The care of chronic disease has become the main challenge for healthcare institutions around the world. As the incidence and prevalence of chronic diseases continue to increase, it is a big challenge for traditional hospital-based healthcare to meet requirements of patients. To meet the growing needs of patients, moving the front desk of healthcare from hospital to home is essential. Home-based healthcare for chronic disease involves many different organizations and healthcare providers. Therefore, there are interoperability problems for cooperation among the various organizations and healthcare providers to provide efficient and seamless home-based healthcare.

This thesis aims to point out an appropriate technical solution to interoperability problems in home-based healthcare. There are different levels of interoperability, such as pragmatic, semantic and syntactic. We explored alternative solutions specifically for syntactic interoperability. We started to identify the interoperability problems among different healthcare centers by interviews and online surveys. Based on this empirical study, we mainly used two current techniques, namely peer-to-peer (P2P) networks and cloud computing, to design prototypes for sharing healthcare data. Comparing these two techniques, we found the cloud-based solution figured out most of the problems encountered in healthcare interoperability.

To identify state of the art, and pinpoint the challenges and possible future directions for applying a cloud-based solution, a systematic literature review was carried out on cloud-based healthcare solutions. Based on the literature reviewed, we suggest a hybrid cloud model, with access controls and techniques for securing data, could be an acceptable solution for home-based healthcare in the future. This cloud model would work as a community for both healthcare providers and recipients, as well as other stakeholders, such as family members and other patients with similar symptoms. Then we conducted a questionnaire study with healthcare recipients and interviewed healthcare providers to gather the requirements for the design of the community. Based on the concept of 'community' from the activity theory model, we designed a prototype to demonstrate our proposed solution. Finally, we proposed the conceptual hybrid cloud model. In our hybrid cloud model, hospitals and primary healthcare centers could continue using their own databases as private clouds. For home-based healthcare data, we argued, the best approach is to store and process the data in public clouds. Healthcare recipients, as the owners of their health data in public clouds, should then decide who can access their data and the conditions for sharing. To evaluate this model, we conducted a two-step case study of diabetes healthcare in Blekinge, Sweden. We found that our improved hybrid cloud model will be feasible in the future for home-based healthcare, and it will benefit both healthcare providers and recipients. To apply this model in practice, we suggest that a professional IT healthcare education team should be created to support both healthcare providers and recipients.
Cloud Computing for Achieving Interoperability in Home-Based Healthcare

Yan Hu
Cloud Computing for Achieving Interoperability in Home-Based Healthcare

Yan Hu

Doctoral Dissertation in Computer Science

Department of Creative Technologies
Blekinge Institute of Technology
SWEDEN
Enter through the narrow gate; for the gate is wide and the road is easy that leads to destruction, and there are many who take it. For the gate is narrow and the road is hard that leads to life, and there are few who find it. "Matthew 7:13-14"
To my little Elsa in Heaven

I love you and I miss you every day.
Dedicated to my beloved family-Cheng and Estelle
Abstract

The care of chronic disease has become the main challenge for healthcare institutions around the world. As the incidence and prevalence of chronic diseases continue to increase, it is a big challenge for traditional hospital-based healthcare to meet requirements of patients. To meet the growing needs of patients, moving the front desk of healthcare from hospital to home is essential. Home-based healthcare for chronic disease involves many different organizations and healthcare providers. Therefore, there are interoperability problems for cooperation among the various organizations and healthcare providers to provide efficient and seamless home-based healthcare.

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To apply this model in practice, we suggest that a professional IT healthcare education team should be created to support both healthcare providers and recipients.
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Yan Hu

March 2017

Karlskrona
Preface

In addition to the Introduction chapter, this thesis includes the following 8 papers as chapters. I am the main contributor for all of the included papers. The included papers have been modified to fit the thesis format, but the contents have not been changed.


Paper VII. Y. Hu, G. Bai, S. Eriksén, and J. Lundberg “Hybrid cloud model for diabetes home-based care -a case study for perceived feasibility in the future”, in Health Informatics Journal, Submitted


The following papers are related to but not included in the thesis

Paper IX. Hu, Y., & Bai, G. “Building up a virtual community for home-based chronic diseases healthcare”. In Usability and Accessibility Focused Requirements Engineering (UsARE), 2014 IEEE 2nd International Workshop on (pp. 40-43). IEEE.

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<td>PHR</td>
<td>Personal Healthcare Record</td>
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<td>ICT</td>
<td>Information Communication Technology</td>
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<td>PDAs</td>
<td>Personal Digital Assistants</td>
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<td>NPÖ</td>
<td>National Patient Overview</td>
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<td>IaaS</td>
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<td>DICOM</td>
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<td>EMR</td>
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<td>HIPAA</td>
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<td>GAE</td>
<td>Google App Engine</td>
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<td>P2P</td>
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Chapter 1. Introduction

1.1 Background

Chronic disease has been the main factor of death, according to report of World Health Organization (WHO), almost 7 out of 10 people died from chronic diseases in 2014 [1]. Usually chronic diseases cannot be prevented by vaccines or cured by medication, nor do they just disappear [2]. Chronic disease last for a long time, and can hardly be cured [3]. Therefore how to provide preventive and monitoring healthcare becomes a worldwide concern. Living with a chronic disease has a significant impact not only on a person’s quality of life, but also on their family, and on healthcare systems. Elderly people living with more than one chronic disease face particular challenges, both medically and socially [3].

Among the various kinds of chronic diseases, which have so far been recognized and categorized as such, diabetes is one of the most common. In Sweden, 397,066 new patients with diabetes were registered from November 2015 to November 2016 [4]. In type 1 diabetes, the human body does not produce insulin, while in type 2 diabetes, the body continues to produce insulin, but the cells fail to use it normally. Only 5% of patients with diabetes have type 1 diabetes [5]. For type 1 diabetes, with the help of insulin therapy and other treatments, even young children can learn to manage their condition. Today people with type 1 diabetes and access to treatment to this can live long, healthy lives. The causes of type 2 diabetes are a combination of genetic and personal lifestyle factors [6]. Therefore, type 2 diabetes is normally treated with lifestyle changes, oral medication, and insulin. The main lifestyle factors include obesity, physical activity, diet, and stress.

Patients with chronic disease need to handle their condition more or less on a daily basis which includes making life-style changes. In the case of diabetes, this includes checking blood glucose frequently and regular exercise. Visiting hospitals or primary healthcare centers frequently to check blood glucose is not only inconvenient, but also wastes healthcare resources. This time to time monitoring limits the patients’ daily activities and is especially inconvenient for elderly people. At the same time, healthcare spending is continuously increasing due to the high occurrence rate of chronic disease and the lack of healthcare resources [7]. Usually, lifestyle, diets and metabolism are the main factors that cause most common chronic disease [8]. Treating chronic disease depends heavily on the patients’ daily behaviors [8]. Therefore, most conditions of chronic disease 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 [9]. Focusing on the features of chronic disease healthcare, traditional hospital-based health healthcare could not meet all the
needs of patients. It is time to move the chronic disease healthcare front desk hospital to home. Home-based healthcare could enable the healthcare 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 and support with the healthcare, such as family members and other patients with similar symptoms.

Nowadays, most elderly people have one or more chronic disease [10]. 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 communicate with healthcare providers. A survey has shown that communication troubles were mainly included too long waiting time, inconvenience for the patient to visit hospitals, and lack of cooperation between healthcare providers [11]. It would therefore seem to be more appropriate to adopt an efficient approach to trace and control the patients’ conditions via healthcare services, such as monitoring and recording physiological signals [12] in the home environment. To overcome the communication problems above, a possible innovation may involve a new approach developed using Information Communication Technology (ICT) more efficiently.

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 [13]. There are already a number of commercial solutions for healthcare self-management. For instance, HealthVault [14], launched by Microsoft, is a web-based Personal Healthcare Record (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, are compatible with this platform to record health data.

eHealth is the use of modern ICT to support healthcare services and medical informatics. The WHO defines eHealth as “the use of information and communication technologies (ICT) for health. Examples include treating patients, conducting research, educating the health workforce, tracking diseases and monitoring public health” [15]. The goal of eHealth is to improve the cooperation and coordination of healthcare, so that improvements in the quality of healthcare and reductions in the cost of healthcare can be achieved at the same time. These obvious benefits have facilitated a rapid development of eHealth in recent years. As a branch of eHealth, mHealth refers to “medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices,
personal digital assistants (PDAs), and other wireless devices[16]”. mHealth technologies aim to inform, motivate, and enable individuals to manage their own health information and knowledge sharing, as well as support communication and community building among both healthcare providers and healthcare recipients.

In 2010, the European Union published an eHealth Action Plan 2012-2020 [17], which aimed to provide smarter, safer and more patient-centered health services.

1.1.1 eHealth strategy
In accordance with the EU eHealth Action 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, an increasing number of developmental needs to be coordinated across the entire sector have been identified. 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, and private and third-sector practitioners. From the recent National Strategy for eHealth [18], 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. Increasingly 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 to 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 highlights 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.

In March 2016, Swedish government published a new eHealth vision for healthcare and social services called Vision eHealth 2025. The aim of this vision is “In 2025, Sweden will be best in the world at using the opportunities offered by digitization and eHealth to make it easier for people to achieve good and equal health and welfare”[19]. In this vision, the three above areas from the eHealth strategy 2010 remain in place, and the vision starts to work on make all relevant actors in the social services and healthcare to reach a more long-term common approach and define a more clear division of responsibilities. In the future, the county councils and municipalities have the responsibility to plan, support, develop, quality assure for enhanced digitalization, while the center government’s responsibility is primarily legislation, supervision, equalization and allocation of resources[20].

1.1.2 Public healthcare ICT services in Sweden

1177 service: 1177 is the national healthcare online service that mainly provides information from Swedish public healthcare providers [21]. Healthcare recipients can search medical and care suggestions for most common diseases, which could help to reduce unnecessary visit to primary healthcare centers. 1177 also provides a call center to support healthcare recipients, and to provide some professional suggestions. Through the 1177 website, healthcare recipients can easily find their nearest primary healthcare centers and other public healthcare providers. Starting in spring 2016, 1177 has provided patients with the ability to access their own records. Patients can review their records by logging in with their personal electronic IDs, but not all patients know about or are able to use this service.

National Patient Overview: 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 [22]. 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 for the last three years. For the convenience of patients’ movements, a patient can give consent to the so-called cohesive record. The cohesive record means that healthcare providers can share medical records with each other anywhere in Sweden [22].

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 access and use the information. Every time 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 accessed the information, as well as where and when it happened [22].

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 disease healthcare, NPÖ can provide certain rights for healthcare recipients. Also, as home-based healthcare involves other parties like family members and other patients with similar 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.

**National Diabetes Register:** To promote evidence-based development of diabetes care by offering up-to-date information about changes in the treatment, other risk factors and diabetic complications, the Swedish National Diabetes Register (NDR) was launched in 1996 [4]. The overall goal of the NDR is to reduce morbidity and mortality and to maximize the cost-effectiveness of diabetes care. NDR is also working to support improvements in the quality of care provided by diabetes care centers at hospitals and primary healthcare centers. Therefore, every known patient with diabetes is registered in the NDR database with information in a standardized form. The patient data contains basic personal information, general health measurements, physiological measurements, medication dosages and non-physiological records as well as lifestyle records. This data forms a standardized record for diabetes patients in Sweden and all diabetes healthcare providers can manage these data. The data are updated each time the patients meet with their healthcare providers. However, the NDR only standardizes healthcare provider-based data; it does very little for home-based diabetes healthcare.

**1.1.3 Healthcare mobile applications**

With the success of smart phones, many healthcare mobile apps have been developed for different groups of people. There are large numbers of mobile apps already on the market intended for self-management of patients. For example, there are more than 20 different mobile apps can support diabetes patients in
Swedish market [23]. In our opinion, an appropriate mobile app for self-management should comply with the following requirements.

- Has basic functions for recording physiological parameters and automatically integrates with as many different kinds of devices as possible.
- Allows data stored in the app to be shared with others as needed when given explicit permission from healthcare recipients.
- Has an easy-to-use and user-friendly interface.
- Supports cloud-based data processing and can display simple reports covering both short-term and long-term periods.
- Abnormal collected data should trigger some form of alarm.
- The app could support building a patient community among its users for discussion purposes.

In our research, Diasend was selected as an appropriate mobile application for the case study. Diasend (Figure 1.1) is a mobile application for the self-management of patients with diabetes. It provides a method for easily uploading information [24]. The collected data are stored in Diasend’s servers as a public cloud. When a user clicks the “Upload Data” button, the app updates the data in the cloud. Based on the accumulated recorded data in the cloud, the app can create different types of reports that can be downloaded or printed. These reports include standard daily glucose, glucose trends, standard daily continuous glucose monitoring (CGM), CGM statistics, insulin administered per week, comparison logbook, etc. If the updated value is higher than a safe level, the value will be shown in red in the report as an alarm. Patients can share their scorecard results with anyone they wish via email by clicking on a Share button (the “…” button). Although there are a number of mobile apps which can even record food and exercise data such as CE-marked medical app Triabetes [25], Diasend offers online access for healthcare providers, without the need for an app or any other software installation. This means that Diasend integrates access to information for patients and their healthcare providers into their cloud server. From February 2017, Diasend has now worked together with Glooko [26].
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 (NIST), “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 1.2). 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. 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.
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-premises, 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 provides 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.

From the view of a deployment model, cloud systems can be divided into four types: public cloud, community cloud, private cloud and hybrid cloud [27]. 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” [27].

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 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, concerns about security, and issues relevant to regulatory compliance [29]. 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 [27].”

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 of achieving better security over cloud-based assets [30].

**Community Cloud**: In accordance with the definition of NIST, a 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 [27].”

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 [31]. 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 designed as what is called “hybrid cloud,” where both internal and external cloud resources can be utilized and managed effectively. A 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 [27].”

Owing to the potential advantages of cost efficiency and scalability, which provided by the public cloud, 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.

1.2 Problem definition and research questions

The traditional healthcare systems were mainly designed to treat acute disease [32]. That means most of the computer or mobile based healthcare information systems were targeted at healthcare providers, either to manage patients' healthcare records, control pharmaceutical prescriptions, or support diagnoses. Although there are several home-based healthcare systems in service now, few of them are integrated with other systems [33]. Additionally, the traditional responsibilities among healthcare providers are independent. However chronic disease healthcare often needs efforts from multiple stakeholders, not only healthcare providers, but also recipients themselves and their families. For home-based chronic disease healthcare, the healthcare providers are diverse, as well as self-management through online services or mobile applications are provided by some commercial companies. 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. Furthermore, different nations and regions have different healthcare laws and guidelines. Due to increased mobility of healthcare recipients, this can cause additional problems concerning differences between different services offered. Sometimes poor collaboration leads to a waste of time and resource. Overall, the current chronic disease healthcare has problems with healthcare resources waste, healthcare services overlap and delay, and lack of collaboration among different healthcare providers, many of these issues are caused by interoperability problems. Both international and national solutions are needed to cover the eHealth interoperability gap, as well as to facilitate the sharing of health data accurately and effectively among different healthcare information systems and applications [20]. 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” [21]. Due to the lack of interoperability among ICT tools and solutions used in healthcare, the healthcare recipients and different healthcare providers sometimes find it difficult to obtain benefits by using eHealth services [22].

Although there are some international standards of healthcare like HL7 [34], or some national guidelines for primarily care [35], there is no specific standard for
chronic disease healthcare. In some cases, the unclear responsibility of healthcare severely reduces the quality of home-based chronic disease healthcare [36]. Many studies show that interoperability is a blazing issue for eHealth research and practice today [22] [23].

In Blekinge County, citizens are provided convenient healthcare services by using ICT tools and solutions. A number of ICT-based tools are used in various healthcare centers and hospitals, however healthcare data from home-based healthcare cannot be reached by most healthcare providers. The emergence of 1177 [21] helps most healthcare recipients to communicate with their providers without face-to-face visit, but there are still several issues it cannot cover, such as long-term monitoring of patients with chronic disease.

The aim of this thesis is to discover the above interoperability problems in current home-based healthcare, and to 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 interoperability problems of current chronic disease healthcare?
Q2. What are the alternative ICT solutions for healthcare interoperability problems, and which one can be used to achieve interoperability in home-based healthcare?
Q3. How can cloud computing be used to achieve interoperability in home-based healthcare?
Q4. How can the proposed cloud model be used in practice?

The research started with a common challenge in current home-based healthcare—interoperability problems. In order to find the details of situations in healthcare interoperability, we collected perspectives from healthcare providers and healthcare recipients, and defined the different levels of interoperability based on the literature. Based on the problems identified through Q1, we endeavored to find 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 cloud computing and tried to come up with a reliable cloud platform to answer Q3. The results of Q3 are a conceptual hybrid cloud model to achieve interoperability in home-based healthcare. With the result for Q3, a real world healthcare case is studied to answer Q4.

1.3 Research methodology

Research methodology (RM) is a collective process of conducting research in a scientific way [37]. In this thesis, we have used mixed research methodology containing both qualitative methods and quantitative methods. The methods we
mainly used included case study, interview, online survey, literature review and prototyping.

Case studies are analyses of persons, events, situations, groups or other systems that are studied holistically by one or more methods [38]. It is a method used to narrow down a very broad field of research into one target topic. Interview is a useful method for data collection, with a high response rate and closer judgment of people’s experiences, opinions, desires and feelings [37]. We started our first case study in Blekinge, Sweden with interviews with 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. A case study is also usually used to validate theoretical models by using them in real world situations [39]. In our second case study, we studied real-world diabetes care situations in Blekinge, Sweden to validate if it is feasible for the proposed cloud model to be applied in future use in chronic disease healthcare in the real world. The study group consisted of 11 people, and included both healthcare providers (one doctor and one nurse in a hospital diabetes center and one hospital nurse in the department taking care responsible for diabetes patients, one primary healthcare center doctor and two primary healthcare center nurses) and healthcare recipients (two patients with type 2 diabetes, one mother of a child with type 1 diabetes, and two elderly people with other chronic diseases). We chose interviews as well because the study was more of an open discussion concerning future feasibility, and we could acquire more in-depth knowledge from face-to-face interviews. Another important reason is that the questions included some technical terms; through face-to-face interviews, those terms could be explained to avoid misunderstandings. The interviews included approximately 10 open-ended questions that covered the participants' current healthcare status, their opinions of home-based healthcare, and their views of the proposed framework. An informal open interview was also conducted during the requirements collection phases with several healthcare providers, as a first step of gathering requirements.

Survey is another method that we used to collect data directly from potential users. In this thesis, we used online surveys as the main research method to obtain responses from healthcare recipients. The main advantages of online surveys are ease of access for the response group—it may be difficult to gain access to people for face-to-face discussions—quick response and low cost [40]. In the thesis, we applied online surveys twice. The first one aimed to analyze current problems and needs in chronic disease healthcare, while the latter one involved the collection of requirements for designing a cloud platform for home-based healthcare.
According to Dawson [41], 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 both 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 to the relevant literature [37]. 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. By starting the systematic literature review in spring 2014, 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 1.1. This evaluation selected 44 articles for our thorough study. 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 [42]. Guidelines for performing systematic literature reviews in related subject area [43] 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. This systematic literature review identifies the state of the art and pinpoints challenges and possible directions for applying cloud computing in eHealth.
Table 1.1 Include and exclude criteria of systematic literature review

<table>
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<th>Include criteria</th>
<th>Exclude criteria</th>
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<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>
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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 [44]. 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 [45]. There are four 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. The third prototype was used to clarify the requirements collected from potential users and the last one is a prototype on the case of type 2 diabetes to prove the technical feasibility of the proposed hybrid cloud.

The following figure shows the timeline of all research methods used in this Ph.D studies. And Table 1.2 lists different research methods used for answering research questions in this thesis.
Figure 1.3 The timeline of research methods

Table 1.2 Research methods for addressing the research questions

<table>
<thead>
<tr>
<th>Research Method</th>
<th>RQ1</th>
<th>RQ2</th>
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<tr>
<td>Case study</td>
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<td>Online Survey</td>
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<td>Literature Review</td>
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<tr>
<td>Prototyping</td>
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1.4 Related work

1.4.1 Different levels of eHealth interoperability

According to the European Union eHealth Action Plan [17] and the Swedish National Strategy for eHealth [18], 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 [46][47]. In the eHealth domain, the most used interoperability is syntactical interoperability and semantic interoperability [48].

Syntactical interoperability is a basic application-level interoperability. It supports multiple applications with different implementation of languages, execution platforms, and interfaces, able 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) [49], use of XML Web-services [50], Simple Object Access Protocol (SOAP) [51] and SQL standards [52]. The syntactical 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 practical 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 [53]. Rong Chen [54] 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 these, 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 problem include the Standard for Systematized Nomenclature of Medicine-Clinical Terms (SNOMED CT)[55] and Digital Imaging and Communications in Medicine (DICOM) [56]. However, these standards are not based on real-life experiences and requirements in some cases, so the expectation of what can be achieved with these standards is too high [57]. For example, HL7 does not consider that different healthcare information systems have different clinical workflows and operational contexts [57]. The challenge of standardization highlights the interoperability issues.
1.4.2 Comparison of public, private, community and hybrid clouds

In the four deployment models for cloud computing, 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. 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, 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 as good as a public cloud, the threat of outside malicious attack will be far less. 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. In addition, it is more flexible and reliable to implement fine-grained access control mechanisms to protect the privacy of health data.

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. Along with other economic reasons, the capability of the development platform is an important reason to adopt a public cloud [58]. Third party eHealth service providers can develop various services, such as historical health analysis, health data mining [59] and Clinical Decision Support System [58], 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 [29]. This will reduce 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 negatively. 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 provide 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 [60]. However, the migration of insensitive data and services to the public cloud part will reduce some of the burden and cost as compared to a purely 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 [61]. 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 these types 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 types of cloud models.
when it comes to security and privacy, customization and legal issues. A private cloud is less appropriate than the other two types of cloud models when it comes to scalability and cost. By combining 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 score weighted method based on score evaluation [62] to compare these three cloud models. We use scoring 1 to 4 to represent from weak (1), general (2), strong (3), and very strong (4) of each factor, as shown in the radar chart below.

![Radar chart of the cloud models for visualization of strengths and weaknesses of key factors](image)

**Figure 1.4** Radar chart of the cloud models for visualization of strengths and weaknesses of key factors

**1.4.3 Cloud computing applied in eHealth**

From the literature review, we found that the research on cloud computing applied in eHealth has mainly been published from 2010 and onwards[63]. The topics discussed covered a broad scope in relation to the use of cloud computing in the eHealth domain. Generally, the topics can be classified into three categories.

1) **Cloud-based eHealth framework design**

One of the most significant advantages of cloud computing is its huge data storage capacity. A number of papers proposed cloud-based frameworks for healthcare data sharing. One of the pioneers in this area, Rolim et al. [63] 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 [64][65][66] proposed a national-level framework for eHealth based on cloud models. For example, Patra et al. [66] 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 healthcare providers can provide them with more appropriate healthcare services, such as remote diagnosis, supervision and emergency calls. Tyagi et al. [62] presented a IoT-based cloud framework for healthcare that involved many stakeholders, in which patients can self-manage and healthcare providers can share healthcare data.

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. [68] and Regola et al. [69], patients’ self-management by Martinovic et al. [70], transition or standardization of data stored in different EHR or PHR systems by Coats et al. [71], and Ekonomou et al. [72], and design of a secure EHR framework [73][74][75][76]. Parekh et al.[77] applied clustering techniques in cloud-based healthcare framework for region-wide diagnosis.

2) Applications of cloud computing

High accessibility, availability, and reliability make cloud computing a suitable solution for healthcare interoperability problems. Papers in this category mostly explored 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.

A number of researchers explored their eHealth applications by using or testing them in public clouds, such as Google App Engine (GAE) [78], Windows Azure [79][80] and Amazon EC2 [81][82][83][84]. The application of Wooten et al. [81] provided patient-to-patient support and information sharing within the patient community. The solution proposed by Benharref et al. [80] 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. [82] designed a Health Cloud Exchange system which shares healthcare records between services and consumers, and includes some privacy controls. Hossain et al. [84] proposed a cloud-assisted speech and face recognition platform for elderly health monitoring, where home-based mobile devices could collect speech and face images, and deliver to the cloud server for possible analysis and classification.

For applications based on the private cloud, Bahga et al. [85] presented an achievement of semantic interoperability between different kinds of healthcare data, while DACRA [86] built a platform for interoperability on the syntax level. Vilaplana et al. [87] 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. [88] 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. [89] proposed an approach to EHR data schema composition with a broker-based access control. Castiglione et al. [90] presented a virtual infrastructure-less cloud solution for secure management of 3D medical
images. In order to reduce the cost of adopting EHRs, Hewlett-Packard Company published a cloud-based platform called Fusion [91] 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 [92] and the government regulations system such as the Health Insurance Portability and Accountability Act (HIPAA) [93].

Gul et al. [94] and Chen et al. [95] 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. [96] implemented a community cloud-based exchange of clinical data between two disparate healthcare providers, which was mainly used in chronic disease healthcare. Liu et al. [97] implemented a hybrid cloud platform called iMAGE to share not only EMR data but also 3D CT images among different healthcare providers.

3) Security or privacy control mechanisms

Healthcare data requires protection to ensure high security and privacy. Access control, an effective method to protect data, is widely used in many studies. Liu et al. [98] 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. [99] implemented cipher text-policy ABE in a security manager module to make it act as an administrative person. ESPAC [100], Narayan et al. [101] CP-ABSC [102], and TR-MABE [103] all proposed a patient-centric ABE access control scheme, and Aljumah et al. [104] designed an emergency mobile access to PHR cloud-based ABE. Zhou et al. [105] presented an ABE-based privacy-preserving cooperative authentication in distributed mHealth cloud computing system. Liu et al. [106] proposed a highly efficient and secure Online/Offline Attribute-Based Signature (OOABS) scheme for mobile health records access control.

Three studies [107][108][109] 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. [110] 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. [111] developed an advanced role-based scheme, called “task-based control,” to determine whether access should be granted to a healthcare cloud. Yang et al. [112] proposed a hybrid solution for
privacy preserving medical data sharing, which means different parts of data using different privacy preserving techniques.

Besides access control, several security protection techniques (trusted virtual domains [30], the watermarking method [113], secure index implementation [114], Fully Homomorphic Encryption [115], secret-sharing schemes [116], modified secret-sharing algorithm [117], and secure and privacy-preserving key management scheme [118]) were also introduced to maintain the high security and privacy of healthcare clouds.

Fabian et al. [119] features attribute-based encryption for selective access authorization and cryptographic secret-sharing for data security in order to share in multi-clouds among different healthcare providers.

However most of the studies above are concept-proof-designs. Only very few studies have been evaluated in the real world or tested by some technical experts. How to apply cloud computing in eHealth practically is still in its initial phase.

1.4.4 Cloud computing used 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. From the literature review, there are mainly three types of services can be applied by cloud computing for home-based healthcare.

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 healthcare data in the cloud, this data will be collected and stored. Healthcare providers or their family members can easily browse the health data if necessary. This ensures that home-based healthcare can be as efficient as hospital-based healthcare, because all the home healthcare 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 comprehensive and accurate decision support 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 robust scientific evidence for high-efficiency and high-quality diagnosis. Some real-time monitoring systems could be built up by big medical data mining techniques for home-based healthcare.

**1.5 Contribution**

The main contributions of the thesis are to identify the current interoperability problems of home-based healthcare, and then to propose a possible solution 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 technological solutions. Furthermore, a hybrid cloud model is proposed for home-based healthcare and this hybrid cloud model is evaluated as to future feasibility for home-based healthcare. The thesis includes 8 academic papers that have been published in or accepted or submitted to international conferences, book chapters or journals. They are listed as follows.

- **Paper VII.** Y. Hu, G. Bai, S. Eriksén, and J. Lundberg “Hybrid cloud model for diabetes home-based care -a case study for perceived feasibility in the future”, in Health Informatics Journal, Submitted
- **Paper VIII.** Y. Hu, S. Eriksén, and J. Lundberg “Future directions of applying healthcare cloud for home-based chronic disease care” in The
The main structure of the thesis in relation to the publications is shown in Figure 1.5. The first three papers begin with the research of interoperability problems in current healthcare. Paper I and Paper II are mainly based on healthcare providers’ perspectives while Paper III is from healthcare recipients’ perspectives. Paper IV focuses on cloud computing technology in eHealth, which is the main technology we have chosen to tackle the interoperability problems. Paper V gathers the requirements of our cloud platform for achieving home-based healthcare interoperability. Paper VI proposes the initial hybrid cloud conceptual model for home-based healthcare. In Paper VII, the hybrid cloud model is improved, and the future feasibility in practice is evaluated by a case study in Blekinge, Sweden. Paper VIII describes the future directions of applying the proposed hybrid cloud in practice.

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 problems. Based on the results and others’ studies, we defined two layers of interoperability in eHealth. Next, a peer-to-peer (P2P) model based on a JXTA platform was implemented to solve the identified eHealth interoperability problems. The prototype could achieve the suggested syntactical 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 the 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 (a 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 healthcare data, and communicate with other patients who are in 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 order to examine existing research on cloud-based eHealth solutions, as well as in accordance with the research findings of RQ2, a systematic literature review of cloud computing in eHealth was conducted and presented in Paper IV. 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. We searched relevant articles, of which 44 papers met the criteria for inclusion by March, 2014. The studies covered 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 indicated that a hybrid cloud platform with mixed access control and security protection mechanisms will be an important research area in future
for developing citizen-centered home-based healthcare applications. This paper mainly addresses the answers to RQ3.

In Paper V, we proposed an online virtual community for home-based chronic disease healthcare. The design idea is inspired by social networking, and is based on the term “community” in activity theory. The requirements of the community were mainly gathered from the questionnaires with targeted healthcare recipients and interviews with healthcare providers. We use “user stories” as they are used in agile software development to describe the functional requirements and the non-functional requirements were briefly discussed as well, and finally a prototype was designed based on the identified user requirements. As a start in our practical development, this paper answers RQ3 from potential users’ point of view.

In Paper VI, different cloud deployment models are compared, and the hybrid cloud is identified as a suitable way to enable patients to share health information for promoting the treatment of home-based chronic disease. Then a conceptual hybrid cloud model is proposed with a prototype. The prototype is developed with OpenStack and AWS, successfully simulating the functions of recording home-based health information, sharing to the private cloud, and optionally sharing to the public cloud. This paper mainly answers RQ3 and through researching particularly with type 2 diabetes, it partly answers RQ4.

In order to validate the conceptual model of Paper VI, in Paper VII, we conduct a two-step case study of diabetes healthcare in Blekinge, Sweden. The study group (n=11) included both healthcare providers and healthcare recipients. The first step is intended to acquire insight into the actual care situation to improve the original conceptual model. In the second step, we validate the feasibility of the improved model. We found that our model for home-based chronic diseases healthcare would be feasible in the future. In this model, hospitals and primary healthcare centers could continue using their own databases as private clouds. For home-based healthcare data, the best approach revealed is to store and process them in public clouds. This paper provides the main answers of RQ4.

Paper VIII discusses some possible future opportunities and challenges to apply this improved cloud model with the huge population for home-based chronic disease healthcare. A professional IT healthcare education team is needed for both healthcare providers and healthcare recipients. For home-based healthcare, a monitoring system with an automatic alarm to healthcare providers is also necessary in some cases. Also, how to record and integrate data concerning exercises through wearable devices in a cloud should be considered. Given the high demand, sharing medical images through the cloud could be another research focus. This paper partly answer our RQ4.
1.6 Conclusion

The main goal of the thesis is to identify and explore the interoperability problems in current home-based 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 case studies with 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 for home-based healthcare not only in Sweden, but also worldwide. During the study, we found that different healthcare providers use different systems, even in such a small county as Blekinge, Sweden. Very few items of patient data can be shared though an internal journal system among doctors. Information sharing among different healthcare organizations and between healthcare providers and recipients becomes a considerable issue. Because of the development of ICT, the patient-centric healthcare model is becoming more and more important, where patients are active participants in their own chronic disease healthcare. In this case, interoperability is still 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. 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 to 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 the healthcare recipient can easily enroll in the sharing platform. Another advantage is that healthcare recipients 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 if properly managed, 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 additional hardware infrastructure with reduced 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 the daily data management of home-based healthcare in the cloud. A number of self-control decision support systems can be embedded in the cloud-
based platform, which can help healthcare recipients to achieve 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 studies so far have presented ideas without real-world case validation [120] [121]. 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 processing data. Due to the huge amount of patient health data in home-based healthcare, the cloud’s big data storage service provides an efficient way to store these data. High accessibility and availability of cloud computing could allow the healthcare data stored in the cloud to be accessed at anytime and anywhere in the world. This 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 support the development of big data mining in healthcare, which can improve both public health statistics and individual monitoring, diagnosis, and treatment. The pay-as-you-go mode of the cloud has significant economic strength, reducing cost for both healthcare providers and healthcare recipients that would like to use cloud-based services. The security and privacy challenges 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 considerable contribution to improve 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 in order 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. Cloud-based patient-centric healthcare for chronic disease healthcare is recommended 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 the base for a social network. We have proposed a cloud-based home healthcare platform as an idea for supporting online virtual community for home-based chronic disease healthcare. The design idea is inspired by social networking and based on the term “community” as it is used in activity theory. In this prototype, healthcare recipients are at the center of their healthcare, and it 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.

In home-based healthcare, self-management is an important approach for chronic disease patients to deal with their diseases by continuously monitoring and recording vital signs of health and other related data. To share the patient-recorded health data is the key process in promoting the treatments of chronic disease, either sharing to healthcare providers or other healthcare related organizations. For addressing these problems, the original hybrid cloud model is presented with implementation of a vertical prototype through researching particularly with type 2 diabetes. Finally, a two-step case study of diabetes care in Blekinge, Sweden is conducted to evaluate future feasibility of the proposed hybrid cloud model. Based on our case study, we found that healthcare recipients—even elderly people—are wishing to participate in their own healthcare. All healthcare providers, healthcare recipients, and family members in our study exhibited positive views concerning our improved hybrid cloud model for home-based chronic disease healthcare. In this model, hospitals and primary healthcare centers could continue using their own databases as private clouds. For home-based healthcare data, the best method we found was to store and process the data in a public cloud. Healthcare providers would have access to these data only when authorized by the patients. It should be up to the healthcare recipients to decide what types of data and with whom they are willing to share. The proposed use of hybrid cloud technology was accepted with little worry about security and privacy. In summary, a hybrid cloud is feasible to be used to achieve interoperability in home-based healthcare for chronic disease, and it is perceived as beneficial for both healthcare providers and recipients.

1.7 Future work

In this thesis, a hybrid cloud model is presented to achieve interoperability in home-based healthcare for chronic disease and the feasibility in practice is validated by a case study. One of the main direction of future work will be to future develop and realize this model in large-scale population. As we found in our case study, home-based healthcare data still cannot be reached by healthcare providers in primary healthcare centers. As big data in the cloud has brought a revolution in healthcare [122], we are aiming to design a real-time monitoring system with alarms for primary healthcare in the future. The calculated threshold values based on analysis of big data in the public cloud, and interpreted and verified by healthcare providers in primary healthcare centers, can help the patients to set threshold values of their daily health parameters. When a patient’s self-recording data is uploaded at home and the values reach the threshold values, the data processing program in the public cloud can send an alarm to his or her responsible primary healthcare center. As soon as the healthcare providers see the alarm, they could contact the patients and give them some feedback. This would contribute to shifting the healthcare paradigm to a more patient-centric approach which focuses on providing support for self-management where it is most crucial.
Until now, medical images cannot be shared between healthcare providers and recipients. The huge data storage capacity in the cloud makes it easier to store and process medical images. This could promote the sharing of medical images between healthcare providers and recipients. We may develop a multi-functional medical images sharing mobile application in the next step. For example, how to pre-process wound images before the healthcare providers review them, such as wounds emphasis, and 3D visualization, are worthy of consideration. For patients with diabetes type 2, wounds can be serious symptoms as well as side effects of their disease.

With the wide use of wearable devices, it is possible for people to record their exercise data [123]. Today most data recorded by wearable devices is stored in device companies’ servers. With the 5G network [124] and multitude of sensors that are being introduced into the healthcare environment, even more healthcare data is being provided. In the future, integration of exercise data with home-based self-management data in our proposed hybrid cloud will be another research orientation.

From our second case study as well as other research findings from the research project “Health in hand [125] ”, we have seen that sharing of home-based healthcare data and the development of a patient-centric paradigm in chronic disease healthcare concerns not only the technical platform and solutions, but also the work practices in different healthcare organizations. A professional IT healthcare education team is needed for both healthcare providers and healthcare recipients. This team could support the future development of our proposed model, also for the integration and interoperability of work practices in healthcare. We would like to help to build up this kind of education team, which would include people who have certificated knowledge in healthcare technology. Since in chronic disease care, self-management is a key factor, the education to help healthcare recipients to use different ICT technologies for self-management would be the main focus. For healthcare providers, training on their working systems and the communications between these systems could be provided frequently, for instance once a year.

In many cases of chronic disease care, healthcare providers suggest their patients to do daily physical exercises as a main method of controlling their condition. With the success of Pokémon Go, mobile games are gaining a great influence on people’s physical activities [126]. Games for health are not limited to serious games any more. Designing digital games for health-promoting entertainment by using augmented reality or virtual reality techniques, to encourage patients with chronic disease to do more exercises, or an educational mobile game to help the healthcare recipients to get more knowledge of their disease could be a relevant future research.
Chapter 2. Using P2P Technology to Achieve eHealth Interoperability

**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

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2.1 Introduction

With the rapid development in technology, world is undergoing a digital revolution in the area of Information and Communication Technologies (ICT) [127]. 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 [46]. One of the ICT applications in healthcare sectors is healthcare practice supported by electronic processes and communication, so called eHealth [128]. 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 [129].

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 [130]. 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 [131].

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 [18].

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 [132].

2.2 eHealth Interoperability

2.2.1 What is eHealth Interoperability?

Healthcare interoperability is highly required among different systems in order to exchange of patient data [48]. 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 [54].

According to Brown and Reynolds [52], 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 [48].

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.

2.2.2 Challenges in eHealth Interoperability

To achieve interoperability in eHealth area, some challenges should be faced [48].

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.

2.3.1 Purpose of interview

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

2.3.2 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 Municipality) 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.
2.3.3 Interview Design

We formulated a semi-structured interview including 30 open-ended questions in the beginning, and reduced them to 12 later on. The reason for this reduction was that some of those questions were already answered through literature or during the interviews 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.

2.3.4 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

2.4.1 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 [133]. 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 [134]:

- 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 [135][136]. 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.

2.4.2 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.

![Figure 2.1 Automatic P2P communication model](image)

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.

2.5.1 Basic framework
In order to clarify the scope of the prototype implementation, we design a basic framework of the whole P2P workgroup communication model shown as Figure 2.2.

![Figure 2.2 Basic framework of the P2P model](image)

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.

2.5.2 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)

**2.5.3 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 Figure2.5.

![Figure 2.4 Healthcare system -MAGNA CURA](image)
2.5.4 JXTA platform development

According to “JXTA JXSE Programmers Guide 2.5” [137], 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.
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.

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.
Chapter 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

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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” [138].

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” [139]. 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 [28]. These services are offered over the Internet by large data and computing center [140]. 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 [28]. 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 [141].

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 [142]. 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 [143]. 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) [144].

The following risks should be address for successful implementation of e-Health in cloud [145].

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 venders 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 vender.

3.2.1 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 [146], 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 [146]. 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 [147]. 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 [147].

### 3.4 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” [148]. 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.

![Figure 3.1 Basic Structure of Proposed Solution](image)

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.

3.4.1 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.

![Simulation Environment](image)

Figure 3.2 Simulation Environment

3.4.2 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.

3.4.3 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 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 3.7 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

3.5.1 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 3.2 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 3.3.
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></td>
<td>339</td>
<td>528</td>
<td>222</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>339</td>
<td>177</td>
<td>242</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>339</td>
<td>399</td>
<td>202</td>
<td>67</td>
</tr>
<tr>
<td></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></td>
<td>339</td>
<td>165</td>
<td>222</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>339</td>
<td>220</td>
<td>202</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>339</td>
<td>216</td>
<td>222</td>
<td>67</td>
</tr>
<tr>
<td></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 3.3, the api_cpu_ms of receive operations in three days are the same. It means in these three days, GAE responses the receive operation using almost same time, GAE is stable. But latency of receive operation is also unpredictable.

### 3.5.2 Discussion

1) Advantages of healthcare information in GAE
Quick development: Google App Engine has developed a framework that allows developers to use Java and Python to develop applications that can run in GAE. It provides Google Web Toolkit to let developers build web application interfaces in GAE quickly and easily. Comparing to Hadoop, GAE doesn’t need to establish a cloud computing environment. We can directly develop and run our e-health applications in GAE.

High Availability: Google provides 100% uptime of GAE, there is no schedule downtime in their plan. It means e-health applications developed in GAE can run every second, 24 hours a year without disaster.

Large Data Table Storage: Google App Engine supports 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 the first 70 characters to its request. But special text data type can store and return unlimited characters. Most of the text healthcare data and images smaller than 500KB 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 to 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 uses 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.
Chapter 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

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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 [149]. At the same time, chronic diseases have now become the leading causes of death [150]. 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 [3].

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 [151]. 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 [18]. 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 [18]; 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 [27], “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 [7]. 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.

4.2.1 Lack of patients centered healthcare system
The traditional healthcare systems were designed for acute diseases [32]. 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 [33].

4.2.2 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 [152]. 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.

4.2.3 Lack of Standards or guidelines for chronic diseases care
Although there are some international standards of healthcare like HL7 [153], or some national guidelines for primarily care [154], there is no standard specific for chronic diseases care. In some cases, the unclear responsibility of care badly reduces the quality of HCDH [36], [152].

4.2.4 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 [152], but most are regional. In developing countries, popularizing rate of chronic diseases healthcare
education is lower [155]. 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 [7]. 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 [12] 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</td>
</tr>
<tr>
<td></td>
<td></td>
<td>□ I have no confidence to do it myself.</td>
</tr>
</tbody>
</table>
6. Would you like to share some of your daily health data to your authorized healthcare providers? □ Yes □ No □ It depends

7. Would you like to share some of your daily health data to your relatives? □ Yes □ No □ It depends

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 (shearing 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.

4.3.1 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.
4.3.2 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.
4.3.3 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.

![Figure 4.3 Answers of healthcare data sharing](image)

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 [148][78], 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 [28]. 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 [27] [156]. 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.

![Figure 4.4 HCDH Cloud Platform](image)

**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
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.
Chapter 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

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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 [15]”. 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 [27]”. 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 [157]. 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 [42]. Guidelines for performing systematic literature reviews in related subject area [43] 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>
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<tbody>
<tr>
<td>USA</td>
<td>14</td>
<td>[64],[69],[71],[75],[76],[81], [85],[89],[91],[93],[96],[107],[109],[111], [82], [100], [101], [104]</td>
</tr>
<tr>
<td>Canada</td>
<td>4</td>
<td>[79], [110], [114]</td>
</tr>
<tr>
<td>Australia</td>
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<td>[68], [72], [86]</td>
</tr>
<tr>
<td>UK</td>
<td>3</td>
<td>[65], [80], [94]</td>
</tr>
<tr>
<td>UAE</td>
<td>3</td>
<td>[95], [98], [113]</td>
</tr>
<tr>
<td>China</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td>2</td>
<td>[30], [116]</td>
</tr>
<tr>
<td>India</td>
<td>2</td>
<td>[66], [83]</td>
</tr>
<tr>
<td>France</td>
<td>1</td>
<td>[108]</td>
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<tr>
<td>Croatia</td>
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<td>Italy</td>
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</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.

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. [63] 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 [64] [65] [66] proposed a national level framework for eHealth based on cloud models. For example, Patra et al. [66]
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.[68] and Regola et al. [69]; patients’ self-management by Martinovic et al. [70]; transition or standardisation of data stored in different EHR or PHR systems by Coats et al.[71] and Ekonomou et al. [72]; and designing a secure EHR framework [73][74][75][76].

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 [78], Windows Azure [79][80] and Amazon EC2 [81][82][83]. The application[81] of Wooten et al. provided a patients-to-patients support and information sharing within patients community. The solution proposed by Benharref et al. [80] 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. [82] 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. [85] presented an achievement of semantic interoperability between different kinds of healthcare data, while DACRA [86] built a platform for interoperability on the syntax level. Vilaplana et al. [87] used queuing theory as the basic means to model the performance of an eHealth system based on the private cloud. Van Gorp et al. [88] 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. [89] 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 [91] 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 [92] and national law system [93].

Gul et al.[94] and Chen et al.[95] proposed a shared EHRs system based on hybrid cloud. In the proposed application of Chen et al.[95], 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. [96] 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. [98] 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.[99] implemented Cipher text-Policy ABE in a security manager module to make it act as an administrative person; ESPAC [100]and Narayan et al. [101] proposed a patient-centric ABE access control scheme; and Aljumah et al.[104] designed an emergency mobile access to PHR cloud-based ABE.

Three researches [107][108][109] 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. [110] 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.[111] 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 [30], Watermarking method[113], Secure index implementation [114] and secret-sharing schemes[116]) 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 [158] ”. 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.
Chapter 6. A Virtual Community Design for Home-based Chronic Disease Healthcare

Abstract - The internet based social network has been applied to serve many social functions, such as democratic decision making, knowledge sharing, education, and healthcare. In this paper, we provide a prototype of virtual community designed for home-based chronic diseases healthcare. We studied the concept “community” from the activity theory model in order to design the prototype with a solid theoretical base. Then we conducted a questionnaire from healthcare recipients and interviewed healthcare providers to gather the requirements for the design of the community. With some user stories we described the requirements as use cases for our design and a conceptual prototype is built based on the requirements. This virtual community servers as a shared platform for all the stakeholders who are engaged in the healthcare activity. With this shared community platform, the interoperability problems of current healthcare systems can be moderated.

Keywords: virtual community, self-management, home-based chronic disease healthcare, requirements, activity theory

6.1 Introduction

Chronic diseases are increasingly becoming a main factor influencing human health and wellbeing all over the world. According to the World Health Organization (WHO) [1], chronic diseases represent 60% of all deaths in the world, and are thus the leading cause of mortality. Chronic diseases last for a long time, and can hardly be cured [159], therefore how to provide preventive and monitoring healthcare becomes a worldwide goal. Since patients suffering from chronic diseases have to be monitored from time to time, it leads to high cost, and becomes time consuming and inconvenient for the patients. This time-to-time monitoring limits the patients’ daily activities and is especially inconvenient for aged people. Since mostly chronic diseases do not need urgent medical diagnosis and treatment [12], we suggest moving the front desk of chronic diseases healthcare from hospital-based to home-based care. This shift may save a lot of patient time and medical resources, and provide a convenient environment for continued living at home despite an increasing need of monitoring of health.

Thanks to the development of information and communication technology (ICT), the above suggested home-based healthcare is now becoming highly recommended [12]. Many physiological signals can be measured by individuals in their living environments during daily activities [160]. This paper will propose one important service function for such a home-based solution, namely virtual community based web-services. With this virtual community, people with chronic diseases can quickly and directly communicate with each other (supporting peer-to-peer learning), and also with healthcare providers and family members concerning their ongoing situation. With various needed services based on this virtual community, patients can have an independent living at home with improved life quality.

This paper will start by discussing the understanding of ‘community’ based on social-psychological activity theory and interpreted in the concrete context of home-based healthcare for chronic diseases. In the second part, a requirement elicitation is carried out based on a survey among potential users (55+ with chronic diseases). In the third part we analyze the collected 27 answers we got concerning the most needed requirements for a virtual community. Based on the defined requirements, in the fourth part we present a prototype we have developed to demonstrate how to design a web-based virtual community to integrate those identified needs for the targeted users, especially elderly users. Finally, we discuss some weaknesses and limitations with the proposed solution, and conclude with conclusions.

6.2 What is a virtual community?

A community is broadly defined as "a group or network of persons who are connected (objectively) to each other by relatively durable social relations that
extend beyond immediate genealogical ties, and who mutually define that relationship (subjectively) as important to their social identity and social practice [161]. Since the introduction of the now widely used Internet, the concept of community today has less geographical limitation, as people can now gather virtually in an online community and share common interests regardless of physical location. This kind of community, with far less constraints due to genealogical distance and far more oriented to shared interests and objectives, is what we call a virtual community. A virtual community is a social network that people interact with through specific social media, of which there are many good examples, such as Facebook and Twitter. This virtual community allows people to communicate with each other about their common interests without considering geographical distance.

Based on the model of Activity Theory (Figure 6.1), a community is generally defined as a group of people who are engaged in conducting activities to approach a shared goal or outcome. In relation to service oriented activity where the object is the recipients of the conducted service activity (not as a materialized object), the members of this community can be divided into three groups: 1) people who are actively conducting the service activities, here called a subject; 2) people who are acted on by the subject, here called an object; and 3) people who are not directly acting or being acted on, but who are associated with the ongoing activity.

The model in Figure 6.1 visualizes the components that compose an activity and interactions in an activity. According to the model, an activity is always conducted by one or several goal-oriented actors, labeled as a subject in the model. The subject is always directed towards or acting on an object in order to produce an outcome. The community in this model is the collective of the above three groups of people involved in conducting the activity. Rules are various regulations for how to conduct activities and serve as mediating function within the community if any disagreement appears in conducting the activity. Tools are artifacts (physical, conceptual, or signs) used by the subject in the process of acting in order to produce the outcome. Division of labor specifies the responsibility within the community, i.e., which parts of the object’s needs should be implemented by which members of the community.
To apply the above concept of community in the activity context of home-based healthcare, we will interpret the model in concrete terms related to the context. The outcome or goal of the activity is to improve the healthcare recipient’s health. The subject is the healthcare providers such as doctors, nurses, family members. The object is the healthcare recipients, in this case they are people who are suffering from chronic diseases. Tools are all kinds of artifacts, which are used to support the activity, physical and non-physical, such as EHRs, Internet, healthcare monitor devices, as well as treatment-related knowledge and methods. The rules regulate the actions of the actors, and consist of for example healthcare laws, privacy and security policies and so on. Division of labor determines the responsibilities of different healthcare providers and healthcare recipients themselves. In this activity model, besides subject (actors) and object (recipients), the community includes also other healthcare actors, such as family members of the care recipients, other healthcare recipients who share the same interest, and research institutes that are associated with the results of the activity.

In home-based healthcare, self-management is highly encouraged, and in this self-management the healthcare recipients become the subject (actor) and the object (being self-acted) simultaneously. The healthcare recipients can also start acting in relation to the healthcare providers, for example if the patient alerts his/her nurse about newly recorded abnormal blood pressure for online consultancy. In this case the role of subject in traditional hospital care is now becoming an object in home-based healthcare. We call this property subject-object mutuality [163]. The design of the virtual community must consider different roles of actors with their expected functions and tools. In the next section, we will focus first on the healthcare recipients’ perspective in the activity context of home-based healthcare.

6.3 Requirements collection of community
6.3.1 Requirements from healthcare recipients

A good virtual community should attract people with the same interests into a meeting place, but more importantly, the virtual community should in this case provide healthcare tools and services. Patient-centered self-management is the main trend for home-based chronic disease healthcare, and the virtual community in this case should first focus on the needs of the targeted patients. There are already some commercial or research-based solutions for supporting self-management. For instance, HealthVault [14], launched by Microsoft, is a web-based PHR system for storing and managing 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, can cooperate with this platform to record health data.

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 [164]. As we mentioned above, in home-based healthcare, patients are at the center of the healthcare, as well as the main users. So we selected online questionnaires to be answered by 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 a good way to get answers to specific questions from a group of people, especially for people whom it is not feasible to visit individually and interview [164]. In this case, the questions are mostly designed for functional requirements as seen from the healthcare recipients’ perspective. Due to the time and resources limitation, for our questionnaires, the questions are published on surveymonkey.com as the electronic form rather than a paper form. The respondents are selected from within an age group consisting of people above 55 years of age and living with one or more chronic diseases. We send out the questionnaires through social network websites, for example, social groups of some specific chronic diseases ex. Diabetes from patientslikeme and facebook. The questionnaire contains 10 questions, and includes both simple Yes or No questions, questions allowing the respondent to choose from a set of pre-supplied answers, and open comment questions. In the end, 25 valid responses out of 27 are gathered. Most of the respondents are from US (8) and Sweden (12). We consider that the geographical difference may effect some results, so the questions are designed to reduce this influence as possible. From the collected answers, we find that the influence is very low.

Problems in current healthcare

The first open question is about the problems people face concerning their current healthcare. Almost all the respondents mentioned that the long time they spend waiting for doctors’ appointments make them uncomfortable. “The resource is limited. It means I need to spend more time waiting for the healthcare service.
And since I am waiting for the doctor, I really also need suggestions to keep my body stable, not get worse.” “Really long queue every time when I visit some hospitals”. In some countries like Sweden, the shortage of healthcare providers leads to long waiting lines for visiting primary care as well as hospitals. Sometimes the patients have to wait so long that they lose the best opportunity for diagnoses and treatments in relation to curing or sustainably managing their diseases. Another big problem the respondents highlighted is lack of information sharing among different healthcare providers. When they come to the new healthcare organizations, their historical healthcare records are difficult to find. “When I went to another hospital which I never visited before, the doctor didn't know my health history, if I am hypersensitive to some drugs, he didn't know, so this may cause some healthcare problems. If I need to have a new scratch test taken to determine what I am hypersensitive to, it wastes time and resources.” “There is no shared information among the hospitals. It cannot help the care providers to communicate to each other.” This causes overlap check-ups for the healthcare recipients, which is a waste of time and resources. Besides the above two quotes, some respondents also point out that the location of the healthcare center is far away from their home, and that it is inconvenient for them to go to healthcare centers frequently.

**Views of online healthcare community**

When asked about the time spent on Internet per day, 60% of the respondents spend more than 6 hours on-line, see Figure 6.2, which means Internet has already become an essential part of their daily lives. Because of the high rate of Internet usage, the online healthcare community is acceptable. All the respondents say they would like to have an online healthcare community, where they could chat with all stakeholders related to their healthcare through one platform. The answers concerning which people they want to chat with through the online community show the following: doctors (96%), other healthcare providers (84%), other people with same symptoms (72%), family members (68%) and some healthcare research institutions (64%).

![Figure 6.2 Hours spent on Internet per day](image)

Figure 6.2 Hours spent on Internet per day
Online community functions design

In Questions 5 to 8, we ask about some specific functions of the online healthcare community. The results are shown in Figure 6.3. From the figure, we can see that all functions we plan to develop are supported by most of the respondents. Question 10 is an open question about other functions they would like to have. Online simple diagnose was one of the most desirable functions. Free seminars and lectures about healthcare is another suggestion by most of the respondents. “Simple medical suggestions and brief 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 information about nearby healthcare centers were also suggested. In Question 9, the respondents were asked which features are important for them as the users of online community. Availability (100%), usability (88%), security (88%) and privacy (84%) all got very high support.

![Figure 6.3 Functions of the online healthcare community](image)

6.3.2 Requirements from healthcare providers

One of the aims of building up this online care community is to encourage the care recipients to be the main driving forces of their home-based healthcare. Still, the virtual community will only develop in a sustainable way if the tools provided support and meet the needs of all the aimed-for user groups. The requirements of healthcare providers are gathered mainly based on interviews and informal discussions with doctors, nurses and homecare providers.

In the current Swedish healthcare system, most nurses are working daily with 5 to 10 different IT systems, and only a few of these systems share data with each other. Sometimes they just record the same simple data repetitively in different systems due to this lack of compatibility between systems, which is perceived as a waste of time and in some way decreases the work enthusiasm. 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 [22]. 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. Even for the healthcare providers, only doctors have full access to the records. When shifting to home-based chronic disease care, NPÖ can provide few access 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. In Europe, there are some projects aim to provide cross-border eHealth services by exchange patients’ summaries between healthcare institutions such as epSOS [165], however, most of them are still in the test phases.

The basic way of communicating with care recipients now is still face-to-face. The emergence of the national digital healthcare portal 1177 [21] helps most healthcare recipients to communicate with their providers without face-to-face visiting, but there are still several issues it cannot cover. For example, it cannot provide medical suggestions because of different care duties, and communication is lagging in some cases due to technical reasons and wrong contact responsible line. Through the minavårdkontakter contact provided by 1177, care recipients can send some message to their providers, but the average response time is around 5 days. And from the care providers’ view, a telephone call is better than sending an online message or email, because it is difficult to understand the text written by the care recipients.

For the management of chronic diseases such as diabetes, the normal way now is that the healthcare recipients go to the hospital, and are checked and given advice by nurses first. The nurses will teach the patients how to self-record every day’s blood sugar values. Then when the patients go back home, they record the data as instructed and send their values via SMS to the nurse. There is an IT management system in hospitals for the nurses, but it does not share any information to neither other care providers nor care recipients.

6.4 Main functional requirements

In this section, we list the simple functional requirements of the online virtual community as documented through our questionnaires. Table 1 is the requirements list of the online community design. The traditional way of documenting requirements consists of contract style requirement lists [166]. This
provides a high level requirements description for a large system. However such requirements descriptions usually cover hundreds of pages and are not reader-friendly. For our community design, we use the user stories style to describe the functional requirements in order to support easy and comprehensive understanding and quick changes. A user story is used with agile software development methodologies. It contains one or more sentences in everyday language to describe what an end user wants to do or needs as part of the functions [167].

Table 6.1. Requirements List

<table>
<thead>
<tr>
<th>User types</th>
<th>Descriptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>All users</td>
<td>As a user, I want to register an account on the online healthcare community and choose my user type based on different roles.</td>
</tr>
<tr>
<td></td>
<td>As a user, when I log in to my account, the information page will be displayed automatically according to my user type.</td>
</tr>
<tr>
<td></td>
<td>As a user, I want to have an online chat with my contact persons such as care providers, care recipients, family members and so on.</td>
</tr>
<tr>
<td></td>
<td>As a user, I want to have alarms to remind me of my care activities.</td>
</tr>
<tr>
<td></td>
<td>As a user, I want to have the all contract persons’ address book with detailed contact information.</td>
</tr>
<tr>
<td></td>
<td>As a user, I want to share some useful healthcare information with my contact persons.</td>
</tr>
<tr>
<td>Care recipients</td>
<td>As a care recipient, I want to contact my care providers directly through the online community for simple diagnose and care suggestions.</td>
</tr>
<tr>
<td></td>
<td>As a care recipient, I want to have some videos for providing healthcare education.</td>
</tr>
<tr>
<td></td>
<td>As a care recipient, I want to record my daily health data myself in the community and share it with people whom I want to share with.</td>
</tr>
<tr>
<td></td>
<td>As a care recipient, I want to have some tools to trace and check my care data, as well as to print it out when necessary.</td>
</tr>
<tr>
<td></td>
<td>As a care recipient, I want to share my care experiences with people who have the same symptoms as I do.</td>
</tr>
<tr>
<td></td>
<td>As a care recipient, I want to book a doctor’s appointment online.  [[]]</td>
</tr>
<tr>
<td></td>
<td>As a care recipient, I want to integrate some healthcare relevant apps in the community based on my individual needs.</td>
</tr>
<tr>
<td></td>
<td>As a care recipient, I want to have the address and open hours information of the nearest healthcare centers.</td>
</tr>
<tr>
<td>Care providers</td>
<td>As a care provider, I want to share some care information with other providers.</td>
</tr>
<tr>
<td></td>
<td>As a care provider, I want to have some online seminars with other providers and my care recipients.</td>
</tr>
<tr>
<td></td>
<td>As a care provider, I want to update the care histories of my recipients to the online community.</td>
</tr>
<tr>
<td></td>
<td>As a care provider, I want to have some decision support systems to help me for providing diagnoses and treatments.</td>
</tr>
<tr>
<td></td>
<td>As a care provider, I want to have a list of every day’s work.</td>
</tr>
</tbody>
</table>
6.5 Non-functional requirement issues

A non-functional requirement is a requirement used to measure the operation of a system, rather than specific behaviors [168]. In software systems, non-functional requirements are also considered as quality attributes. For our community design, usability, security and privacy, as well as availability are main issues of non-functional requirements [169].

Usability: Usability is defined as “the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use.” [170]. According to [171] usability can be measured by five variables which are defined as learnability, efficiency, memorability, errors, and users’ satisfaction. The main users of this online community are elderly people with chronic diseases, thus the designed services in the virtual community should be extremely simple to use and easy to learn. As design guidelines, we follow the “Ten usability heuristics [172]”, especially principles about knowing the users’ needs, special visibility for elderly, consistency with elderly’s daily language, and helping them recognize previous experience (reducing recall problem for elderly).

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 [32]. 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 legislation. Technical considerations and definition of sensitive information have to be addressed when segmenting data [173].

Security: Security is assurance that only authorized persons or entities can gain access to patients’ data. Employees’ illegitimate access and theft is one of the most frequent reasons of data leakage [32], 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 for the online community development [32].

Availability: As an online healthcare community, being available 24/7 is very important, because some functions, such as monitoring, tracking, alarming are critical for users’ lives. Availability means also that the authorized users should be able to access the community from anywhere. More and more people, even elderly with chronic diseases are traveling worldwide, and the healthcare community must be mobile in the sense that it must allow them access from anywhere in the world, just like when they are in their own home.

6.6 Prototype design
With the requirements specified above, we will demonstrate a simple prototype in the following. We adopt a horizontal prototyping strategy, which means that the prototype should cover most parts of the required users’ functions, without implementation of details[174]. Since it is a user-centered online community prototype, we try to keep it simple to use and easy to learn. The home page of the community is shown in Figure 6.4, which is a very simple site for sign-up and sign-in with some guidance. 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 when they register in the system. After successfully registering, the information related to the role in the community will be displayed based on the user types. The role of the users decides the information and activities they can have access to in the online community.

When the user has finished registration and logged in to his or her account using a user name and password, the system will automatically direct the user to his or her sites according to the specified user role. As shown in Figure 6.5, Anna Nilsson is a healthcare recipient, and the profile site has her basic information and the information relevant to her, such as her healthcare community, tools and rules that apply to her in her role. The contacts list in the middle has detailed information about 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 who have the same conditions can easily find her and they can share care experiences with each other. Figure 6.6 is the profile page of a healthcare provider, Maria Karlsson; similar to the recipient’s page, it contains her basic information and contacts list. In the right-bottom part, the tasks she has to do today are listed as a reminder.

![Figure 6.4 Home page of the community](image-url)
Figure 6.5 Healthcare recipients’ profile

Figure 6.6 Healthcare provider profile
The page “my community” is designed based on the needs of the respondents who answered the questionnaires see Figure 6.7. All the contact persons are listed in the right, including healthcare providers, family members and others. They can chat with each other when they are online, so the healthcare recipients can get feedback immediately from the healthcare providers without physically having to visit any healthcare organizations. The community also provides a space for users to post discussions, videos, links to websites etc. to share with their contacts. Another important function is that the community will always show information about the nearest healthcare centers based on the gathered user geographical data. The scheduled care activities will be shown rolling in red to remind the recipients.

![Figure 6.7 Healthcare community page](https://imiscare.org/my_community)

The most important function of the home-based healthcare community is to provide a self-management platform for the healthcare recipients. In our design, it is in the recipients’ “My tools” page, shown in Figure 6.8, 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 covering a long period as well to show the doctors and other care providers when they have an appointment. Online appointments are also proposed to reduce the waiting time.
for 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 includes functions for updating care history, appointment reminders, decision support systems for diagnoses and treatments and so on.

Figure 6.8 Healthcare recipients’ tool page

6.7 Discussion and limitation

The above prototype presents a general view of the design for a virtual community for home-based healthcare of chronic diseases. The design aimed to integrate healthcare recipients, healthcare providers and other relevant stakeholders into one community. This virtual community makes it possible to share the same platform for all the stakeholders who are engaged in the healthcare activity. With this shared community platform, the interoperability problems of current healthcare systems can be moderated. There exist various ways of applying ICT in eHealth, for example cloud computing. 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 for 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. Besides, there are lots of existing privacy control mechanisms and security techniques in cloud computing which could help sensitive healthcare data protection. This will lead to radical new circumstances for offering eHealth services and constructing our new generation of healthcare information systems. The proposed virtual community in this paper will in the next step be implemented based on the cloud platform to ensure its accessibility, availability, and mobility, with careful design of security and privacy.

There are some limitations of this paper. Firstly, the healthcare recipient group that responded to our questionnaire was not large, due to the limited scope of our investigation and our restrictive rules (over 55 and have at least one chronic disease), so the care recipients’ needs would require further investigation in the next step, based on a much larger sample. Secondly, as we are aiming to design a patient-centered healthcare community, the requirements of care providers would also require further investigation. In this case, they were gathered through interviews and informal discussions with only a few respondents, due to the time limitation for the study, so further work is needed to gain a better understanding of the needs of the care providers as well. However, the aim of this study was to develop a first prototype of a system for supporting the development of a virtual community for home-based chronic disease healthcare. This prototype can in future be used in a participatory design process to help future users envision and enact how new technological solutions can support and enhance healthy independent living and disease self-management.

6.8 Conclusion and future work

This paper proposed an online virtual community for home-based chronic disease healthcare. The design idea is inspired by social networking and based on the term “community” in activity theory. The requirements of the community were mainly gathered from the questionnaires with targeted healthcare recipients and interviewers with healthcare providers. We use “user stories” as they are used in agile software development to describe the requirements, and finally a prototype is designed based on the identified user requirements.

In the future, we will demonstrate this prototype to the potential users for evaluation. Further, more extensive interviews and surveys will be conducted with both healthcare recipients and healthcare providers to get more in-depth requirements from their respective perspectives. After this, we will develop the tools for supporting an online community based on cloud technology and test the proposed solution with future users for continued improvement and redesign. Ideally, such tools should be continuously further designed in use, together with the users, as part of quality lifecycle product and service management as well as part of the development of quality healthcare provision and self-management.
Chapter 7. Sharing Health Data through Hybrid Cloud for Self-Management

Abstract- Nowadays, patient self-management is encouraged in home-based healthcare, especially for chronic disease care. Sharing health information could improve the quality of patient self-management. In this paper, we introduce cloud computing as a potential technology to provide a more sustainable long-term solution compared with other technologies. A hybrid cloud is identified as a suitable way to enable patients to share health information for promoting the treatment of chronic diseases. And then a prototype on the case of type 2 diabetes is implemented to prove the feasibility of the proposed solution.

Keywords: Chronic disease, information sharing, self-management, cloud computing, hybrid cloud

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7.1 Introduction

Chronic diseases have become a main challenge to health 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[159]. It is very inconvenient for a chronic diseases patient to be monitored frequently, especially for the aged people with more than one chronic diseases. Due to the continuously increasing of chronic diseases patients, the spending on medical care is also growing rapidly[175]. Usually, it is not necessary to have urgent medical diagnosis and treatment for chronic diseases treatment. Therefore it is more appropriate to adopt effective approach to trace and control the patients’ conditions via the healthcare services such as physiological signals monitoring and recording at the home environment [176].

Thanks to the development of information and communication technology (ICT), the feasibility of home-based healthcare has been highly raised. Many physiological signals can be measured by people at their living environments in daily lives [176]. If various healthcare parameters could be shared to the care providers and other people related to the home-based healthcare by the care recipients themselves at home, it will save a lot of time and resources, as well as increase the quality of chronic diseases care.

However, the process of this long-term monitoring will generate massive samples of patient self-recording health data. Consider the huge number of patients, there is a big volume of data to be mined. Most of patients do not have much knowledge on healthcare data. They may not have the ability to catch “signals” from their daily healthcare. So if they share their health data to third party for analysis, they can receive some useful feedback or some suggestions. It will help them to have a clearer understanding of their state of health. In case the patients volunteer to share their dairy health data to other healthcare research institutions or service providers, it will benefit the research of the chronic diseases, and give improved and appropriate treatments to the patients as well.

This paper begins with the description of home-based healthcare for chronic diseases. According to the comparison of different cloud deployment models in Section 3, hybrid cloud is evaluated as the most suitable model in healthcare. In Section 4, we design a prototype for healthcare recipients’ self-management based on hybrid cloud deployment model. Section 5 addresses the conclusion and future work of our research.

7.2 Home-based care for Chronic Diseases

Chronic diseases influence patients in long last duration. Usually, lifestyle, diets and metabolism are the physical actives 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 [9].

Home-based healthcare could enable the care recipients to live assisted 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 be more active in their healthcare, involving some self-management activities and sharing the valuable health information to their care providers or other research institutions [177].

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. There are already some commercial or research-based platforms for healthcare self-management such as HealthVault [14] and Apple Health [178].

7.2.1 Type 2 Diabetes

Diabetes is a disease that patients need to be monitored continuously for a number of parameters, such as blood sugar level, blood pressure and so on. Simultaneously, the effect of environmental factors such as nutrition, stress and exercise should also be taken into account when managing this disease [179]. It would be beneficial and efficient if these various aspects of parameters could be recorded by the patients themselves at homes. According to the report by WHO, almost 1 in 10 adult has diabetes in the world, measured by elevated fasting blood glucose (>=126mg/dl). People with diabetes have increased risk of heart disease and stroke, and are 10 times more likely to need a lower limb amputation than people who do not have diabetes. It is also one of the leading causes of renal failure, visual impairment and blindness.

According to the information gathered by C. Nordqvist [180], lacking of enough proper functioned insulin production, the cells in the body have improper responsiveness to insulin, or both, are the reasons cause diabetes. There are three types of diabetes: type 1 diabetes, type 2 diabetes and gestational diabetes. Over 90% of all cases of diabetes worldwide are type 2 diabetes. Most type 2 diabetes patients will have the condition of prediabetes first. The blood glucose level of a person had prediabetes is higher than normal, but not high enough for a diabetes diagnosis. As one kind of chronic disease, type 2 diabetes will get worse gradually. In addition, obesity causes the body to release chemicals which will destabilize the bodies cardiovascular and metabolic systems, this will lead to a much higher risk of developing to type 2 diabetes [180].

People could control their symptoms of type 2 diabetes by keeping a healthy diet, losing weight, doing a plenty of exercises, and monitoring blood glucose level [180]. Therefore, it is possible that patients can self-manage at home by daily
recording blood glucose level parameter, diet, insulin intake, physical exercise, feet checking, psychological status (such as mood and pressure) and living habits (such as smoking and alcohol abuse), and then sharing to healthcare providers. This study will start with the self-management of type 2 diabetes to prove the feasibility and practicality of the notion, and then try to apply the pattern to other chronic diseases.

7.3 Cloud Computing in eHealth

Several benefits will be brought by adopting cloud computing in the current healthcare systems, such as health information management system, laboratory information system, pharmacy information system and so on[85].

Cloud computing “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”[27]. The obvious advantages like high scalability, availability and security of cloud services, make it a trend of applying cloud computing in eHealth area since last few years[181]. Since the patient daily health data is in a huge amount, cloud storage service seems to be a preferable way to sharing of these data among hospitals and healthcare organizations or third party research institutions. The big healthcare data in the cloud can be processed by remote services, such as different IT systems in hospital and other healthcare organizations, as well as some third party online care services. These features give more reasons to adopt cloud computing in sharing health information.

7.3.1 Comparison of different cloud deployment models

There are four cloud deployment models: public, private, community and hybrid clouds. Each model has its own advantages and drawbacks. Since in the healthcare domain, deploying a community cloud will bring obvious problems, due to 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.

7.3.1.1 Security and Privacy

Security and privacy of healthcare data is one of the key factors in building the trust of patients. A public cloud is hosted by a third party enterprise, 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 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 hosts sensitive data and workflow in its private cloud part, and can provide the same security and privacy guarantee as a private cloud.

7.3.1.2 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 [58]. Third party eHealth service providers can develop various services, such as historical health analysis, health data mining and Clinical Decision Support System [58], 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 [29]. 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.

7.3.1.3 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. 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.

7.3.1.4 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. The costs of expansion, updates and long-term maintenance will be a burden to an organization which uses a private cloud. The investment cost of adopting a hybrid cloud is approximate to that of a private cloud [60]. 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.

7.3.1.5 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[61]. 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 [182] to compare these three cloud models, as shown in the radar chart below.

![Radar charts of clouds](image_url)

Figure 7.1 Radar charts of clouds
7.4 Prototype design

A prototype is defined as an early model or demonstration of a system which is built to test the feasibility of a concept, solution or process [183]. It has been widely used in system development and research. In this section, the whole structure of the hybrid cloud platform will be designed and depicted for a clear demonstration of the expected purpose. Then an implemented vertical prototype will be presented, which is though incomplete, with the key functions of recording health information, sharing to private cloud and optional sharing to public cloud.

7.4.1 Conceptual Scenario of Health Information Sharing

The Figure 7.2 below describe a conceptual scenario that how the self-management healthcare data will be shared to a hospital or other care providers (private cloud) and third party healthcare service or research institution (public cloud) in order to receive home-based healthcare services, improve the treatments as well as contribute to researches.

Figure 7.2 Conceptual Scenario of Sharing Health Information.

7.4.1.1 Share to Hospital or other care providers

Based on the eHealth policies in EU and Sweden [184], we suggest that the healthcare recipients should have some trust agreements with their providers before they sharing daily healthcare data to the hospitals and other healthcare organizations’ private cloud. Because some care providers like doctors need a complete record including personal information from patients. In most cases, nurses or other medical personals are involved this home-based case, they just
want the patients’ data related to their services. The agreements is including all these issues. The healthcare providers will also guarantee a fine-grained data access control mechanism and security protection techniques to keep the privacy and security of the shared information in the private cloud. The shared health information could be integrated into electronic records in hospitals and healthcare centers.

7.4.1.2 Share to Third Parties
As known to all, privacy and security are patients' greatest concerns[185]. Besides these, when healthcare recipients considering to share their personal health information to the third parties of public cloud which were not fully trusted, the most important thing is the control rights of data. Personal information is inappropriate to be shared in the public cloud, so a tracking ID is the identification. To make the shared health data meet the requirements of specific purposes is a key feature because it is not necessary to share all the home-based healthcare data to the third parties.

7.4.1.3 Share among Healthcare Providers and Third Parties
When the health information needed to be shared to another organization, it is important to inform the care recipients with reasons. Then the action of sharing should be authorized by the patient before the transferring of health data. In this scenario, a patient’s health record could be shared between third party organizations and healthcare providers in some emergency cases. Every time when a health record is shared in an emergency case, it needs to be recorded for verification.

7.4.2 System Design

7.4.2.1 Health Record Structure
Table 7.1 shows each element of the patient-recorded health record and which cloud deployment they are mainly stored. The elements are mainly referenced from the CCD template[186] and PatientsLikeMe [187]user charts.

<table>
<thead>
<tr>
<th>Record Element</th>
<th>Content</th>
<th>Cloud Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Record Identification</td>
<td>Personal information, tracking ID</td>
<td>Private</td>
</tr>
<tr>
<td>Personal health status</td>
<td>Diagnosed diseases, other health related information</td>
<td>Private</td>
</tr>
<tr>
<td>Physiologic measurements</td>
<td>Blood pressure, blood glucose, heart Rate, etc.</td>
<td>Private, Public</td>
</tr>
<tr>
<td>Non-physiologic records</td>
<td>Mood, pain, fatigue, insomnia, blurry vision or other related symptoms</td>
<td>Private, Public</td>
</tr>
<tr>
<td>-------------------------</td>
<td>---------------------------------------------------------------------</td>
<td>----------------</td>
</tr>
<tr>
<td>General health measurements</td>
<td>Weight, height, cholesterol, etc.</td>
<td>Public</td>
</tr>
<tr>
<td>Medication Dosage</td>
<td>Amounts of injected insulin per day, other medicines information</td>
<td>Private</td>
</tr>
<tr>
<td>Life style records</td>
<td>Food records and physical activities</td>
<td>Public</td>
</tr>
<tr>
<td>Family health history</td>
<td>Diseases and health situations occurred to immediate families</td>
<td>Private</td>
</tr>
<tr>
<td>Patient notes</td>
<td>Free texts except information above</td>
<td>Public</td>
</tr>
</tbody>
</table>

When sharing to a public cloud, the Personal information (includes name, address, etc.) of the Record identification will be removed for personal’s privacy protection. The Tracking ID is a randomly-generated global-unique ID. This will be used to track the patients in the emergency case. Before sharing to the public cloud, all other elements in the record could be choose to share or not based on the willingness of patients. The format of this health record is inherited from HL7-CCD and contained in an XML file.

### 7.4.3 Prototype Simulation
On the preliminary stage of the whole hybrid cloud platform, it is necessary to establish the connections among all the roles involved for exploration. Therefore an initial prototype is implemented, which is composed of a simple patient client, an OpenStack system with all components hosted in virtual machine, and Amazon Web Services. The patient client has been implemented with the functions of recording health information, sharing to private cloud and optional sharing to public cloud. The structure of health data inherits from HL7-CCD. The prototype is programmed by Java, with AWS SDK, open source libraries dom4j [188] for XML parsing and Joss [189] for OpenStack Swift API.

#### 7.4.3.1 Health Data Recording and Sharing
Since this version of prototype is used to test the key functions of the incomplete working system, the interface of patient client is kept in simple. One of the interfaces is shown in Figure 7.3. This interface classifies some health record elements, which are defined in section 7.4.2.1. After inputting health data, patients can save the record in local as an CCD similar XML file, upload the record to private cloud, or press the “Sharing Options” button to share to public cloud, which will be performed in another interface.
The “Sharing Options” is shown in Figure 7.4. In this interface, patients can choose which health record elements to share based on their willingness. Patients can also choose where they want to share or what service they want to receive, such as diabetes research lab or clinical decision support system.
7.5 Conclusion and Future Work

In home-based healthcare, self-management is becoming an important approach for chronic patients to deal with their diseases by continuously monitoring and recording health vital signs and other related data. To share the patient-recorded health information is the key process to promote the treatments of chronic diseases, either sharing to healthcare providers or other healthcare related organizations. For addressing these problems, we implemented a vertical prototype of the conceptual hybrid cloud solution. As a result, the prototype, which is developed with OpenStack and AWS, successfully worked with the functions of recording home-based health information, sharing to the private cloud and optional sharing to the public cloud. Through researching particularly with type 2 diabetes, we believe the proposed solution is also feasible to manage chronic diseases just with slight modification, since the method of segmenting valuable and suitable health data is similar.

To integrate with automatic health devices and personal mobile devices is a vital task of home-based chronic disease self-management in the future. The automatic way of health data collection is not only to facilitate patients to record massive data, but also to reduce errors due to lacking of medical knowledge. This kind of cloud based solution is a driving force for interoperability and no patient data locked in one product. And all the data will have an entire backup in private cloud and in patient client devices. It gives patients their own controls over their data. However, to make the data interoperability at an international level, it requires worldwide organizations to coordinate various applications from local level. For achieving an interoperable solution, common medical coding system standards and health record standards such as CDA or CCD are should be implemented in the solution for electronic health information exchange.
Chapter 8. A hybrid cloud model for diabetes home-based care: a case study for perceived future feasibility

Abstract- Recently, the healthcare domain has begun to adopt cloud computing; however, it is still in its initial phase. We previously presented a conceptual hybrid cloud model for chronic disease home-based care. In this paper, we conduct a two-step case study of diabetes care in Blekinge, Sweden. The first step is intended to acquire insight into the actual care situation to improve the original conceptual model. In the second step, we validate the feasibility of the improved model. We found that our model for home-based chronic diseases healthcare will be feasible in the future. In this model, hospitals and primary healthcare centres could continue using their own databases as private clouds. For home-based healthcare data, the best approach revealed is to store and process them in public clouds. To realize this model, we suggest that a professional IT healthcare education team should be created to support both healthcare providers and recipients.

Keywords: Diabetes, home-based care, chronic disease, hybrid cloud and mobile apps

Submitted to Health Informatics Journal, 2017


8.1 Introduction

Chronic diseases have been the main factor in deaths in recent years. According to WHO reports, approximately 7 of 10 people died from chronic diseases in 2014 [1]. Among the various kinds of chronic diseases, diabetes is one of the most common. With the development of information and communications technology (ICT), cloud computing has been applied to support chronic disease care [191]. We previously proposed a conceptual model of a hybrid cloud intended for self-management of home-based chronic disease care [192]. The main purpose of this paper was to validate the model in a real-world case study, using diabetes care in Blekinge, Sweden as an example. A two-step case study was conducted whose goals were to improve and validate the conceptual model and to collect suggestions for diabetes self-management and to anticipate future trends that will emerge when cloud computing is applied to home-based healthcare. Section 2 introduces the background of this study while Section 3 describes the methods. The results are presented and analysed in Section 4, some additional issues are discussed in Section 5. Finally, Section 6 concludes the paper and proposes directions for future research.

8.2 Background

In Sweden, 397,066 new patients with diabetes were registered in the last 12 months [4]. In type 1 diabetes, the human body does not produce insulin, while in type 2 diabetes, the body continues to produce insulin, but the cells fail to use it normally. Only 5% of patients with diabetes have type 1 diabetes [5]. For type 1 diabetes, with the help of insulin therapy and other treatments, even young children can learn to manage their condition and live long, healthy lives [5]. The causes of type 2 diabetes are a combination of genetic factors and personal lifestyles [6]. Therefore, type 2 diabetes is normally treated with lifestyle changes, oral medication and insulin. The main lifestyle factors include obesity, physical activity, diet and stress. Patients with diabetes need to check their blood glucose frequently. Visiting hospitals or primary care centers frequently to check blood glucose is not only inconvenient, but also wastes healthcare resources. Thanks to ICT technology, it is possible for a patient to check his or her blood glucose at home but easily share the data with the healthcare providers and other relevant people via devices and smart phones. Programs running in the cloud can process the data and store it effectively and securely [193]. The advent of a healthcare cloud means that more ICT technologies could be used for home-based healthcare, especially for chronic diseases such as diabetes [194].

To promote evidence-based development of diabetes care by offering up-to-date information about changes in the treatment, other risk factors and diabetic complications, the Swedish National Diabetes Register (NDR) was launched in 1996 [4]. The overall goal of the NDR is to reduce morbidity and mortality and to maximize the cost-effectiveness of diabetes care. NDR is also working to support
of improvements in the quality of care provided by diabetes care centers at hospitals and primary care centers. Therefore, every known patient with diabetes is registered in the NDR database with information in a standardized form. The patient data contains basic personal information, general health measurements, physiological measurements, medication dosages and non-physiological records as well as lifestyle records. This data forms a standardized record for diabetes patients in Sweden and all diabetes healthcare providers can manage these data. The data are updated each time the patients meet with their healthcare providers. However, the NDR only standardizes healthcare provider-based data; it does very little for home-based diabetes care.

In our previous work [192], we proposed a hybrid cloud model for home-based chronic disease (Figure 8.1). In this model, home-based healthcare data is stored and processed in the cloud. The storage and processing services are provided by businesses (called the public cloud), while the data generated by hospitals and other healthcare providers are stored and processed in their own cloud servers (called private clouds) [27]. For data in the public cloud, healthcare recipients can choose what data can be shared and with whom that data can be shared. Healthcare providers can also access the data based on prior agreements and provide feedback. The data in the private clouds could be shared within the private cloud to different care providers. Some additional data exchange would occur in emergency cases. To validate the feasibility of this conceptual model, we decided to conduct a real-world case study.

![Figure 8.1 Proposed hybrid cloud model for home-based chronic disease management](image)

**8.3 Methods**
A case study is usually used to validate theoretical models by using them in real world situations [39]. In our research, we studied real-world diabetes-care situations in Blekinge County, Sweden. The study group (n=11) included both healthcare providers (one doctor and one nurse in a hospital diabetes centre and one hospital nurse in the department taking care responsible for diabetes patients, one primary care centre doctor and two primary care centre nurses) and healthcare recipients (two patients with type 2 diabetes, one mother of a child with type 1 diabetes, and two elderly people with other chronic diseases). The main research question was “Is the proposed model appropriate for future use in chronic disease care in the real world?” The study was divided into the two steps shown in Figure 8.2.

![Case study processes diagram]

In the first step, our main purpose was to gain insight into the real-world situations involved in diabetes care as well as those of other chronic diseases in Blekinge, Sweden and to gather information about the usage of mobile apps. The goal was
to improve the conceptual model after this step based on the acquired knowledge. With the success of smart phones, many healthcare mobile apps have been developed for different groups of people. There are large numbers of apps already on the market intended for self-management of patients with diabetes. For our study, we would like to select an app that matches the following features as closely as possible.

- Has basic functions for recording glucose values and insulin records and automatically integrates with as many as different kinds of devices as possible
- Allows data stored in the app to be shared with others as needed when given explicit permission from care recipients
- Has an easy-to-use and friendly user interface
- Supports cloud-based data processing and can display simple reports covering both short-term and long-term period
- Abnormal collected data should trigger some form of alarm
- The app should support building a patient community among its users for discussion purposes
- Because our study involves people in Sweden, the app should have a Swedish version

Based on the above, we began the process to select the app to use in our case study app through diabetesappar.se [23], a website that includes almost all the diabetes-related apps on the Swedish market. We looked through the descriptions of all the available apps and found that Diasend and Diabetes Guru most closely matched our requirements, but Diabetes Guru is mainly used by Children with type 1 diabetes [195]. In our case, type 2 diabetes patients and elderly people were the main target group; therefore, we finally selected Diasend as the study app (Figure 8.3). Diasend is a mobile application for self-management of patients with diabetes. It provides a method for easily uploading information [24]. The collected data are stored in Diasend’s servers as a public cloud. When a user clicks the “Upload Data” button, the app updates the data in the cloud. Based on the accumulated recorded data in the cloud, the app can create different types of reports that can be downloaded or printed. These reports include standard daily glucose, glucose trends, standard daily continuous glucose monitoring (CGM), CGM statistics, insulin administered per week, comparison logbook, etc. If the updated value is higher than a safe level, the value will be shown in red in the report as an alarm. Patients can share their scorecard results with anyone they wish via email by clicking on a Share button (the “…” button). Diasend also offers online access for health care providers, without the need for an app or any other software installation. This means that Diasend integrates patients and their healthcare providers into their public cloud.
The second step was to validate the improved model with the study group. In this step, we showed and described our proposed model to the study group and asked them to provide feedback on the model and to evaluate whether it could serve as a future trend chronic disease care. The most valuable types of data to record and share and the challenges involved in using this model for huge populations were also discussed.

We conducted interviews with both healthcare providers and recipients. We chose interviews because the study was more of an open discussion than a structured evaluation, and we could acquire more in-depth knowledge from face-to-face interviews. Another important reason is that the questions included some technical terms; through face-to-face interviews, those terms could be explained to avoid misunderstandings. The interviews included approximately 10 open-ended questions that covered the participants' current healthcare status, their opinions of home-based healthcare and their views of the proposed framework.

### 8.4 Results

#### 8.4.1 Case study results: Step 1

In Blekinge, 23 primary care centres and 2 hospital-based medical clinics offer diabetes care services [4]. Based on the information received in the first step, we found that each healthcare worker works with approximately 3–5 different IT systems in their daily work, and some amount of repeated work is involved. However, for some IT systems, such as the work calendar system for hospital nurses, the real usage is low. The nurse in the department of diabetes care said:

"The nurses on the previous shift use the work calendar computer system to record the nursing work that need to be done during the next shift, but few of the nurses like to use it. I do not know why, but we mostly still use a white board to hand over work."
Moreover, there is no common terminology standard in use among the different IT systems; however, there is an internal journal system that serves to share patients’ data among different healthcare providers. Starting in spring 2016, the national healthcare services 1177 [21] has provided patients with the ability access their own records. Patients can review their records by logging in with their personal electronical IDs, but not all patients know about or are able to use this service.

Most of the patients with type 2 diabetes do not measure their blood glucose regularly; instead, they are called in to the primary care centers or clinics to have it measured one or two times per month. Other patients measure their blood glucose themselves, at home, but do not share these values with their healthcare providers. For security reasons, the healthcare providers spend a great deal of time calling patients on the telephone or sending them regular mail; the patients are requested to send regular mail replies. However, the diabetes care teams (both hospital care providers and primary care givers) would really prefer to be able to communicate regularly with these patients via a digital option such as email. In Blekinge, only the diabetes centres in the hospital are connected to the Diasend cloud services; when patients have a Diasend account and are willing to share their data with their doctors, the doctors in the hospital can be given access to view their reports online. However, for most type 2 diabetes cases, care is provided by care providers other than hospital doctors, such as primary care providers. From the patients’ perspective, this hospital-driven care model sometimes results in delays in receiving the medical treatments. Most patients are willing to measure and record their blood glucose at home regularly with the support of their healthcare providers. They also wish to be able to communicate in a timely manner with nurses when needed. One type 2 diabetes patient said:

"For most patients who have type 2 diabetes, it is not necessary to check into the hospital very often—we can check blood glucose at home ourselves if we are taught to do so. In addition, we can measure our blood glucose at home whenever we don't feel well. If I find anything I could communicate with the nurses as soon as possible."

Based on the information we obtained from the interviews in Step 1 of the case study, we improved our cloud model for diabetes healthcare home-based healthcare as shown in Figure 8.4.
The improved model is a hybrid cloud model that includes private clouds administered by the hospital and primary care centers as well as public clouds for home-based self-management data. This model is based on the idea that diabetes patients can measure their blood glucose and other parameters themselves at home using various devices. Then, they can upload the resulting values to the app’s public cloud automatically. Compared with the previous model, this model divides private clouds into those administered by the hospital and those administered by the primary care centers. The reason is that, in Sweden, these are the main two healthcare providers for patients with diabetes, and they play different roles in caring for these patients. The data stored in the private clouds of these two care providers are different: we cannot consider them as similar private clouds. In general, as mentioned earlier, there are a number of companies or organizations that perform chronic disease home-based healthcare services. The data they collect are stored and processed in their own secure connected public clouds. However, in this improved model, we introduced Diasend’s public cloud only as an example to simplify the model presentation based on the true healthcare situation of diabetes patients. In this improved model, the doctors at the hospital can access the public cloud only if the patient authorizes them to do so. The
hospitals and the primary care centres can have an internal journal system for sharing specific patient data between their private clouds. Note that all these methods for sharing data already exist in Blekinge, Sweden. However, improving the communication between patients with diabetes and their primary care providers is currently the most pressing demand. Due to laws and policies, the public are not allowed to access data in private clouds. In this improved model, we are considering a possible mechanism for primary care that could minimize the effects of the current healthcare information systems. It is designed so that care providers at primary care centres can help their patients set the threshold values for their daily health parameters. Calculated threshold values obtained by analysing the big data in the app's public cloud could also be used to set threshold values. When a patient uploads data from home and the value reaches a threshold value, some data processing program in the app’s public cloud could send an alarm to that patient's responsible primary care centre. Subsequently, after the care providers see the alarm, they could contact the patient and provide feedback. In this way, the primary care centres just need to monitor the online alarm systems in the public cloud: they do not need to change their current internal information systems or add new ones.

8.4.2 Case study results: Step 2

The participants' opinions about home-based healthcare are listed in Table 1, divided into five categories: hospital healthcare workers, primary healthcare workers, patients with type 2 diabetes, family members of children with type 1 diabetes and elderly people with other chronic diseases. From the results, we found that both healthcare providers and recipients with chronic diseases like the idea of practicing home-based rather than the traditional hospital-based healthcare. All the healthcare recipients are willing to share their home-based healthcare data with their providers, but some of them are not willing to share that information with their family members. All the participants are willing to anonymously share home-based healthcare data with third-party research institutions for better diagnosis and treatment. From the healthcare providers’ perspective, they would prefer to only have access to the data; they do not want to manage or own the data. One nurse who works in a hospital diabetes centre said:

"I once deleted a patient’s data when I used another system, and it could not be recovered. Therefore, after this bad experience, I think having only access to data such as that provided by Diasend would be good enough."

Blood glucose, blood pressure, medication, dietary sugar content and exercise are the main data types that the interviewees think would be valuable and suitable for self-recording—but the care providers do not have high confidence that their
patients will accurately record food, exercise and habits. One doctor in a diabetes centre said:

"We have met patients who said they do not smoke who smell strongly of tobacco."

The healthcare recipients feel confident about testing and recording themselves, but they also want some education and support from their healthcare providers. The hospital diabetes centres have already worked with the mobile app Diasend; they feel it works quite well and encourage their patients to use it. Most of the healthcare recipients had heard about some self-management mobile apps, but only a few have actually used them. However, all the healthcare recipients indicated a high interest in using such apps in the future. Considering the barriers for home-based healthcare, all the healthcare workers worried that the new technologies might decrease the time spent on diagnosis and treatment because they would need time to adapt to the new technologies and more time to teach their patients to use them effectively. In addition, the healthcare recipients do need some help and education in using devices and mobile apps to properly test and record their data. Some also worried about data centre availability.

Table 8.1. The opinions of home-based healthcare

<table>
<thead>
<tr>
<th>Views of home-based healthcare</th>
<th>Healthcare providers</th>
<th>Healthcare recipients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Views of home-based healthcare data sharing</td>
<td>Hospital healthcare workers</td>
<td>Primary healthcare workers</td>
</tr>
<tr>
<td>Like the idea, would help ease the shortage of hospital resources</td>
<td>Like the idea, would improve primary care quality</td>
<td>Like the idea, need support</td>
</tr>
</tbody>
</table>

| Would like to have access to relevant data, but do not want to manage that data | Would like to have the access to relevant data, but do not want to own the data | Would like to share with the care providers, but not necessarily with family members | Would like to share with the care providers | Would like to share with the care providers, but not necessarily with family members |

Table 114
<table>
<thead>
<tr>
<th>Views of anonymou s sharing home-based healthcare data with third-party research institutions</th>
<th>Must be based on the willingness of the patients, must have a clear research purpose; if so, it can help in future diagnosis and treatment</th>
<th>Must be based on the willingness of the patients</th>
<th>Would like to share through authorization</th>
<th>Would like to share through authorization</th>
<th>Would like to share through authorization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valuable and suitable health data to record and share at home</td>
<td>Blood glucose, blood pressure, medication, dietary sugar content, exercise</td>
<td>Blood glucose, blood pressure, medication, dietary sugar content, exercise</td>
<td>Blood glucose, blood pressure, medication, images of wounds in some case</td>
<td>Blood glucose, blood pressure, exercise, images of wounds in some case</td>
<td></td>
</tr>
<tr>
<td>Confidence concerning home-based care</td>
<td>Most patients can record themselves with some instructions, but no confidence about data of personal habits</td>
<td>Most patients can record themselves with some instructions, sometimes with assistance from family members</td>
<td>Have confidence, but would like assistance from primary care centres</td>
<td>Have confidence, can get support from children’s care centre if needed</td>
<td>Have confidence, but would like assistance from the primary care centres and home care nurses</td>
</tr>
<tr>
<td>Have heard or used some healthcare mobile apps</td>
<td>Yes, work with Diasend and Libre Link</td>
<td>Yes, but not for home-based care</td>
<td>Yes, but have only heard about some diabetes self-management apps</td>
<td>Yes, used some such as Diabetes Guru and an app provided by the glucose devices</td>
<td>Yes, but have only heard of apps such as Apple Health</td>
</tr>
<tr>
<td>Barriers for home-based healthcare</td>
<td>Very busy, no time to learn and teach patients the new</td>
<td>Worried whether it will increase the working time spent</td>
<td>Worried whether there would be support</td>
<td>Less support from care providers, worried about</td>
<td>It takes time to learn new technologies, worried</td>
</tr>
</tbody>
</table>
We showed our proposed model to the interviewees, presented the workflows and explained how the data could be recorded, stored and processed. We then asked for their thoughts and suggestions about the proposed model. Table 2 shows the detailed results. All the interviewees think this is the future model of home-based healthcare, and they are not worried about privacy and security of the data. They also hoped the model would will be used for other chronic disease home-based care as well as diabetes. An old lady with other chronic diseases said:

"This is the future! I would like to have this healthcare model. I’m not worried about data security and privacy, I think the people working to protect these data are more capable of that than I am."

All the participants had heard about cloud computing but not all are clearly understood it. Therefore, we explained cloud computing to them in a simple and comprehensive manner. After the explanations, all the participants thought that cloud computing was a suitable technology to apply. In particular, they thought the hybrid cloud model was reasonable, in which the home-based healthcare data stored in the public cloud would not affect the healthcare organizations’ private cloud data. In the end, all the healthcare workers thought laws and policies should be considered before implementing the model. One nurse mentioned that when applied to a huge population, the acceptance of new technologies is another challenge of this model that must be considered.

"Technology has developed very quickly, and it is not easy, particularly for elderly people, to follow its development.”

Poor user interface designs of IT systems and mobile apps and inadequate user support could be other factors that would hinder wide adoption of this model.

Table 8.2. Participants' opinions about the proposed cloud model

<table>
<thead>
<tr>
<th>Healthcare providers</th>
<th>Healthcare recipients</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital healthcare workers</td>
<td>Primary healthcare workers</td>
</tr>
</tbody>
</table>

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### View of proposed model

- **It is a good idea, but face-to-face check-ups are still needed when the patients feel uncomfortable. Not too worried about privacy and security**
- **This is the future. Cloud computing could be a suitable technology to apply. Not too worried about privacy and security**
- **It would be good to have technological solutions for home care. Not worried about privacy and security**
- **We hope this approach will work in the future. We trust skilled IT security people to keep health data secure.**
- **Systems like this will not only be used for diabetes care but also for other chronic disease care. Not worried about privacy and security**

### Knowledge of cloud computing

- **Have heard or know about some public clouds such as Apple cloud. Cloud computing could be a suitable technology to apply in this case.**
- **Have heard or know about some public clouds such as Apple cloud. Cloud computing could be a suitable technology to apply in this case.**
- **Have heard of cloud computing, but do not really know about it.**
- **Have heard about cloud computing and know a little about some public clouds such as Apple cloud.**
- **Have heard of cloud computing, but do not really know about it.**

### Perceived Challenges of the proposed model

- **Policies and laws, the acceptance of new technology, the fast development of technology**
- **Policies and laws, the acceptance of new technology**
- **Usability, educational programs, user support**
- **Usability, availability, user support**
- **Usability, educational programs, user support**

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### 8.5 Discussion

The study, although conducted at a small scale, indicated an openness to adopt cloud solutions for home care among all the main stakeholder groups. The model we used to illustrate a cloud service was a hybrid cloud. We explained the concepts quite briefly, and this model seems to be acceptable model according to the participants. A huge number of applicable laws and policies protect healthcare data collected by hospitals and other healthcare centers. The existing databases in
hospitals and healthcare centers can be considered as private clouds. The home-
based care records data would mainly be stored in commercial public clouds and
could be assessed by healthcare providers. Based on the experiences of using such
mixed data, care providers could provide better diagnosis and treatment. It has
already been started to use by diabetes care in Blekinge, Sweden. Given this
successful step, hybrid clouds could be widely used in home-based chronic
disease care.

To promote home-based healthcare in the future, some additional points need to
be discussed. In our information society, technology has developed rapidly, and
many people always feel slightly behind and find it difficult to catch up, which
tends to make the acceptance of new technologies in healthcare lower than
expected. To our surprise, in this study, we found that in some ways, care
providers have less interest than care recipients in adopting new technologies. One
doctor in a diabetes centre said:

"IT technology has developed so fast that if we ask our patients to try a
new technology, it seems that we also have the responsibility to teach
them to use it—but, actually, we are not good at technology either."

There are two main reasons for this lack of enthusiasm for new technology. One
is that the healthcare providers are still using some poorly designed IT systems
that reduce their work efficiency [196]. Another is that most patients think it is the
healthcare providers’ responsibility to teach them to use these technologies;
however, most healthcare providers feel that they lack IT knowledge themselves.
To cover this gap, we feel that some professional healthcare IT education teams
could emerge in the future that provide education and support to both healthcare
providers and healthcare recipients.

For IT systems or mobile applications design, one old lady in the study group said:

"It has to be easy to use; the fewer buttons the better! And there should
not be much text, and make the font big!"

One nurse who works in a diabetes centre said:

"It would be better if home-based healthcare mobile apps could be
accessed with people's Mobile Bank IDs instead of creating new accounts
if the patients agree, because remembering too many accounts and
passwords is a difficult task for elderly people."

And one doctor in a primary care centre said:

"Based on my own experience, iPads are much better and easier for
elderly people to use than mobile phones."
From the different users’ viewpoints, we found that any IT systems and mobile apps must be easy to use and have user-friendly interfaces because most patients with chronic diseases are elderly people. Integrating access with patients' electronic personal IDs [197] is another possibility for future design. Finally, smart tablets may be more appropriate than smart phones because they have bigger screens.

Regarding data sharing, healthcare data is highly sensitive data; therefore, it is important to have access control and security protections. The mechanism through which patients can decide with whom and what kind of data to share is still the preferred way to meet situations with different requirements [32]. Because diabetes healthcare providers think exercise data is valuable to record in the future, how to record and integrate such data in a public cloud should be considered as well. Wearable devices could be an option. In addition, in our interviews, one old lady said:

"Once, I had a wound on my right leg, and it was very painful. I went to the wound centre and they treated me—but it did not help at all, the next day, it was worse. I could not even move, so I tried to add my doctor’s Facebook and send pictures to her, but I did not get a reply."

So far, medical images cannot be shared between healthcare providers and patients in Blekinge, Sweden; consequently, there is also a deep desire to be able to share medical images.

### 8.6 Conclusions and future research

Based on our case study, we found that healthcare recipients—even elderly people—are willing to participate in their own healthcare. This makes home-based care feasible as a future trend for chronic disease care. All the participants in our study exhibited positive views of our improved model for home-based chronic disease care. The use of hybrid cloud technology was accepted with little worry about security and privacy. We conclude that our hybrid cloud model for home-based chronic diseases healthcare can benefit both care providers and recipients; however, healthcare recipients will be the big winner. To realize this model, a professional IT healthcare education team is needed for both healthcare providers and healthcare recipients. Because most users will be elderly, all the home-based care IT systems or mobile apps should be designed in a user-friendly way. For home-based healthcare data, the best method we found was to store and process the data in a public cloud. Care providers would have access to these data only when authorized by the patients. It should be up to the healthcare recipients to decide what types of data and with whom they are willing to share.
In future, we will design a monitoring system with an alarm. This will help realize the communication between patients with diabetes and their primary care centres as described in the proposed model. Wearable devices can make other types of data input possible, for example, we plan to explore adding exercise data. Given the high demand, sharing medical images through the cloud should be another research focus.
Chapter 9. Future Directions of Applying Healthcare Cloud for Home-based Chronic Disease Care

Abstract-The care of chronic disease has become the main challenge for healthcare institutions around the world. To meet the growing needs of patients, moving the front desk of healthcare from hospital to home is essential. Recently, cloud computing has been applied to healthcare domain; however, adapting to and using this technology effectively for home-based care is still in its initial phase. We have proposed a conceptual hybrid cloud model for home-based chronic disease care, and have evaluated its future feasibility by a case study of diabetes care in Blekinge, Sweden. In this paper, we discuss some possible future opportunities and challenges to apply this cloud model with the huge population for home-based chronic diseases care. To apply this model in practice, a professional IT healthcare education team is needed for both healthcare providers and healthcare recipients. For home-based healthcare, a monitoring system with an automatic alarm to healthcare providers is also necessary in some cases. Also, how to record and integrate exercises data through wearable devices in a cloud should be considered. Given the high demand, sharing medical images through the cloud should be another research focus.

Keywords-future trends; hybrid cloud; chronic diseases; home-based care

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9.1 Introduction

The care of chronic disease has become the main challenge for healthcare institutions around the world. According to a WHO report in 2014, almost 90% of deaths in Sweden are caused by chronic diseases [198]. As the incidence and prevalence of chronic diseases continue to increase, traditional hospital-based healthcare is less able to meet the requirements of patients. To meet the growing needs of patients, moving the front desk of healthcare from hospital to home is essential. Home-based healthcare could enable the care recipients to live independently at home. Healthcare providers could reach the patients based on their shared daily health data, and provide clinical suggestions. Also, for home-based healthcare, more people are encouraged to assist with the care, such as family members and other patients with similar symptoms.

The development of Information Communication Technology (ICT) has enabled people to enter a modern digital society. Our quality of life is promoted by the application of ICT in all fields. In the healthcare domain, by widely using personal computers, smartphones, and other self-monitoring devices, ICT has brought healthcare in a new era [179]. All of the ICT technologies could help improve the quality of home-based healthcare.

In recent years, cloud computing has been used to support healthcare. The obvious advantages of cloud computing, like big data storage, pay-as-go online software services, and powerful data analysis capacity make it a great benefit to apply cloud computing in home-based healthcare [11]. In our previous work, we have proposed a conceptual hybrid healthcare cloud model for home-based care. Moreover, we have tested the feasibility of the model by a case study of diabetes care in Blekinge, Sweden [199]. We believe that cloud-based solution is a future trend of healthcare technology. To prefect and realize our hybrid healthcare cloud in large-scale population, there are other technologies to be further explored.

This paper mainly discusses future opportunities and challenges of applying cloud model with the huge population for home-based chronic diseases care. Section 9.2 is a brief introduction of our research project, while in Section 9.3, we give a brief description on our Swedish case study. Section 9.4 lists some opportunities and challenges are discussed in Section 9.5. Conclusion and the suggestions of future work conclude the paper.

9.2 Health in Hand Project

The Indo-Swedish R&D project Health in Hand –Transforming Healthcare Delivery is a project funded by VINNOVA (Reg.No.2013-04660) for three years. The main objective of the project is to establish long-term Indo-Swedish R&D collaboration around leading-edge applied health technology, with a focus on mobile health services, namely mHealth. mHealth technologies usually mean “medical and public health practice supported by mobile devices, such as mobile
phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices [16]”. In this project, we mainly refer to “mobile services which inform, motivate and enable individuals to manage their own health information and knowledge sharing, as well as support communication and community building among both patient and caregiver communities [125]”. The project uses participatory design as a research approach, to focus on the local design of design methods, techniques, and tools that promote participatory design for mHealth development [200].

One of the aims of the project is to discover possible solutions to enhance collaboration around the complex systems which are the base for innovative mobile technologies in healthcare among different healthcare providers and between healthcare providers and recipients. In the final year of the project, the study is focusing on concerning up-scaling and commercialization of mHealth technologies in collaboration with industry and public sector [125]. In the beginning of the project, we tried to develop applications based on mHealth technologies. When we had our first Swedish case study, we found that there were already a number of mobile applications in the market, so we move our research focus to how to integrate these mobile applications into current healthcare system.

9.3 A Case Study in Swedish Diabetes Care

In our previous work, we have studied on how to adapt cloud computing to healthcare domain and have proposed a conceptual hybrid cloud model for home-based chronic diseases. In this conceptual model, healthcare recipients using mHealth technologies for self-recording home-based healthcare data, and communicating with their healthcare providers, is one of the key elements. Within the scope of the project, we have conducted a two-step case study in diabetes care. The purpose of this case study was to improve the conceptual model and test its feasibility on one hand, and to explore some possible technical trends for up-scaling and commercialization of this model on the other hand [199]. The improved model is shown in Figure 9.1.

This model is a hybrid cloud model, which contains private clouds from the hospital and primary care centers, as well as public clouds for home-based self-management data. This model is based on that diabetes patients can measure their blood glucose and other parameters themselves at home via a few devices and upload the values to the app’s public cloud automatically. The secure connected public cloud of the app not only stores the data, but also deals with the data with the help of powerful data processing capacity of cloud computing to monitor the threshold values and create different kinds of reports. The doctors at the hospital can access the public cloud if they have the authorization of their patients. Between the hospital’s and primary care centers’ private clouds, there is an internal journal system for sharing partly patients’ data sharing. All these ways of sharing data already existed in Blekinge, as well as other counties in Sweden.
The improved communication between patients and primary care providers is the most pressing demand of the day.

This model visualizes the current data sharing of home-based diabetes care, as well as provide a cloud computing solution to enhance collaboration around the healthcare systems and mobile applications based on mobile technologies. For other types of chronic diseases, this model could also be used for data sharing. From our interviews with both healthcare providers and healthcare recipients, we found that it is feasible to apply this hybrid cloud in future home-based healthcare. For the model’s up-scaling and commercialization, there remains future work to be further explored.

![Conceptual hybrid cloud model](image)

**Figure 9.1 Conceptual hybrid cloud model [199]**

### 9.4 Future Opportunities

#### 9.4.1 Professional healthcare IT education

From our case study, we found that all eleven participants feel ICT technologies have developed very fast, and it is quite difficult for them to follow the steps of the development. The lack of IT knowledge sometimes reduces the enthusiasm of users to try new ICT technologies in healthcare. Especially with mobile technologies used for home-based healthcare, healthcare recipients thought it was healthcare providers’ responsibility to teach them to use the mobile applications or self-recording devices. However, most of the healthcare providers thought they were not good at technology themselves. Although there are use guides from the service or device providers, the healthcare recipients still ask lots of technically
related questions to their healthcare providers. From our case study, we were surprised to find that healthcare providers are less interested in adopting new ICT technologies than healthcare recipients. The reason is that they felt their main work is diagnosis and treatment, and that using new technologies reduced their work efficiency in some way.

In this situation, building up a professional healthcare IT education team is of utmost importance. This education team should be built by people who have certificated knowledge in healthcare technology. It could be supported by government or set up as an independent commercial organization. The educational programs provided by this team should address both healthcare recipients and healthcare providers. For healthcare providers, training on their working systems and the communications between these systems could be offered frequently, like once a year. Since in chronic diseases care, self-management is a key factor [152], the education to help healthcare recipients to use different ICT technologies for self-management would be the main focus.

9.4.2 Mobile doctor
Another trend of home-based chronic diseases healthcare is the mobile doctor. The mobile doctor here refers to having a communication with a primary care doctor through a phone, tablet or computer. Healthcare recipients could receive primary care at any place of their convenience. In Sweden, there are two of this kind of services on the market, KRY [201] and Min Doktor [202]. The difference between these two services is that KRY provides a booked 15 minutes video meeting with doctors while Min Doktor provides the communication with the doctors with messages all day round. Both these two services are linked with personal ID; healthcare recipients must log in with their social security number. This will guarantee the healthcare recipients could receive the same benefits as they are visiting local primary healthcare centers.

Both these services are still in their beginning phases. In the future, we believe more and more chronic disease healthcare recipients will choose this type of remote primary care to communicate with their healthcare providers. How to promote and improve the quality of these mobile doctor services should be under discussion.

9.4.3 Real-time monitoring system
In Sweden, most patients with chronic diseases now contact more often with primary a healthcare center than with a hospital, which means primary healthcare centers take more responsibility for chronic diseases care. However, from our case study, we found that the communication between patients and primary healthcare centers is still based on regular mail and telephones.

As big data in the cloud brought a revolution in healthcare [122], a real-time monitoring system with alarm could be a possible mechanism for primary care. The calculated threshold values by the big data in the public cloud, together with
healthcare providers in primary healthcare centers, can help the patients to set threshold values for their daily health parameters. When a patient’s self-recording data is uploaded at home, and the values reach the threshold values, the data processing program in the public cloud can send an alarm to the responsible primary care center. As soon as the care providers see the alarms, they could contact the patients and give them some feedback. The design and development of this real-time monitoring system could be another future direction to apply a healthcare cloud for home-based chronic diseases care.

9.4.4 Wearable devices to record exercise data
According to WHO, lack of physical activities is a significant risk factor for chronic diseases such as stroke, diabetes, and cancer. However, an estimated 23% of adults and 81% school-going adolescents are not active enough [203]. In most cases of chronic disease care, healthcare providers suggest their patients do daily physical exercise as the main method to control their condition. With the widely use of wearable devices, it is possible for people to record their exercise data [123]. Today most data recorded by the wearable devices is stored in device companies’ servers. With the 5G network [124] and several sensors that are being introduced into the healthcare environment, and which provide even more healthcare data.

In the future, integrating this exercise data with other home-based self-management data from both mobile applications and sensors will be an important trend.

9.4.5 Medical images sharing
The huge data storage capacity in the cloud makes it easier to store and process medical images. This will promote medical image sharing between healthcare providers and recipients. In Blekinge, Sweden, until now, there is no such kind of medical image sharing system, but the demands are keen according to our case study, especially for aged people who live independently. They want to be able to take photos of wounds at home and send them to the healthcare providers in wound centers, which would be better than regular visiting. Moreover, the healthcare providers in wound centers also thought it could save time to treat the wounds.

A multi-functional medical image sharing mobile application could be a future research orientation. For example, how to pre-process the wound images before the healthcare providers review them, such as wound highlight, 3D visualization, are worthy of consideration.

9.4.6 Games for health
Mobile games have a significant influence on people’s physical activities, as illustrated by the success of Pokémon Go [126]. Games for health are not limited to serious games anymore. Designing an entertaining and fun digital game to encourage patients with chronic diseases to do more exercises or an educational
mobile game to help the healthcare recipients to get more knowledge of their diseases could be a new interest for both game and healthcare industry.

9.5 Future Challenges

Challenges to future development of healthcare cloud in home-based chronic diseases care also need to be carefully considered and addressed

9.5.1 User-friendly information system design

Most patients with chronic diseases are aged people. Thus the new information systems designed for home-based chronic diseases need to be user-friendly. In additional, smart tablets are easier to use for aged people than smartphones since the screen is bigger.

9.5.2 Data leakage of public cloud

In home-based healthcare, most self-recording data from home environment is stored in public cloud. Thus, it is a risk of data leakage. Access control and data security protection are always necessary for healthcare related data.

9.5.3 Reliability of third party healthcare services

There are a huge amount of healthcare mobile applications to support home-based chronic disease care, but not all of them are reliable. According to study on medical related mobile apps, less than half of the studied apps are reliable [204], which means if healthcare recipients use these unreliable apps, they may get wrong information and advice about their diseases. To overcome this challenge, the companies provided healthcare services, responsible government agencies and mobile app users should make efforts together.

9.6 Conclusion And Future Work

We found that our cloud model is feasible to be applied in home-based chronic disease care in the future. It will help to promote patient-centric healthcare in Sweden. In this paper, we mainly address the future trends of applying healthcare cloud for home-based chronic disease care. To upscale and commercialize the healthcare cloud, professional healthcare IT education, mobile doctors, real-time monitoring systems, wearable devices to record exercise data, medical image sharing and games for health could be the main future directions. User-friendly design, data privacy and security, and reliability of services would be challenges to promote healthcare cloud development. In the future, we will put the focus on one or two above issues in our continued research.

9.7 Acknowledgment

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ABSTRACT

The care of chronic disease has become the main challenge for healthcare institutions around the world. As the incidence and prevalence of chronic diseases continue to increase, it is a big challenge for traditional hospital-based healthcare to meet requirements of patients. To meet the growing needs of patients, moving the front desk of healthcare from hospital to home is essential. Home-based healthcare for chronic disease involves many different organizations and healthcare providers. Therefore, there are interoperability problems for cooperation among the various organizations and healthcare providers to provide efficient and seamless home-based healthcare.

This thesis aims to point out an appropriate technical solution to interoperability problems in home-based healthcare. There are different levels of interoperability, such as pragmatic, semantic and syntactic. We explored alternative solutions specifically for syntactic interoperability. We started to identify the interoperability problems among different healthcare centers by interviews and online surveys. Based on this empirical study, we mainly used two current techniques, namely peer-to-peer (P2P) networks and cloud computing, to design prototypes for sharing healthcare data. Comparing these two techniques, we found the cloud-based solution figured out most of the problems encountered in healthcare interoperability.

To identify state of the art, and pinpoint the challenges and possible future directions for applying a cloud-based solution, a systematic literature review was carried out on cloud-based healthcare solutions. Based on the literature reviewed, we suggest a hybrid cloud model, with access controls and techniques for securing data, could be an acceptable solution for home-based healthcare in the future. This cloud model would work as a community for both healthcare providers and recipients, as well as other stakeholders, such as family members and other patients with similar symptoms. Then we conducted a questionnaire study with healthcare recipients and interviewed healthcare providers to gather the requirements for the design of the community. Based on the concept of ‘community’ from the activity theory model, we designed a prototype to demonstrate our proposed solution.

Finally, we proposed the conceptual hybrid cloud model. In our hybrid cloud model, hospitals and primary healthcare centers could continue using their own databases as private clouds. For home-based healthcare data, we argued, the best approach is to store and process the data in public clouds. Healthcare recipients, as the owners of their health data in public clouds, should then decide who can access their data and the conditions for sharing. To evaluate this model, we conducted a two-step case study of diabetes healthcare in Blekinge, Sweden. We found that our improved hybrid cloud model will be feasible in the future for home-based healthcare, and it will benefit both healthcare providers and recipients. To apply this model in practice, we suggest that a professional IT healthcare education team should be created to support both healthcare providers and recipients.