A Conceptual Framework for IoT-based Healthcare System using Cloud Computing

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Abstract

Internet of Things (IoT) envisions a future in which anything/anyone/anyservice can be linked by means of appropriate information and communication technologies which will bring technological revolution in the fields of domestics, smart homes, healthcare systems, goods monitoring and logistics. This paper presents the applications of IoT and addresses some essential parameters and characteristics of each of the applications of IoT. In this paper, we have deeply explored the role of IoT in healthcare delivery and its technological aspects that make it a reality and examine the opportunities. A cloud based conceptual framework has been proposed which will be beneficial to the healthcare industry implementing IoT healthcare solutions.

***Index Terms*—Internet of Things; Cloud Computing; Healthcare**

I. INTRODUCTION

Nowadays, the Internet is used by more than two billion customers around the world to browse contents, send and receive emails, access multimedia resources, play online games, and social networking. Moreover, the Internet is also expected to serve as a global platform to interconnect physical objects or *'Things'*, thus, enabling new ways of working, interacting, entertaining and living [12, 13]. Internet technology has become ubiquitous within our society which is infiltrating all aspects of our lives, and it is better to call it as necessity rather than a convenience. The term IoT, first used by Kevin Ashton, describes the emerging global, Internet-based information service architecture [15]. The IoT incorporates concepts from pervasive, ubiquitous, and ambient computing, which have been evolved in last two decades and have now reached at some level of maturity. The IoT is envisioned as a network of billion people, objects, machines interacting to one another, invisibly connected with sensors, actuators, making useful in everyday lives. The future will be dominated by the *'Internet of Things'* which will serve as a global platform to interconnect physical objects, things, humans, thus, enabling new ways of working, communicating, interacting, entertaining, and living. The IoT is a novel paradigm in which every physical object which you wear, what/where you drive, what you read/see, and anything including the people you meet, the places you go, will be connected, addressed and controlled remotely [1]. As the cost of IoT devices, mobiles and network connectivity continues to drop, and it is easy to see that everything and everyone are online over wireless network for 24 hours in a day. The Communication technology has become faster, ubiquitous and cheaper which will surely changes the way the people access information. The adoption of RFID based sensor technology and other similar technologies are spurring innovation and the development of the Internet of Things [7, 8]. This novel integrated RFID Sensor—Internet framework shall form the core technology around which a smart environment will be shaped. The information generated will be shared across diverse platforms and applications, to develop a common operating picture (COP) of an environment, where control of certain unrestricted *'Things'* is made possible [10]. The IoT uses the concept of object hyperlinking which promises humans to live in a smart, highly networked world, which allows for a wide range of interactions with this environment. Object hyperlinking aims to extend the Internet to the real world by attaching object tags with URLs as meta-objects to tangible objects or locations. Most of them rely on some kind of unique marker integrated in or attached to the object. Some of these markers can be analyzed using different kinds of wireless near field communication (for instance RFID tags [3] or Bluetooth beacons [4]), others are visual markers and can be analysed using cameras, for instance standard 1-D barcodes [5] or their modern counterparts, the 2-D barcodes [6]. These object tags can then be read by a wireless mobile device and information about objects and locations retrieved and displayed [2]. The computing for the IoT may be processed locally or embedded in microcontroller enabled devices or even implanted in the human body [11]. The huge data generated from various sources may even reside in the *'Cloud'*, which requires greater processing power to retrieve information in a secure and reliable manner.

The shift from the Internet used for interconnecting end-user devices to the Internet used for interconnecting physical objects that communicate with each other and/or

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with humans will open a multiple businesses and market opportunities in a seamless manner in the fields of smart city, e-health, real-time monitoring of industrial processes, and intelligent logistics and various others [14].

II The IoT-based Healthcare System

The healthcare represents one of the top challenges that every country is facing today. Although healthcare industry invests heavily in information technology, yet the promised improvement in patient safety and productivity have not been realized up to the standards. Even today organizations still rely on paper medical records and handwritten notes to inform and make decisions. Digital information is siloed between departments and applications. Sharing of patient data among clinicians, departments and even patients is rare and complex. Embracing cloud and IoT technology in healthcare may be the answer to enabling healthcare organizations to focus their efforts on clinically relevant services and improved patient outcomes which will make health monitoring, diagnostics and treatment in more timely and convenient manner with the reduced costs. The IoT can bring multiple benefits to healthcare through the use of RFID tags, sensors/ detectors, intelligent equipments, etc. It enables online interaction of patients, identification and tracking of patients, doctor‘s locations, tracking of patient medical reports and equipment‘s tracking and tracing medical supply chain, logistics, drug management and drug counterfeit detection, etc.

The Internet of Things has capabilities to connect D2M (Device-to-Machine), O2O (Object-to-Object), P2D (Patient-to-Doctor), P2M (Patient-to-Machine), D2M (Doctor-to-Machine), S2M (Sensor-to-Mobile), M2H (Mobile-to-Human), T2R (Tag-to-Reader). It intelligently connects humans, machines, smart devices, and dynamic systems which ensure the effective healthcare and monitoring system, medical asset monitoring and medical waste management system [27]. For instance, wearable bands on patient‘s wrist can track pulse, blood pressure, red blood cell counts, glucose and cholesterol level and constantly send the reports to medical actor‘s smart phones or tablets as well as reminders to take the medication, walking etc to patient‘s smart phones.

The Internet of Things is going to revolutionize healthcare in terms of investment, security, privacy, reliability and return-on-investment (ROI), if truly trusted by medical enterprises and community. The tracking and monitoring of patients and healthcare actors are one of the biggest challenging research directions for IoT Healthcare. In one of the findings by US Institute of Medicine argues that medical errors persist as the number 3 killer claiming the lives of some 400,000 people each year. Some of these errors involve:

- Missed and delayed diagnoses.
- Failing to order appropriate tests or initiate follow up.
- Inability to access patient‘s medical history.
- Prescribing the wrong pharmaceutical drug.
- Not knowing whether a patient is allergic to a certain drug.

Due to possibility of such human-entered error, healthcare needs automation where the devices have the ability to gather data on their own which reduces the risk of errors. Fewer errors can mean increased efficiency, lower costs and improvements in healthcare services where an error can literally be the difference between life and death.

III Related Work

Recent technological advances in sensors facilitate are highly suitable for Healthcare Application. Wireless Body Area Sensor Networks (WBASNs) are emerging as promising enabling technologies to implement e-health [19]. A WBASN for health monitoring consists of multiple sensor nodes worn by patient that can measure and report the patient‘s physiological state.

Microsoft has launched a web page [16] where consumers using PHR from Google Health can have their personal health information transferred to a Microsoft Health Vault account. As the demise of Google Health brings into sharper focus the challenges of establishing an online PHR business model, PHRs will see a 33% gain in revenue through 2015 as doctors push patients to use health IT systems [17]. The Microsoft Connected Health Framework (CHF) architecture [18] consists of process models, service models and information models.

Henry Mayo Newhall Hospital in Valencia, California (USA) has implemented the concepts of IoT. They wanted to enable doctors to spend less time at computers and more time with the patients. Realizing the potential of the Internet of Things, the hospital has created an Intelligent System using Microsoft technology that vastly speeds up the access of patient data. The system connects 175 new thin clients‘ devices that draw centralized computing power and its physicians‘ own tablets and other devices from existing data centres and systems, creating anywhere, anytime access to data from patient records to test results, prescriptions and more. By focusing on this one aspect of its business, the hospital is able to provide better care while vastly improving doctor efficiency. Henry Mayo implemented an intelligent single sign-on solution from Health Cast and Microsoft to vastly simplify the data-access process.

The major advantages seen by hospital after implementing this new system were:

1. Advances in sensor and connectivity technology are allowing devices to collect records and analyze data that was not accessible before. The new system allows doctors the secure access to review lab tests, enter prescriptions, or look at patient records, cut-in

medication delivery time by two-thirds from either installed terminals or their own laptops, tablets or smart phones, so they can provide care from anywhere in a fraction of the time.

2. Hospital‘s previous system was cumbersome and time-consuming, running a variety of separate software applications, including those for patient medical records, timekeeping systems, medical imaging repositories, speech recognition software and emails. The doctors and staff needed to access information throughout the day from different locations across the hospital and logging in each time could take up to two minutes and doctors had to memorize a large number of usernames and passwords. Now with new emergence of this solution, the proximity badge automatically enters the username, and only one password needed to be entered at the beginning of the day. Because of this staff members are less likely to forget their login information or locking themselves out of the system. The new solution was so easy to use that Henry Mayo‘s IT staffs has seen a 70 percent drop in password-related help-desk calls.

The AT&T Medical imaging and information Management Solution (MiiM)[20], enables health professionals, to expedite patient care by means of web-enabled virtual collaboration and mutual interpretation of patient images, such as X-rays, computed tomography (CT) or Magnetic Resonance Imaging (MRI) scans[20]. The system allows users access to review patient images almost instantly, from anywhere, giving attending physicians critical point-of-care updates and time to see more patients. This significantly reduces long-term technology costs and speeds patient care management.The solution can also enable national hospital networks to manage referral patient image when transferring to and from other institutions, anywhere in the world. Accenture cloud migration services help these advances in clinical workflow gain faster adoption in the healthcare.

It is clearly visible from all above implementations of e-healthcare by Microsoft, Henry Mayo or AT&T have contributed significantly in building the environment for e-Health Cloud. But these efforts are still limited to Cloud-based storage solutions and Healthcare applications or systems or platform solutions automating single entity in the health care industry. These are the cloud-based system to automate the process of collecting patients‘ vital data via a network of sensors connected to legacy medical devices, and to deliver the data to a medical center‘s –eloud” for storage, processing, and distribution. The main benefits of the system are that it provides users with 7-days-a-week, real-time data collecting, eliminates manual collection work and the possibility of typing errors, and eases the deployment process.

Through Our proposed system we would like to build a network among all the entities (hospitals, doctors, patients, Labs, Pharmacist, Nurses) participating in healthcare. This proposed model will not only limited to the entities under one umbrella but will cover nationwide entities. We tried to implement the concepts of IoT where these entities would be directly communicating to cloud. For example, the patient would be wearing some sensors/RFID tags continuously fetching his current health conditions and simultaneously uploading on the cloud which can be accessed by other health actors almost instantly. It replaces the process of having a health professional come by at regular intervals to check the patient‘s health condition (BP, sugar level, heart beat, pulse rate), instead providing a continuous automated flow of information. In this way, it simultaneously improves the quality of care through constant attention and lowers the cost of care by eliminating the need for a caregiver to actively engage in data collection and analysis. There are people all over the world whose health may suffer because they don‘t have ready access to effective health monitoring. But our proposed model where we are creating the network among all healthcare actors are now making it possible for reaching the doctors to the patients to make health recommendations instead of vice-versa by securely capture patient health data(medical history, reports) from a cloud.

IV. **Proposed Framework for IoT-based Healthcare System on Cloud**

Patients today are more educated to their diseases and better advocates for their own healthcare which increasingly demands access to the latest technologies. They want to seek the best care at the best cost and are willing to investigate their options. As a result, demands for access to personal patient records are increasing and organizations need to keep up. When citizens can access bank accounts from anywhere in the world, withdraw money, get balances and make payments, why they cannot have universal access to their secure health information. With advancement of technologies like IoT and Cloud, and rising adoption of bring-your-own-device (BYOD) working practices , the sharing of data and collaboration among services will have transformative impact on personal healthcare. Based on the same concept, we proposed a comprehensive *Cloud-IoT* healthcare system to empower depressed patients over their treatment process. In this proposed framework we created a Network consisting of all the health Actors for sharing and collaboration of data and service on single platform.

The stakeholder involved in the healthcare scenario include: patients and family members, healthcare professionals (doctors, nurses, attendants), pharmacists, medical labs, hospitals and public authorities such as auditing or legal authorities that need to access healthcare data under specific conditions and which are also responsible for validating and authorizing of these health actors. The proposed *Cloud-IoT* based integrated solution will consists of various applications like e-prescribing system, EHR (electronic health records), personal health records, clinical decision systems, pharmacy system etc. Figure 1 presents a proposed *Cloud-IoT* based healthcare framework. This framework will offer broad range of healthcare applications to different stakeholders at

different levels. The physicians can use *Cloud-IoT* for their improved clinical results and improved diagnosis of patients. The patients can do their self assessment for monitoring their health. They can find hospitals and other related organizations for providing improved healthcare services. The personal monitoring devices are used to monitor and collect patient's physical activity data or sleep information. Besides it, the cloud service provider offers *Platform as a Service (PaaS)* and *Infrastructure as a Service (IaaS)* to host Cloud-IoT healthcare applications.

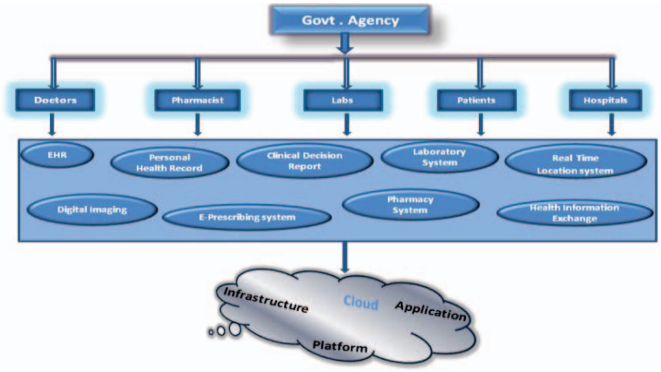

Figure 1. Cloud-IoT based healthcare framework

A) Use Case Scenario

The above proposed framework is presented below in more detailed manner. In order to refine the application framework presented in Figure 1, we have analyzed the processes of the proposed system. The actors and data flows involved in above framework are highlighted in Figure 2.

Consider an example use case as shown in Figure 2. The patient wears a monitoring device to collect own physical and sleep activities information. These monitoring devices can be sensors/RFID tags which are strategically placed on the human body. Sensors/RFID tags can be worn as stand-alone devices or can be built into jewellery, applied as tiny patches on the skin, hidden in the user's clothes or shoes, or even implanted in the user's body thus creating WBASN. Each node in the WBASN is typically capable of sensing, sampling, processing, and wirelessly communicating one or more physiological signals. It can also help to determine the user's location, discriminate among the user's states (e.g., lying, sitting, walking, running), or estimate the type and level of the user's physical activity. The activity data are uploaded from the device, via the EHR system, to user front end for manual uploading. The data then hosted in the cloud's EHR application back-end and saved in the patient's medical profile. The stored data may be shared with the doctors and hospitals on demand by the patients. The health professionals, such as cardiologists and radiologists expedite patient care by accessing the stored patient data. The patients and labs by mutual consent can also upload X-rays, Computed Tomography (CT) Scans or Magnetic Resonance Imaging (MRI) scans in patient's medical e-profile and that would be shared via cloud platforms in real time with top specialists anywhere in the world, enabling diagnosis and recommendations overnight. Courses of treatment and outcomes could also be monitored anywhere in the same way. If someone travelling overseas fell ill, they could provide local doctors on the ground with direct and immediate access to their health records, and get more appropriate treatment as a result.The medicines precribed by Doctors is available to Pharmacist also. A pharmacist would be able to check a person's allergies when issuing a prescription through patient's medical profile. A hospital attending a traffic accident could check an individual's blood type and pre-existing conditions mentioned in his profile.

By means of above IoT-Cloud collaboration patients' digitized health information—medical histories, scan images, blood types, allergies, medical labs reports can flow freely across the world, accessible via secure authentication and will be easily interpreted by health actors. The system allows health actors access to review patient images almost instantly, from anywhere, giving physicians critical point-of-care updates and time to see more patients. This system will significantly reduce long-term technology costs and enhance speedy patient care management. The solution can also enable private and government hospital networks across the nation to manage referral patient image when transferring to and from other institutions, anywhere in the country.

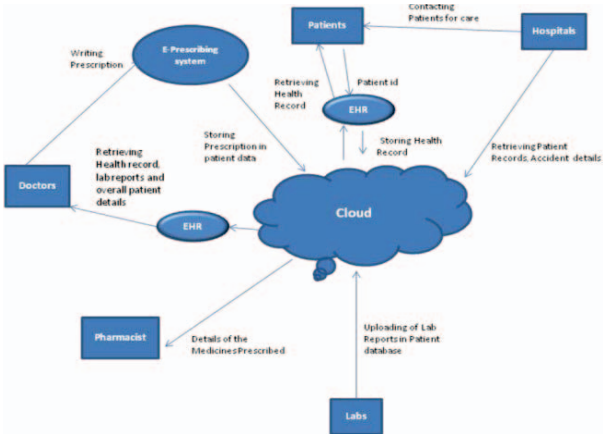

Figure 2. Actors and data flows in Cloud-IoT based healthcare framework

V. Conclusions and Future Scope

This paper tries to emphasize on an IoT-Cloud enabled healthcare system not only to realize the illustration and traceability of healthcare actors but guarantee the improved healthcare services. We have proposed a cloud-IoT framework in which medical information can be safely transferred, with the consent of the patients and other health actors. Through our proposed system we would like to build a network among all the entities (hospitals, doctors, patients,

Labs, Pharmacist, Nurses) participating in healthcare which certainly leads to the improvement in communication and collaboration among these entities providing better care and services to the patients. The proposed IoT-Health Cloud represents an enabling technology for many healthcare providers to face many challenges such as rising healthcare delivery costs, information sharing, and shortage of healthcare professionals better care and enhanced services for the patients. However, the benefits gained are offset by issues of trust, privacy, and security in addition to several technical issues that must be addressed before healthcare providers can fully adopt and trust the IoT-Health Cloud. A complete model for implementing the security is still required.

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