INTERNET OF THINGS DEVICES AND ISSUES IN IOT SYSTEM DEVELOPMENT FOR HEALTHCARE

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ABSTRACT

This paper presents a review of Internet of Things (IoT) devices and issues in IoT system development for healthcare systems. In this study, key issues which led to the development of anIoT system in the healthcare field are emphasized and the associated IoT devices to solve these issues are identified. As IoT applications began to expand in all sectors and industries, some potential and issues have been recognized by both the engineering professionals and the medical professionals that can be solved or facilitated using IoT systems.This paper delves into the main issues that trigger IoT in the healthcare system and the IoT devices that are widely used either by the healthcare worker, healthcare provider, patients, and other people interested in constantly monitoring their health. Subsequently, this study explores the benefits and future opportunities of the IoT system and devices in the healthcare system.

Keywords—Internet of Things, healthcare, IoT devices

1. INTRODUCTION

Although the term Internet of Things (IoT) started to become popular in the last decade, the IoT concept wasintroduced way back before 1990.John Romkey invented a toaster that can be turned on and off through the internet at the end of 1989 [1]. However, the device did not gain any popularity and the idea was shelved until the end of 1999 when Kevin Ashton from Procter and Gamble coined the term IoT [2]. He associated Radio Frequency Identification (RFID) as a crucial component of the Internet of Things. IoT applicationsstarted to emerge in 2008, onwards where many internets connected devices have been developed and distributed to the mass market [3].

IoT is a network of devices connected through the internet. IoT can be made up of billions of intelligent interacting entities that enabling people and things to communicate without time or location limitation [4]. It permits interaction between physical devices, machines and cloud servers in real-time. As internet connectivity is improved through a cable or wireless. AnIoT system can be implemented more easily as the communication infrastructure and means are readily available [5].Hence, the immediate applications of IoT are plausible, especially in domains such as healthcare, agriculture, city and home/office automation, industrial and energy management, and so on [6-8].

Prior to IoT, computers and the internet rely heavily on inputs by a human. Without the input and information from humans, such as through typing of data, scanning of documents, taking images, recording sound; computers and the internet will not be able to process those data and provide valuable output. However, the limitation is that humanscannot provide and collect precise data continuously as we are restricted to time, capacity and resources[9]. As the world is progressing in Industry 4.0, IoT plays asignificant role due to its heterogeneity in connecting things and functionality [10]. IoTnot only can communicate between human to machine (H2M) but also machine to machine (M2M) without human involvement. IoT devices can collect data round the clock and

feed the data to the computers. The data can be processed and analyzed and through machine learning and artificial intelligence (AI), a human can obtain valuable output from the collected data as and when required [11].

Today, the application of IoT in healthcare has emerged and continues to expand due to its efficacy to facilitate doctor-patient connectivity that can either save lives or improve patient's health with reduced cost [12]. Current applications of IoT in healthcare include monitoring patients with emergency care, patient's health condition and progress also for use in rehabilitation [12]. Patients are usually connected to the IoT healthcare system either through wearable or implanted sensors. Although IoT has been used largely in the current healthcare setting, several major issues arise from the system architecture, sensor and data such as high energy and power consumption, noisy data, large storage for database and vulnerability for the attack [13-15]. Hence, existing IoT healthcare architecture requires improvement to overcome the aforementioned issues.

This paper presents a review of IoT devices and issues in IoT system development for the healthcare system.The issues that led to IoT and the IoT healthcare application devices are explored. Section 2 discusses IoT in healthcare. Section 3fcouses on the healthcare problem that is directed to the development of IoT in that sector. Section 4describes the IoT devices developed for healthcare applications.

2. IOT IN HEALTHCARE

Even before the current global pandemic COVID-19, healthcare has always been the top priority for most countries. A good healthcare system is one of the components which reflects on the efficiency of a government. As IoT applications began to be implemented in many sectors such as manufacturing, agriculture, smart home, and personal use, IoT is needed to become a solution to lessen the shortcomings in the current healthcare system.

There are many advantages where individuals and society can benefit from the integration of IoT into the healthcare system. One of the main benefits is to bridge communication between people with healthcare personnel[16]. As there is more and more medical information available on the internet, people began to assess the information on their own without having the ability to determine whether the information comes from reliable sources or not. People will begin to perform self-diagnosis based on this information and sometimes they will believe they have the more severe disease than they do. This will drive them to seek medical attention in the hospital even though it is not necessary. IoT devices that can collect vital information from the person will transmit the data to the healthcare personnel and provide a precise diagnosis before taking the necessary action. Therefore, IoT is crucial for healthcare assessment, health monitoring and automatic detection of critical medical issues[17].The IoT system in healthcare is sometimes referred as the Internet of Healthcare Things (IoHT). However, in this paper, we will refer it as IoT for a common understanding.

3. IOT DEVELOPMENT IN HEALTHCARE

Apart from what has been mentioned in the previous section, many other healthcare issues require an IoT system to facilitate or alleviate those issues. This section will discuss the current healthcare system issues, which led to the IoT system's development, as shown in Figure 1.

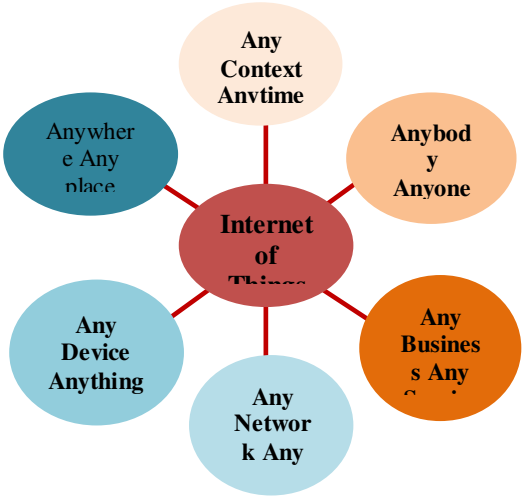

Figure 1: Dimension of IoT System [2]

Healthcare issues commonly experienced by most countries will be related to the growth of the population, urbanization of rural areas, and reduction of birthrate, increase in elderly population and distribution of resources utilization in the country [18]. The following contents will elaborate on some of the healthcare issues that require the involvement of IoT to reduce the burden faced by the personnel in healthcare sectors and the general population.

3.1 Specific demographic

There is a specific demographic which may require extra supervision when it comes to healthcare management. In this section, the demographic discussed is the elderly population, infants or children, and soldiers or enforcement groups while performing their duties.

Health management of the aging population puts a heavyweight not only on the family member but also on the society as a whole [19].With the improvement of life expectancy, the population of elderly is gradually increasing annually. The elderly usually have health problems that requiremedical attention from time to time. Also, some of the elderlypopulation lives alone in the house without constant supervision from the family or the guardian. There is a risk of them falling at home or having difficulties performing daily life activities such as going to the bathroom or taking their medication according to the recommended time. IoT devices attached to their body or installed in their home will help evaluate and supervise their daily activities.

The second demographic that requires extra attention is infants and children. Like the elderly, their inability to perform daily activities independently requires extra supervision from the people around them. Usually for newborns, monitoring their body temperatures is very important to avoid them from having health issues resulting from high fever. IoT devices and monitoring systems can be applied to give better protection to children.

The third demographic is the soldiers or enforcement group while performing their duties. The soldiers equipped with IoT devices will relay their location and vital signs to their commander or base station [20]. IoT devices will be crucial to monitor the health status of the soldiers during wartime. If the soldiers are lost or injured, IoT devices attached to them will transmit valuable information to receive rapid medical attention.

Lastly, concerning the Covid-19 virus pandemic, infected patients need to be quarantined. It will prevent them from infecting other healthy people. While in quarantine, healthcare personnel who are treating the patients are exposed to the infection as they are in close contact with the patients. If the patients are provided with IoT devices, the frequency of healthcare personnel visiting the patients can be reduced [21]. This is because they will retrieve the data such as the body temperature, heartbeat and blood pressure reading without being in close contact with the patients. The healthcare personnel can personally perform checkups when the patients are in serious condition.

3.2 Continuous monitoring

One of the issues which requires theIoT system in healthcare is the continuous monitoring of patients. When a patient is in the hospital, constant monitoring can be performed regularly. However, when the patient is discharged, patient's commitment is needed for monitoring, such as attending the follow-up appointments according to the allocated time.The patients must also conduct self-monitoring and relay the doctor's information during the follow-up appointment [22].This will be a burden to the patients, and the doctor's information may not be accurate since it depends on the patients' effort.Through IoT, continuous monitoring of patients can be done mostly outside of the hospital. The doctor will be able to extract the data and evaluate the condition of the patient.The data obtained from IoT devices will be more accurate, unbiased, and assist the doctor in performing thorough diagnostics.

3.3 Accessibility to rural areas

It is the responsibility of every country to ensure that healthcare is accessible to every citizen regardless of location and place. When the patient is coming from a remote location, it is costly to seek medical attention. There will be cost incurred when the patientscome to the healthcare facilities for a checkup or when the doctor comes to perform a checkup at the patients' home.The number of medical staff stationed in rural areas is limited. They will only provide treatment of low severity cases [19]. One of the reasons for IoT to be developed is for the doctor to remotely acquire the patients' information through the internet network. Only when the doctor evaluates that the patients require a medical checkup at the hospital will they be contacted for an appointment.

Early detection of diseases

One of the problems in healthcare is the early detection of diseases [19]. Without early detection capability, the patients may not get the appropriate treatment and his or her condition may become worse. With the assistance of IoT devices, any minor symptom exhibited by the patients can be detected and help the doctor provides a more accurate judgment on the disease. Early detection also can be considered as one of the factors to accelerate the emergency response.A patient who is about to get a cardiovascular stroke may give signs which can be detected by IoT devices to alert related personnel for emergency response.

There are many more issues related to healthcare, leading to more development of new IoT devices and systems and improvement of the current IoT devices available.The process will continue as long as new issues were found, and the outcome will improve the healthcare system and benefit the society.

4. IOT DEVICES

IoT devices come in many forms such as sensors, home appliances, gadgets and much other equipment connected to the internet as described in Figure 2. The devices can be attached to the user body, as equipment where they can use them when needed. Alternatively, the device can be placed in a room or setting in proximity to the user [23].This section will explore IoT devices that are commonly used and how these devices contribute to solve issues in healthcare industries.Typically, IoT devices for healthcare can be divided into two categories, which arethe IoT body ware devices and the non-body ware devices [19]. Section 4.1 and 4.2 will discuss the IoT devices under the body ware category, and Section 4.3 and 4.4 will discuss the IoT devices related to healthcare.

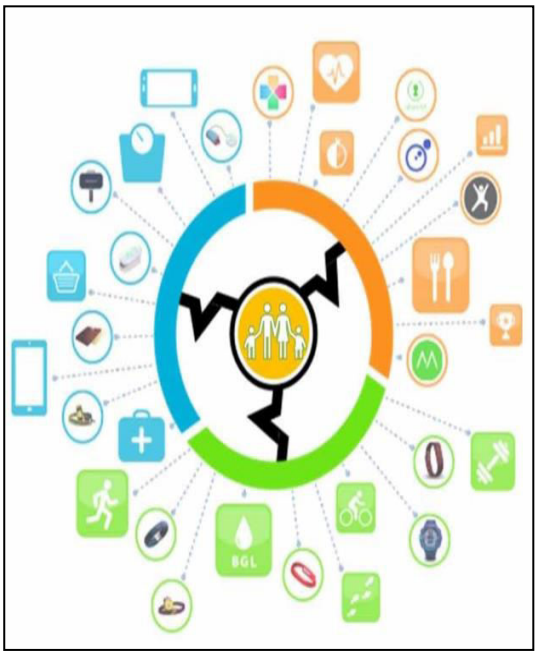

Figure 2: Overview diagram of Internet of Things in Healthcare [19]

4.1 WearableDevices

Wearable IoT devices are becoming popular and are worn not only by patients but also by healthy people who are particular about their health. For example, a smartwatch is a wearable IoT device commonly used to detect heart rate, temperature, and daily steps are taken. A wearable IoT device will have the characteristic of having at least some form of contact with the wearer'sbody commonly in contactwith the skin. By placing the sensor in contact with the skin and at a specific location, vital human signs such as body temperature, blood pressure and pulse rate can be detected. Apart from the wrist, the wearable IoT devices can also be attached to the fingers, earlobes, ankle, thigh, head and be embedded into a shirt for the user to wear.

The observation of body temperature is one of the essential elementsin healthcare diagnosis. The temperature provides a definite sign for a human to support homeostasis [19].A temperature sensor like a thermometer embedded in a bracelet or wristwatches will be sufficient to detect the body temperature.For babies and infants, a temperature sensor is patched on the baby's underarm to detect the baby’s temperature and detect fever

[24].Sensor patches can also be inserted inside the bra to directly collect daily heat changes related to thetumor's cellular activities [24].It is a proactive measure to enhance breast cancer's early detection, one of the most frequent cancer occurrences among women.The data can then be transmitted to the internet via an infrared or RFID module. Another type of sensor used is the thermistor sensor which can detect fever and heart stroke [1]. For the thermistor sensor to be effective, it must be close to the human body. Research is conducted to develop flexible sensors that can be embedded into the clothing where the user can wear comfortably without restricted movement.

Pulse oximetry is a device that measures the oxygen saturation level and monitors the blood level differences with regards to the cardiac cycle [25].However, the location of the pulse oximeter on the human body is not similar to the temperature sensor. The pulse oximeter will be attached to the finger or earlobe. The Light-Emitting Diodes inside the pulse oximeter will emit light to the attached location. The photodetector will detect the amount of infrared received, which corresponds to oxygen saturation inside the human body.Some of the available IoT devices for oxygen saturation monitoring are equipped with Bluetooth capabilities to transmit the data to the dedicated data collecting equipment [19].

Electrocardiogram monitoring or also known as (ECG) tracks the electrical activities of the human heart such as the rhythm and heart rate [26][19].Many parameters can be collected from ECG, which will give great assistance to the doctor to diagnose heart problems. The current sedentary lifestyles, unhealthy diet intake and work and related financial stress have caused many related heart problems. Apart from ECG, other devices related to heart problem detection will be the pulse sensor. The pulse sensoridentifies health issues such as cardiac block, lung embolism, and vasovagal syncope[1].Although pulse can be detected from the chest, wrist, earlobe, fingers, the wrist is commonly used since it gives the user comfortability for the device's long-term wearing[1].Blood pressure monitoring [26] is also one of the main monitoring components related to determining the well-being and condition of the heart.

Respiration rate sensors can detect health issues such as asthma attacks, hyperventilation due to panic attacks, lung cancer, and tuberculosis. It detects the respiratory rate or the number of inhalations per minute [1].However, the sensor must be inserted in the nasal opening to detect the airflow when the user is breathing. It may cause the user some discomfort and not practical for long hours of usage. Other IoT devices related to healthcare are the UV sensor attached to the fingernails to detect and inform users if they were exposed to high doses of UV radiation[26]. IoT devices that are still under progress are headband, which emits small low-intensity currents to the human brain to alleviate mood and reduce depression connected to the internet for healthcare professionals, especially the psychiatrist, to monitor patients' mood and behavior.

4.2 Implantable Devices

IoT devices are also categorized under body ware categories; however, the devices are not worn by the user but are implanted instead. These devices are inserted under the patient skin or in any part of the body to acquire the most accurate data that cannot be detected by simply putting the sensor in contact with the patients' skin [25].Glucose monitoring is implemented by allowing the IoT devices to be implanted into the patients' abdominal tissue [25]. The glucose level inside the body is monitored every thirty seconds, and data transmission occurred twelve times per hour. With the availability of glucose level reading, insulin intake can be controlled for diabetic patients. Another device is implantable Neurol simulators [25]. This device provides electrical impulses into the brain or the spinal cord to alleviate the pain experienced by the patients.The possible application of body ware IoT devices on the patientsis shown in Figure 3.

4.3 Stationary Devices

The non-body ware IoT devices are also known as stationary devices. These devices are standalone devices and do not require to be worn by the user. It includes intelligent wheelchairs that can monitor the user's vital signs and share their location through GPS tracking [1]. Intelligence wheelchairs will be very beneficial to the hospital's medical staff. Supervision towards patients who require wheelchairs can be reduced and their movement and health status can be monitored remotely.

Other IoT devices which are under stationary devices are mechanical robots [27]. Mechanical robots can monitor patients' vital signs, alert patients to take medication according to time, advise patients on a food diet, and exercise daily exercise based on the patients' medical history [1]. The robot can also upload daily monitoring data to the servers that can be analysed by the doctor when required.

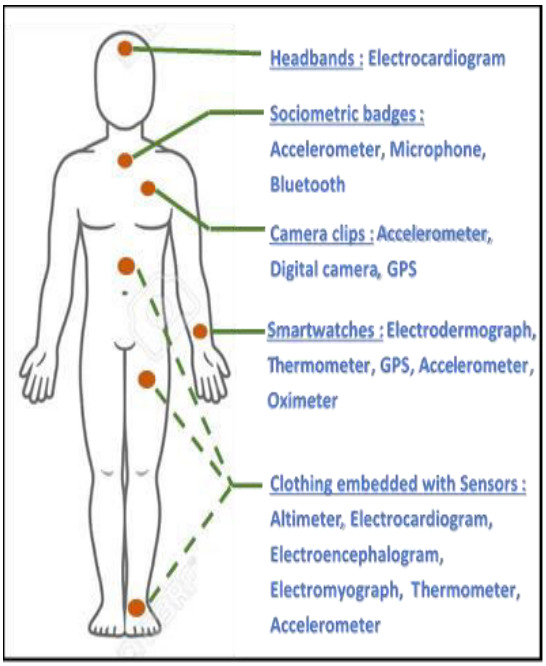

Figure 3: Application of body ware IoT devices on the user [1]

4.4 Integrated System

An integrated system is an environment where a collection of IoT devices is installed together to serve the purpose of monitoring. One of the applications will be in a setting for monitoring the elderly. This setting can be achieved by configuring the house to be equipped with IoT devices, as shown in Figure 4. Also known as smart homes, it has monitoring capabilities that can alert caretakers if the elderly fell or do not conduct their daily activities as usual [19]. Doppler radar can be installed inside the house in order to detect when the elderly experience risk of falling. A thermal camera can also be installed inside the house to monitor the body temperature of the elderly continuously. If any occurrence of falling or fever, a notification can be transmitted to the guardian or caretaker to arrange further treatment [28-29]. The house can also be integrated with stationary devices such as intelligent wheelchairs and mechanical robots as discussed in the previous chapter to provide a comfortable living for the elderly resident.

Figure 4: Doppler based radar to monitor falling [23]

The identification of health risks or health monitoring using gait patterns with IoT sensors has been discussed in many studies [30-32]. Gait is the method by which a human can move from one to another points. These includes walking, running, hopping, swimming and cycling. Since walking is one of the most common activities in human daily movement, studies of human balance and gait patterns are very important especially for disabled people or patients with chronic diseases such as stroke [33], Parkinson [34] and Alzheimer [35]. The IoT system is equipped with several applications of gait behavior tracking or remote monitoring for patients with high risk of injury due to falls [36], with the location information [37]. A wireless system to remotely detect gait information for disease analysis by medical institution has been presented using insole plantar pressure sensing system for the IoHT [38]. A data shoe system has been developed using integration of insole sensors of force resistive resistance (FSRs) [39] and social ability to observe gait behaviors of elderly in smart home [40]. In [37, 41], a wireless system has been proposed using IoT-shoe and smartphone sensors to analyze abnormality gait patterns in real-time detection. Moreover, a smart shoes system has been proposed in classifying gait posture using a smartphone application to provide the gait information to customers [42].

5. CONCLUSION

This paper presents a review of IoT devices and issues in IoT system development for healthcare.It can be seen that IoT implementation provides many benefits and will increase the efficiency of the healthcare industry in many ways. The investment of setting up the system as well as the acquisition of IoT devices may be costly in the initial stage. However, in the long run, it will lower the overall cost especially withcontinuous monitoring of patients, accessing patients in rural areas, early detection and prevention of diseases and distinguishing minor and severe cases. Although ongoing issues such as security and data protection may be susceptible to abuse, but the benefits of IoT utilisationin healthcare far outweigh its deficiencies.

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