IoT Based Smart and Portable System for Remote Patient Monitoring and Drug Delivery

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Abstract. In recent, there has been significant development in the healthcare technology particularly due to Internet of Things (IoT). The ubiquitous computing has brought a progressive change in the field of healthcare. In this way, the wellbeing experts are serving the society in a superior manner by utilizing such IoT based gadgets. This paper presents an IoT based model “Smart Portable Intensive Care Unit” for real-time patient monitoring with an additional feature of drug delivery from the remote location. The proposed model assisting the healthcare professionals and the relatives of the patient to monitor the physiological data of the patient from the remote location. The patient’s physiological data is transmitted to the cloud. An android based mobile application is developed to fetch the patient’s data from the cloud database in real-time. The authenticity of the user is maintained throughout the data communication process. The patient’s data is transmitted on the mobile application of the doctor both in analog and digital form. The doctor can also set the flow of drug infusion from a remote location. The proposed model can be effectively used for the patients admitted in the hospital or inside the ambulance.

Keywords: Remote Monitoring; Internet of Things; Smart drug delivery; Ubiquitous Computing.

1. Introduction

There have been significant advancements in the field of computer network and data communication. The technology like IoT has enabled all the objects to communicate with each other over the network. IoT provide object-to-object and object-to-computer communication. IoT enables sensors or devices or objects present in the network to communicate independently with other objects in the network [1]. Therefore, every object can be considered as a smart object [2,3]. IoT is an assistive technology for healthcare, smart cities, agriculture, transportation, domestic and goods monitoring[4]. IoT has become a vital part of the society, therefore, it is becoming a necessity rather than accessibility [5]. In recent years there has been immense growth in the field of healthcare due to IoT[6], which improves the monitoring efficiency [7]. The nursing staff of a hospital can view the physiological parameters of the patient from anywhere through IoT implementation [8]. The body sensor area network (BSN) along with IoT facilitates transmission of the physiological parameters of a patient in real time. Therefore, a doctor or relatives of a patient can monitor a patient anytime, anywhere. In this paper an IoT based model “Smart Portable Intensive Care Unit (SPICU)” is proposed, which is a remote diagnostic unit. SPICU helps the medical staff to view the vital parameters of the patient to make a diagnostic decision. In country like India when a patient was taken to a hospital through ambulance the main problem is that there is no specialist doctor inside the ambulance. It is quite possible that a patient may stuck in the
traffic jam and this could lead to a life-threatening condition for a patient. SPICU provides the virtual presence of the doctor inside the ambulance by transmitting the vital parameters of the patient to a doctor. Therefore, the mortality rate caused by late arrival of the patients in hospitals can be reduced [9].

The proposed solution is not only transmitting the vital parameters of the patient to a doctor in real view, but a doctor can also view the patient through live video streaming. The medical staff can also deliver the drug through infusion pump after diagnosing a patient. Every activity right from the patient’s data to doctor’s diagnostic decision is recorded in the database.

2. Related Work
Healthcare is one of the topmost challenges worldwide for the researchers. The IoT in the field of healthcare can bring multiple benefits through sensors, actuators and smart devices [5], [10]. The technology like WSN (Wireless Sensor Area Network) enables to sense, monitor and to track the data using smart and intelligent sensors. The rapid advancement in this technology contributes to the development of the IoT [11]. An IoT based smart health care system was proposed to transmit the patient data in real-time [12]. To collect the body parameters of the patient, required sensors are attached with the patient and with the help of Arduino uno controller data is transmitted to the cloud. Web based ECG monitoring system [13] is proposed by the authors to transmit the ecg data. For this purpose AD8232 ecg sensor developed by Texas Instruments is used by the authors. The collected data is transmitted to the MQTT cloud, which can be fetch through the web application. Smart Health Care (SHS) was proposed by Catarinucci et al to fetch the patient’s physiological (vital signs) and environmental data (location) to detect the real-time variation [14]. IoT based healthcare system has been diversely used in multiple fields from pediatric care to elderly care [15].

Table 1. Areas of Healthcare.

| Area                        | Usage                                                                 |
|-----------------------------|----------------------------------------------------------------------|
| Fall Detection              | Helpful for the old age and physically challenge people.             |
| Medical Fridges             | To measure and inform the internal temperature so is to protect the  |
|                             | organic elements.                                                    |
| Sportsmen Care              | The application is specifically useful for the professional sportsmen|
|                             | to measure the physiological parameters such as weight and blood     |
|                             | pressure etc.                                                        |
| Patient Surveillance        | Specifically used for monitoring of the patient from the remote      |
|                             | location.                                                            |
| Chronic Disease Management  | Taking care of the patients suffering from chronic diseases in the   |
|                             | absence of attendant. Therefore, it is helpful to reduce number of   |
|                             | attendants in the hospitals.                                          |
| Ultraviolet Radiation       | Is helpful to notify people not to enter in an ultraviolet area.      |
| Sleep Control               | Helping to capture the data of a patient during the sleep hours.      |
| Dental Health               | Enables dentist to know the brushing habits of a person through a    |
|                             | smart toothbrush.                                                    |
Remote patient monitoring is a key feature of IoT based system. It allows the medical staff to monitor and diagnose a patient from the remote location [16], [17]. A remote monitoring system for the heart disease patients is suggested for the pervasive health service [18]. In healthcare IoT is effectively used for the multiple applications. The various areas of IoT in the field of healthcare [19] are shown in Table 1.

3. Methodology

SPICU (refers to Figure 1 and Figure 2) is an IoT based health monitoring cum drug delivery system. A doctor cannot deliver drug to a patient without diagnosis. Therefore, a five parameter (Heart Rate, Non-Invasive Blood Pressure, Body Temperature, Blood Saturation, and ECG) vital sign machine is attached with patient. The vital signs of the patients are transmitted in JSON (JavaScript Object Notation) form to the cloud-based server. The technical specifications of the vital sign monitor are given in Table 2.

A desktop application and a mobile application is developed to get/post the patient related data to/from cloud database. Therefore, with the help of mobile application, it is feasible for the doctor to view the physiological parameters of a patient in real-time. The mobile application can also control the infusion pump from the remote location.

![Figure 1. Schematic diagram of SPICU](image-url)
A five-syringe infusion pump is developed for the infusion purpose. The infusion pump is duly calibrated from one of the NABL (National Accreditation Board for Testing and Calibration Laboratories) laboratory, approved by Ministry of Science and Technology. The mobile application can fetch the patient’s data and it can also post the doctor’s instructions to/from cloud base server. As and when a patient is in the ambulance a notification is send to the mobile phone of the doctor to let him know that a patient is inside the ambulance. After the authentication doctor can view the vital parameters of the patient through the mobile application. JWT (Java base Web Tokens) are used to maintain the authenticity. Another vital feature of SPICU is drug delivery. After viewing the vital parameters of the patient, a doctor can give command to deliver the drug. Therefore, an infusion pump available inside the ambulance is connected with the patient through IV routes.

**Table 2. Technical Specifications of Vital Sign Monitor**

| Model               | Ulterius-501                                      |
|---------------------|--------------------------------------------------|
| ECG                 | Standard 12 Leads                                 |
| SPO2 Saturation range | 0-100%                                              |
| Pulse range         | 20-250 bpm                                         |
|                     | 40-280 mmHg (SYS)                                 |
| NIBP                | 10-225 mmHg (DIA)                                 |
|                     | 10-240 mmHg (MAP)                                 |
| Temperature         | 0-50°C                                             |
| Display             | 320*420 Pixels TFT Screen                          |
| Power Supply        | 220-240 V, 50Hz                                   |
| Network             | LAN/ Wi-Fi (802.11n)                               |
| Battery             | 12V/1.2 AH (Lead Acid)                            |
| Weight              | 1.8 kg                                            |
4. Results

India has shortage of adequate number of qualified medical doctors although doctor to population ratio in India is improving [20] but still it is a matter of concern. The proposed system would be helpful for all the patients who need remote assistance of a specialist doctor at home/ hospital/ old-age home or during transition.

The proposed model allows the doctors to:

- Fetch and view the required vital parameters of the patient on his mobile phone application.
- Release the drug from the remote location, after viewing the vital parameters of the patient.
- Access the complete history of the case from the real time clinical database.

The doctor can view the patient’s vital sign data transmitted through vital sign machine in real-time as shown in Figure 3.

The patient’s data on the Doctor’s mobile application is represented in both analog and digital form as shown in Figure 4. Through the ECG tab, available on the mobile application doctor can also view the ECG of the patient. This mobile application has been tested in both 3G and 4G network and has been working efficiently.
Another good feature of the model is to control the drug infusion rate from the remote location. The patient’s physiological data is transmitted to the cloud database after every 10 seconds. This data has been stored in encrypted form in the Real Time Clinical Database (RTCDB) in the cloud, which can be accessed any time after the proper authentication.

5. Future Scope and Conclusion
The present invention discloses an IoT based drug delivery system to transmit the vital parameters of the patient in real-time. This system can be effectively used to monitor the data of patients by doctor, relatives of a patient, inside hospitals and inside ambulance when a patient is in transition. It is a real-time diagnosis system with an extra feature of drug delivery through the infusion pump. The National and International patent of the proposed model has been published, as per WIPO (World Intellectual Property Organization), this work is having good novelty [21-22]. The doctor can also deliver the drug from the remote location after viewing the patient’s data. The sensors attached with patient are generating large amount of data, therefore, to discover the hidden useful facts, data mining can be used [23]. In future, through machine learning the efficacy of the system can also be improved. Approaches like machine learning can also assist to improve the efficacy of the system to provide better services to healthcare professionals.

References
[1] F. Restuccia, S. D’Oro, and T. Melodia, “Securing the internet of things in the age of machine learning and software-defined networking,” IEEE Internet Things J., vol. 5, no. 6, pp. 4829–4842, 2018.
[2] S. Purri, T. Choudhury, N. Kashyap, and P. Kumar, “Specialization of IoT applications in health care industries,” in 2017 International Conference on Big Data Analytics and Computational Intelligence (ICBDAC), 2017, pp. 252–256.
[3] Kaushal, Rajesh Kumar, Surya Narayan Panda, and Naveen Kumar, “An IoT Based Approach to Monitor and Replace Batteries for Battery Operated Vehicle.” IOP Conference Series: Materials Science and Engineering. Vol. 993. No. 1. IOP Publishing, 2020.
[4] P. Rajan Jeyaraj and E. R. S. Nadar, “Smart-monitor: patient monitoring system for IoT-based healthcare system using deep learning,” IETE J. Res., pp. 1–8, 2019.
[5] S. Tyagi, A. Agarwal, and P. Maheshwari, “A conceptual framework for IoT-based healthcare system using cloud computing,” in 2016 6th International Conference-Cloud System and Big Data Engineering (Confluence), 2016, pp. 503–507.
[6] P. Kumar and K. Silambatarasan, “Enhancing the Performance of Healthcare Service in IoT and Cloud Using Optimized Techniques,” IETE J. Res., pp. 1–10, 2019.
[7] S. Selvaraj and S. Sundaravaradhan, “Challenges and opportunities in IoT healthcare systems: a systematic review,” SN Appl. Sci., vol. 2, no. 1, p. 139, 2020.
[8] E. T. Tan and Z. A. Halim, “Health care monitoring system and analytics based on internet of things framework,” IETE J. Res., vol. 65, no. 5, pp. 653–660, 2019.
[9] N. Kumar, S. Panda, P. Pradhan, and R. Kaushal, “IoT Based Hybrid System for Patient Monitoring and Medication,” EAI Endorsed Trans. Pervasive Heal. Technol., vol. 5, no. 19, 2019.
[10] J. A. Stankovic, “Research directions for the internet of things,” IEEE Internet Things J., vol. 1, no. 1, pp. 3–9, 2014.
[11] L. Da Xu, W. He, and S. Li, “Internet of things in industries: A survey,” IEEE Trans. Ind. Informatics, vol. 10, no. 4, pp. 2233–2243, 2014.
[12] Z. M. Kalartithi, “A review paper on smart health care system using internet of things,” Int. J. Res. Eng. Technol., vol. 5, no. 3, p. 8084, 2016.
[13] A. Mishra, A. Kumari, P. Sajit, and P. Pandey, “Remote web based ECG Monitoring using MQTT Protocol for IoT in Healthcare,” Development, vol. 5, no. 4, 2018.
[14] L. Catarinucci et al., “An IoT-aware architecture for smart healthcare systems,” IEEE Internet Things J., vol. 2, no. 6, pp. 515–526, 2015.
[15] S. M. R. Islam, D. Kwak, M. D. H. Kabir, M. Hossain, and K.-S. Kwak, “The internet of things for health care: a comprehensive survey,” IEEE Access, vol. 3, pp. 678–708, 2015.
[16] N. Kumar, S. N. Panda, P. Pradhan, and R. Kaushal, “IoT based E-Critical Care Unit for Patients In-Transit,” Indian J. Public Heal. Res. Dev., vol. 10, no. 3, pp. 46–50, 2019.
[17] B. Almadani, M. Bin-Yahya, and E. M. Shakhshuki, “E-AMBULANCE: real-time integration platform for heterogeneous medical telemetry system,” Procedia Comput. Sci., vol. 63, pp. 400–407, 2015.
[18] C. Li, X. Hu, and L. Zhang, “The IoT-based heart disease monitoring system for pervasive healthcare service,” Procedia Comput. Sci., vol. 112, pp. 2328–2334, 2017.
[19] Z. Alansari, S. Soomro, M. R. Belgaum, and S. Shamsi, “The rise of Internet of Things (IoT) in big healthcare data: review and open research issues,” in Progress in Advanced Computing and Intelligent Engineering, Springer, 2018, pp. 675–685.
[20] R. Kumar and R. Pal, “India achieves WHO recommended doctor population ratio: A call for paradigm shift in public health discourse!," *J. Fam. Med. Prim. Care*, vol. 7, no. 5, p. 841, 2018.

[21] “Portable and Smart Intensive Care Unit.” [Online]. Available: https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2016035098&redirectedID=true. [Accessed: 01-Apr-2020].

[22] “Portable and Smart Intensive Care Unit.” [Online]. Available: http://ipindiaservices.gov.in/PatentSearch/PatentSearch//ViewApplicationStatus. [Accessed: 01-Apr-2020].

[23] N. Jothi, W. Husain, and others, “Data mining in healthcare--a review,” *Procedia Comput. Sci.*, vol. 72, pp. 306–313, 2015.