

Cloud Computing: A Key Enabler for Smart Healthcare

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Abstract—Cloud computing acts as a key success factor to leverage and enable development of smart healthcare. Healthcare sector is information critical industry that deals with human lives. Transforming from traditional paper work to automated and electronic healthcare has enhanced the medical process and implemented green concepts by saving loads of papers and physical files not to mention error prone efficient medical services. Evolvement of information and communication technology accelerated the agile way of thinking and facilitated the innovation of smart technologies such as telemedicine, smart mobiles, smart cards, robots, sensors, RFID's that are context aware and able to sense and diagnose complex situations since these systems are ubiquitous, online, intelligent, predictive and capable to decide and interact with the environment. These diverse smart systems and technologies requires a way to integrate and work in different technology platforms in order to be utilized in easy, efficient and effective way. Cloud computing offers a flexible, cost effective, collaborative, multi-tenant technology which acts as a key role in transforming the traditional electronic healthcare into smart healthcare that combines the latest technologies via the internet on pay-per-use basis. This research paper represents the definition of smart healthcare and the role of cloud computing as a key success factor for enabling smart healthcare.

Keywords-Cloud Computing; Smart Healthcare; Smart Home

I. INTRODUCTION

The advent of information technology has brought many advantages as well as challenges to healthcare sector. Improving efficiency and error prone cost effective real time quality of healthcare services are the basic objectives of automating and digitalizing the way people access and process their information. Traditional method of healthcare had various issues such as the healthcare work flow process was dependent on paper work. Physical file storage was done in the clinic/hospital storage cabinets which offered limited capacity against the increasing population demands. Lack of real time communication between patients in rural places caused insufficient service and sometimes death or severe side effects to the patients in case of crisis. Increasing number of patients and their multiple needs of reports, x-rays and laboratory tests leads to insufficient storage, waste of time and effort to search for data especially for some old data. IT solutions such as electronic health brought huge benefits in solving issues of

human errors and providing an agile way of accessing and processing large volume of patient's information as well as saving papers and storage space. However, the increasing number of population and the accelerating innovations of nanotechnology, smart phones, healthcare devices, sensors, RFID's..., have created big issues of how to integrate and link all this together, where to save these huge amount of information and access it so easy[1]. The trend to innovate smart houses for home care especially for elder and disabled people and their communication with the hospital via the internet also needs to be highly sufficient to deliver the medical service in real time. Cloud computing evolved as a new IT paradigm to provide an agile method to deliver healthcare services in smart way. Cloud computing is a business model that has inherited the benefit of other technologies such as grid, distributed, utility computing, pervasive, ubiquitous and virtualization to deliver cost effective, scalable, multi-tenant and pay-per-use services. It is suitable for easy and complex systems. The huge benefit of cloud computing in healthcare is that it will support current electronic healthcare sector and the future trend smart healthcare systems as it provides latest standardize applications through SaaS, IT tools for developers via PaaS, virtualization and infrastructure with IaaS. It facilitates the communication between the patient and the doctor from any device\any where through the internet in real time that will deliver higher quality real time cost effective agile healthcare services. This paper is organized as follows: section two defines smart healthcare. Section three defines the importance of smartness in health care sector. Section four discusses benefits of cloud computing for healthcare sector. Section five discusses role of cloud computing in smart healthcare. Finally section six discusses the challenges and future work of cloud computing in smart healthcare sector.

II. SMART HEALTHCARE

The need to improve the quality and efficiency of healthcare not only in hospitals but also in homes is becoming more and more important for patients and society worldwide. The availability of new technologies such as micro technologies, telecommunication, smart mobiles, and flexible sensors facilitated the development of user-friendly devices that are more comfortable and secure for the patient. Smart healthcare contains smart systems, telemedicine, smart

devices, sensors, smart clothes, smart cards, RFID, smart hospitals and smart homes. These smart buildings, devices, applications and systems are designed and developed to be aware of their context in order to gather the patient's information in efficient, effective and quality way that can assimilate information to support care decisions. A smarter healthcare system is interconnected for capturing accurate data, faster and for performing more detailed analysis which means integrating the data towards patient-centric approach. Smart healthcare is instrumented with digital and electronic devices in order to automatically capture accurate real-time information. Smart healthcare is intelligent as it applies advanced analytics to improve research, diagnosis and treatment. Overall smart healthcare integrate clinical, financial, operational and other information into an interconnected environment of medical intelligence that helps doctors deliver more personalized care, take smarter decisions and deliver higher quality care. Listed below is some of the smart healthcare content. [2]

A. Smart Homes

Smart homecare refers to smart homes that contains smart applications and electronic devices to assess both the user's emotional state and body health state that integrates humans, health signals (ECG, EMG, SKT and RSP), and services (health promotion, diet and recreation advices) [3]. Smart homecare provide assistive technologies for supporting people with specific demands such as elderly people, disabled or patients in their daily activities by enhancing the physical spaces in their homes with information, communication and sensing technology to make these smart homes sensitive and responsive to the presence of people and provide assistive services in different areas of life, including assistance to carry out daily activities, health and activity monitoring, enhancing safety and security, getting access to social, medical and emergency systems as illustrated in Fig 1.

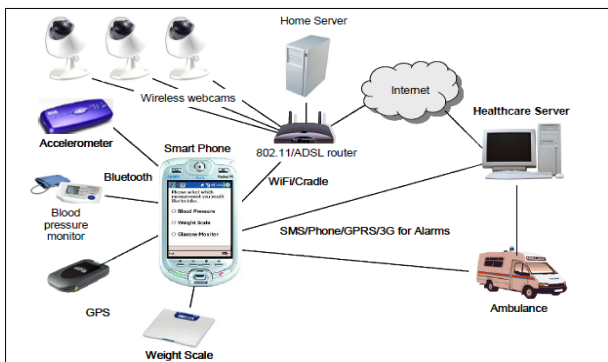


Figure 1. Smart Home

Complex systems are connected together using smart phones and wireless wearable sensors that enables analysis of the sensor data on a local or remote device in real-time and it has inbuilt emergency and location functions for external assistance to be alerted automatically in the case of an

emergency which will assist in monitoring the patient and delivering quality real time medical services [4].

B. Smart Hospitals

Smart hospitals consist of various departments and sections that are better connected with electronic smart devices, accurate up to date information, faster and more detailed analysis. Smart hospital rooms use real-time location tracking devices to collect the patient's information from the EMR to computer screens in the patient's room.



Figure 2. Smart Hospital Room

These smart hospital rooms are intelligent enough to give different sets of patient data to different categories of providers as indicated for example in Fig 2. [5] Screen (1) shows Patient's Screen which is for identifying and tracking patients caregivers and day's activities while screen (2) represents Caregiver Screen, which gives clinicians access to essential information, including allergies and medication regimens in addition to assisting nurses and aides quickly to document vital signs and complete basic tasks on a touch screen that will update the EMR. Finally screen (3) represents Smart Board, which replaces the conventional dry erase board at the nursing station as it lists patients' names and their associated caregivers in addition to updating the staff on new physician orders.[5]. Smart hospitals depends on the usage of smart healthcare cards that refers to mini computers without display screens or keyboards which contain an embedded integrated secure microcontroller with internal memory or memory chip. Smart cards are used for various purposes such as patients Identification and authentication, matching patients to their particular data, synchronizing data from different sources, security and access control. Smart healthcare cards can be integrated into current systems and processes to provide reduced administrative time and cost by automating patient identification, reducing number of rejected claims and faster payments. Another component of smart healthcare is wearable technology inform of smart cloths that contains sensors for monitoring the patient's vital signs [6]. However, since smart healthcare is instrumented, interconnected and intelligent, it combines all complex systems of the healthcare communities such as pharmacies, insurance companies, laboratories, research and development via the internet.

III. IMPORTANCE OF SMARTNESS IN HEALTHCARE SECTOR

Since the advent of various smart technologies including the existence of many complex systems and communities of healthcare that needs to be integrated and aware of its context to enable accurate sharing of real time information. Smart healthcare provide quality of service, efficient administration, better patient communication, improved public health and security as follows:

A. *Quality of care*

In medicine seconds can make difference between life and death for example if someone has heart attack his/her life depends on timely access to current and accurate information for doctors or emergency department to take the right procedures to save his/her life. With smart healthcare enhanced doctor-to-doctor communication is optimized and physicians can instantly share patients test results with other doctors, healthcare providers, labs, pharmacies, and clinics which will streamline the process of consultation and improve healthcare service delivery. In addition to improved prescription writing and pharmacy interaction through electronic prescriptions, not to mention availability from anywhere and from any device is another benchmark as physicians and other healthcare providers can review the complete medical history of a patient, regardless of the location of either the patient or the provider. Improved emergency support as accessing and processing patients' records will be more efficient and effective since interoperable systems provides an immediate access to lab results that allows the physicians to review test results as soon as possible that includes patients drug information which provides more comprehensive updated data at the time of care that will reduces suffering and save lives. In case of public health smart healthcare systems offers automated tracking that supports medical research and practices such as bio surveillance, quick response to disease, chemical or biological attacks, improved monitoring of adverse drug effects [7]

IV. CLOUD COMPUTING AND HEALTHCARE SECTOR

Cloud computing is a model that enables convenient, on-demand network access to a shared pool of configurable computing resources such as (networks, servers, storage, applications and services) that can be rapidly provisioned and released with minimal management effort or service provider's interaction [8]. Cloud computing has unique features such as on-demand self-service, ubiquitous network access, resource pooling, rapid elasticity and pay-per-use pattern. It offers different kinds of service delivery models to the clients' such as Software as a Service (SaaS), Platform as a Service (PaaS) and infrastructure as a service (IaaS) through four service deployment models private, community, public and hybrid clouds. However, selection of these cloud delivery and deployment service models depends on clients' data sensitivity and management requirements. Cloud computing are useful for both healthcare sectors (hospitals, clinics, insurance companies, pharmacies, research and development) and clients (patients) as it improves the utilization of their resources to the maximum. It reduces complexity and risk, delivers a shorter time to value and enables efficient

administration of electronic health records and personalized medicine goals for improved safety and quality service of care. However, Cloud computing benefits healthcare sector with scalability, cost reduction, data availability, reliability and resilience. According to Schweitzer [9], Haughton [10], and Kabachinski [11] that cloud computing can reduce electronic health record (EHR) start-up expenses which will encourage its adoption. Several informatics innovations have demonstrated that cloud computing has the potential to overcome these difficulties [12-17]. Gartner stated that cloud service revenues to reach 148.8 billion USD by 2014, with large percentage from the healthcare cloud sector [18]. In the following section some of the benefits of cloud computing for healthcare sector will be discussed as follows:

A. *Cost Saving*

There is no need to invest and buy new IT infrastructure or pay licensing cost, no need for upgrading and maintenance as all of this are done by cloud service provider that charges only for the service used which saves huge amount of capital cost. For example cloud computing can reduce electronic health record (EHR) startup expenses, such as hardware, software, networking, personnel, and licensing fees.

B. *Clients Assistant*

Clients who are benefiting of healthcare services include short and long duration patients, old people, disabled people and people who have diseases such as cancer or HIV. Cloud computing is internet based computing that enables the world to be more instrumented, interconnected and intelligent through its different types of service delivery and deployment models that are selected according to the clients requirements on pay-per-use basis. SaaS clients can access healthcare portals through a web browser via internet and interact with the doctors or any related party on real time basis. They can share information, make appointments, pay online, consult a doctor and so on. For elder people they can monitor their health status in home through smart healthcare devices and share their information such as Microsoft HealthVault [19].

C. *Healthcare Organizations Assistant*

Cloud computing offers SaaS for the hospitals and related healthcare parties real time accurate up to date shared communication, in addition cloud computing offers PaaS for the healthcare programmers and developers to innovate and do their research and programs as service on demands with latest technological tools. However, through IaaS healthcare organizations are delivered virtual machines that will free them from investing in IT infrastructure and the burden of managing it as cloud service provider is responsible of facilitating all of this on pay-per-use basis.

D. *Single Point of Access*

Cloud computing provides collaboration between the systems. The patient's record are recorded once but accessed and processed from many places. If the patient inputs his/her vital signs from an electronic device at his/her home which is connected to the doctor device and lab device then all of the

parties can view his/her health status and give the best service for them which saves time, effort and cost not to mention saving the patient's life in some cases.

E. Multi-Tenancy

Different kinds of users can access the required patients record according to their authorization from a shared single access point which utilizes the storage space and prevents redundant data in addition to patients' data is updated by all parties that makes it accurate and helps the doctors for better quality medicating services.

F. Sustainable and Green

Sustainability is provided through improved resource utilization, more efficient systems, and less usage of papers. Transportation efforts and cost of petrol are less for example a hospital collaborates with physicians, nursing homes and home health agencies. Physicians exchange information online with the hospital and other providers about lab results, medications, allergies and patient health status. The patients can share their information with healthcare related party from home. Through usage of SaaS less effort and faster real time green medical services are gained.

G. Accurate handling of Biomedical Data

Cloud computing provides the flexibility of accessible data from multiple endpoints from operating rooms, to examining rooms which offers real time efficient data gathering. Multiple care providers can update and track patients EHR [20].

H. Optimized Security

In spite of security being an issue from the beginning of time from traditional to electronic system but in cloud computing it is more optimized than traditional systems, in part because providers are able to devote resources to solving security issues that many clients cannot afford [21].

I. CLOUD COMPUTING ROLE IN SMART HEALTHCARE

Cloud computing plays a key success factor as an enabler for smart healthcare is delivered inform of service delivery and deployment models and can be used for delivering the required service to healthcare as follows:

A. Pre-Hospital

Taking care of people health and wellbeing starts by preventing the illness and leading healthy life, delivering primary care includes the diagnosis, treatment and management of health issues with services delivered predominantly by physicians. Pre-Hospital primary smart healthcare identify and address the broader determinants of health including population health, sickness prevention, and health promotion with services provided by physicians and other healthcare medicine. Cloud service provider offers healthcare organization different service layers which are IaaS, PaaS and SaaS. These healthcare organizations use IaaS virtual machines that illuminate the need for the healthcare organizations to spend on buying IT infrastructure with licensing and maintenance cost. In addition to the usage of

SaaS for their accessing and processing the work flow that range from accessing and processing the patient's medical records to hospital records. Clinical documents are stored in and retrieved from the cloud servers and are made available to appropriate authorized recipients. However, during pre-hospital emergency healthcare delivery, emergency case data is stored in the ambulance service database servers. Upon ambulance arrival data is shared and retrieved between all the related healthcare parties and is made readily available to authorized users to insure that timely and accurate patient information is made available at the point of care when needed. In terms of smart healthcare systems people are making appointment through SaaS, registering to the hospital systems and sharing their information with the doctors. In case of elder and disabled people they are connected from their smart homes with smart electronic devices that collect their real time vital signs data and send an alert to the doctors in emergency cases. Cloud service provider delivers the service to the people and healthcare organizations each according to their requirements as illustrated in Fig 3. [7]

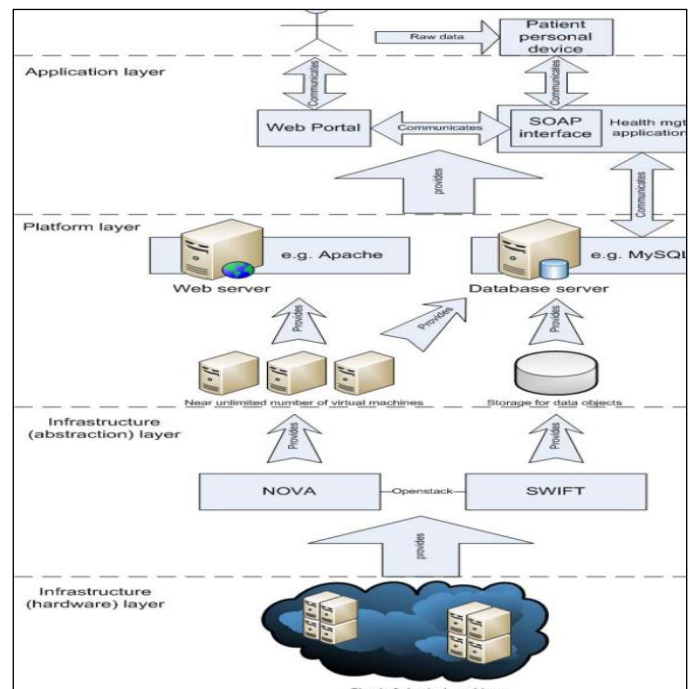


Figure 3. Healthcare System on Cloud Computing

Patients use SaaS to register their information and take appointments before arriving to hospital. Healthcare organization use SaaS for achieving their daily tasks such as registering the patients, making appointments, collaborating with insurance companies...etc. Cloud computing offers the latest technology and management so the healthcare actors will only consider quality of real time cost effective services. Another major area that cloud computing features helps smart healthcare systems in medical research area for drugs or disease tracking in addition to educating people on how lead healthy life and how to act in disaster or emergency cases.

B. In-Hospital

Cloud computing provide the access control mechanism and privileges to the healthcare staff according to the task requirement and for the portion of information required. Cloud computing offers IaaS to healthcare organizations that includes virtual machines and storage that can scale up and down according to healthcare organizations needs, also it will offer which mean that cloud computing takes the responsibility of managing the IT and leaving healthcare service providers to concentrate on delivering a real time quality of service. SaaS offers efficient information sharing between different complex smart systems such as smart hospital rooms that has the patients' real time information and other department such as laboratory and smart operating room in order to get real time accurate patients information that will enable delivering quality of medical service.

C. After-Hospital

In this stage smart healthcare usage of cloud computing SaaS is for tracking the patients from their home, office in any location (ubiquitous) from any smart devise (pervasive) any time (availability), tracking diseases, reaching people in rural places, collaborating with the other healthcare communities such as insurance companies, research and development for critical diseases and so on. However, platform as a service (PaaS) is needed to provide the smart healthcare developers cost effective latest technology tools to develop the robots and the software needed in nanotechnology field and in any critical healthcare related field on pay-per-use bases which is so important as low cost and up to date technology facilitate the developer with more agile new ways of thinking and developing new technologies for healthcare sectors especially for disabled and elderly people.[7]

I. CONCLUSION AND FUTURE WORK

Cloud computing facilitates healthcare providers to focus more on increasing quality of delivered healthcare services instead of managing their IT and simplifies information sharing among various healthcare institutions involved in the care process, which is of utmost importance in healthcare. Continues evolvment of new healthcare devices have been invented to sense humans' vital signs and monitor any critical change in his/her health status. These devices are connected through internet. The need for cloud computing raised as it provides a technology platform inform of services on demand that facilitates scalable communication without the need of buying new hardware or software to be able to deal with all technology innovations. Through this paper an overview of healthcare and the role of cloud computing as an enabler to transform healthcare to smarter greener with a proposed future work for implementing built in security for ensuring trust in deploying trusted cloud computing paradigm for smart healthcare sector since cloud computing does not come with benefits only. Moving the infrastructure and sensitive patient data from hospitals to the cloud can pose severe security and privacy issues [22]. One of the main security and privacy challenges is to facilitate cloud patient-centric and data-centric

protections for patient's personal data, such as accessing, using, storing, updating and distributing electronic health data that should be controlled according to patient's privacy policies and consent. Insuring security in healthcare cloud must be achieved from various perspectives as our proposed solution as follows: Trusted Client as the electronic devices used from the client's side should have security built in using trusted platform module (TPM) and mobile trusted platform module (MTM) to insure optimized security through authentication, encryption and attestation features of TPM and MTM [23]. In addition to Trusted Cloud as the infrastructure should have security built in using TPM as a chain of trust with all of its features and virtual TPM for the virtual machines that will provide encryption and attestation features of TPM and vTPM. As for storage it should have self encrypting drive (SED) built in for authentication and encryption. However, network also has to be secured through trusted network connect (TCN) that is built in security to provide an industry standard approach to network security and network access control [23]. Service level agreement (SLA) which is agreement made between the cloud service provider, healthcare sector and /or the clients should be monitored from the government for the cloud service provider to adopt better and clearer policies and practices in order to build trust on this cloud services.

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