Mobile Cloud Computing in Healthcare System

Hanen Jemal(✉), Zied Kechaou, Mounir Ben Ayed, and Adel M. Alimi

REGIM: REsearch Groups in Intelligent Machines, National School of Engineers (ENIS), University of Sfax, 1173, Sfax 3038, Tunisia
{hanen.jemal,zied.kechaou,mounir.benayed,adel.alimi}@ieee.org

Abstract. Mobile Cloud Computing (MCC) is a potential technology for mobile web services. Accordingly, we assume that MCC is likely to be of great avail to healthcare domain. MCC offers new kinds of services and facilities for patients and caregivers. In this regard, we have tried to propose a new mobile medical web service system. The proposed system called Medical Cloud Multi Agent System is a complex system which integrates MCC and Multi Agent System in healthcare with view to improving healthcare system.

Keywords: Mobile Cloud Computing · Mobile web services healthcare · Cloud Computing · Medical Cloud Multi Agent System · Multi Agent System

1 Introduction

Mobile Cloud Computing (MCC) is an integration of Cloud Computing (CC) into the applications of mobile devices. New advances in CC and mobile technology have inspired different patterns of cloud health care services and devices. In the cloud system, health-data can be stored and transmitted to medical caregivers from everywhere and response can be returned to patients through web service network. In this article, we present a MCC solution through a healthcare web service.

The motivations for the use of MCC in healthcare consist in several benefits that can be derived from the combinations of mobile and CC: ABI Research study showed that more than 240 million businesses will use cloud mobile services by 2015. "Traction will push the revenue of mobile cloud computing to $5.2 billion" [1].

In our study MCC offers significant benefits to our healthcare solution such as:

- *Collaboration:* MCC technology maintains collaboration and team care delivery.
- *Performance:* MCC model can improve rapid access to computing, share information more easily, large storage of big data (cloud-based medical records) and reduce costs.
- *Modernization:* MCC will lower the barriers for modernization and innovation of healthcare applications.
- *Scalability:* several patients utilizing the healthcare applications.
- *Portability:* the ability to remotely access applications and data and provide functionality for managing information in distributed and ubiquitous applications.

M. Núñez et al. (Eds.): ICCCI 2015, Part II, LNCS 9330, pp. 408–417, 2015.
DOI: 10.1007/978-3-319-24306-1_40

Our research defines hybrid system that combines Muli Agent System (MAS), Web Service and MCC. In this paper we will only detail the MCC and our healthcare web services. This paper is organized as follows: At first we started with an introduction, subsequently section 2 describes the existing cloud healthcare solutions and a state of the art of MCC. Section 3 presents our cloud hospital architecture designed to mobile healthcare applications. Finally, we conclude with a summary of the article with further suggestions for additional advancement.

2 Cloud Computing and Mobile Cloud Computing in Healthcare

2.1 Cloud Computing in Healthcare

CC is simply an architectural model that employs many of the same components used in datacenters around the world today in a more flexible, responsive, and efficient way [2].

According to NIST (National Institute of Standards and Technology, USA), "Cloud Computing is a model for enabling convenient, on-demand work access to a shared pool of configurable resources (e.g. networks, servers, storage, applications and services) that can rapidly be provisioned and released with minimal management effort or service provider interaction"[3].

CC consists of hardware and software resources made available on the internet as managed third-party services. These services typically provide access to advanced software applications. Cloud technology providers deliver applications via internet, which are accessed from a web browser, while the business software and data are stored on servers at a remote location.

In cloud technology the information is shared from clients to the organization through the virtual data centers. The cloud technology includes three models: SaaS (Software as a service), PaaS (Platform as a service) and IaaS (Infrastructure as a service).

Cloud in healthcare information is speedily becoming the most important trend for the development of healthcare information systems [4]. CC can improve medical services and benefit biomedical research providing Centralization, Collaboration and Virtualization:

- Centralization: by saving time and cost through providing an easier access to and retrieval of data.
- Collaboration: doctors can collaborate together on cases, researches, through sharing resources, information and files.
- Virtualization: it is the core axis of IaaS (Infrastructure-as-a-Service).

Recent studies indicate that CC can facilitate the biomedical informatics research communities. Reports show that as many as 30% of healthcare organizations are either implementing or operating cloud-based solutions[1] .

[1] CDW 2011 Cloud Computing Tracking Poll http://www.cdw.com/cloudtrackingpoll

JiunnWoei and his colleague [5] identify a key factor for hospitals to make decision through Cloud Computing technology. The purpose of this study is to examine the factors that will change the decision to adopt CC technology in Taiwan's hospital. Pankaj & Inderveer in 2013 [6] presents a Cloud Based Intelligent Health Care Service (CBIHCS) that performs real time examination of patient health data for diagnosis of chronic illness, like diabetes, collected from different wireless sensory medical equipments. The authors utilized Principal Component Analysis for attribute selection and k-nearest neighbor (KNN) and Naïve Bayes for classification of patient health status.In [7] authors utilizes Aneka [8] framework to create an autonomic cloud environment for hosting ECG (Electrocardiography) data analysis services.

Kuo in 2011 [9] designate that Cloud Computing can change the execution and adoption of medical information technology, in particular for the development of EHR (Electronic Health Records). In [10] authors use high performance computing of Amazon Web Service to facilitate genomic findings.

In 2011 Piette and his colleagues [11] present a CC based Voice over IP (VoIP) service for diabetic patients, the patients subscribing the cloud service received VoIP calls with prerecorded voice messages as self-care reminders. In this study, the advantages of this cloud computing based healthcare service are cost effective, and it can be extended globally easily. In practice, the Fujitsu in Japan [12] propose a cloud computing solution for hospitals. In addition, Microsoft also defines a cloud computing technology in order to improve the quality of care. This solution reduced costs in Italy Pediatric research [13]. In its healthcare industry project [14], IBM proposed the use of CC in the United States hospitals: patients' data are stored in a cloud database, patients can be monitored at home via this cloud service and doctor can use the cloud platform to make a diagnosis at home.

2.2 Mobile Cloud Computing in Healthcare

The purpose of Mobile healthcare (m-healthcare) is to provide mobile healthcare users easy and quick access to the resources (e.g., PHR patient health records) and offers a variety of distributed services. The aim of applying MCC in healthcare applications is to reduce the limits of traditional medical applications (e.g., security, small storage, and medical errors [15,16]).

The Mobile Cloud Computing Forum considers MCC as "an infrastructure where both the data storage and the data processing happen outside of the mobile device" [17]. In [18] MCC is defined as a new model for mobile applications: "it will be transferred to a centralized and powerful computing platform in the cloud".
There are several advantages of MCC such as [19]:

- Extending battery lifetime: the technique of computation offloading is proposed in order to migrate the complex treatment from limited devices (mobile devices).
- Improving data storage capacity and processing power: MCC is developed to enable mobile users to store/access cloud data.
- Improving reliability: the storage of data on a number of computers in the clouds improves reliability.

- Dynamic on demand provisioning of resources and scalability: It is a flexible way for s running the applications without advanced reservation of resources and adding services.
- Multi-tenancy: providers of service can share the resources in order to support a variety of applications and large number of users.
- Ease of Integration: several services from diverse service providers can be integrated simply through the cloud.

In the literature there are only few works about MCC applications in healthcare such as, Upkar Varshney [20] who presents five key of mobile applications in the pervasive healthcare environment:

1. Comprehensive health monitoring services enable patients to be monitored at anytime and anywhere.
2. Intelligent emergency management system can manage the large call volume received from accidents or incidents.
3. Health-aware mobile devices which detect blood pressure, pulse-rate and level of alcohol.
4. Pervasive access to healthcare information allows caregivers and patients to access medical data.
5. Pervasive lifestyle incentive management can be used for paying healthcare expenses and other healthcare charge.

In the same way, [21] proposed a prototype of m-healthcare information management system called @HealthCloud and based on MCC and Android operating system.

In practice, Tang and his colleagues implement a telemedicine homecare management system [22] in Taiwan to monitor patients with hypertension and diabetes. The system examines 300 patients and stores more than 4736 records of sugar and blood data on the cloud.

Then, [23,24] present a solution to protect the patient's health information: [23] utilizes P2P paradigm to ensure security and data in the clouds. In [24] authors present security as a service to defend mobile applications.

This solutions present very talented research in the MCC applications as it is the result of the collective profits of mobile and cloud technologies, but these solutions presents several disadvantage listed in table1 and there are no complete systems which offer complete solutions for healthcare. In section 3 we present our MCMAS solution that combines MAS and MCC in healthcare domain.

3 Proposed Architecture

Our research defines a hybrid System that combines Multi Agent System, Web Service and Mobile Cloud Computing.

In this paper we will only detail the MCC and our healthcare web services.

This architecture (Fig. 1) is related to the previous works in the healthcare domain when authors introduced MAS for healthcare and present the interaction in an agent-based architecture for healthcare [25,26]. This architecture is composed of a set of autonomous agents adapted to the interaction.

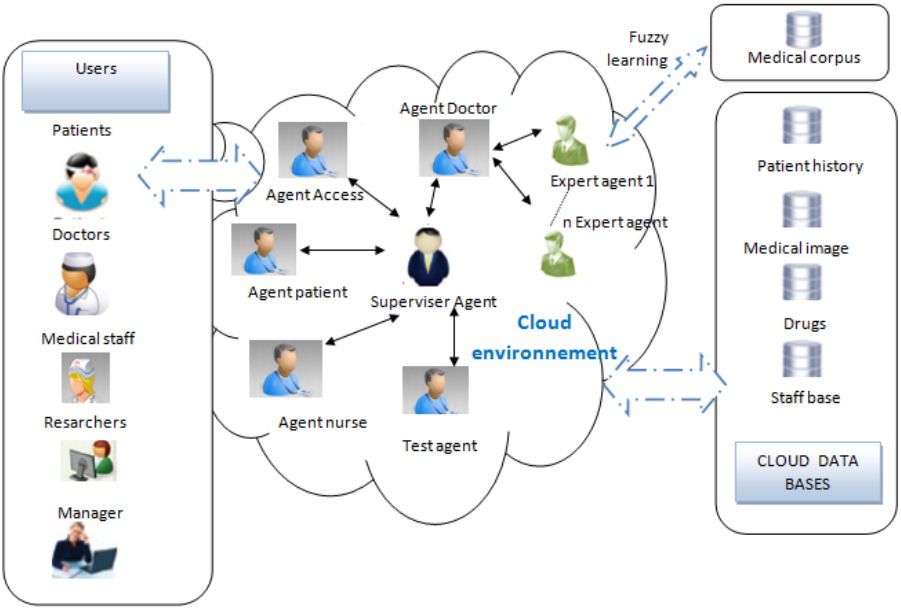

Fig. 1. Our MCMAS architecture

The agents of our hospital can be classified in two groups or layers [25]:

- Intelligent agents or super agent (Agent doctor, Agent patient, Agents nurses….)
- Swarm layer inspired from the Swarm Intelligence fields (applies the collective behavior of groups to resolve a problem.) such as office, medical materials …

This architecture includes the two previous layers of intelligent agents, representing a medical organization with different roles and communication patterns, and facilitating interoperability, and the accessibility to information.

The purpose of our study consists in the development of a medical framework able to solve a large variety of medical problems. Consequently, we designed cloud architecture consisting of multiple distributed agents placed in the cloud environment.

The main functionality of the prototype is to provide users with a mobile interface in order to manage healthcare information, the applications platform is a tool for several users:

1. Hospital staff: it represents all the agents that are concerned in providing care to patients in the healthcare system. This community should be able to know and confirm the abstract representation of the theoretical model of the hospital as well as manipulate and utilize the results of the system. The main categories of this category are:

- Medical personnel: physician, surgeon, radiologist, anesthetist, etc.
- Nursery personnel;
- Technicians: such as laboratory personnel

- Admission and discharge personnel;
- Medical support personnel: security, archive, supplying, cleaning, etc.

2. Team study: such as researchers, engineers.
3. Non hospitalized patients represent the main users of the healthcare system and the core of the care system.

Our aim is that agent's work in the background to provide ambient intelligence to the users (Doctors, patient's, nurses…) who reside in the cloud environment. In other word the agents communicate with each other, acquire their behavior and receive information through medical cloud data.

4 Implementation of a Prototype

A new medical system called MCMAS (Medical Cloud Multi-Agent System) is proposed. This is a complex system which integrates hybrid solutions, i.e., MCC and Multi agent System in healthcare, in order to make care as efficient as possible. The web services and service-oriented architecture (SOA) technologies have been used to our prototype. This architecture offers a model combining the benefits of both Mobile technology and CC (Fig. 2).

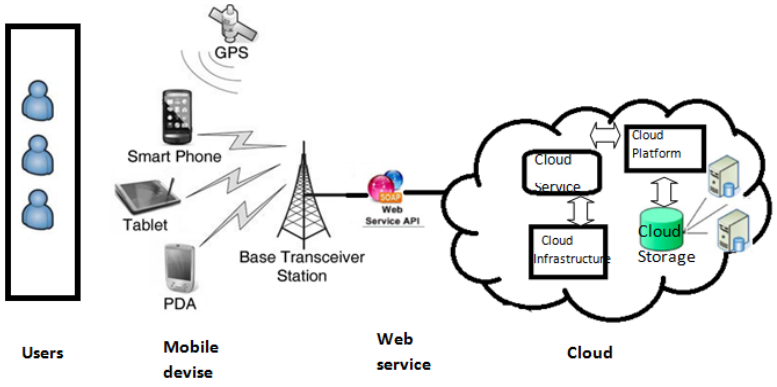

Fig. 2. Mobile Cloud Computing Architecture

We define several services such as:

- Patient appointment: patient can choose a date for remote consultation
- Remote consultation: patient can make consultation in real times by sending and receiving message from doctors.
- Resource allocation: doctors and patients can remote allocate resources (IRM, scanner...).

- Connection to CC storage (e.g. patient health records): The system application allows caregivers to save and upload distributed medical data.
- Image viewing by supporting the DICOM image.
- Patient registration: patients can make registration remotely as well as choose the medical center and the suitable medical unit.
- Medical analysis results viewing: the content of the test resides remotely into the cloud storage.

Table 1 lists the most positive points, the disadvantages of existing works and the positive features of our Medical Cloud Multi Agent System (MCMAS). In fact there are no complete systems which offer complete solutions for healthcare.

Table 1. Advantages and disadvantages of existing works in healthcare and the position of our system

Existing works	Advantages	Disadvantages
Doukas *et al,* [21]: @HealthCloud	• Seamless connection to CC storage (e.g., medical images, patient health records) utilizing web services Patient health record management system. • Image viewing and annotation. • Data encryption and user authentication.	• Absence of remote consultations. • No cloud appointment. • Just a prototype. • Focus only on the medical imaging. • Absence of security.
Tang *et al,* [22]: homecare management system	• Telemedicine system. • Homecare management.	• Specific patient (only monitor patients with hypertension and diabetes).
Hoang and Chen, [23]: MoCAsH	• Utilizes P2P paradigm to ensure security and data in the clouds.	• Just a solution to ensure security.
Nkosi and F. Mekuria [24]	• Present security as a service to defend mobile applications.	• Just a solution to ensure security.
Our MCMAS	• Patient appointment. • Remote consultation. • Resources allocations. • Connection to CC storage (e.g. patient health records). • Image viewing. • Patient registration. • Medical analysis results viewing	

To implement our proposed application we use JADE (Java Agent Development Framework) as a software framework for developing multi-Agent systems. JADE provides a set of interfaces for the design of agents implemented in Java [27].

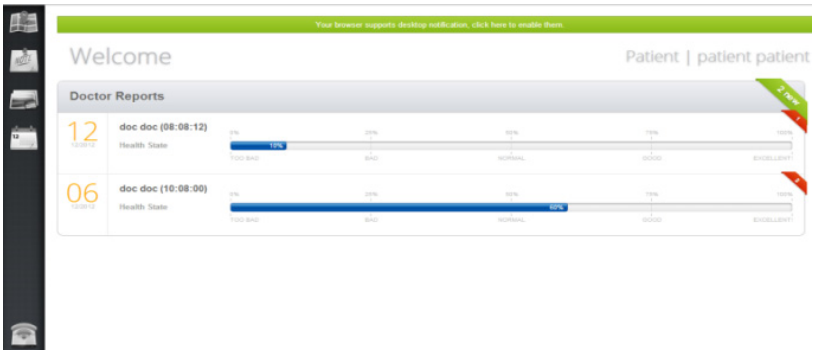

Fig. 3. Consultation report

The main purpose of this article is to define a prototype of mobile internet application in the cloud environment for healthcare system, in which patients are able to get immediate aid ((Fig. 3) interface doctor reports present the heath status of patient) and make an appointment (Fig. 4) form the corresponding doctors.

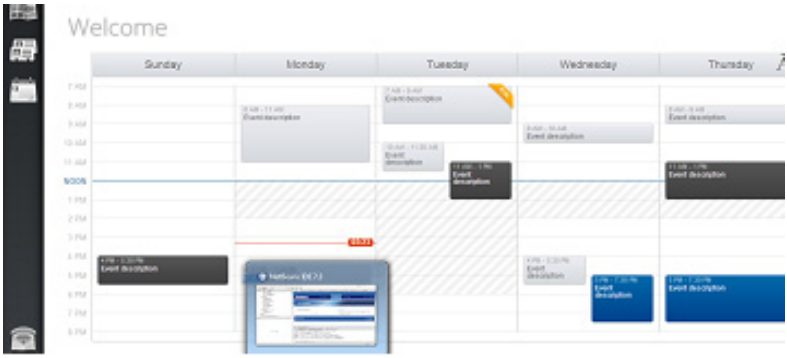

Fig. 4. Patient appointment

5 Conclusion

The presented work is an effort towards the integration of MCC in the health delivery process. Advances in Information Technologies such as mobile computing and CC are creating new opportunities to improve the health care ecosystem. Thus Mobile and CC provide the essential functionalities that make them suitable to be used in the remote healthcare domain.

The proposed architecture in this article will be appreciated in the future, as it is the consequence of the combined profits of both mobile and cloud technologies.

MCC is related to cloud computing although both are at their early stage of development. Besides, CC has five significant challenges such as availability, performance, security, interoperability and privacy. Those basic challenges are shown in (Fig. 5).

As a future work, we plan to introduce the usage of several improvements or possible extensions to the architecture and deploy our prototype in the real healthcare environment in order to evaluate the applications in terms of user tolerability and performance.

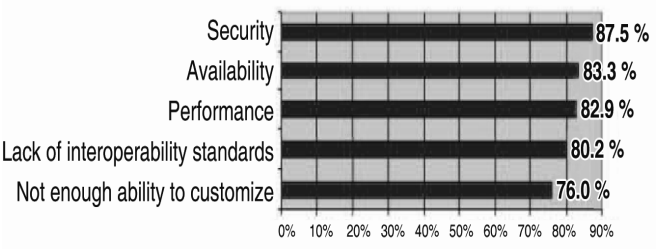

Fig. 5. Challenges in Cloud Computing [28]

Acknowledgements. The author would like to acknowledge the financial support of this work by grants from the General Direction of Scientific Research and Technological Renovation (DGRSRT), Tunisia, under the ARUB program LR11ES48.

References

1. Sharma, A.K., Soni, P.: Mobile Cloud Computing (MCC): Open Research Issues. International Journal of Innovations in Engineering and Technology (IJIET) **2**(1) (February 2013)
2. MacVittie, L., Murphy, A., Silva, P., Salchow, K.: White Paper Controlling the Cloud: Requirements for Cloud Computing (2010)
3. http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf
4. Low, C., Chen, Y.H.: Criteria for the evaluation of a cloud based Hospital information system outsourcing provider. Journal of Medical Systems **36**(6), 3543–3553 (2012)
5. Lian, J.W., David, C., Wang, Y.T.: An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital. International Journal of Information Management (2013). Elsevier
6. Kaur, P.D., Chana, I.: Cloud based intelligent system for delivering health care as a service. Computer methods and programs in biomedicine (2013). Elsevier
7. Pandey, S., Voorsluys, W., Niu, S., Khandoker, A., Buyya, R.: An autonomic cloud environment for hosting ECG data analysis services. Future Generation Computer Systems 147–154 (2012)
8. Vecchiola, C., Chu, X., Buyya, R., Aneka, A.: Software platform for.NET based cloud computing. In: IOS 2009, pp. 267–295 (2009)
9. Kuo, A.M.H.: Opportunities and challenges of cloud computing to improve health care services. Journal of Medical Internet Research (2011)
10. Fusaro, V.A., Patil, P., Gafni, E.D., Wall, P., Tonellato, P.J.M.: Biomedical cloud computing with Amazon web services. PLoS Comput Biol (2011)
11. Piette, J.D., Maendoza-Avelares, M.O., Gancer, M., Mohamed, M., Marinec, N., Krishnan, S.: Preliminary study of a cloud-computing model for chronic illness self-care support in an underdeveloped country **40**(6), 629–632 (2011)

12. Japan, N.E.C.: Fujitsu roll out cloud computing services for hospitals. In: Telecom paper Africa/Asia (2012). http://www.accessmylibrary.com/article1G1290052791/japannecfujitsuroll.html%20Accessed%2020.02.13
13. Lisa, B.A.: Hospital uses cloud computing to improve patient care and reduce costs. http://www.microsoft.eu/cloudcomputing/casestudies/hospitalusescloudcomputingtoimprovepatientcareandreducecosts.aspx (accessed February 20, 2013)
14. Ostrovsky, G.: IBM's cloud computing coming to a hospital near you (2010). http://medgadget.com/2010/08/ibmscloudcomputingcomingtoahospitalnearyou.html (accessed February 20, 2013)
15. Kohn, L.T., Corrigan, J.M., Donaldson, S.: To Err is human: building a safer health system. National Academy Press, Washington (1999)
16. Kopec, D., Kabir, M.H., Reinharth, D., Rothschild, O., Castiglione, J.A.: Human errors in medical practice: systematic classification and reduction with automated information systems. Journal of Medical Systems **27**(4), 297–313 (2003)
17. Ali, M.: Green cloud on the horizon. In: Jaatun, M.G., Zhao, G., Rong, C. (eds.) Cloud Computing. LNCS, vol. 5931, pp. 451–459. Springer, Heidelberg (2009)
18. White Paper: Mobile Cloud Computing solution brief. AEPONA (2010)
19. Sailaja, R., Sheela Devi, M.V.: Mobile Cloud Computing: a lookup. In: International Conference on Computing and Control Engineering (ICCCE) (2012)
20. Varshney, U.: Pervasive healthcare and wireless health monitoring. Journal on Mobile Networks and Applications **12**(2–3), 113–127 (2007)
21. Doukas, C., Pliakas, T., Maglogiannis, I.: Mobile healthcare information management unitizing cloud computing and android OS. In: Annual International Conference of the IEEE on Engineering in Medicine and Biology Society (EMBC), pp. 1037–1040, October (2010)
22. Tang, W-T., Hu, C-M., Hsu, C-Y.: A mobile phone based homecare management system on the cloud. In: Proceedings of the 3rd International Conference on Biomedical and Informatics (BMEI), vol. 6, pp. 2442 (November 2010)
23. Hoang, D.B., Chen, L.: Mobile Cloud for Assistive Healthcare (MoCAsH). In: Proceedings of the 2010 IEEE Asia-Pacific Service Computing Conference (APSCC), p. 325, February 2011
24. Nkosi, M.T., Mekuria, F.: Cloud computing for enhanced mobile health applications. In: Proceedings of the 2nd IEEE International Conference on Cloud Computing Technology and Science, p. 629, February (2011)
25. Jemal, H., Kechaou, Z., Ben Ayed, M.: Swarm intelligence and multi agent system in healthcare. In: 6th International Conference of Soft Computing and Pattern Recognition (SoCPaR) (2014)
26. Jemal, H., Kechaou, Z., Ben Ayed, M., Alimi, A.M.: A Multi agent system for hospital organization. International Journal of Machine Learning and Computing **5**(1), 51–56 (2015)
27. JADE Home Page: Java Agent Development Framework (JADE) (2004). http://jade.tilab.com/
28. Shen, Z., Tong, Q.: The security of cloud computing system enabled by trusted computing technology. In: Proceedings of International Conference on Signal Processing Systems (ICSPS) (2010)