Enhancing Healthcare Facility in Rural Areas Using Internet of Things (IoT)

Chiew Cae-Li, Naresh Kumar Appadurai and
Kamalanathan Shanmugam

Abstract--- *Internet of Things (IoT) in recent years, facilitates in revolutionizing the introduction, and acceptance of healthcare facilities in rural areas. IoT offers a more efficient way to access healthcare and at the same time better manages the cost of implementing it. The main usage of IoT in healthcare is monitoring patients' health conditions without having being required to be physically present. As powerful as IoT may sound, it also comes with many security challenges as well as using energy efficiently. A number of research papers have proposed multiple ways of handling these challenges and the different types of sensors used in these IoT devices. After thorough research, a combined analysis of health data recorded in several countries have also been reviewed to aid in identifying the requirements of patients especially those in remote areas. The aim of this research is to give an insight on how IoT usage in healthcare is able to revolutionize the entire industry, moving on from its traditional ways of caring for patients. This research paper is a compilation of different viewpoints of IoT in healthcare from different papers, explaining in detail why and how IoT is used in this industry and the steps taken to mitigate the challenges faced.*

Keywords--- *Internet of Things (IoT), Wearable Sensor, Radio-frequency Identification (RFID), Healthcare, Patients, Technology, Pulse Oximeter, Local Positioning Sensor (LPS), Global Positioning System (GPS).*

I. INTRODUCTION

In today's world, healthcare plays a significant role is everyone's lives, no matter their position, for example, a factory worker and the president of a multinational company would still need to get treatment for their health if they ever were to fall ill. Hence, there is no doubt that everyone, at some point, would hold healthcare dearly to their hearts. Therefore, mankind is often trying to find ways to improve and revolutionize the way health is being treated across the globe, be it in a first world country or a third world country where getting treatment would be considered lucky. Health systems are dynamic, because they adapt according to the current demographic and environmental changes. With health systems being there to improve mankind's health whenever illnesses have struck them down, no doubt that there will be an increase in life expectancy over the years.

This indirectly means that there will be an increase in demand of medical resources and staffs to accommodate the increase in population [1]. More data would need to be collected and analyzed too, in order to make wise decisions that'll affect millions of lives. Thus, to achieve an optimal healthcare system to accommodate the needs of the society soon, the participation of technology is essential.

Chiew Cae-Li, School of Computing & Technology, Asia Pacific University of Technology and Innovation, Technology Park Malaysia, Bukit Jalil, Kuala Lumpur, Malaysia. E-mail: caeli.june98@gmail.com

Naresh Kumar Appadurai, School of Computing & Technology, Asia Pacific University of Technology and Innovation, Technology Park Malaysia, Bukit Jalil, Kuala Lumpur, Malaysia. E-mail: naresh@apu.edu.my

Kamalanathan Shanmugam, School of Computing & Technology, Asia Pacific University of Technology and Innovation, Technology Park Malaysia, Bukit Jalil, Kuala Lumpur, Malaysia. E-mail: kamalanathan@apu.edu.my

Internet of Things (IoT) is one of the growing topics of the era we live in. IoT devices are simply devices (such as TV, skipping rope, toothbrush, coffee machine, etc.) that have the ability to connect to the Internet and transmit its data collected over to the cloud [2]. Inanimate objects that have the ability to link with the internet are able to form new types of communication between things and people, and between things themselves. These devices are usually embedded with sensors, microprocessors and other kinds of data communication hardware to process data collected from its surroundings. This way, data collected can be processed and analyzed to ensure proper decisions can be made based on the statistics and analysis of data. IoT so crucial because it has the ability to change the way humans live, learn and work.

In this research paper, a thorough review on how the Internet of Things (IoT) is currently being implemented in healthcare in today's world and its application in contributing to a more efficient healthcare system will be discussed. Different classifications of IoT in personalized healthcare systems and its applications are introduced and explained. Next, various types of sensors and microprocessors as well as the limitations of IoT in healthcare are also discussed in this paper.

II. RESEARCH BACKGROUND AND LITERATURE REVIEW

According to [2], IoT is basically any inanimate object that has the ability to connect to the internet and transmit data collected over to the cloud for analysis. [1] Points out that the demand of medical resources and staff to accommodate the increase in population is escalating at a fast rate, which means more data is needed to be analyzed in order to make wise decisions that would affect millions of lives. In consonance to that, a study from the Health Policy Institute from Georgetown University has found that adults residing in rural areas are more prone to experiencing greater rates of being diagnosed with chronic conditions compared to those in urban areas [3].
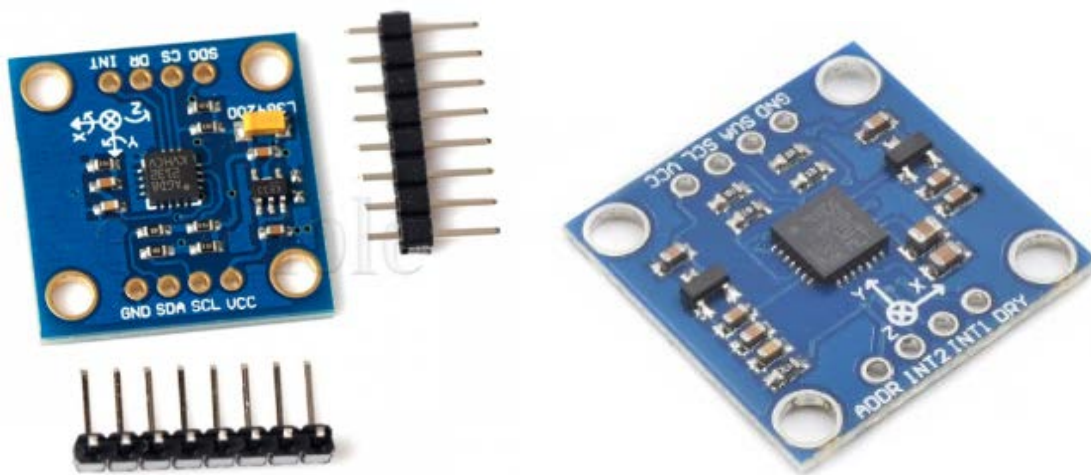

Figure 1: Left: Gyroscope Sensor. Right: 3-axis Accelerometer

However, contends that IoT remains to be a relatively new field of research and its potential use in healthcare is an area still in its infancy. Hence, many challenges such as security, privacy, energy usage and durability are faced by this field has claimed that remote monitoring of patients' conditions is a method to help them receive the

treatment they need without compromising their convenience and preference of living independently outside the hospital [4], [5]. Also supports this idea, and mentions the benefits of remote monitoring, which includes early pathology detection, prevention and overall checkups. This can be reinforced by explaining in detail how battery-operated monitoring devices can be used by senior citizens by wearing them as wristbands and the type of sensors and microprocessors used. According to [6], numerous sensors, motion trackers, locating technologies and cloud computing are recommended to be used in this proposal. [7] has described in detail of the types of sensors are needed to monitor the users' motion, namely 3-axis accelerometers, gyroscopes and magnetometers.

These sensors help in detecting the patient's movements, the data collected by these sensors will be sent over to the cloud for processing and lastly sent to medical staffs or even the patient's smart phone. In the event an emergency occurs where an elderly patient falls down, these sensors will be able to detect the fall and notify the authorities, shortening the waiting time for an ambulance to arrive.

One of the few suggestions on wearable devices in healthcare is made by [8], on his study of this topic, where wearable devices are integrated in the user's body. By doing so, these devices are able to execute treatments to the patient when the situation calls for it. For instance, in diabetic patients, the device will infuse a suitable amount of insulin into the patient's bloodstream immediately when their insulin level decreases below the average rate. According to [4], there are two (2) different classifications of IoT in personalized healthcare systems – clinical care and remote monitoring.

2.1. Clinical Care

Clinical care refers to the monitoring systems driven by IoT sensors or other devices that are used in hospitals to monitor patients whose physiological status requires close attention, such as their blood sugar level, blood pressure, etc. The sensors used in this classification of personalize healthcare system will be implemented to collect comprehensive physiological information of the patient, which will be analyzed and stored in the cloud. These data will then be sent to medical professionals wirelessly to be reviewed and observed, to ensure the right treatment or medication will be given to the patient. This lessens the need of doctors or nurses to regularly checkup on patients, as they are able to check on them from an application regardless of where they are in the hospital. This eliminates the need of health professionals to proactively engage in data collection and analysis by checking on the patient in regular intervals. Not only will clinic care improve its quality on monitoring patients, but also lowers the cost of care, giving more access to people from all backgrounds [4].

2.2. Remote Monitoring

Late detection of chronic diseases due to lack of access to healthcare may lead to death to many people living in remote areas all around the world. Remote monitoring provides easy access of healthcare for those who require necessary and regular attention, such as patients with chronic conditions, patients with disabilities and elderlies. These patients require constant medical checkups by medical professionals to ensure their health is maintained and they're at their optimum state. This classification of personalized healthcare systems offers early pathology detection, prevention, overall checkups to prepare for the requirements and needs of the patients, and homecare instead of expensive visitations to the clinic, making it more accessible for those in remote areas [5].

Remote monitoring is basically patients receiving treatment from their remote home instead of having the need to travel to a hospital. Instead of having to travel to get the necessary treatments, treatments find them, which makes it a whole lot easier for them. By doing so, patients are able to receive treatment without compromising their convenience and preference of living independently outside the hospital. Remote monitoring is able to securely capture every patients' health data detected and collected from different kinds of sensors, implement complex algorithms to process and analyze them, and broadcast it to multiple medical professionals via wireless connections who are able to give proper medical advice to patients, informing them about the do's and don'ts and what is needed to be done, just like a normal visit to the doctor, but not needing to travel the distance [9].

III. PROBLEM STATEMENT

The healthcare system in today's era is dynamic and ever-changing (trying to adapt to the environment changes, increase in demand of medical resources and staff and many more), hence an efficient system is needed to help patients get appropriate treatment by professionals and medical staff will not be burdened by having by being understaffed. In other words, traditional healthcare systems are struggling to keep up with the rapid increase of needs and requirements by patients in this dynamic environment. A system to collect data is extremely needed (vital readings from patients) to help doctors and nurses diagnose the patient quickly and accurately as every second counts. Furthermore, patients with chronic diseases living in remote areas are always facing issues to travel to medical centers to receive health checkups, not to mention how costly medical treatments are. In conclusion, they forgo their health altogether, which only leads to health deterioration [10].

This research study needs to be conducted to help the society be aware of the problems faced by these people, and also to fully understand what is required of an optimal solution to ease the people's burdens.

IV. AIM AND OBJECTIVES

The main aim of this research is to provide an insight and a detailed explanation of how the Internet of Things is currently implemented in healthcare worldwide, as well as proposing an IoT device/system on how to solve the issues faced as mentioned in the problem statement earlier.

A few of the objectives that has been formulated in order to achieve the aim stated above is:

a. To identify the problems faced by patients residing in rural areas and the inconvenience they have to go through to receive medical checkups.

b. To assess the type of vital readings that nurses collect from patients and the time intervals between each data collection, which will be implemented in the IoT device.

c. To identify and review the implementation of IoT in healthcare.

d. To have a deeper understanding of the two (2) different types of classification of IoT in personalized healthcare systems – clinical care and remote monitoring.

e. To study the different types of commonly used sensors in IoT monitoring devices.

V. RESEARCH QUESTIONS

The research questions are constructed based on the problems and issues faced by patients in rural areas and overworked medical staffs.

a. What are the challenges faced by patients living in rural areas when it comes to receiving necessary health treatments?

b. How does avoiding health checkups contribute to deteriorating one's health?

c. What are the challenges faces by medical staffs in understaffed medical facilities?

VI. SIGNIFICANCE OF THE RESEARCH

The findings of the study of Internet of Things in healthcare will greatly contribute in benefiting healthcare systems today as technology plays a crucial role in this era. This study will help in identifying the common problems faced by residents in rural areas and its contributing factors, which will redound in proposing a suitable and fitting solution to the problem.

VII.   RESEARCH METHODOLOGY

The type of information that will be used in supporting this research is statistical data from surveys carried out by other researchers in alignment with the topic chosen.

This research will be supported by detailed information obtained by referencing from legitimate sources such as journal articles, reports, and research papers. The few publications that have been chosen to be referenced from are IEEE, ACM and many more.

Resources required to aid in this research are split into two (2) types of sources, namely the primary source and secondary source. In this case, the primary source is direct accounts of actual findings, studies and observation written by researchers. This source can be in the form of official records, results, surveys as well as unanalyzed statistical data. The secondary source refers to the analyzed primary source information, a study and inspection of the findings. The research resources used in this research are journals, books, reports, etc.

This study is a qualitative study, as healthcare is something everyone holds closely to their hearts, understanding different opinions are extremely crucial as it helps open our minds and see things from the interviewees point of view. For example, there are some issues that patients in rural areas might be facing that we don't relate with urban areas. Conducting a qualitative research, it helps us understand their opinions better as they build upon their responses. Furthermore, this research method is chosen because as the interviewees elaborate their viewpoint, it will directly add depth and significance to the data collected by the interviewer. The qualitative research method is an un-structured and non-standardized research method, which encourages informal and casual relationships between the interviewer and interviewee [11]. As we already know, personal health might be something people are unforthcoming about. Hence, by conducting this research methodology, the interviewees are more likely to feel comfortable sharing their personal information on their health with the interviewer. These types of interviews are informal, meaning there are no pre-determined list of questions, and focuses on the what, how and why of the issue. The interviewee is allowed to talk freely on the topic and share their viewpoints and therefore, is non-directive.

There are two (2) types of audience targeted to conduct this interview, which are people with chronic conditions or the elderly living in rural areas and overburdened medical staffs. By doing so, the requirements of the proposed system can fully be fulfilled and executed to ensure the satisfaction of the people.

The specific method of data collection to be used in conducting the research is by conducting interviews for patients in rural areas and surveys for medical staffs. This is because medical staffs are already busy with their hectic lives, and conducting an interview will be too time consuming. Firstly, the interview with patients will be recorded for analytical purposes. Each opinion given by the interviewee will be jotted down and classified under the inconvenience they face living in rural areas in terms of healthcare and their opinions on how to fix it. Secondly, the survey conducted with medical staffs will use Google Forms as its platform. This platform is chosen for its ability to store the feedback received, allowing detailed analysis to be performed. Furthermore, Google Forms makes it easier to pass the survey to the respondents as it is an online platform, all the researcher has to do is share the link to the form.

In terms of research, journal articles and reports are used in referencing in this proposal. Quota sampling method is used in choosing resources according to the specific characteristics needed to help aid in this proposal and to support the general idea. For example, specific keywords are used as a quota to obtain the chosen resources, like journal articles based on the application of Internet of Things in Healthcare are only chosen, not all papers about IoT are chosen. Quota sampling is also used to help choose respondents to interview or complete the survey as they are selected according to the specific characteristics chosen by the researcher. The term specific characteristic here refers to the quota for selection of members of the sample (age, interest, profession, etc.). The people chosen to be interviewed are in accordance to the quota set, which is the interviewees have to be patients or elderlies residing in rural areas, and the surveys should only be submitted by overburdened medical staffs.

Quota sampling is entirely non-random, and is commonly used for interviews and surveys [12]. The population is divided into specific subgroups and these groups are exclusive. Next, the proportions of these subgroups are identified, and lastly the researcher will select respondents from these subgroups to conduct the interview or research and the sample result will represent the whole population [13]. This sampling method is non-probability and is a subjective approach. It is suitable as this research is focusing on a range of conditions (different applications of IoT in healthcare).

One of the practical limitations that could affect the data collection process in an interview is the quality of data interpreted by the interviewer. This depends on the interviewer's ability as certain people have the ability to conduct an interview and collect data with precision. However, some might not be gifted with this ability and might interpret what the interviewee is trying to convey inaccurately and miss the whole point entirely. Furthermore, the interviewer might have a biased mindset, which will indirectly affect the input responses [14]. Another limitation faced when collecting data by conducting a survey is that because it is not a face-to-face data collection method, the researcher is unable to see underlying meanings to the respondents' opinions in the answers submitted in the survey. Moreover, the answers given might be short, which makes it hard for the researcher to understand the reasoning behind their viewpoint. Hence, totally misunderstanding what the respondent was trying to express. Last but not least, as this is

submitted via Google Forms, an online platform, the respondents have no obligation in submitting it, an might be doing it just to help the researcher collect data. Thus, there is no way of knowing if the answers submitted are legitimate, or just answering for the sake of completing the survey [15]. This will greatly affect the result of the entire outcome when the researcher analyses the data collected.

VIII. OVERVIEW OF THE PROPOSED SYSTEM / SOLUTION

8.1. Addressing the Problems and its Functionality

As mentioned earlier, one of the problems faced by residents in rural areas is that receiving medical treatment is highly inconvenient as they have to travel far, and if they're diagnosed with a chronic disease, this makes things even harder for them. Hence, after much analysis, the proposed system is to bring health treatments to the patients instead. The patients' vital data will be collected and sent over to the cloud for analysis, and medical staffs will also be able to assess the analyzed data to monitor their patients as well as to make important decisions. For instance, increasing or decreasing their medicine dosage, determine if their vitals are stable enough for a surgery to be performed, etc. By doing so, this helps address the stated problem where rural residents rarely receive medical checkups due to the inconvenience they have to face to receive one.

Another problem is faced by medical staffs, as mentioned earlier, the healthcare system in today's world is always changing and extremely dynamic. Hence, traditional healthcare systems adopted by old school hospitals are facing an issue where medical staffs are overworked and heavily burdened. The proposed system to address this problem is able to automatically collect readings from patients at customized time intervals, that will be set by the nurse or doctor. The IoT device will use the embedded sensors to collect the patients' vitals and notify the medical staff of the data collected for them to analyze. In the event where the patient's vitals are not normal, for example, their heart rate has skyrocketed, an alert stating the patient's room number and personal details will immediately be sent to the medical staff on duty, or the nearest medical staff. This is extremely crucial because in the medical field, every second counts when it comes to saving a life. A fraction of a second wasted will change the entire outcome. Hence, this feature in the proposed system will not only ease the burden of the medical staffs but also help in having an efficient system to help save more lives.

8.2. Architectural Designs

There are numerous IoT enabling technologies suitable to be used in applying IoT in healthcare. Various types of systems and sensors can be used to develop the optimal device needed in this solution. This device will be made using an Arduino board and programmed using the Arduino IDE.

8.2.1. Sensing Technologies

Sensors are essential in creating any IoT based application or device. The sensors that are needed in this IoT wearable device are piezoelectric sensors (able to detect and monitor the heart rate), temperature thermistors (which detects the temperature of the skin's surface), motion trackers (monitors the patient's movements, keeping them aware of ensuring they maintain sufficient activities according to the doctor's request in having a healthy lifestyle by exercising). One of the sensors suggested is the pulse oximeter, as shown in Figure 3 [6]. This sensor is used for

monitoring patients in critical care. It helps monitor the patient's heart rate and pulse oximetry – a test to measure oxygen saturation level in the patient's blood [16].

Figure 2: Pulse Oximeter Sensor Module

8.2.2. Location Technologies

Global positioning system, or more commonly known as GPS is one of most important real-time location systems (RTLS). RTLS is able to detect the approximate (accurate up to 10m) current geolocation of someone or something [17], [18] Due to its dependency on the satellite, this system is able to locate an entity under differing weather conditions. In other words, the external environment will not affect the system from detecting objects. This feature is extremely crucial as the GPS plays a significant role in navigating ambulances to locate patients despite the weather. However, there is one con with the GPS tracking system – it is unable to detect the precise location when indoors. This is due to the structure of the building that blocks the signals being transmitted. Thus, LPS (local positioning system) is a better alternative in this case, providing higher accuracy indoors. This is because it measures the radio signals travelling between an entity and a disposition of receivers locating it [6], [19].

8.2.3. Cloud Computing

After introducing numerous sensors to monitor the patient's signs, large amounts of data will inevitably be produced, analyzed, shared and stored. This is where cloud storage comes in handy, due to its flexibility on increasing or decreasing its storage space on demand. Furthermore, the cloud supports collecting data from the sensors in the IoT devices, processes them and shares them with other devices connected to the internet. For instance, the patient's monitored heart rate and body temperature will be collected, analyzed and sent to their mobile devices, so that they are aware of how their body is doing, or even sending these data to medical staffs despite being far away from them geographically. These staffs will then be able to identify if any anomaly arises in the patient's vital readings. Last but not least, the cloud does not take up physical space when being implemented. In a small wearable IoT device, the cloud is the optimal way of storing data without occupying space.

IX. CONCLUSION

In conclusion, there are more areas to IoT that can be expanded to be useful in various fields. This proposal will help make an significantly large amount of lives easier, and revolutionize the way people view healthcare. It will be

something everyone has the opportunity of receiving and not just for the upper social class. Medical staffs will be able to balance between their work life and personal life as these IoT devices are able to help in monitoring patients for them. Despite the limitations IoT brings, the possibilities of recreating a better world outweighs it all.

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