure 5.1 Number of studies across years

Figure 5.2 Research type distributions.
5.3.1 Discussion of the topics in the reviewed articles

1) Cloud-based eHealth framework design

Since one of the most significant advantages of cloud computing is its huge data storage capacity, six papers proposed cloud-based frameworks for healthcare data sharing. One of the pioneers in this area, Rolim et al. [51] designed a framework for data collection by using sensors attached to medical equipment, and the collected data can be directly stored in a cloud, which can be accessed by authorized medical staff. Some studies [52] [53] [54] proposed a national level framework for eHealth based on cloud models. For example, Patra et al. [54] argued especially that their cloud-based solution on a national level would provide a cost effective way in dealing with patient information for rural areas. By encouraging people in rural areas to upload their personal healthcare information to the health cloud, the care providers can provide them with more correct healthcare services, such as remote diagnosis, supervision and emergency calls.

Other studies related to this category of framework design are more specific as regards application areas, such as the design of a Virtual Research Environment by both Simth et al.[55] and Regola et al. [56]; patients’ self-management by Martinovic et al. [57]; transition or standardisation of data stored in different EHR or PHR systems by Coats et al.[58] and Ekonomou et al. [59]; and designing a secure EHR framework [60][61][62][63].

2) Applications of cloud computing

High accessibility, availability and reliability make cloud computing a better solution for healthcare interoperability problems. Papers in this category mostly applied cloud technology for healthcare data sharing, processing and management, and can be categorized based on three types of cloud platforms, namely, public cloud, private cloud and hybrid cloud.

Six papers presented their eHealth applications by using or testing in public clouds such as Google App Engine [64], Windows Azure [65][66] and Amazon EC2 [67][68][69]. The application[67] of Wooten et al. provided a patients-to-patients support and information sharing within patients community. The solution proposed by Benharref et al. [66] used
the mobiles of seniors to send the patients’ data automatically to the cloud, and the patients themselves could decide with whom to share the data. Mohammed et al. [68] designed a Health Cloud Exchange (HCX) system which shares healthcare records between services and consumers with some privacy controls.

For applications based on the private cloud, Bahga et al. [70] presented an achievement of semantic interoperability between different kinds of healthcare data, while DACRA [71] built a platform for interoperability on the syntax level. Vilaplana et al. [72] used queuing theory as the basic means to model the performance of an eHealth system based on the private cloud. Van Gorp et al. [73] applied virtualization techniques to allow patients themselves to build their own lifelong PHRs. The PHR can then be shared with other stakeholders who are authorized and interested. Wu et al. [74] proposed an approach to EHR data schema composition with a broker based access control. In order to reduce the cost of adopting EHRs, HP published a cloud-based platform called Fusion [75] for securely managing and sharing healthcare information on large scale. Other studies also used the private cloud to integrate the EHR systems with other systems like healthcare billing system [76] and national law system [77].

Gul et al. [78] and Chen et al. [79] proposed a shared EHRs system based on hybrid cloud. In the proposed application of Chen et al. [79], the patient’s medical data are stored both in a hospital’s private cloud and public healthcare cloud. A mechanism is set up to make sure that the owners of the medical records can decide when their records should be protected in normal or emergency situation. Dixon et al. [80] implemented a community cloud-based exchange of clinical data between two disparate health care providers, which was mainly used by chronic disease healthcare.

3) Security or privacy control mechanisms

Healthcare data require protection for high security and privacy. Access control, an effective method to protect data, is widely used in many studies. Liu et al. [81] applied an identity based encryption (IBE) system in access control of PHR, and this identity-based cryptography system can
reduce the complexity of key management. Attribute based Encryption (ABE) is one of the most preferable encryption schemes used in cloud computing. For example, Fakhrul et al.[82] implemented Cipher text-Policy ABE in a security manager module to make it act as an administrative person; ESPAC [83]and Narayan et al. [84] proposed a patient-centric ABE access control scheme; and Aljumah et al.[85]designed an emergency mobile access to PHR cloud-based ABE.

Three researches [86][87][88] mixed ABE and IBE to identify access on different levels (normal and emergency), which can handle more complex situations than a single scheme. Role based access control is based on ABE, which is an automatic procedure for authenticating healthcare user information and allocating corresponding role to guarantee all associated operations. Tong et al. [89] introduced a Cloud-based Privacy-aware Role Based Access Control model for controllability, traceability of data and authorized access to healthcare resources. Sharma et al.[90]developed an advanced role-based scheme called task based control to determine whether access should be granted to a healthcare cloud.

Besides access control, several security protection techniques (Trusted Virtual domains [44], Watermarking method[91], Secure index implementation [92]and secret-sharing schemes[93]) were also introduced to maintain the high security and privacy of healthcare clouds.

5.4 Discussions

The presented review shows that cloud computing technology could be applied in several areas of the eHealth domain. The majority of studies introduced cloud computing technology as possible solutions for achieving eHealth interoperability. Although worldwide it is acknowledged that ICT technologies, such as cloud computing, can improve healthcare quality, most papers in this review are from developed countries. The present review does show, however, increasing studies from other developing countries.

Almost all the studies suggest that due to the huge amount of patient health data, especially in the case of daily care, the cloud's big data storage service provides a better way to store these data. The data can be shared among hospitals and third party research institutions or other
healthcare organizations even on a national level. The huge data storage capacity of the cloud would help the development of big data mining in healthcare, as well as diagnosis and treatment. Pay-as-you-go mode of the cloud has significant economic strength, reducing cost for all healthcare organizations which would like to use cloud-based services.

The patients-centric healthcare model will be a future trend where patients are active participants in their own healthcare. Some studies presented cloud-based patients-centric healthcare applications by the users-centric feature of cloud computing. This will not only encourage healthcare receivers to be involved in their own healthcare, but also the cloud-based healthcare platform will provide a technical solution and a social network. In addition, healthcare receivers’ participation constitutes an efficient healthcare education in terms of patient’s self-management.

High accessibility and availability of the cloud could help the healthcare data stored in the cloud to be accessed at anytime and anywhere in the world. If healthcare receivers could make parts of their healthcare data in public cloud open, which means that data can be “freely used, reused and redistributed by anyone – subject only, at most, to the requirement to attribute and sharelike.”[96]. When the open data become available in the public cloud, it can be processed by remote services, such as medical systems in hospital, clinic decision support systems, expert systems, or distributed to other medical personnel. Around one third of the studies also show that the security and privacy gaps of healthcare data in the cloud could be solved by access control encryption schemes and security protection techniques. This would make it possible to move current server-client based eHealth services to cloud-based eHealth services and make more contribution to improve the current healthcare by high-technologies.

The present review also noted some challenges to using cloud computing in eHealth. Healthcare data contain sensitive information, and dealing with sensitive data in the cloud could lead to some legal issues. Besides, it is important to select cloud providers carefully to guarantee the confidentiality of healthcare data.
Based on the review, we could find that a hybrid cloud model which contains access controls and security protection techniques would be a reliable solution. The EHRs in the hospitals and other healthcare centers could keep their data in private clouds, while patients’ daily self-management data could be published in a confident public cloud. Patients as the owner of their health data should decide who can access their data and the conditions for sharing.

5.5 Limitations
The present review has certain limitations. The most obvious one is the external validity or generalizability. Since cloud computing is a relatively new technology, the number of published works for our review topic is not so large. In order to have a wider spectrum of studies, the selection rate is slightly higher. Since all the databases we used for searching articles contain some intelligent search techniques, we did not create as many synonyms of “eHealth” as we may do. This may have caused some data loss. Since cloud computing came after 2010, and most of the studies in this review are conference papers with concept-proof-designs. Only very few studies have been evaluated in the real world or tested by some technical experts.

5.6 Conclusion
Research on applying cloud computing technology to eHealth is in its early stages; most researchers have presented ideas without real-world cases validation. The obvious features of cloud computing technology provide more reasons to adopt cloud computing in sharing and managing health information. The main purpose of our review is to identify some challenges and feasible cloud-based solutions which can be applied in eHealth. The current review suggests that with the unique superiority of the cloud in big data storage and processing ability, a hybrid cloud platform with mixed access control and security protection mechanisms will be a main research area for developing citizen centered home-based healthcare system.
6 Building up a Virtual Community for Home-Based Chronic Diseases Healthcare

Abstract— with the development of Internet, social networks get more and more popular, it brings us an idea of designing a virtual community for home-based chronic diseases healthcare. In this paper, we conduct a questionnaire to gather the requirements of the community and describe them with user stories. Afterwards, a conceptual prototype is developed based on the requirements. The proposed virtual community involves healthcare providers, healthcare recipients and other people relevant to the home-based healthcare into one platform. It will solve the interoperability problems of current healthcare systems, as well as provide a technical solution of home-based healthcare.

Key words—Virtual community, home-based healthcare, chronic disease, requirements.
6.1 Introduction
The success of social network like Facebook and Twitter let people with same interests build up a virtual community to communicate with each other no matter the differences of geographical distribution. A virtual community is a social network that people interact through specific social media. It is crossing geographical and political boundaries in order to pursue the same interests or goals [131].

Nowadays, chronic diseases affect the population all over the world. According to the World Health Organization (WHO) [132], chronic diseases represent 60% of all deaths in the world, which are the leading cause of mortality. However, chronic diseases can only be controlled but not cured [133]. Since they last long time duration, provide efficient chronic diseases healthcare become a worldwide goal in healthcare domain. In fact, the patients suffered from chronic diseases have to be monitored from time to time. That’s very high cost, time consuming and inconvenient for most of patients, especially the limitations to patients’ daily activities and inconvenience of aged people. Meanwhile most of the cases for chronic diseases do not need urgent medical diagnosis and treatments [40]. If moving the chronic diseases healthcare from hospital-based to home-based, it may save a lot of time and resources, and providing efficient healthcare.

Thanks to the development of information and communication technology (ICT), the feasibility of home based eHealth has been highly raised [40]. Many physiological signals can be measured by individuals in their living environments during daily activities [134]. If there is a virtual online community for people with chronic diseases, the home based healthcare could enable people independent living at home and improves the quality of lives for them. By this community, healthcare recipients can not only communicate with each other, but also with healthcare providers, families and other research institutions quickly and directly.

This paper starts with a questionnaire of people over 55 with one or more chronic diseases to gather the patients-centered requirements of online community. According to the results of questionnaire, we describe the functional requirements in user stories style. The non-functional
requirements are discussed in section 4. Finally, a prototype of virtual community for home-based chronic diseases healthcare is developed. The last section is our discussion of this virtual community and the limitations of our works.

6.2 Requirements Collection of Community

A good online virtual community could not only perform as the functions of community, but also can integrate some healthcare tools. In this community, patient-centered self-management is the main trend for home-based chronic diseases healthcare. There are already some commercial or research-based solutions for the mentioned way of self-management. For instance, HealthVault [7], launched by Microsoft, is a web-based PHR system to store and maintain health and fitness information. There are a lot of specific third-party applications, such as blood pressure management tool or medical image viewer, as well as hundreds of devices, such as blood glucose meter, blood pressure monitor, could cooperate with this community to record health data and manage health.

In order to meet most users' needs when designing the online virtual community, we begin with requirements specification. There are two types of requirements in website design and software engineering, functional requirements and non-functional requirements [135]. As we mentioned above, in home-based healthcare, patients are the center of the healthcare, as well as the main users. So we selected online questionnaires from the potential healthcare recipients as the key data-gathering technique.

Questionnaires include a series of questions designed to elicit specific information from the users. Well-designed questionnaires are better way to get answers to specific questions from a group of people, especially for people who are infeasible to visit them all [135]. In this case, the questions are mostly designed for functional requirements in the healthcare recipients' perspective. In our questionnaires, we publish our questions on surveymenkey.com as the electronic form. The respondents are limited of age above 55 with one or more chronic diseases. We send out the questionnaires through some social network websites, such as
patientslikeme and Facebook. It contains 10 questions mixed with simple Yes or No questions, choose from a set of pre-supplied answers and open comment questions. In the end, 25 valid responds are gathered, and most of the respondents are from US and Sweden.

A. Problems in Current Healthcare

The first open question is about the problems they faced in their current healthcare. Almost all the respondents mentioned that the long time waiting for doctors’ appointments make them uncomfortable. “The resource is limited. It means I need to spend more time to wait the healthcare service. And when I waiting for the doctor, I really also need suggestions to keep my body stable, not be more serious.” “Really long queue in every time when I visit some hospitals”. In some countries like Sweden, the shortage of healthcare providers leads to the long waiting query of hospitals, sometimes the patients lose the best time for diagnoses and treatments. Another big problem proposed by the respondents is lack of information sharing among healthcare providers, when they come to the new healthcare organizations, their historical healthcare records were difficult to find. “When I went to another hospital which I never visited, the doctor didn't know my health history, if I have hypersensitivity reaction for some drugs, he didn't know, so this may produce some healthcare problems. If I need to have a new scratch test, it wastes time and resource.” “There is no shared information among the hospitals. It cannot help the care providers to communicate to each other.” This brings the healthcare recipients overlap check-ups, which is a time and resources waste. Besides above two, some respondents also point out the location of healthcare center is far away from their home, it is inconvenient for them to go to healthcare centers frequently.

B. Views of Online Healthcare Community

When asking about the time spend on Internet per day, 60% spend more than 6 hours, which means Internet has already been an essential part of their daily lives. Because of the high rate of using Internet, the online healthcare community is acceptable. All the respondents would like to have an online healthcare community which they could chat with all stakeholders related to their healthcare through one platform. The results
on which people they want to chat with through the online community are doctors (96%), other healthcare providers (84%), other people with same symptoms (72%), family members (68%) and some healthcare research institutions (64%).

C. Online Community Functions Design

In Question 5 to 8, we ask about some functions of the online healthcare community, the result is shown in Fig.1. From the figure, we find out that all functions we plan to develop are supported by most of the respondents. Question 10 is an open question on other functions they are willing to have, online simple diagnose was one of the most desirable functions. Free seminars and lectures for healthcare is another suggestion by most of the respondents. “Simple medical suggestions and little medical diagnosis”, “Diagnosis, chatting, forum, online seminar” “diagnosis online” and “Healthcare lecture” were mentioned most. In addition, fast contact and response, risk prediction, decision support systems and nearby healthcare centers information were also suggested. In Question 9, the respondents were asked which non-functional features are important for them as the users of online community, availability (100%), usability (88%), security (88%) and privacy (84%) are all got very high supports.

Figure 6.1 Functions of the online healthcare community

6.3 Main Functional Requirements

Since one of the aims of building up this online care community is to encourage the care recipients be the main forces of their home-based healthcare. The requirements of healthcare providers are gathered mainly
based on our previous interviews and informal discussions with doctors, nurses and homecare providers.

In this section, we list the simple functional requirements of the online virtual community through our questionnaires. Table 6.1 is the requirements list of the online community design. We use the user stories style to describe them for easy understanding and quick changes. A user story is used with agile software development methodologies. It contains one or more sentences in the everyday language to describe what an end user to do or need as part of function [136].

Table 6.1 Requirements List

<table>
<thead>
<tr>
<th>Users types</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>All users (As a user)</td>
<td>I want to register an account on the online healthcare community and choose my use type based on different roles. When I login my account, the information page will be displayed automatically according to my user type. I want to have online chat with my contact persons like care providers, care recipients, family members and so on. I want to have alarms to reminder my care activities. I want to have the contract persons address book with the detail contact information. I want to share some useful healthcare information to my contact persons.</td>
</tr>
<tr>
<td>Care recipients (As a care recipient)</td>
<td>I want to contact my care providers directly through the online community for simple diagnose and care suggestions. I want to have some videos of healthcare education lectures. I want to record my daily health data myself in the community and share it to people who I want to share with. I want to have some tools to trace and check my care data, as well as to print it out when necessary. I want to share my care experiences with people who have the same symptoms as me. I want to book a doctor appointment online.</td>
</tr>
<tr>
<td>I want to integrate some healthcare relevant apps in the community based on my individual needs.</td>
<td></td>
</tr>
<tr>
<td>I want to have the address and opening time information of the nearest healthcare centers.</td>
<td></td>
</tr>
<tr>
<td>Care providers (As a care provider)</td>
<td></td>
</tr>
<tr>
<td>I want to share some care information with other providers.</td>
<td></td>
</tr>
<tr>
<td>I want to have some online seminar with other providers and my care recipients.</td>
<td></td>
</tr>
<tr>
<td>I want to update the care histories of my recipients to the online community.</td>
<td></td>
</tr>
<tr>
<td>I want to have some support decision systems to help me for diagnoses and treatments.</td>
<td></td>
</tr>
<tr>
<td>I want to have a list of every day’s work.</td>
<td></td>
</tr>
</tbody>
</table>

### 6.4 Non-Functional Requirement Issues

Non-functional requirement is a requirement used to measure the operation of a system, rather than specific behaviors [137]. In software systems, non-functional requirement is also considered as quality attributes. For our community design, usability, security and privacy, as well as availability are main issues of non-functional requirements [138].

**Usability:** The main users of this online community are elderly people with one or more chronic diseases, it should be extremely simple to use and easy to learn. As a result, the user interface design of our online community will follow “Ten usability heuristics [139]” as a guideline.

**Privacy:** The patient health information includes personal information, details of medical history, symptoms, treatments, associated diseases or even the family health history. It is important to ensure that only the patients can authorize exactly who can view the shared health information and for what purposes [11]. All the information generated by a patient is not at the same sensitive level. Data segmentation may provide a method to protect specific sections of health information while giving choices to patients, and abiding requirements of legal. Technical consideration and definition of sensitive information have to be addressed when segmenting data [140].
Security: Security is assurance that only authorized persons or entities can access to patients’ data. Employees’ illegitimate access and theft is one of the most frequent reasons of data leakage [11], as well as innocent disclosure because of system problems. Another issue is unauthorized access and malicious attacks from outside. So the encryption, identification and access control of patient health data are not optional of the online community development [11].

Availability: As an online healthcare community, it should be available in 24 hours every day. The authorized users could be able to access the community anytime anywhere.

6.5 Prototype Design
With the requirements specified above, we develop a simple prototype for conceptual design. It is a kind of horizontal prototyping, which refers that the prototype should cover the user interactions’ functions as many as possible with not so deep details [22]. In our prototype, the roles of users are divided into three types: healthcare recipient, healthcare provider and others like family members and researchers. The user type is selected by the users in registration. After successfully registered, the information related to the role of the community will be displayed based on the user types. The role of the users decides the information and activities they can have in the online community.

When the user finished registration and login in to his or her account by user name and password, the system will automatically turns the user to his or her sites according to the role. As shown in Figure 6.2, Anna Nilsson is a healthcare recipient, and the profile site has her basic information and the information relevant to her, like her healthcare community, tools and rules. The contacts list in the middle has detail information of all her care providers and other people relevant to her healthcare. In the right-bottom part, she can note her main symptoms so that people has same conditions can easily find her and share with each other’s care experiences.
The page “my community” is designed based on the needs of questionnaires respondents, see Figure 6.3, all the contact persons are listed in the right contain healthcare providers, family members and others. They can chat with each other when they are online, so the healthcare recipients can get the feedbacks immediately form the healthcare providers without visiting any healthcare organizations. The community also provides a space for users to post some discussions, videos, websites etc. to share with their contacts. Another important function is that the community will always show the nearest healthcare centers information based on the gathered user geographical data. The scheduled care activities will be shown rolling in red to reminder the recipients.
The most important function of home-based healthcare community is to provide a self-management platform for the healthcare revivers. In our design, it is in the recipients’ “My tools” page, shown in Figure 6.4, the recipients update their basic physiological parameters, emotions and diet daily for record and trace. The authenticated healthcare providers can access the data and give some suggestions to recipients. The recipient can print out this data in a long period as well to show the doctors and other care providers when they have an appointment. Online appointment is also proposed to reduce the waiting time of meeting doctors. In addition, personalized tools are introduced to the users so that they can use them based on their own needs. The healthcare providers’ tools page including functions of updating care history, appointment remaindering, decision support systems for diagnoses and treatments and so on.
6.6 Discussion and Limitation

The above prototype presents a general view of the community, which is a patients-centered virtual community for home-based chronic diseases care. The design integrates healthcare recipients, healthcare providers and other related people into one community. The virtual community makes it possible to have only one platform for all the stakeholders who contribute to home-based chronic diseases. It will solve the interoperability problems of current healthcare systems, as well as provide a technical solution of home-based healthcare. There are a lot of ICT technologies in eHealth applications, in our case, we believe cloud computing would be an applicable technology. Cloud computing is beginning to demonstrate its great potentials in our daily healthcare due to its powerful services in
managing big data, accessibility, flexibility, scalability and cost-effectiveness services. Cloud technology mitigates the need to invest in IT infrastructure, by providing access to hardware, computing resources, applications, and services on a ‘per use’ model. And thus it dramatically brings down the cost and eases the adoption of technology. This will lead to radical new circumstances for offering eHealth services and constructing our new generation of healthcare information systems.

However, there are some limitations of this paper. Firstly, the respondents group of questionnaires was not so big due to our restrictive rules (over 55 and have at least one chronic disease), so the loss of care recipients’ needs is possible. Secondly, as a patient-centered healthcare community, the requirements of care providers are gathered not so formal and detailed due to the time limitation, so there must be some uncover needs of the care providers.

6.7 Conclusion

This paper proposed an online virtual community for home-based chronic healthcare. The design idea is from online social networks. The requirements of the community were mainly gathered from the questionnaires with target group people. We use “user stories” of agile software development to describe the functional requirements and the non-functional requirements are briefly discussed. Finally a prototype is designed based on the requirements. In the future, we will show this prototype to the potential users for evaluation. And former interviews or surveys will be conducted through the healthcare providers to get more in-depth requirements in their perspectives. In the end, we will develop the online community based on cloud technology and put it into use as soon as possible.
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