HEALTHCARE APPLICATIONS ON MOBILE CLOUD COMPUTING

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ABSTRACT

With the tremendous explosion in mobile devices in these recent years, mobile devices are able to be considered as a platform to deliver, access, and secure healthcare data information in mobile healthcare application. Although the rapid technology advancement in mobile device nowadays makes it gained more computing capability compared to the past decades, mobile devices still have the limitation of memory storage and battery capacity making them unable to run heavy algorithms. This paper conducts a comparative study on mobile computing to get a better solution for mobile healthcare application. This study included the comparison of mobile cloud computing architecture and its approach, and also the possible data management system for the healthcare applications. At the end of this paper, we proposed mobile cloud architecture relevant to health care applications that store and manage personal healthcare data. We believe that this architecture can bring benefits to healthcare center.

KEYWORDS

Cloud Computing, Mobile Cloud Computing, Mobile Cloud Architecture, Healthcare Application

1 INTRODUCTION

Cloud computing is the use of computing resources that are delivered as a service over a network. Mobile cloud computing is defined as the usage of cloud computing in combination with mobile devices. All data are stored on the internet rather than on the individual devices [1].

In the advanced technology era, technology innovations are increasing tremendously. Mobile devices play a very vital and significant role in our real life. It has good processing speed and storage, and wireless network where resources can be shared among users. Many organizations have integrated their business with mobile devices. The rapid progress of mobile computing [2] becomes a powerful trend in the development of IT technology as well as commerce and industry fields. However, the mobile devices are facing many challenges in their resources (e.g., battery life, storage, and bandwidth) and communications (e.g., mobility and security) [3]. Recently, exploration on how health care services can utilize the latest advanced technology where it can be implemented as a mobile application for data retrieving and data management purpose has been done.

The current healthcare data management is done in the hospital itself. Every hospital has their own data management system to manage every single detail of the patients who had visited their hospital. When a patient makes his first visit to a hospital for a medical checkup, he has to provide his personal details to the hospital. The same patient is still required to do the same when he visits other hospital even if both hospitals are managed by a same company. This illustrates that all hospitals could not retrieve a patient's medical records and personal details from other hospitals in real time. However, mobile cloud computing can enhance the data management of patients' records so that patient's data can be retrieved easily by medical staffs anytime and from anywhere.

The development of telecommunication technology in the medical field will help to improve the treatment and diagnosis of patients.

By using this advanced technology, patients can share their healthcare information without boundary. This would be a great improvement to the quality of the healthcare services in the future if these services can be applied on mobile application.

The study involves the area of mobile cloud computing in healthcare application, network resource on mobile cloud and healthcare database management. For our comparative study of this area of existing work, we propose the most suitable mobile cloud technology approach.

The main goal of this research is to study the issues related to the architectural design of mobile cloud computing in healthcare applications. The objectives are:

- To make a comparative study of existing mobile cloud architecture,
- To find the most suitable solution on mobile cloud computing architecture for healthcare application,
- To propose a framework for healthcare application using mobile cloud computing technology.

This paper presents a relative study on mobile cloud computing. Section II provides a brief overview of background study on mobile cloud computing environment. Section III discusses about the various architecture and approach of cloud computing. Section IV expresses about a proposed ideal architectural in cloud computing environment, followed by the conclusion in Section V.

2 BACKGROUND STUDY ON MOBILE CLOUD

From the concept of mobile cloud computing, the general architecture of mobile cloud computing can be shown in Figure 1.

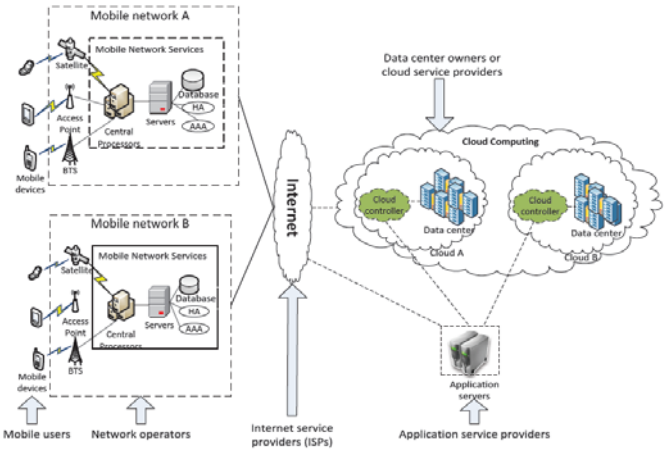


Figure 1. Mobile Cloud Computing Architecture. [4]

In Figure 1, mobile devices are connected to the mobile networks via base stations (e.g., base transceiver station (BTS), access point, or satellite); information (e.g., ID and location) and requests required from mobile users are transmitted to the central processors; mobile network operators is able to provide services to mobile users as AAA (for authentication, authorization, and accounting) based on the home agent (HA) and subscribers' data stored in databases; subscribers' requests are next to be delivered to a cloud through the Internet and cloud services are provided [4].

This mobile cloud architecture requires a strong network bandwidth connection to collect data from mobile devices. Data then goes through several layers until they reach the cloud center where all data are stored and managed. Thus, mobile cloud computing is divided into four layers: 1) Access layer which includes service interface to the client, service registration and reasonable service access, 2) Basic managing layer (located between service and server group) which provides management, service and managing system, 3) Virtual layer where all the virtual functions can be realized by software realization, and 4) Physical layer which represents the hardware components that supports mobile cloud service [5]

There are several common issues found in the mobile cloud computing, for example mobile

device is running on small batteries, the main memory (RAM) of mobile device is small and limited which is not able to execute large and complex algorithms for applications [6]. On the other hand, the network resource is also one of the issues that need to be looked into. Cloud computing requires network facilities in order to access the cloud. Even though network facilities are quite advanced nowadays, there are still some areas/countries where the cost of network facilities is high or still without any network facilities.

Apart from that, when the database and servers are outsourced to the third-party, the database and servers are no more fully under self-control. This needs extra emphasis to ensure that the data and processes are kept safely and confidentially especially the healthcare data. The purpose of employing cloud computing technology is to enhance data accessibility and data sharing among users anytime and from anywhere. This has raised another issue that is, data management issue. Data management concern is about how the data could be accessed without interfering other transactions, database security issue and so on.

There are a lot of researchers proposing different ways of solutions/architectures to overcome these issues in order to make the mobile cloud computing to be more advanced. Several ways of architectural for mobile cloud computing related to healthcare application were discussed.

3 RELATED WORK

There are various types of cloud healthcare application, mobile cloud healthcare application, and cloud computing architecture. Some of these healthcare applications which are considered as well-known architectures have been discussed and presented in the following.

3.1 Cloud Healthcare Application

Cloud healthcare application is an application that involves the concept of cloud to store and manage the healthcare data only. An existing cloud healthcare embedded with cloud is found as below.

Patient's Data Collection in Health Care Institutions

The processes for patients' data collection required a lot of manual work. A solution was proposed to attach sensors to medical equipments to automate the processes of patients' vital data collection and make the patient's information becomes available in the cloud environment [7].

As shown in Figure 2, there are *sensor nodes* attached to the patient's medical equipment to transmit and collect data through wireless network communication [7].

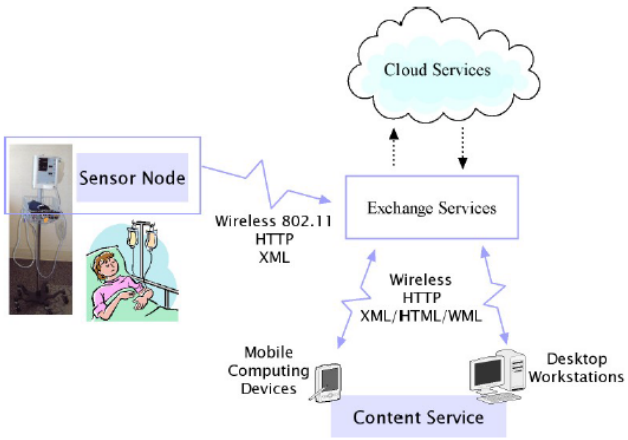


Figure 2. A cloud computing solution for patient's data collection in health care institutions [7]

Exchange Services will be responsible in collecting data from sensor nodes and put on the cloud storage, and process request (request from medical staff device) from *Content Service* to retrieve information from the cloud storage.

The advantages of this application are that it not only provides round the clock and real-time data collecting from the patient, it also eliminates manual data collecting work and eliminates the mistakes made during manual data collecting. Medical staff can always access the patient's information data through the cloud storage, and the wireless networking connection on these devices means that setting up of extra cable is not required.

3.2 Mobile Cloud Healthcare Application

Mobile healthcare which is embedded with cloud is an application that involves the concept of cloud to store and manage the healthcare data. An existing mobile healthcare embedded with cloud is found as below.

Mobile Cloud for Assistive Healthcare (MoCAsH)

According to Hoang and Chen, Mobile Cloud for Assistive Healthcare (MoCAsH) which relies on intelligent mobile agents and context-aware sensor records in its context middleware component for adaptive monitoring and power/resource-saving had been proposed [8]. From this architecture, the limitations of Grid infrastructure has been solved by deploying the best suited Cloud features for resource scalability and user accessibility. Figure 3 shows the architecture design of MoCAsH which encompasses four main components: 1) sensors and mobile agents, 2) intelligent context-aware mobile cloud middleware, 3) collaborative cloud computing platform, and 4) a Cloud portal [8].

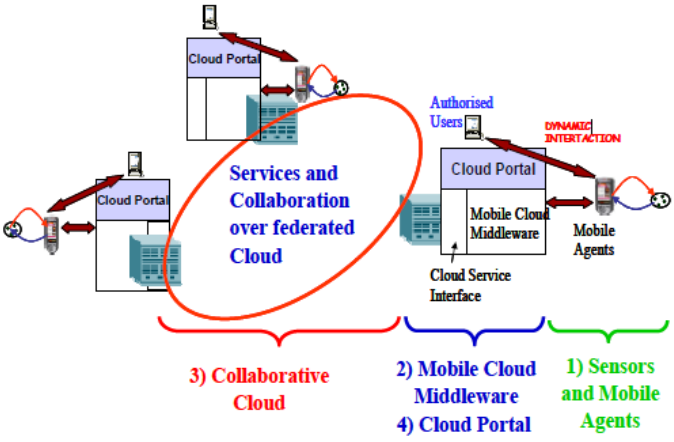


Figure 3. Architecture of mobile cloud for Assistive Healthcare (MoCAsH) [8]

Sensors act as data sensing where medical data will be inputted into the mobile. Data that is collected by the sensors will be transferred to the mobile cloud middleware. At this stage, data are analyzed, processed, and the most special component is that this mobile cloud middleware has an intelligent monitored data analysis which is able to get the data from the sensor nodes and process it to provide a quality data. For example, body temperature can be detected from the patient through the mobile agent; this data is then processed through this intelligent model to produce useful data.

3.3 Mobile Healthcare Application

Mobile healthcare application is the application that embeds healthcare related services into mobile devices. These applications are usually connected to a central system which is owned by healthcare centers through the communication network.

i) Mobile Healthcare Service (MHS)

Mobile Healthcare Service (MHS) System as shown in Figure 4 is an infection control application that uses mobile device together with RFID (Radio Frequency System) technology to position and identify both persons and object that are inside and outside the hospital [13].

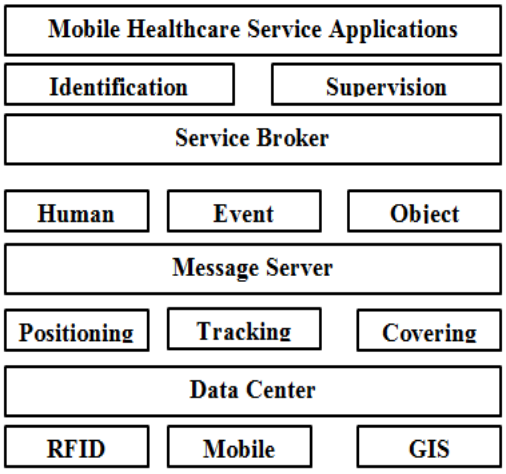


Figure 4. Architecture of MHS System [13]

Hospital and Government are able to receive patient's location and medical data/ information from the patient's mobile device by sending them

through the RFID technology. These data are then analyzed in real-time so that the hospital or government could have the latest update for a disease or infection that has taken place in the country.

ii) Healthcare Alerts Management System (HAMS)

Healthcare Alert Management System is a healthcare service application that runs on mobile devices to manage alerts in hospital [14]. All the urgent requests in a hospital are referred to as alert. Example of hospital alerts are operations rescheduling, laboratory result and adverse drug events. HAMS receives alerts signal and deliver them to the right person at the right time. These alerts are delivered via short message service (SMS) to the mobile device, e-mail and ICQ (I Seek You) to the involved users such as doctors and nurses. By having a HAMS which could effectively route and monitor alerts, the hospital is able to provide quality and cost-effective healthcare services to its customers.

3.4 Mobile Cloud Architecture

Significant architectures which are related to mobile cloud are discussed as follows:-

i) Clone Cloud Architecture

This proposed idea is introduced by Chun to improve the performance of hardware limited mobile devices [9]. This architecture creates a virtual clone of the mobile device execution environment in the cloud. Task execution is said to be transferred to those virtual devices. Health care data which have been tracked and transmitted into the mobile cloud will be also transmitted to the virtual devices. Clone acts as a way to backup data storage if the mobile device is lost or damaged. Health care data information is very crucial as it must be fully available to be accessed by medical staff when necessary. Tasks will be offloaded from primary (mobile device) to a computational infrastructure hosting a cloud of mobile device clones. All the data are processed at the clone and then sent back to the primary (mobile device). Figure 5 shows the architecture of clone execution for mobile devices.

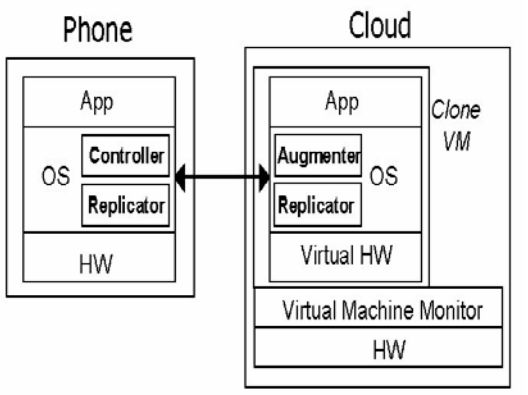


Figure 5. Clone Execution Architecture for mobile device. [9]

Clone cloud is very useful especially for data management in the medical field as data management would generate a huge synchronizing process in mobile cloud and this consumes a lot of energy power in the smart phones. Smart phones might run out of battery life if the medical staff is using it non-stop daily. Thus, this system transforms a single-machine execution (smart phone computation) into a distributed execution (mobile device plus cloud computation) in which the resource-intensive part of the execution is run in powerful clones [9]. This explains that data processing does not need to be done in a single mobile device computation. Data processing part would be sent to the clone to be integrated and then sent back to the smart phone once these execution tasks have been completed. The processing part would just stop at the mobile device side but it would be done by the clone side. Clone acts as a mirror image of a mobile device running on a virtual infrastructure [9]. By this way, mobile devices do not need to use its own CPU so frequently in order to reduce battery consumption.

ii) Offloading Approaches Architecture

With the modern cloud technology, mobile devices can be considered to be a platform for delivering health information [6]. However, mobiles face some challenges to run heavy applications on a mobile device. No matter how powerful a smart phone device can be, it will not be as powerful as a computer. Because of the size constraint of a mobile device for portability

purpose, a mobile device has a very limited battery capacity. This becomes the main reason why mobile devices may have the computation and memory limitation, and it will be an issue when a mobile device has to run a heavy application such as delivering health information.

Two types of offloading approach are proposed to be the solution for the limitation on mobile devices. First approach clarifies that when a mobile device needs to run a heavy application, it will outsource the heavy application to surrogate system, execute the particular heavy application on the surrogate system and send back the output result of the device [15]. The second approach is to clone the mobile device at the cloud and heavy algorithm can be executed at the cloud of clones. By these two offloading approaches, a mobile device is relieved from executing those heavy applications[9].

Normally, the limitation of mobile cloud computing is the power supply of a mobile device which is very low as compared to other electronic device. The main memory available is not big enough to run complex application.

When the data storage is outsourced to the service providers, it is hard to ensure that the data is 100% safe and remain confidential in the cloud. Therefore, security and data protection as well as database management must be enforced if an institution wishes to outsource their database or system application to retain the database integrity and database consistency. These are very important for critical institutions like bank and healthcare.

M.T Nkosi and F. Mekuria proposed a solution that solves the limitations stated above. They suggested that we offload the security algorithm to another cloud separate from the cloud that stored the institute's data. Whereas, the user's mobile only sends data and receives the result from the cloud through the network. By this way, the power consumption of mobile device can be reduced and on the other hand increase the database security that is stored in the cloud.

iii) Service Oriented Architecture (SOA)

Service oriented architecture (SOA) is an ideal stage of a cloud computing environment to improve current cloud computing architecture to be a more efficient system [11]. In this architecture, users are able to switch between different compatible cloud environment provided by different providers, and these providers have to create a federation of cloud resources to be able to share with each other.

SOA must also have Multitenancy property to ensure the efficiency of a cloud environment. Figure 6 shows the example of single and multi-tenancy programs [11] which is a property that lack in the current cloud computing architecture.

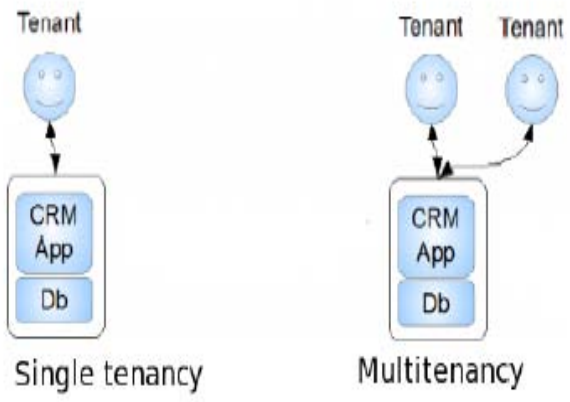


Figure 6. Comparison of Single Tenancy and Multitenancy [11]

A single tenancy program is an application that runs on the cloud server and only one user is able to access it. Multitenancy program is an application that runs on the cloud server but can be accessed by many users simultaneously.

If all modern cloud architectures can be switched to SOA, then it will be an added advantage for all users, developers and cloud service providers who are using cloud computing nowadays especially on mobile devices' users that are able to transfer their data regardless of different operating system with the different cloud service provider. If the healthcare application is able to implement this architecture, then the advantage is that the patients' data are able to be

transferred to another cloud provider in an emergency case. But there are disadvantages of this architecture too. Imagine if all cloud providers provide the compatible cloud environment for users to switch freely to another provider, then the users have no reason to stick to a particular company.

Besides that, if healthcare application is developed for this architecture, there would be a security issue such as patient data confidentiality. A patient's record is very confidential and should not be leaked to other parties. As a solution to this issue, only those trusted cloud providers of same healthcare service in cloud environment are allowed to form the federation of health information resources. By this way, the security of any confidential documents can be ensured.

4 DISCUSSIONS

This paper takes the position that mobile cloud computing will be a core component of our future mobile healthcare application. There are three different types of technologies that are being applied in healthcare applications due to the emerging of use of mobile and cloud technology. Table I shows the comparison of these three types of technologies which have been studied in the above section.

5 PROPOSED ARCHITECTURE

Most of the mobile clouds computing only give attention to the architecture to improve the system performance by reducing the use of mobile device's memory and power consumption but they seldom concern about the data management in the cloud. Data management such as concurrency control, database recovery and security is crucial in maintaining a database integrity and consistency.

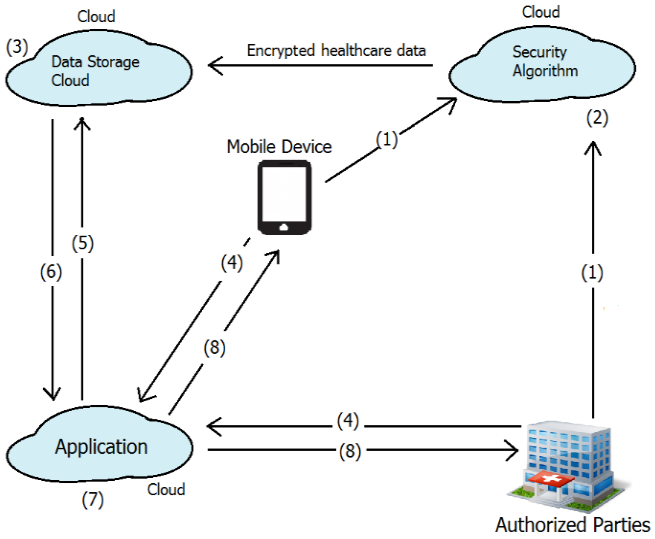
From the comparative study of the existing work, we propose the most suitable technology for mobile cloud computing approach in healthcare application as shown in Figure 7.

Table 1. Comparison of Mobile Healthcare Application, Cloud Healthcare Application, and Mobile Cloud Healthcare Application

	Strengths	Weaknesses
Mobile Healthcare Application	- Provide real-time data collection	- Data storage problem - Small power supply - Not affortable to run complex algorithm
Cloud Healthcare Application	- Provides real-time data collection - Eliminates manual workloads by medical staff. - Reduce spending on technology infrastructure.	- Data can only be accessed when network connection is available. - Weak data privacy protection
Mobile Cloud Healthcare Application	- Provide real-time data collection - Relocate data through embedded database storage - Exists inteligent monitored data analysis - User easy access - Reduce spending on technology infrastructure.	- Lack of strong security mechanism - Weak data privacy protection - Data can only be accessed when network connection is available.

It involves mobile devices, three different functions of clouds, *data storage cloud* for storing the patient/ user's data, *security cloud* that consists of security algorithm to encrypt the data before the data is sent to be stored in the data storage cloud, and finally the *application cloud* that contains the main algorithm to run the calculation and services provided by the applications and integrated systems from the authorized parties. To improve the application's reliability and security, clouds from different cloud service providers are encouraged.

The workflow of the application is such that, first, the user (include both patient and authorized parties) input the data into the mobile device/system either manually or through the embedded sensor. The mobile device/system will then send these data to the security cloud to encrypt them before they are stored in the data storage cloud.



(1) Send healthcare data	(5) Acquire data
(2) Encrypt healthcare data (in the cloud)	(6) Send data
(3) Store the data (in the cloud)	(7) Data is decrypted for processing and the result is sent to the user in encrypted form (in the cloud)
(4) Request for services	(8) Decrypt and view the result

Figure 7. Proposed architecture for mobile cloud computing

Whenever the user requires a service from the application, the mobile device/system will invoke the application cloud. The application cloud will then acquire necessary data from the data storage cloud. Notice that, the data is transferred in the encrypted form to the application cloud. The application cloud will then decrypt the data for further processing. The result of the process is encrypted and sent to the mobile device/system of the user.

This architecture provides several benefits that other architectures fail to provide. It provides loose coupling among the components. Each cloud and the mobile device have its own responsibility in the application. If any failure occurs, it only affects one of the components, the other functions of the system are still workable. It is easier to support and maintain the application in such arrangement because the other functions would not be greatly affected.

The mobile device is prevented from running complex and massive algorithm that requires a lot of memory and CPU power. The mobile device only receives the data input from the user, sends them to the security cloud, invokes the application cloud and decrypts the result received from the application cloud. This could solve the small CPU power and memory of mobile device issue.

Apart from that, this architecture provides better security which is very crucial to protect the healthcare data in the application. All the data are transferred in the encrypted form except the sending of raw data from the mobile phone/integrated system to the security cloud. The encryption key in the security cloud is specific to a user. The intruders may get the encryption key in the security cloud but they do not know to whom the encryption key belongs to, and there is no data stored in the security cloud. The decryption key to decrypt the data in the data storage cloud is placed inside the application cloud and the only way to get the decryption key is through the association of the mobile device to the application cloud. Once the processing of the data is completed, the result is encrypted and sent to a mobile device that has the only decryption key for the set of result. It is not going to be easy for the intruder to get the right encryption or decryption key to the right set of data.

Most prominently, our proposed architecture does provide the facility for other authorized parties to share the healthcare data. Data sharing is a significant issue in medical field. Most of the mobile cloud computing architectures do not have this facility that makes the healthcare application fails to adapt to their architecture.

6 CONCLUSION

Mobile cloud computing is emerging. The technologies are progressive that there are tremendous mobile devices and powerful cloud computing provides. However, the architecture for mobile cloud computing is still uncertain for

most of the field. One of them is the medical field. The mobile cloud computing architectures proposed by the researchers are mainly focused on how to reduce the mobile device workload such as avoiding executing massive algorithm and system resource like CPU power and main memory. Mobile cloud computing in healthcare application requires much more than that. Healthcare data must be kept confidential and secured in the database (cloud) besides being shared among the authorized parties. So, except for the system performance, mobile cloud healthcare application architecture must accomplish with data security in the database during data transmission and data sharing among several parties. The architecture that we proposed does fulfill the requirements for mobile cloud healthcare application. Hopefully, this architecture can bring huge benefits to the healthcare institutions and other fields that require data security and data sharing of critical data/ information.

7 ACKNOWLEDGEMENT

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