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IoT Based Hybrid System for Patient Monitoring and Medication

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Abstract

BACKGROUND: In recent years, a lot of research work has been done to transmit vital parameters of the patient using IOT (Internet of Things). The information related to Patient is sent by means of WBAN (Wireless Body Area Network) and sensors to the healthcare database. This has been shown a great potential to transmit vital parameter of the patient at a remote location. Remote monitoring of patient(s), including vital signs, sound and video is to be transmitted, particularly when a patient is in transit. By transmitting the imperative parameters of the patient to a specialist diminishes, the ideal opportunity for starting treatment and permits the emergency crew to be better prepared. This will facilitate a doctor to make a diagnostic conclusion.
OBJECTIVES: This study aims to develop an advance system to transmit the vital parameters of the patient to the smart phone of the doctor at a remote location. After seeing essential parameters of the patient, the specialist can convey/endorse the medication from the remote area.
METHODS: To monitor patient's data in real-time an android application is developed which helps the medical staff to monitor the patient from remote location. All the patient related information is stored in Real Time Clinical Database.
RESULTS: The proposed model will allow the doctors to monitor physiological parameters (HR, NIBP, Temp, ECG, SPO2) of the patient, as well as endorse medication from the remote location. This system will be helpful to provide virtual presence of the doctor inside the ambulance and to provide lifesaving drugs to the patient while the patient is in transit.
CONCLUSION: The present invention provides a fully integrated system for the doctor to view the vital signs of the patient from the remote location in real-time.

Keywords: Remote Drug Delivery, Vital Sign Transmission, WBAN, Computer Controlled Drug Delivery.

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1. Introduction

Administration of drug delivery has substantially improved due to advancement in technology. It plays an effective, important and vital role in the healthcare industry. During the past decade, due to the availability of universal mobile telecommunication systems, high bandwidth and sensor, not only affect the daily life of a person but also caused a revolution in the healthcare industry. As a result of these advancements "Phones" are turned into "Smart-Phones", hence smart phones are not only used for the better communication, but also assists healthcare professionals, as a tool in many ways.

Modern ICU/CCU are equipped with instruments like bedside monitor, infusion pump etc. which assists healthcare professionals to monitor and diagnose a patient effectively. What if a patient is dying due to non-availability of a doctor? What if a health professional is physically present on site but is not authorized to

administer any drug without the recommendation of a qualified doctor? Such circumstances increase risk to patient's life. Mortality rate is increasing in India due to delayed arrival of ambulance to the hospitals during the golden hours [1]. In a country like India, such incidents happen daily in large numbers. It is also emphasized here that in most of the occasions, the travelling distance from the site to a nearest hospital is 40-50 kilometres and it takes at least one-hour time to reach the destination. This is quite scary especially in those situations when the patient's condition is continuously deteriorating.

The doctor cannot see the vital signs of the patient and he must rely upon the attendant's statement who is accompanying the patient to administer the drug. A communication error in this scenario between the doctor and the attendant could result in a loss of life. In such cases the first half or one hour is very critical for a patient, who needs immediate medical aid at the earliest possible. So, it is important that life of such patient should be immediately shifted to the safe hands. In the past, many research activities had been decisive on monitoring health status of the patient (in real time), diagnose a patient from a remote location, enhancing and developing telemedicine solutions [2]. There is an immediate need of a smart, portable technology which can enable quick and virtual access to a Doctor of real-time emergency case. Therefore, it is a need of the time to develop an IOT based patient monitoring system, which will allow the doctor to view as well as diagnose a patient from the remote location. Henry Mayo Newhall Hospital, California (USA) has implemented an IoT based solution for the doctors so that they can give more time to their patients even from remote location [3]. Similar kind of studies have already been implemented in various countries like Russia and China [4-5]. In this paper, we have proposed the architecture of a remote-controlled Hybrid Drug Delivery system (HDDS) which can be used in ICU/CCU deployed inside an ambulance. The subsequent part of this paper is divided as follows: section 2 provides related works, section 3 presents the methodology, results and discussion are in section 4, section 5 ends up with a conclusion and future scope.

2. Related Work

Extensive work has been done to transmit the vital parameters of a patient to a hospital/ medical centre or to a doctor who is at a remote location where he/she can monitor/ analyse the patient. Telemonitoring is a remote monitoring system that includes the usage of audio, video and technology to monitor the status of a patient [6]. Telemonitoring allows the researcher to provide high quality medical solution to patients [7]. In recent years, IoT based systems had been proposed and used in healthcare to obtain the patient data ubiquitously along with Wireless Sensor Network (WSN). [8-9]. An IoT based smart health care system was proposed by vikas et al, which allows to monitor patient's data remotely [10]. Carlos et al. proposed a cloud computing solution for the same to distribute vital parameters of the patient, which can be analysed by a doctor from remote location [11], wearable sensors are used to capture the vital signs of the patient. Tia Gao et al. developed VitalMote that facilitate medical professionals to monitor vital signs as well as geographical location of the patient until the patient is admitted to the hospital through transportation. In their study, they used electronic triage tags which help medics to know the status of the patient [12]. Biswasjit et al. proposed a web cluster/ grid computing to renovate data from sensor to short-term results [13]. Yuan et al. proposed a wireless PDA (Personal Digital Assistance) based monitoring system for intrahospital/ interhospital transport [14], with an aim to monitor the physiological data of the patient when the patient is in transport. The drug delivery system was consisting of microcontroller, wireless sensors and computer network to transmit the patient data. Handheld devices, such as smart phones and PDAs to receive the patient data. Burno et al. proposed MOHLL (Mobile Health Living Lab) to transmit ECG (Electrocardiography), SPO2 (Oxygen Saturation) and body temperature using a ZigBee microcontroller to a central data server [14]. Van Halteren et al. developed MobiHealth project that transmits patient data remotely using wireless communication and the incorporation of sensor to Body Area Network (BAN). MobiHealth does not support automated monitoring and patient feedback [15]. Bingchuan et al. proposed web based real time monitoring system, CARA (Context-Aware Real-Time Assistant) that may be used to analyse real-time vital parameters of a patient and home monitoring system for self-governance for elderly persons [16]. Shaosheng Dai et al. Recommended prototype of a wireless physiological multi-parameter monitoring system which is supported by mobile communication [17]. This system facilitates a patient to monitor his/her physiological parameters and upload them in a central management system of hospitals. The proposed model enables a doctor to make a diagnostic conclusion. Luca Fanucci et al. proposed remote monitoring of vital signs for CHF (Chronic Heart Failure) patients; this enables the medical staff to diagnose the patient without regularly visiting a patient and take appropriate action [18]. Nicola et al proposed an IOT based solution, the author used Wireless Body Area Network (WBAN) to transfer the patient data to Health Care Record (HCR) database with the help of wireless local area network (WLAN) [19]. Therefore, IoT in the field of healthcare giving multiple benefits to patients as well as healthcare providers [20].

Patient related data transferred through WBAN plays a critical role, as incorrect data may cause to wrong treatment [21]. Therefore, confidentiality, dependability and integrity must be protected. Moreover, a large amount of data produced by the sensors is in unstructured format and therefore, difficult to process and understand. Distributed computing, cloud computing and advanced processor allows researchers to manipulate with unstructured data [22]. Existing work, relevant to the field

shows that presently there are some systems available to transmit the vital signs of the patient to doctor/ healthcare staff/ relatives of the patient at a remote location. This is a unidirectional mode of communication, where a person from remote location can view the vital signs. The current study is proposing a system which will not only transfer the vital signs to a doctor at a remote location but will allow a doctor to select the name and quantity of the drug to be delivered. With this doctor can not only diagnose a patient from a remote location, but he/she can prescribe a patient.

3. Methodology

The architectural model of a hybrid drug delivery system is proposed which can deliver the drug to the patient from the remote location after viewing the physiological parameter of the patient. The present invention provides a fully integrated system for the doctor to view the vital signs of the patient from the remote location in real-time. The doctor can give the command to release the medicine from the remote location after viewing the patient's data. To transmit the vital signs of the patient in real view, a five-parameter vital sign monitor (Ulterius 501 Tele ECG) is used. The vital sign monitor is capable to measure HR (Heart Rate), NIBP (Non-Invasive Blood Pressure), ECG (Electrocardiogram), SPO2 (Peripheral Capillary Oxygen Saturation) and Temperature. The hardware specification of vital sign monitor is given in table 1.

Table 1. Specification of the Vital Sign Monitor

Model	Ulterius-501
ECG	Standard 12 Leads
SPO2 Saturation range	0-100%
Pulse range	20-250 bpm
NIBP	40-280 mmHg (SYS) 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

The vital sign monitor transmits the patient data in JSON (Java Script Object Notation) form to the cloud. The json format of the data is shown below:

```
{
"ID": machine_id,
"HR": HR_value,
"SPO2": SPO2_value,
"TEMP": Temp_value,
"SYS": SYS_value,
"DIA": -DIA_value,
"MEAN": -MEAN_value,
"ECG": "ECG_value"
}
```

It keeps sending vital parameters to the cloud after every ten seconds. Thereafter, the mobile application fetches these vital parameters. The doctor can view the vital signs of the patient on his/her phone for decision making purpose. The other feature of vital sign monitor is that, it also provides the facility to take the printout of the ECG.

A desktop application has also been designed to retrieve the vital sign(s) of the patient after two-way authentication. The two-way communication is required to maintain the authenticity. All the patient related information, like vital sign, the rate of infusion, the name of drugs etc. is stored in the Real Time Clinical Database (RTCDB). The Patient related information from the database can be accessed only after the authentication. The working model of hybrid drug delivery system is shown in figure 2. Due to hybrid nature, this drug delivery system can be effectively used for patient monitoring as well as for drug dispensing from the remote location. The hybrid nature of the system makes this study different from the existing studies. It can be used inside ambulance, inside the train, ICU/CCU as well as to take care of elderly age and critically ill patients.

Figure 1. Five Parameter Vital Sign Monitor Device

The proposed model is recommended to assists the doctor for:

- Accessing the required vital parameters of the patient with graphical view from the remote location after the proper authentication.
- Control the release of medicine from a remote location, after receiving the physiological parameters of the patient
- Using the same system inside the ambulance/ICU/CCU/bedside of the patient.
- Accessing the detailed history of the patient from the database

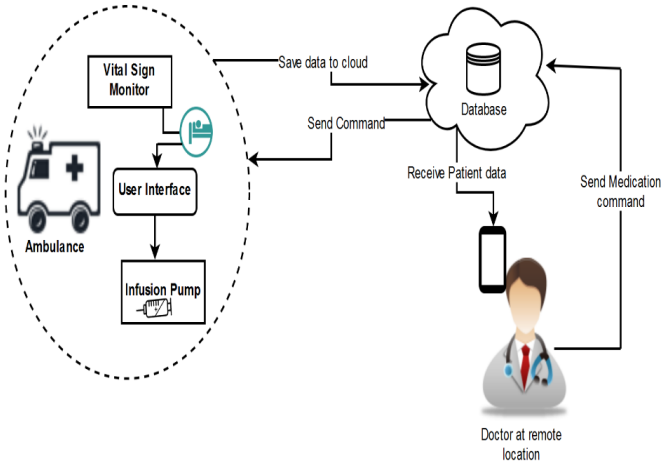


Figure 2. Working model of hybrid drug delivery system

3.1 Accessing Vital Parameters of the Patient

To access the vital parameters of the patient one desktop application and one mobile application has been developed. Both applications can fetch all the patient related data. The desktop application pushes the data to the cloud, whereas mobile application retrieves the data from the cloud. The cloud datacentres facilitate storage, utility services along with scalability and reliability [8]. All the patient related data which is stored in the Real Time Clinical Database (RTCDB) is in JSON format.

JSON data such as patient name, patient id, machine id, heart rate, temperature, SPO2 and NIBP (Non-Invasive Blood Pressure) are read through the mobile application. Doctor can see the data of a patient on his/ her mobile phone after every 10 seconds in a graphical view. It will assist a doctor to make a diagnostic decision as data coming in the graphical format.

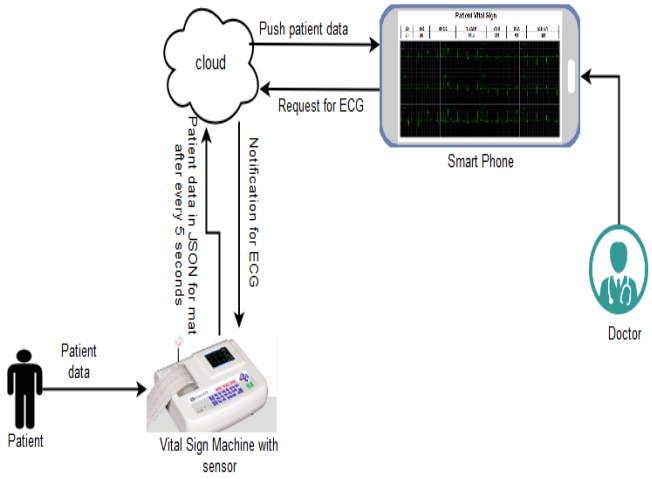


Figure 3. Communication between Doctor and User Interface

Figure-4 shows how the different layers in the architecture model for patient monitoring interacts with each other. The hardware layer consists of infusion pump and vital sign monitor, which send/receive the data through the middle layer e.g. application layer. Data of infusion pump is managed through the Raspberry-pi microcontroller. Data is sent to middleware application designed in python programming language. Similarly, data of vital sign monitor is also sent to the cloud through the middleware. Therefore, both infusion pump and vital sign monitor should be on same network.

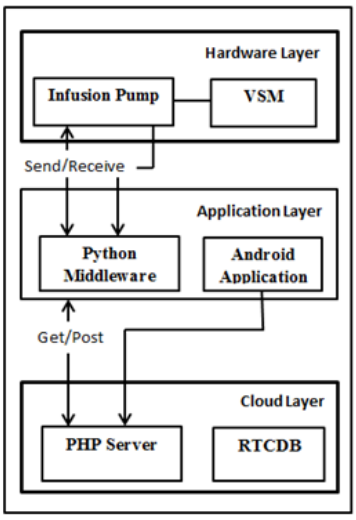


Figure 4. Three Layer Architectural Model for Patient Monitoring

The application layer is the most important layer of this model, which interacts with the hardware as well as the cloud layer.

3.2 Release Medicine from Remote Location

The dispensing is by means of an automatic syringe dispenser. The doctor can give command from his mobile and the appropriate syringe dispenses the required medicine to the patient through IV route. Information such name of the drug, the rate of infusion and time to infuse the drug is enclosed in the form of a packet. The information from the doctor's phone is forwarded to the RTCDB located in the cloud. The web application pushes the packet to the python application, which de-capsulate the frame and send instruction to the infusion pump.

3.3 Access the Detailed History of the Patient

Patient data like name, age, the name of the drug, current infusion rate, total drug infused, and vital parameters are stored in a RTCDB. The detailed history of a patient can be obtained from the database for the case study. One copy of the same is stored in the laptop in excel sheet, which may be accessed by the local health care staff or the doctor after the case is over. This may also be used by the researchers as a case study.

4. Results and Discussion

Patient's physiological data is transmitted in real-time to the mobile phone of the doctor, which will help him/her to make a diagnosis as shown in figure-5. Considering the security issues, patient's data is available only after proper authentication

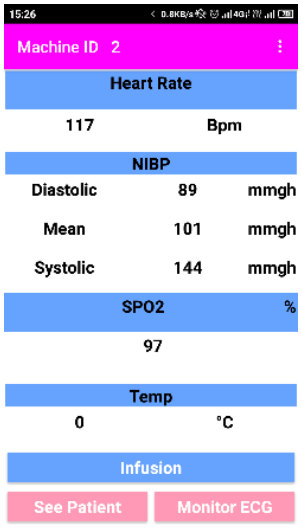


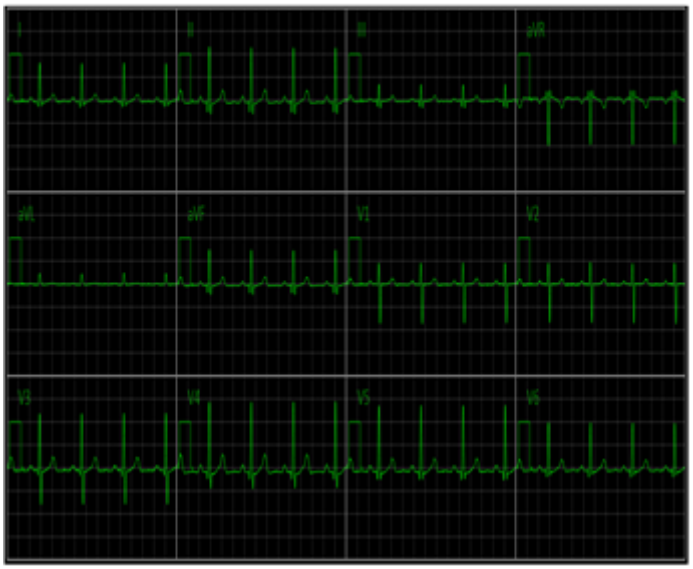
Figure 5. Vital Sign in Real View on Android Application

Data related to the vital signs of the patient can be collected on an ad-hoc basis for research purposes, but due to proprietary communication protocols this can be challenging [23]. Therefore, for our study, we used data set provided by David Liu et al. (2012). The data set was recorded from patients undergoing anaesthesia at the Royal Adelaide Hospital. The time interval to read the data is 10 seconds. The mobile application plots the graph accordingly as shown in figure 6. ECG of the patient is available only on demand of the doctor. If a doctor wishes to see the ECG he has to select ECG option on his phone. At the same time a notification through the cloud is transmitted to the attendant available with the patient.

The key feature of the proposed model is to deliver the drug from the remote location. Hence, the mobile application also enables the doctor to deliver the drug from the remote location after viewing the physiological data of the patient.

The mobile application pushes the data to the cloud in the form of a packet. This packet consists of time, amount of drug in ml, syringe number and direction. Wearable sensor is used recently for the remote patient monitoring [24-25]. As the proposed model is designed for the patients in transits/ICU/CCU/ Hospitals so, we are not using wearable sensors. We recommend that there is need to work on the wearable sensors.

ID	HR	SPO2	TEMP	SYS	DIA	MEAN
40	80	--	--	132	93	103



5. Conclusion and Future Scope

The present invention discloses a hybrid drug delivery system that comprises a feedback-controlled hybrid drug delivery system. The proposed model is an IoT based hybrid drug delivery system that allows the caregiver to monitor and diagnose the patient from the remote location. The National and International patent for the

same has been filed and published, as per comments received from the World Intellectual Property Organization (WIPO) this patent is having novelty [26-27]. The feedback mechanism is one of the key features of this model that facilitates the doctors to diagnose after seeing the vital parameters of the patient in real time. As huge amount of data is generated by the sensors, so it is a challenging task to manage this bulky data with the traditional software. Therefore, big data can be used to analyze and manage the bulky data. Through the data mining technology some hidden factors in the data can also be found. In future, the Health Insurance Portability Accountability Act (HIPAA) may be integrated to protect the privacy. The application interface of the model interacts with the cloud interface through the internet; therefore, a good internet speed is required to interact with the cloud application, which is the only limitation of the study. The proposed model can effectively transfer the patient's data using 3G/4G network, but there is a scope to refine this model so that it would work effectively even in 2G network

References

1. Athavan, K., Balasubramanian, G., Jagadeeshwaran, S. and Dinesh N. Automatic ambulance rescue system. Int J Adv Technol Eng Res. 2012;86–92.
2. Bourouis A, Feham M. U BIQUITOUS M OBILE H EALTH M ONITORING. 2011;3(3):74–82.
3. Tyagi, S., Agarwal, A., & Maheshwari, P. (2016, January). A conceptual framework for IoT-based healthcare system using cloud computing. In 2016 6th International Conference-Cloud System and Big Data Engineering (Confluence) (pp. 503-507). IEEE.
4. Santos, J., Rodrigues, J. J., Silva, B. M., Casal, J., Saleem, K., & Denisov, V. (2016). An IoT-based mobile gateway for intelligent personal assistants on mobile health environments. Journal of Network and Computer Applications, 71, 194-204.
5. Ni, L. M., ZHANG, Q., TAN, H., LUO, W., & TANG, X. (2013). Smart healthcare: from IoT to cloud computing. SCIENTIA SINICA Informationis, 43(4), 515-528.
6. Meystre S. The Current State of Telemonitoring: A Comment on the Literature. Telemed e-Health [Internet]. 2005;11(1):63–9. Available from: http://www.liebertonline.com/doi/abs/10.1089/tmj.2005.11.63.
7. Hussein, A. F., Burbano-Fernandez, M., Ramírez-González, G., Abdulhay, E., & De Albuquerque, V. H. C. (2018). An automated remote cloud-based heart rate variability monitoring system. IEEE Access, 6, 77055-77064.
8. Mahmud, R., Koch, F. L., & Buyya, R. (2018, January). Cloud-fog interoperability in IoT-enabled healthcare solutions. In Proceedings of the 19th international conference on distributed computing and networking (p. 32). ACM.
9. Natarajan, K., Prasath, B., & Kokila, P. (2016). Smart health care system using internet of things. *Journal of Network Communications and Emerging Technologies (JNCET) www. jncet. org*, *6*(3).
10. Vippalapalli, V., & Ananthula, S. (2016, October). Internet of things (IoT) based smart health care system. In *2016 International Conference on Signal Processing, Communication, Power and Embedded System (SCOPES)* (pp. 1229-1233). IEEE.
11. Rolim CO, Koch FL, Westphall CB, Werner J, Fracalossi A, Salvador GS. A Cloud Computing Solution for Patient's Data Collection in Health Care Institutions. 2010 Second Int Conf eHealth, Telemedicine, Soc Med [Internet]. 2010;(i):95–9. Available from: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=5432853.
12. Gao T, Greenspan D, Welsh M, Juang R, Alm A. Vital signs monitoring and patient tracking over a wireless network. 27th Annu Eng Med Biol Conf [Internet]. 2005;27(1):102–5. Available from: http://www.ncbi.nlm.nih.gov/pubmed/17282121
13. Biswas J, Maniyeri J, Gopalakrishnan K, Shue L, Eugene PJ, Palit HN, et al. Processing of wearable sensor data on the cloud - a step towards scaling of continuous monitoring of health and well-being. 2010 Annu Int Conf IEEE Eng Med Biol [Internet]. 2010;3860–3. Available from: http://ieeexplore.ieee.org/document/5627906/
14. Lin YH, Jan IC, Ko PCI, Chen YY, Wong JM, Jan GJ. A wireless PDA-based physiological monitoring system for patient transport. IEEE Trans Inf Technol Biomed. 2004;8(4):439–47.
15. Konstantas D, Widya I, Dokovsky N, Koprinkov G, Jones V, Herzog R. Mobile Patient Monitoring: The MobiHealth System. 2004;2(5):365–73.
16. Yuan B, Herbert J. Web-based real-time remote monitoring for pervasive healthcare. 2011 IEEE Int Conf Pervasive Comput Commun Work PERCOM Work 2011. 2011;625–9.
17. Dai, Shaosheng and Zhang Y. A wireless physiological multi-parameter monitoring system based on mobile communication networks. Comput Med Syst. 2006;474–8.
18. Luca Fanucci, Member, IEEE, Sergio Saponara, Member, IEEE, Tony Bacchillone MD, Pierluigi Barba, Isabel Sánchez-Tato and CC. Sensing Devices and Sensor Signal Processing for Remote Monitoring of Vital Signs in CHF Patients. IEEE Trans Instrum Meas. 2013;62(3):553–69.
19. Bui N, Zorzi M. Health care applications: a solution based on the internet of things. Int Symp Appl Sci Biomed Commun Technol [Internet]. 2011;0–4. Available from: http://dl.acm.org/citation.cfm?id=2093829
20. Chacko, A., & Hayajneh, T. (2018). Security and privacy issues with IoT in healthcare. *EAI Endorsed Transactions on Pervasive Health and Technology*, *4*(14).
21. Li, M., Lou, W., & Ren, K. (2010). Data security and privacy in wireless body area networks. IEEE Wireless communications, 17(1), 51-58.
22. Mohammed J, Lung C-H, Ocneanu A, Thakral A, Jones C, Adler A. Internet of Things: Remote Patient Monitoring Using Web Services and Cloud Computing. 2014 IEEE Int Conf Internet Things(iThings), IEEE Green Comput Commun IEEE Cyber, Phys Soc Comput [Internet]. 2014;(iThings):256–63. Available from: http://ieeexplore.ieee.org/document/7059670/
23. Liu D, Görges M, Jenkins SA. University of Queensland vital signs dataset: Development of an accessible repository

of anesthesia patient monitoring data for research. Anesth Analg. 2012;114(3):584–9.
24. Malasinghe, L. P., Ramzan, N., & Dahal, K. (2019). Remote patient monitoring: a comprehensive study. Journal of Ambient Intelligence and Humanized Computing, 10(1), 57-76
25. Zhu, Z., Liu, T., Li, G., Li, T., & Inoue, Y. (2015). Wearable sensor systems for infants. Sensors, 15(2), 3721-3749
26. https://patentscope.wipo.int/search/en/detail.jsf?docId=WO2016035098&_cid=P21-K594OZ-67141-1
27. http://ipindiaservices.gov.in/PatentSearch/PatentSearch//ViewApplicationStatus