A Cloud Computing Solution for Sharing Healthcare Information

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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

I. 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" [1].

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" [2]. 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 [3]. These services are offered over the Internet by large data and computing centers [4].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 [3]. 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 [5].

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.

II. 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. [6] 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 [7].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) [8].

The following risks should be address for successful implementation of e-Health in cloud [9].

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.

A. Relationship between E-Health and Cloud Computing

In our research, we found that e-health and cloud computing have some relationships which we list them in Table I.

TABLE I. RELATIONSHIP BETWEEN E-HEALTH AND CLOUD COMPUTING

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

Table I shows that cloud computing can mostly meet the needs of e-health. 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 [10], therefore sharing healthcare information in different cloud service, the solution should be different, as well as the requirements should also be different.

III. 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 [10]. 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 [11]. 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 [11].

IV. 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" [12]. 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 Fig. 1.

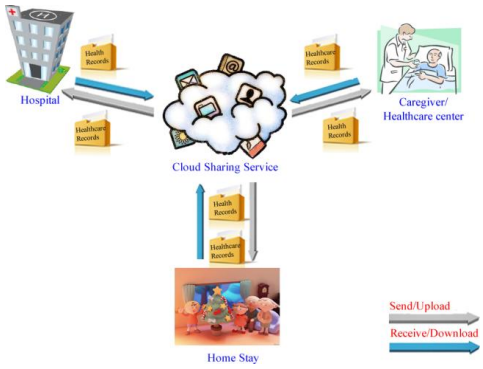

Figure 1 Basic Structure of Proposed Solution

From Fig. 1, we define three sources of healthcare information - hospital, healthcare center (care providers) and home. Based on combination with previous scenarios, we add source "home" into our scenario now. In this case, hospital and healthcare center (care providers) also want to directly access and get information from each other. The activity of home is uploading basic health information of the citizen to support healthcare planning and treatment. Also users are allowed to maintain their records at home. We use Google App Engine to simulate this scenario and discuss advantages and disadvantages of sharing healthcare information in cloud.

A. *Simulation Environment*

The simulation environment includes Google App Engine and three clients. Google App Engine is simulated as current healthcare information sharing platform. Three clients are simulated as hospital, healthcare center/care providers and home, which are the three sources of healthcare information and three users of healthcare, shown in Fig. 2.

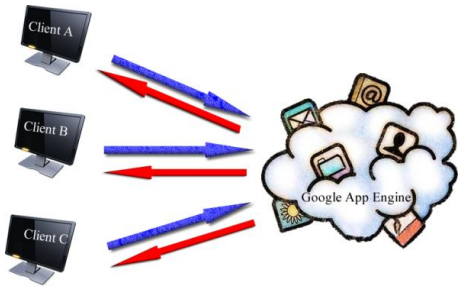

Figure 2 Simulation Environment

B. *Prototype Structure*

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

C. *Simulation Results*

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

1) *Sharing Healthcare Information between Hospitals and Healthcare Centers*

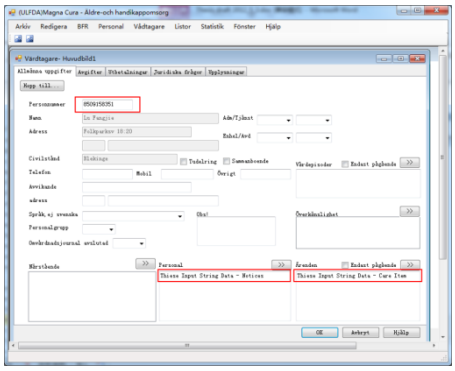

Figure 3 Healthcare center – Data Sending

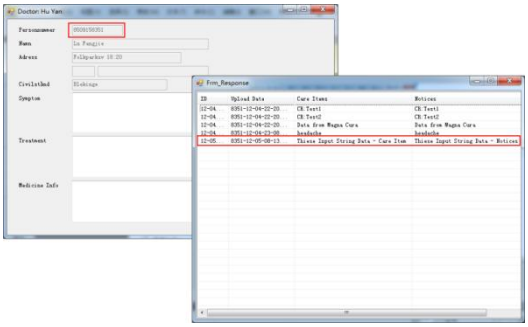

Figure 4 Hospital - Data Receive

Fig. 3 and Fig. 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. Fig. 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.

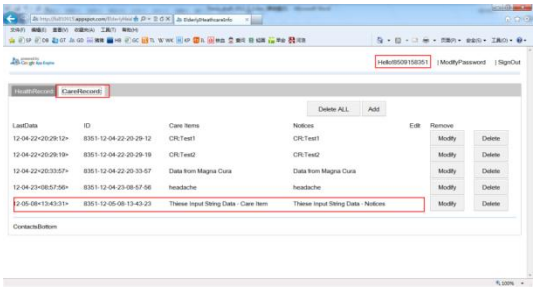

Figure 5 Online Data Management for healthcare plan

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

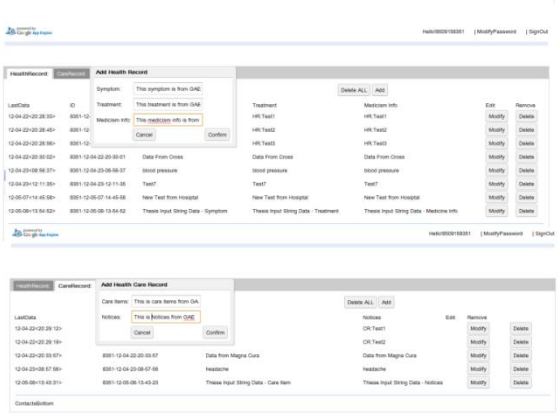

Figure 6 Online Add New Data

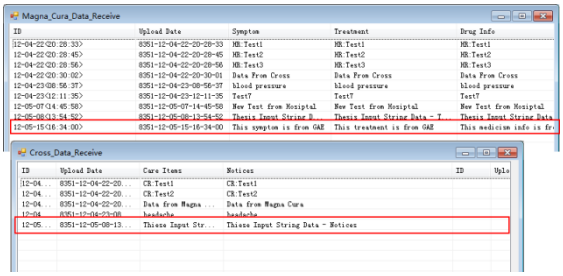

Figure 7 Hospital and healthcare center receive data from online service

Fig. 6 and Fig. 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

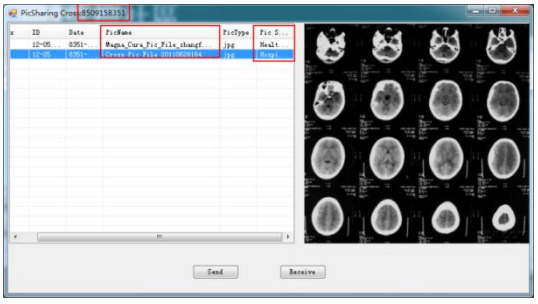

Figure 8 Picture Sharing

Fig. 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.

V. RESULTS ANALYSIS AND DISCUSSION

A. Data analysis

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

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

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

TABLE II. LATENCY AND STABILITY OF SENDING OPERATION

Type	**Binary Length (char)**	**Size (KB)**	**Latency (ms)**	**Cpu_ms (ms)**	**Api_cpu_ms (ms)**
jpg	88152	59.2	856	383	215
jpg	236588	138	1279	360	224
jpg	371032	153	568	525	233
jpg	326912	218	727	418	242
jpg	720216	279	818	523	252
jpg	929964	396	1716	1116	261
jpg	699904	482	1242	600	270
jpg	702464	502	1882	940	279
jpg	1185452	530	Error: Overflow	X	X
jpg	1033728	600	Error: Overflow	X	X
jpg	1413120	693	Error: Overflow	X	X
jpg	1440428	979	Error: Overflow	X	X
jpg	1784236	1280	Error: Overflow	X	X
jpg	3037868	1741	Error: Overflow	X	X

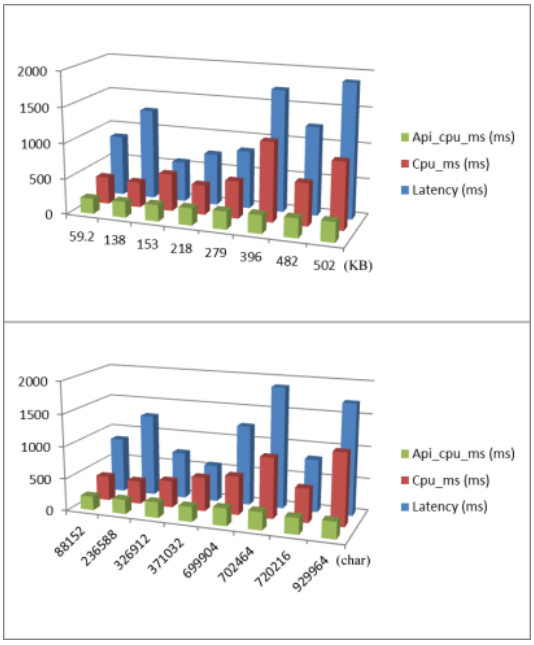

Figure 9 Latency and Stability of Sending Operation

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 Fig. 9, when data size increase the api_cpu_ms increasing; and the increasing tendency of binary length is similar to cpu_ms. It shows GAE can handle data and store data into entity which stable in sending operation. But latency has no relationship between data size and binary length, which means latency in GAE is unpredictable.

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

TABLE III. LATENCY AND STABILITY OF RECEIVING OPERATION REGARDING DATE

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

From table III, 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.

B. Discussion

1) Advantages of healthcare information in GAE

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

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

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

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

Authorized Information: Google App Engine supports authorized information system by using entity data storage. Through simulation, server allows users register to their own account and store information. Clients can only gain access to

authorized user's information by using server account. This can ensure the security of the healthcare data sharing.

2) Disadvantage of healthcare information in GAE

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

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

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

VI. 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, 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.

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