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APPLICATION OF INTERNET OF THINGS (IoT) IN HEALTHCARE

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ABSTRACT

The Internet of Things (IoT) can be simply defined as connecting to the internet all the physical places and things in the world for the vast amount of benefits it offers. Once connected to the internet one can send or receive information or both. Smart things have an ability to send and/or receive information. IoT is gaining vast recognition from a wide range of domains like agriculture, healthcare, academia, transportation, manufacturing etc by the development of smart systems. This paper focuses on the application of IoT in Healthcare systems which allow achieving excellent personalized healthcare at affordable costs. The application of this technology in healthcare domain allows medical facilitators and centers to operate more competently giving patient better treatment compared to the conventional methods. This paper discusses five such applications used in the healthcare domain. Further, it discusses the benefits offered by introducing this technology in the domain and also the challenges faced in implementing such systems in real life. The paper concludes by discussing the future of IoT in healthcare and how it has opened a world of possibilities for the next decade to see a revolution in the treatment and diagnosis of disease.

KEYWORDS — *healthcare, Internet of Things(IoT), IoMT, medical devices.*

INTRODUCTION

IoT as defined means that connecting to the Internet all the things in the world for the tremendous benefits it gives to the people worldwide in different domains. The subset of this is when we just refer to all the things related to a medical domain i.e medical device and application are connected to each other and can help monitor or track the status of patients with different ailments. This is termed as the Internet of Medical Things (IoMT) or healthcare IoT. The medical devices communicate to each other as they are connected via the online computer networks. These devices further linked to cloud platforms on which the captured data can be stored and used by the medical professional for analysis. It helps in improving and safeguarding patient's life by taking timely decisions related to their health. The concern medical professional can use the data received from IoMT to take healthcare decision of that particular patient. According to [1] IoMT will reach worldwide $136.8 billion by 2021. As of now, 3.7 million medical devices are connected to each other, transmitting critical information of the patients to the healthcare systems to which

these devices are connected. With the rise in the population worldwide, the burden on the healthcare systems will always keep on increasing. With this and the rising cost of medical care, IoMT is the only and better solution to deal with this necessity of the day.

In this paper, different wearable, portable devices related to IoMT, which are used with comfort in daily life by variety of patients with different health issues, are discussed. Application of IoT in healthcare can be looked at in two ways, one for the improvement of care and the other is for tracking, monitoring, and asset maintenance in medical domain. Further, this paper concludes with the benefits offered by IoMT compared to the conventional method and the challenges faced in implementing IoMT widely under different scenarios.

LITERATURE REVIEW

Use of body wearable sensors has recently gained a lot of attention from people of all age groups. Personal healthcare monitoring, activity awareness and fitness calculation have been on priority by use to these powerful tools. There exist many papers in the literature proving the importance of these devices in the daily life of people and how it has changed the medical domain for good.

Shah and Chircu, 2018, provide a systematic literature review on IoT and Artificial Intelligence (AI) in healthcare. Seventy-five peer-reviewed articles are considered for their study. The paper reveals the applications used by people worldwide in this domain. Top applications are categorized by them and also identifies the gap for future work.

Yacchirema *et al.,* 2018, proposes an innovative fall detection system for elderly people in indoor environments. For collecting the real-time data of the movements of elderly people a 3D-axis accelerometer embedded into a 6LowPAN wearable device is used. An alert is sent to the family members when a fall is detected.

Abas *et al.,* 2018, discusses IoT healthcare solutions with its applications and challenges. The papers point to a different category of applications. Further, it discusses the importance of doing an analysis of this healthcare data. It also points to the challenges in adopting this technology.

Malwade *et al.,* 2018, describes mobile and wearable technologies in healthcare for elderly people. Its emphasis on the adoption of this technology to improve the life of elderly people.

Pinto *et al.,* 2017, discusses many IoT based health care system for elderly people. It triggers emergency alerts while monitoring the patient's critical health and vital information. It provides great assistance to elderly people and their family to remotely monitor them.

Farhani *et al.,* 2017 proposes the need to move from clinic/hospital-centric healthcare to patient-centric healthcare where the focus will be on the patient and the patient will be more actively involved on the basis of the vitals and other medical information. A multi-layer architecture has been proposed for the patient-centric ecosystem.

APPLICATIONS OF IoT IN HEALTHCARE

Some of the applications of IoT in healthcare are discussed below:

Smart senior care systems

Zanthion [8] is a medical alert system that can be worn by any person on clothes or as designer jewelry. It is typically used for senior citizens. It uses multiple sensors including GPS, motion, acceleration, heart rate, blood pressure that help in automatic fall detection, senior activity monitoring, and perimeter alert for seniors or if the senior citizen remains motionless for too much time then in all the cases an alert is sent to the family who can help. Another system for fall detection using IoT and Big data is proposed by [3]. When the fall is detected the system immediately takes action by automatically sending notifications to the people responsible for taking care of the respective people. The system also stores this data on the cloud to further share with medical professionals helping them analyzing the fall detection reasons in an

elderly person. We-Care [6] is another such IoT based Health care system for elderly people. The author of the work discusses many such similar systems for elderly.

Autobed: Bed tracking technology

When an issue is raised in the healthcare domain, the patient's life is always at the priority. In cases of emergency, every minute counts to save the patient's life. In such a situation once the patient enters the hospital premises, it is utmost important to allocate a bed to the patient at the earliest possible which will enable the doctors to give emergency treatment or get them ready for the surgery as per the need. This is a challenging task in big hospitals as there are many other factors to be considered while allocating a bed to the patient apart from tracking which are the vacant beds in the hospital. Autobed [9] is a complicated algorithm that helps in suggesting all the possible vacant beds for the patient. Mount Sinai hospital in New York, US along with GE Healthcare worked on this problem to better manage to allocate beds to the patients [9]. They used radio frequency tags and wifi to look around which beds were available. The hospital has more than 1000 beds and serves approx 59,000 patients a year. With the help of Autobed tracking technology it was able to reduce the waiting times of emergency patients by 50% and overall resulting in 90% constant occupancy of beds in the hospital round the year. Autobed also considers other factors while allocating the bed. For example, if a male is occupying a bed in the room then another bed should be allocated to male only. Also if a patient is admitted for example to get a treatment from a specific disease then the bed should be allocated near the doctor's location so that less travel time for the doctors as well.

Glucose monitoring systems

Dexcom [10] helps to continuously monitor the glucose of the patient using sensor technology. It gives exceptional performance due to its user friendly features which makes it very convenient to use. The reports are generated in the form of graphs and visuals making it very easy to understand whether the glucose is going high or low. It sends an alert to inform the user in case the glucose level is going out of the expected range in higher or lower side. Additionally it has an option to see the glucose profile on demand. A research by [11] also proposes glucose monitoring system for the patients admitted in intensive care unit. It collects the patients glucose data four times a day and automatically stores it in hospital management system. Doctors can monitor the data from this system. Another similar research by [12] uses bluetooth low energy implantable glucose monitoring system. Authors of [13] present a similar system for patients with diabetes. It uses a long term implantable sensor which sends the glucose data every two minutes for closing monitoring the patient's glucose status. Another non-invasive blood glucose monitoring system is proposed by [14] which uses near-infrared (NIR). In the end visualized reports are generated to track the glucose levels of the patients. Another such system is designed by type 2 diabetes mellitus [15]. The results can be monitored via WAN such as wireless internet.

Echocardiograms (ECG) monitor

QardioCore [16] is an innovative wearable chest strap ECG monitor that helps to track continuously wireless ECG, skin temperature, heart rate, heart rate variability, respiratory rate and activity tracking on the smartphone. It helps to get a medically accurate ECG with more than 20 million data points in a day which can help get deeper heart health insights and shares that data automatically with the doctor. It is best suited for people with increased health risk caused by a history of heart attacks or strokes, high blood pressure, high cholesterol, diabetes, and excess weight. There are more chest strap monitors [17] and also armband-based ECG monitors [18] developed. There are also ECG monitors integrated with electroencephalogram (EEG) sensors [19] in the helmet. EEG helps in monitoring brain activity including sleep disorders, progress post a head injury, driver drowsiness [20], stress management [21] using a wearable headband.

Asset Maintenance

Asset maintenance could be yet another challenging task especially when dealing with healthcare domain. The need for any medical equipment or medicine or support items could come up anytime and unable to collate the same quickly could lead to some uninvited trouble. One of the ways to have automated asset tracking is with the use of RFID tags [22]. These tags can be attached to the asset or kept in the box containing them. When an item is needed a request could be sent and with the help of the readers, these tags can give the nearest location of the item. These items could be stored in different physical places in the hospital. This offers a lot of benefits including improved visibility into medical assets, location and availability, prevent loss and theft of movable assets, optimize investments in inventory and equipment and forecast demand. There are also four major concerns with the use of RFID in hospitals. RFID may influence the medical process, daily hospital activities may be affected due to RFID tags, overall costs may be an unexpectedly high and potential cyber security risk. There are various other technologies used for asset management in hospitals [23, 24].

CONCLUSIONS

This section summarizes the challenges faced by today's world in the healthcare domain. To overcome this challenge how adaption of IoMT can help and the future of healthcare IoT.

A. Challenges

The rapidly rising population facing more frequently either some chronic health disease or outbursts of epidemics is getting an ever-increasing challenging task for the medical professionals. The conventional way of visiting the doctor in clinic or hospital when the patient falls sick or monitoring some chronic diseases so that the doctor can note some observations and suggest treatments results in either long waiting queues or getting some general medicines applicable to all. In this method, the patient is not at the center of caregiving and not being actively participated in the medical process. Some more challenges faced in this conventional method of the medical profession are as follows:

1. Demand for healthcare services has increased but the medical workforce is still limited.
2. Due to demand in the rising health issues and limited medical workforce, the cost of medical expenses is increasing. Further quality time cannot be given to understand the patient's perspective.
3. Increase in the elderly population (above 60 years) is expected to reach 2 billion in 2050 [25]. This age group usually needs more medical facilities and resources.
4. Conventional method does not offer an option to monitor whether the patient is following the treatments prescribed by the medical practitioner like medications, exercise etc.

B. Benefits

To overcome the challenges faced in the conventional method of dealing in the healthcare domain, there is a need to adapt IoMT or healthcare IoT which offers the following benefits:

1. Doctors can check the patient's data in real-time avoiding the effort to physically check each and every patient resulting in saving a lot of time and being more involved with the patient's health status.
2. A lot of costs can be saved due to the use of technology and frequent visits to the doctor for routine checkups to know the health status. Doctor visits would be needed only when the health status is not as per the recommendations.
3. Either these devices come in the form of wearable or portable devices with ease of use and friendly operations on smartphone applications.
4. Patients lifetime monitoring records can be easily available on few clicks anytime and anywhere as they are maintained on the cloud. In addition, this can help predict the patient's future health.

5. In many cases, if the reading of the patient's health goes beyond the recommendation range then immediately online assistance can be availed.
6. IoMT offers to personalize or tailor the service or need as per the patient requirements.
7. IoMT works with integrating different technologies without concerning about the complexity. The healthcare data can be further used to analyze and get some predictions.
8. Use of IoMT can result in better healthcare resource management.
9. IoMT offers a holistic solution to everyone's needs.
10. Health professionals around the world can get connected using this and work on the cure for any disease or health issue at the international level using this collaborative opportunity.

It is possible to achieve the above benefits and more provided the entire healthcare domain which includes clinics and hospitals to adopt the healthcare IoT. In such a situation, the system will automatically become patient-centric rather than doctor-centric or clinic/hospital-centric which is the existing scenario.

C. Future

With the increase in the demand to move from clinic/hospital-centric healthcare to patient-centric healthcare, the future of IoMT looks bright. With the unlimited promises that IoT has to offer, there are a few challenges that need to be overcome to make it into a mainstream platform. As a huge volume of medical data needs to be received, processed and communicated with utmost care and precision, data management could be one of the challenges with IoMT. Scalability of these applications should be possible to handle multiple requests from a larger audience at the same time. As these applications could be used from smartphone, tablets, computers etc., the interfaces should be designed in a self-learning way. As IoMT goes beyond the boundaries of the countries, it has raised concerns with interoperability, standardization and other regulatory affairs. Lastly, since it is handling every patient's personal and critical information, security and privacy need to be maintained.

IoMT promises to revolutionize the healthcare industry by facilitating more personalized, preventive and collaborative care to improve one's everyday life experience.

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