A review on internet of things and its applications in healthcare

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ABSTRACT

Internet of Things is a buzzword in the computing and present technological world. IoT can change the way human being live their life by making it their more convenient and smart. IoT has the capability to add intelligence in real world objects and make them communicate with each other. IoT provides a common infrastructure through which different devices can be connected and communicate smartly. Sensor networks, RFID (Radio Frequency Identification), Wi-Fi (Wireless Fidelity), IP (Internet Protocol), ZigBee, AI (Artificial Intelligence), Bluetooth etc. are few technologies which will make IoT applications more successful and also powerful. IoT solutions for healthcare in the developing countries have brought revolutions to reduce mortality rate and provide healthcare in low cost. Smart IoT based healthcare applications plays a vital role in tracking and monitoring patient's healthcare information, their activities through powerful sensor technologies which enables clinical care to make smarter decisions. In keeping view on all these, this paper will review IoT technologies, IoT healthcare devices and its IoT based applications in healthcare.

KEY WORDS: IoT (Internet of Things), RFID (Radio Frequency Identification), IP (Internet Protocol), IT (Information Technology), ZigBee, EHR (Electronic Health Record).

1. INTRODUCTION

There is a drastic change in Human being's life after the development of information and computing enabled technologies. Internet of Things (IoT) compromises the set of technologies which is used to observe the current status of the real world objects and talk to them intelligently. However, there is no standard definition of IoT among academicians, researchers and public communities. IoT is a technological revolution which will change Human's life style completely in the upcoming years. Internet of Things (IoT) is a new paradigm which is the outlook of IT and communication and its future is totally dependent on the innovative development in the areas of wireless sensors, Internet, RFID etc. Sensors are going to play a vital role in the development of IoT applications which basically used to identify, monitor, automate and control the real world objects. Nurses play a vital role in healthcare management by utilizing various IT applications (Singh and Senthil, 2015). These applications could be made IoT oriented to realize the maximum benefits to save their useful time. On the other hand IoT based devices and applications can help patient to monitor and control their health activities. There exist huge database of medical and healthcare information that is accessed by scientist and medical practitioners for their research and clinical activities. But most of these search engines do not provide optimized search results providing redundant information and creates information overloading. BioNav systems (Nyati, 2013) cater to meet these requirements by minimizing navigation costs but do not resolve the issues related to time wastage completely. Application of IoT driven search engines specifically for medical databases will help in scientific and health care research reducing search time with optimized navigation cost. Therefore IoT driven healthcare devices and application has the prospect to fulfil the requirements of a wide spectrum of users starting from medical scientists, practitioners, service providers, nurses and above all patients across the world.

IoT Technologies: Various technologies that empower IoT applications are Radio Frequency Identification (RFID), Bluetooth, Internet Protocol, Wireless Sensor Networks, Artificial Networks, Wi-Fi, ZigBee, AI, Smart Sensors, Barcodes, Electronic Product Code, Near Field Communication, Actuators etc. Some of them are represented in Fig.1.
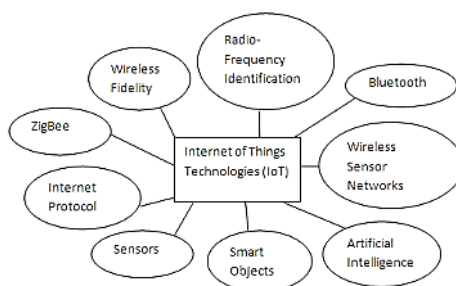
Figure.1. IoT based Technologies

Radio-frequency identification (RFID): RFID plays a vital role in IoT applications. It identifies the objects and people in real world environment attaching a tag with real world object which consist of a small chip. RFID reader

is used to communicate with tag through the incoming and outgoing query signals which can be sent to the database. The database can be connected to the processing centre to identify the objects with the help of these signals.

RFID is used by Manipal Hospital Bangalore for porter management which saves lot of time for nurses which they use to waste by making unnecessary calls (Swedberg, 2012). A study done on nurses in India showed the 33 percentage usage of Electronic Health Record (Singh and Muthuswamy, 2013). EHR systems can be combined with RFID and Hospital Information System (HIS) to reduce medical and diagnosis errors instead of using only RFID systems (Ajami and Rajabzadeh, 2013), thereby more use of EHR systems by nurses. However, RFID deals with sensitive patient information which required more research on security and confidentiality point of view (Ajami and Rajabzadeh).

Bluetooth: It is a technology which replaced data cable using wireless capabilities in order to reduce the cost of data transmission to save energy in a network. It is used to connect devices within short range. 2-8 devices can be connected through a common channel called as Piconet. Bluetooth can be used as a wireless body area network device to monitor the patient's health information. A health profile is developed using Bluetooth technology which is used to connect different health monitoring devices to laptop, desktop and computers in wireless manner (Patel and Wang, 2010).

Internet Protocol: It is the main network communication protocol used by internet developed in 1970's. It has two versions IPv4 and IPv6. IPv6 referred in 21st century protocol. IPv4 addresses are divided into 5 classes named as A, B, C, D, E based on their IP ranges. IPv4 offers 4.3 billion addresses while IPv6 provides 85,000 trillion addresses (Bicknell, 2009).

ZigBee: ZigBee is one of the network protocol which is mainly used to enhance the properties of wireless sensor networks. ZigBee is an IEEE 802.15.4 standard. Reliability, scalability, low data transmission rate are the main advantages offered by ZigBee protocol. A huge number of biomedical devices use ZigBee or Bluetooth to transmit and measure the data. These devices can monitor and manage data through a data centre which transmits the information to the patient and healthcare professionals, accessed through web, PC or cell phones (Ullah, 2012; Schmidt, 2002; Chen, 2001). Many healthcare applications are developed using ZigBee or Bluetooth as a wireless interface.

Wireless Sensor Networks (WSN): WSN is a network of smart devices or objects which monitors the environmental conditions such as location, motion, pressure, sound, vibration. Wireless Sensor Networks plays an important role in IoT field. Wireless Sensor Networks are used in number of fields including healthcare information monitoring. Sensors used in human body can monitor the patient's medication effects and inform the doctors about the same (Chorost, 2016).

IoT Healthcare Applications and Devices: IoT plays an extremely significant role in the present generation healthcare system. The application of IoT in healthcare involves use of embedded sensors and actuators as part of the treatment in patients. The IoT based invasive monitoring systems helps in extensive monitoring and tracking of the physiological status of the patients. The use of RFID technology in one of the leading hospitals in Ohio was used to track the activity of hand washing of medical practitioners and other healthcare providers. The use of such IoT-based technology helped to avoid infections related death tolls and also reduced financial loss for the organizations (Babu, 2016). The application of IoT in the development of medical devices are diverse and benefit the healthcare systems by reducing mortality rates, clinic visits, length of hospitalization thus leading to better clinical experiences among patients. The applications of IoT in the creation of medical devices cater to the needs of various heathcare domains. Various medical based IoT driven devices are represented in Fig.2.
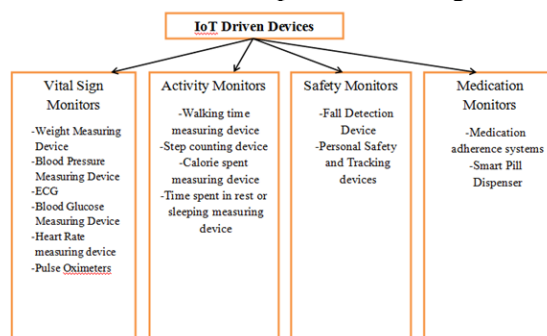
Figure.2. IoT based Medical Devices

The various IoT-driven applications and devices which have radically improved health care systems are discussed below:

Remote Patient Monitoring System: The remote patient monitoring system is a combination of RFID and IoT based technology which helps to constantly monitor patients through medical sensors, communication and analytics devices. The data collected in the process are sent to processing centres where it is analysed meticulously and relevant

information are extracted for further clinical actions to be taken and also created opportunities for future research and development activities. The IoT network enables secured transmission of data from source to destination without compromising with the quality of healthcare and patient life style (Babu, 2016; Zanjaland Talmale, 2016).

Health Smart Homes using IoT: The number of aged people has rapidly increased in several countries including USA, Brazil and Japan. Moreover most of the families have become nuclear wherein elderly people tend to live alone in their homes for the major portion of the day and hence are prone to diseases and medical emergencies which need immediate attention and care. The aged people also need special care and attention after undergoing surgical treatment or critical health treatments post release from the hospital. These patients sometimes fail to get enough medical care and monitoring unable to afford round the clock nursing supervision. The idea of Health smart homes using IoT has evolved keeping in mind these issues which cater to provide solutions to patients at home using monitors and alerts for relatives and nurses when required by the patients. The technology used is a combination of the concept of telemedicine and information systems. Intel Corporation has developed such a system which is based on ultra sound technology. The system worn as a wrist band helps to detect patient movement and sets an alarm incase of any abnormal behaviour such as patient falling. But the device fails to detect other emotional factors and pain which is extremely important when the patient is alone at home. The study by Leandro Y Mano, (2016) proposes the use of camera and wireless architecture based network system that helps to resolve these issues and enables monitoring of elderly patients in their homes. The Smart Architecture for In-Home Healthcare system (SAHHc) uses sensors and decision makers to capture images and infer information from the emotions and feelings the patient, experiences. The sensors which are distributed in the patient's home environment capture all relevant information and then send it to the decision making element of the SAHHc system. The decision maker processes the information received and takes decision either to send alert or to prevail patient health. The system uses the power supply and the internal communication system of the house but also has the provision of battery backup in case of outages. The camera captures the image of any person as soon as the one enters the room and matches with the patient's image in the database. If a match is found the SAHHc system recognizes the person as the patient and immediately the monitoring of the patient is started (Mano, 2016).

Health IoT platform based on Intelligence System: An intelligent platform for Home Based Health IoT is developed. It monitors the patient's information using smart sensors. This system consists of 3 components iMedBox, iMedPack and Bio-Patch. iMedBox is mainly used to provide strong connectivity and interoperability. iMedPack uses RFID and functional material to facilitate medication management. Bio-Patch is used to monitor patient's health symptoms. iMedBox is act as an service delivery point by connecting all Bio-Patch, iMedPack and back end services (Yang, 2015).

IoT for Rural Healthcare Monitoring and Control: An IoT based approach proposed for rural health patient monitoring system. It monitors patient's health symptoms. RFID sensors are used to record the patient health information. This urgent information is through the sensor is sent via a sink node to the gateway computer using internet. The person registered with rural healthcare centre will monitor the patient's health information for any drastic change with standard health parameters and the same can be communicated to the doctors via SMS or alert messages (Rohokale, 2011). A Health IoT framework is proposed for people who live in remote areas through synchronization of data from the sensor to cloud via a mobile application (Rajput and Gour, 2016).

Personalized Service Model for sharing medical devices: This personalized service model system uses mobile applications that measures metabolic activity which can be used in a family or other public office environment. In the system, it is assumed that that multiple users communicating with common or different health care centre share an IoT based glucose meter. A personal mobile device is used to register the glucose meter in the IoT server. The system recognizes a valid registered user and once measurement of glucose level is completed using the glucose meter, the data is transmitted to the diabetes meter located at the health care centre. The next user using the same glucometer can take the measurement in similar fashion and transmit the data to a different health care centre. Hence although the same glucometer is used for the measurement, the destination of sending the data can be dynamically determined by the user. This provides customized healthcare service to people working in public Institution or at home and enables them to share medical devices by the use of mobile and IoT based healthcare device using routing protocols offered by IoT platform server (Lee, 2015).

Ingestible Sensor: The ingestible sensor developed by Proteus Digital Health helps to monitor if the patients are taking medicines prescribed by the doctor. The device is developed using high volume semiconductor and pharmaceutical components. It also helps to get complete information on patients health related patterns and understand the efficiency of medical treatment received by the patient enhancing accuracy in taking effective healthcare related decisions.

IoT based Hearing Aids: The applications of IoT for innovation of hearing aids have created wearable technology for the ears which is used for communication, fitness management and also provides biometric data. Doppler Lab has invented hearing device which uses various EQ and advance audio effects that creates a studio like feeling for

the listener. The system transforms all audio too exactly as per the user requirement and liking and thus enhances user's sound experience.

IoT based Mood Enhancing Device: IoT based technology has been used to enhance mood with the help of a device that transmits low intensity currents to the brain which help to elevate mood of an individual. "Thync" is a device which is developed using proprietary neuro signalling technology that sends signals to the brain through neural pathways. These signals help to balance the chosen nerves and helps individual to be calm and achieve comfort.

IoT based Healthcare Charting: Healthcare charting is an extremely important activity which doctors have to do manually during patient check-ups, physical examinations, patient monitoring and documentation of patient history and medication. The use of IoT based technology by the company Augmedix has helped medical practitioner get rid of such redundant and time consuming activity allowing them to spend more time on patient treatment and other medical activities. Augmedix uses smart glass technology like Google glass incorporating voice command system allowing practitioners record patients and enter data received into a hands-free system using HIPAA-certified encrypted data. The system not only enables to collect data quickly but also transmits and stores information in a secured environment eliminating the chances of data loss or miscommunication.

Adverse Drug Reaction System: Adverse drug reaction (ADR) occurs due to injury cause by the intake of medication. The reaction can happen after single dosage of the medication or prolonged used of the same. A study by Jara (2010) proposed an IoT based ADR system which captures data related to patient's medical history and allergy profile from electronic health record available. Then the drug used by the patient is identified by the use of barcode or NFC-enabled devices. The pharmaceutical intelligence system helps to identify if the drug is compatible with the patients allergy profile and health record. iMedPack is one such product which is commercially available that addresses similar issues using RFID and controlled delamination materials (CDM) (Jara, 2010; Chowdhary, 2015).

Children Health Information System: Children's health information related awareness emphasizing on nutrition, emotional, psychological and behavioural developmental problems is a very important issue to be addressed in the present time and age. There has been extensive research in these areas which has guided researchers to device IoT driven Child Health Information Systems that help to address issues related to child development and nurturing in an effective way. A study by M. Vazquez-Brisenoet. al (Vazquez-Briseno, 2012) proposes the use of an interactive totem in the paediatric ward to educate and amuse hospitalized students and also encourage them to adopt good nutritional habits (Islam, 2015; Vazquez-Briseno, 2012).

Rehabilitation Management: There exists presently shortage of health experts across the globe having ability to provide active and efficient services to patients with functional and mental disability. Patients with physical impairment, psychological disability need medical care as well as rehabilitation to help them return back to normal life and continue their regular professional and personal life. IoT can be used to improve the quality of rehabilitation treatment to these patients and improve the quality of their lives. The study by Fan (Fan, 2014) proposes an ontology based design using IoT for creating a Smart Rehabilitation System. The system helps to connect all necessary resources for seamless information transaction. The applications of IoT based such rehabilitation systems can also be used for prisoners, hemiplegic patients and also train students suffering from autism (Fan, 2014; Islam, 2015).

Oxygen Saturation Monitoring: Pulse oximetry is a non-invasive blood oxygen monitoring device that helps to detect oxygen saturation in the blood. IoT driven pulse oximeter system developed by Nonin (Wrist OX2) is a wearable device using Bluetooth technology and the sensors connect to the Monere platform which helps in monitoring of service compositions for failure diagnosis. The study by Larson (Larson, 2013) also proposed an integrated pulse oximeter system using IoT catered for telemedicine related applications (Larson, 2013).

Body Temperature Management: Body temperature monitory is a very important activity in health care related services because temperature of the body is an extremely decisive factor for the diagnosis of diseases and health conditions of patients. The temperature of the body needs to be maintained at an internal temperature of 98.6 degrees to maintain a condition of equilibrium with the internal environment of the body. Various IoT based body temperature management systems have been proposed and implemented that helps to track and monitor human body temperature. One such system in the m-IoT system that uses a body temperature sensor embedded in TelesB mote which shows attained variation in body temperature for an individual and also variations of the same across a time frame. On the contrary, the home gateway based system transmits the user's temperature using infrared detection. These systems also use RFID based technologies for the monitoring of human body temperature (Islam, 2015; Chowdhary and Acharjya, 2016).

2. CONCLUSION AND FUTURE WORK

Internet of Things has potential to change the way of human living standards especially from the healthcare point of view. We cannot predict how our life will take its turn in the next 10 years. Internet and related technologies have affected human life immensely since the past decades. Healthcare driven IoT systems thus has the potential that would allow healthcare providers to give optimum quality healthcare service to their customers also predict their

health problems at early stages reducing mortality rates. This paper is a current review of application of IoT technologies in healthcare and related monitoring devices and applications. IoT based technological trend has been adopted by many reputed world class companies and they are working towards enhancing such technologies more and implement them to realize further benefits. IoT applications in healthcare have huge opportunities of future research and development but at the same time needs to create markets across the globe with innovative yet affordable devices. The IoT based products developed should be able to reach out to customers of both developed and developing countries and hence great emphasis has to be given to make products efficient, standardized yet economical. Therefore the scope of future research in IoT lies in developing energy efficient, affordable products catering to all spheres of human life. Issues like security and privacy in healthcare applications are also areas that need to be addressed efficiently for successful adoption of IoT technology.

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