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Applications of Cloud Computing in Health Systems

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Abstract

Introduction: Equitable access to health services is one of the health justice criteria. E-health can sometimes be helpful in this regard. This study is aimed to find the use of cloud computing services across health system.

Method: In the present review article, numerous research papers from different resources, such as MEDLINE, IEEE and Science direct, were studied. Based on the subject, 210 studies were found. After quality analysis of the papers, 78 studies were selected, from which 53 articles were directly related to the applications of cloud computing in health system.

Findings: Cloud computing services are widely used in various industries. Therefore, health system takes advantage of the services. Findings indicate that, the applications of cloud computing in health system, including telemedicine, medical imaging, public and personal health, clinical and hospital information systems, medical decision support system, care, secondary use of health data, serve as different types of specialized software used to analyze gene sequences and archive huge biological data. Generally cloud computing services are available in two sectors in any health system as follows: E-health services and Bioinformatics.

Conclusion: Facilitated access to the E-health services and big data in health systems are the main features of exploiting cloud computing services in health systems. Using cloud computing in health systems not only makes health services more affordable, but also helps nations to achieve health equity.

Keywords: cloud computing, E-health, Cloud E-health

1. Introduction

Justice plays significant role in health systems and one major popular expectation from sovereign governments is to move toward equity, which according to definition of WHO, means closing the gap between socially, economically, demographically, or geographically categorized groups in term of access to resources, opportunities, and facilities. In the context of healthcare, equity is often defined with impartial access to health and hygiene resources and fairness of health determinants (World Health Organization, 2016). Some studies suggest that investments in ICT in health domain may reduce disparities in the process of care (Lee, 2015). On the other hand, others believe that ICT holds the potential to improving the quality, safety and equity of health care, but it also has the potential to unintentionally increase disparities in health and health care (Kieschnick & Raymond, 2011). As we know, most ICT services in health are delivered as E-health service. E-health is the response of modern technology to the health inequity, but when poorly implemented, has a potential for widening the access gap between wealthy people with great access to computers and networks or people who can use these technologies effectively and other people who fall in neither of these categories. This means that a major challenge ahead of E-health is to cross the digital divide between gender, social, geographical, age groups and reach out to people who need the E-health services the most (Eysenbach, 2001; Oh, Rizo, Enkin, & Jadad, 2005) Meanwhile, the growing demands for up-to-date healthcare services, which is mainly due to increasing health-awareness of populations, and the often unsuccessful struggle of regional and national administrations to satisfy this level of demand can be alleviated by e-health solutions, but the lack of infrastructure required for such solutions limit their short and medium term potential. For example, Medical Body Area Network (MBAN), which is a good solution for real-time health monitoring, requires massive amount of scalable ICT infrastructure for data storage and real time processing of information pertaining to millions of patients, which makes it unaffordable for most countries (Lu, Ranjan, & Strazdins, 2014). It is common to describe such massive volumes of complex data with the term "big data". This term is also closely associated with the methods required for capturing, storing, processing, and managing such massive quantities of data. In health system, the major sources of health related to big data could be categorized as: (a) payer–provider big data consisting of electronic health records, insurance records, pharmacy prescriptions, patient feedback, responses and (b) genomics-driven big data comprising genotyping and sequencing data (Abbas, Bilal, Zhang, & Khana, 2014; Barker & Stuart Ward, 2013). One of the ICT innovations which could solve the health inequity and health big data problems is cloud computing model. The Cloud computing is not a new concept; it can date back to 1961 at the MIT Centennial when John McCarthy opined that "computation may someday be organized as a public utility" (Dai, Gao, Guo, Xiao, & Zhang, 2012). Cloud computing is a conceptual model about computer services including a set of servers with remote access to share resources like storages, networks, applications and platform as services. This model prepares opportunities to centralize data storage and real time access to resources and services (Mell & Grance, 2011; Wikipedia, 2016). The cloud computing model is composed of five essential characteristics, four service models, and four deployment models. The five essential characteristics are: On-demand self-service, broad network access, resource pooling, rapid elasticity and measured service. Three models as service layers of cloud are: Data as a Service (DaaS), Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS). And finally four deployment models of cloud are: private cloud, community cloud, public cloud and hybrid cloud. The definition of cloud computing models is presented by national institute of standard and technology (NIST) in a study entitled: "NIST definition of cloud computing" (Mell & Grance, 2011) and another study entitled: "cloud computing: A Perspective study" (Lizhe, Kunze, & Tao, 2008). Cloud computing uses service oriented architecture (SOA) and virtualization technics to be a powerful model. According to cloud computing adaption survey in 2009 in USA and Canada, 32% of healthcare organization use the cloud computing and have taken advantage of its benefits (Mimecast survey, 2010). One method that has successfully tackled the above said challenges is the cloud computing. This technology is expected to make significant changes in the future of electronic health services, and some even predict that by 2020, around 80% of the current online services will be running on the cloud (Sanjay, Ahuja, & Zambrano, 2012). So it seems that health system will take advantage of cloud benefits like other industries. This study is conducted to find out the applications of cloud computing in health system.

2. Method

This review study was intended to present some important concepts about cloud computing services. As such the study discussed the findings of some studies using different scientifically valid publication databases like the MEDLINE, IEEE and Science direct. Based on the subject of the study, 210 studies were found. After quality analysis of these studies, 78 articles were selected of which 53 articles were directly related to the applications of cloud computing in health system. To investigate the quality of the articles in possession, they were evaluated in terms of title, abstract, introduction, research method, results, discussion and references. The scholarly articles were published from 2008 to 2016 were obtained through a comprehensive and detailed review.

3. Findings

According to previous studies, the cloud computing layered model was applied in different aspects of health system. One of the major aspects using cloud computing in health systems is E-health services. The critical importance of applying cloud computing in E-health is to the point that the term "E-health Cloud" has been generated. The capabilities of cloud can alleviate some restriction induced by ICT infrastructure on realization of broader E-health services (Kuo, 2011). Electronic health services are provided in many areas some of which include: Health information system, telemedicine services, personal health record, electronic medical record and electronic health record (Comyn, 2009). The service layer model of E-health Cloud includes:

(1) Data as a Service: presents data (e.g., databases)

(2) Software as a Service: provides software in cloud (e.g., clinical Information systems) where consumers such as healthcare providers get access to the software in the cloud.

(3) Platform as a Service: extends the basic infrastructure with High-level integrated environment to design, build, test, deploy and update online healthcare applications.

(4) Infrastructure as a Service: presents physical processing and storage resources.

Broad spectrum of recipients of services from cloud computing in health systems could be: patients, healthcare organizations, insurance companies, researchers, epidemiologists, etc. (Dai et al., 2012; Kuo, 2011). In the following sections, some of the applications of cloud computing in health systems are presented.

3.1 Healthcare information system as a Service

Apart from the benefits of healthcare information system for health care organizations, software and hardware cost, complexity and inflexibility issues of healthcare system have raised a lot. So, the development of low cost technology is essential to reduce the charges. Cloud computing helps to develop and solve various healthcare issues, including the costs. Cloud computing brings significant benefits to healthcare information systems. It can solve various healthcare issues, such as data storage, data transmission, high setup cost, software maintenance and optimizing resources (Masrom & Rahimli, 2014). For example, in 2012, Yoo et al. managed to combine virtualization technology, a virtual desktop infrastructure, and 400 virtual machines to a construct a cloud within Bundang Hospital of Seoul National University (Korea) to allow managed but easy and pervasive access to hospital information from mobile devices throughout the hospital (Yoo, Kim, Baek, Suh, Chung, and Hwang, 2012).Another example is a work carried out in 2011 by Yao et al. The community cloud-based medical service delivery framework (CMSDF) developed in that work allowed resource exchange between a large general hospital and its affiliated healthcare institutions. They also tested a prototype CMSDF, where a cloud-based virtual desktop infrastructure (VDI) of a large hospital was allowed to share its medical software (as SaaS) with its affiliated healthcare institutions (Yao, Han, Ma, Xue, Chen, & Li, 2014).

3.2 Telemedicine as a Service

Nowadays, cloud computing is used as ICT infrastructure for telemedicine projects. Telemedicine and cloud computing allows health services to be provided with a lower-cost and thus greater availability. In a study in India, researchers studied the implementation of a telemedicine project and reported a number of bugs in the form of low bandwidth or high cost. They developed a cloud-based solution to address these issues (Matlani & Londhe, 2013). In a project in Australia concerning cloud-based telemedicine, the cloud was combined with multiple concepts such as E-appointment, E- consulting, Telemedicine, and E-Prescription to enable patients to use the internet for maintaining remote connection with their physicians and discussing their health-related problems. The resulting system allowed the physician to easily access the patient's medical history, files, test results, etc. This system also provided the physician with data regarding the patient's physiological status through body sensor networks. In that work, telemedicine design was implemented as a hybrid system composed of various communication techniques and hardware including web camera for video feed, Microsoft Expression Encoder 4, and also Windows Azure virtual machine as the server, since it allows adequate video/ audio processing through live streaming media server (Lu, Ranjan, & Strazdins, 2014).

3.3 Personal Health Record (PHR) as a Service

Another high potential application for the cloud in E-health is to manage access to personal health records (PHR) and Electronic Health Records (EHR). The MyPHRmachines system developed in the Eindhoven University of technology is a combination PHR system and cloud technology, which allows users to access raw PHR database via specialized software and share and analyze the PHR data made available. In the architecture of this system, data and software components are separate but software sharing measures allowing joint use of health-related data are predicted. Another advantage of this architecture is its ability to delegate access to different users with more flexibility but also adequate security. For example, patients using MyPHRMachines can share selective health information with a physician without needing to worry about improper storage (and thus misuse) by physician or any third party, as shared data cannot be stored beyond a time limit, and unshared data is securely out of reach of third party software components, services, and specialists (Van Gorp & Comuzzi, 2012). Another cloud-based platform allowing convenient PHR management is the Microsoft HealthVault. This architecture allows patients to store, manage, and share their PHR by providing them with convenient means of importing their health data from a wide range of medical devices into the HealthVault without any need to intermediary tools and software. Once imported, medical data can be easily monitored, managed, and shared through a GUI. This program also possesses advanced sharing features allowing different level of control over shared data, multi-profile sharing, and sharing with designated health organizations, devices, or software applications, all under supervision of data owner. HealthVault can also be embedded into or developed with desktop and mobile applications, as it is based on standard sharing protocols like SOAP, CCR/CCD and XML and is equipped with programmer APIs (Sunyaev, Chornyi, Mauro, & Kremar, 2010).

3.4 Clinical Decision Support System (CDSS) as a Service

E-health services and cloud technology can also be used to augment Clinical Decision Support system (CDSS).

For example, Brayan et al. developed and tested a cloud-based CDSS on a new information management and sharing framework for the repository proposed by Clinical Decision Support Consortium (CDSC), (Middleton, 2009). This repository consists of data concerning hypertension, diabetes, and coronary artery diseases and is based on a community cloud hosted by Partners HealthCare. In that architecture, the cloud hosts a CDSS rule engine that stores a limited data set pertaining to primary care patients and can announce preventive care notification (based on this limited data set) to clinician and end users. That study provided an adequately implementable remote and asynchronous cloud-based decision support system. However, the remaining challenges ahead of actual implementation of cloud-based CDSS, which span over different topics such as governance, semantic interoperability, and usability, need much further work by both biomedical informatics and computer science experts. But overall, one major contribution of that study was the evidence supporting the feasibility of cloud-based decision support systems and their potential applicability in improving these systems for different groups of health care providers (Dixona, Simonaitis, Goldberge, Paterno, Schaeffer, & Hongsermeierf, 2013).

3.5 Biological Software as a Service

Some biologic subject areas such as genomics and proteomics have already been overwhelmed with big data. Wining DNA sequencing throughput, in the race between computer speed and DNA sequencing is the evidence. Nowadays cloud computing model solves the problem of big data in biological software. As an example of big data in biology, we can mention the Gen-Bank (NCBI, 2016). The size of data in this repository is over 150 billion nucleotide bases in more than 162 million sequences in 2013 (Schatz, Langmead & Salzberg, 2010). Using a cloud computing to solve this problem is called “bioinformatics cloud” in some studies. This cloud model delivers a large variety of services from data storage, data acquisition, to data analysis, which in general fall into four categories which are known as DaaS, SaaS, PaaS, IaaS (Dai et al., 2012). Operational samples of each layer are presented in Table1, Including services AWS Public Datasets (Amazon organization, 2016), Cloud Aligner (Sourceforge, 2016), Eoulsan (Jourdren, Bernard, Dillies, & Le Crom, 2016), CloVR (National Human Research Institute, 2016).

Table 1. Examples of services in bioinformatics clouds based on each layer

Layer	**DaaS**	**SaaS**	**PaaS**	**IaaS**
Service	AWS Public Datasets	Cloud Aligner	Eoulsan	CloVR
Description	*Cloud-based archives of GenBank, Ensembl, 1000 Genomes, Model Organism Encyclopedia of DNA Elements, Unigene, Influenza Virus, etc.*	*Fast and full-featured MapReduce based tool for sequence mapping.*	*Cloud-based platform for high throughput sequencing analyses.*	*A portable virtual machine for automated sequence analysis using cloud computing.*

Another example of using cloud in bioinformatics is Azure Blast. Another potential for cloud-based development is in optimization of the BLAST life science algorithm and other data intensive scientific tools in the field of bioinformatics. In case of the BLAST algorithm, pairwise alignments can be carried out independently so parallelization of algorithm is not difficult but rather unaffordable because of large-scale of resources required. With the cloud technology however, there is a better chance for achieving a more readily available large-scale alignment search. One example of this approach is the Azure Blast, which can combine the computing power of thousands of Azure instances running on different machines (Lu, Jackson, & Barga, 2010).

4. Discussion

Based on a study about the translational biomedical informatics in the cloud, the applications are categorized in 4 segments as follows: Bioinformatics (molecules and cells); Imaging informatics (tissues and organs); Clinical informatics (individuals); and Public health informatics (populations) (Chen, Qian, Yan, & Shen, 2013).In another study, the application of cloud in the health scope is divided into six categories referred to as: Telemedicine/Tele consultation; Medical imaging; Public health and Patients’ self-management; Hospital management/Clinical information systems; Therapy; and Secondary use of data (Griebel, Prokosch, Kopcke, Toddenroth, & Christoph, 2015). Finally, the extent of use of cloud computing in the health system can be classified in two subject areas which include E-health services, and Bioinformatics services. Table2 shows the number of found articles from the introduced resources.

Table 2. The number of studies categorized based on found applications

	Application scope	Number of studies
1	E-health services	38
2	Bioinformatics services	15

Nowadays, most software projects of the world which are in the form of Total Systems are implemented as a Web application (Tabatabaei Tabrizi & Sadighi Moshkenani, 2008). In the same way, the countless opportunities provided by the cloud technology for healthcare systems include provision of pay-as-you-go pricing models allowing reduced need for initial capital investments in the ICT infrastructure, better utilization of ICT resources and thus better quality of healthcare services, and provision of efficient and scalable tools for sharing and management of massive volumes of medical information such as EHR and medical files distributed across E-health systems (Lu, Ranjan, & Strazdins, 2014). Addressing the challenges of a modern e-health system (e.g. scalability, agility, cost effectiveness, and ubiquitous availability of medical information) requires extensive collaboration among multiple domains of healthcare and informatics, which according to many experts, can be achieved through innovative cloud-based solutions, and thereby bring about significant changes in the quality and availability of health care services, and speed, universality and ease of health care research (Abbas et al., 2014; Kuo, 2011). However, the cloud computing services face challenges like data security management.

5. Conclusion

Obviously, the applications of cloud computing in health systems are not limited to the examples which were mentioned in this study. Using cloud computing in any kind of E-health services will be efficacious when we need qualitative parameters including On-demand self-service, broad network access, ICT resource pooling, rapid elasticity in ICT and measured services. Various applications are developed based on the nature of the service which provides sharing resources in four levels (DaaS, SaaS, PaaS and IaaS). The point is that, the use of cloud computing in health systems not only makes health services more affordable, but also helps nations to achieve health equity.

Competing Interests Statement

The authors declare that there is no conflict of interests regarding the publication of this paper.

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