IoT based E-Critical Care Unit for Patients In-Transit

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Abstract— Quite often, we see patients dying due to non-availability of doctor on site or because the person on site is not authorized to administer any drug without the recommendation of a qualified doctor. Therefore, to get a doctor's prescription, either the doctor is called telephonically or the readings of the vital sign monitor, installed (if any) in ambulances, are described to the doctor by the person attending on the patient. The drawback of telephonic communication is that the doctor cannot actually see the monitor and he has to rely on the attendant for the information and further for administering the drug. In such cases, the patient may suffer due to communication errors between the doctor and the attendant. As such, there is a need for smart and secure technology which can enable quick and easy virtual access of doctor to the patient in real time. The present paper reports on the development of a fully integrated system, i.e. Smart and Portable Intensive Care Unit (SPICU) that would provide a REAL TIME ACCESS of the vital parameters of a patient to the concerned doctor at a remote location, in an easy and convenient manner i.e. on his Smart Phone. In turn, the doctor can easily monitor Vital Signs of the patient in real time and inject life-saving medicines at required time duration from a remote location. In this paper the working model of a low-cost multi-syringe infusion pump is described. The reported infusion pump would enable a doctor to deliver drug(s) from remote location. The obtained results pave a way towards the development of a low cost portable drug delivery system that can be installed in ambulances/ICU/CCU and to transfer the vital parameters of the patient to the doctor.

Keywords: Telemonitoring, cloud computing, remote health monitoring

INTRODUCTION

Remote monitoring of patients, including vital signs, audio and video is becoming necessary, especially when a patient is in transit. By transmitting the vital parameters of the patient to a doctor reduces the time for initiating treatment and allows the emergency crew to be better prepared(1). In recent years, there has been massive research in ICT (Information and

Communication Technology), particularly in the area of Wireless Sensor Network (WSN). Low power microcontroller may create the backbone of a remote healthcare system, which enables delivering high-quality resource-optimal care “anytime anywhere”[2]. Telecommunication system allows us to deliver audio, video, text data and both way communication at high speed data rate. In case of critical situation/emergency/road accidents emergency transportation, real time diagnosis provides precise decision making parameters during the critical minutes while transporting to the hospital. This can increase the possibilities of survival[3]. Thus, transmitting the vital parameter of the patient well on time may help out emergency staff in hospitals in a well prepared manner even before the patient gets shifted to the hospital through the ambulance. Such type of technology will help both the patient and healthcare professionals to interact as and when required. The scope of this study is to design a portable and smart drug delivery system that can transmit the vital parameters of the patient and provide the virtual presence of the doctor inside an ambulance in emergency cases.

OVERVIEW OF EXISTING DRUG DELIVERY SYSTEM

Literature review has been conducted using the terms: Remote Drug Delivery, Telemonitoring, Distant Monitoring and Vital Sign Monitoring. Mobile phones are used to provide many facilities; therefore, multiple mobile applications are available today. Further development in this era allow mobile devices to fetch physiological and environmental parameters to enhance quality of life and remote monitoring[4]. It is possible now to collect, distribute and process bedside data of a patient in real time[5]. Immense research work has been done to transmit the patient data to a doctor in hospital or medical centre remotely. Where a doctor can monitor or analyse the patient data and take suitable action. An IoT (Internet of Things) based solution is proposed by[6] using Wireless Body Area Network (WBAN) to store patient data to health care record database. Telemonitoring shows a great potential to improve the health of patients suffering from diabetes and chronic heart failure[7]. In telemonitoring cardiopulmonary diseases and chronic heart failure are the most common applications. Tele-monitoring is a remote monitoring system that includes the usage of audio, video and IoT technology to monitor the status of a patient[1]. Apart from telemonitoring, Cloud Computing proves to be helpful for the development of Healthcare systems. It is the best solution with cheap cost, flexibility, better quality of service as well as scalability[8]. Moreover, advancement in the era of distributed computing, cloud computing and advanced processors allowed researchers to manage and process with unstructured data[9]. The key element of the present invention is bi-directional communication between doctor and patient. This study would allow a doctor to prescribe the drug from remote location after viewing the physiological data of the patient. This is especially important for the monitoring of critically ill patients in transit or in hospitals.

MATERIALS AND METHODS

Healthcare support system is an important sector which needs to be handled carefully by the government for improving the health of the citizens. Cloud computing is found to be very effective through the continuous monitoring of the patients. Along with cloud computing architecture, wearable sensor technique as well as radio frequency identification device is also found to be efficient. Sometimes, the combination of cloud computing and wireless body area network is also efficient in monitoring of the patients[10]. The main objective of this paper is to enable health care professionals to assess vital parameters of the patient to facilitate drug delivery. The present invention provides a fully unified system to doctor with REAL TIME ACCESS to the vital parameters of a patient from a remote location. The doctor can view the selected vital parameters of the patient on his Smartphone in real time, and also can control the release of medicine to the patient from a remote location or during the transition in an easy manner. For our study, we have used a five parameter Vital Sign Monitor (VSM), which is connected with the patient, to store and display the vital signs. The working model of the proposed system is shown in the figure-1. Vital sign monitor transmits the vital parameters of the patient to the interface application hosted on Raspberry-pi microcontroller. This application further pushes the vital parameters to the cloud in JSON (Java Script Object Notation) format, which are further displayed on the mobile phone of the doctor using android application.

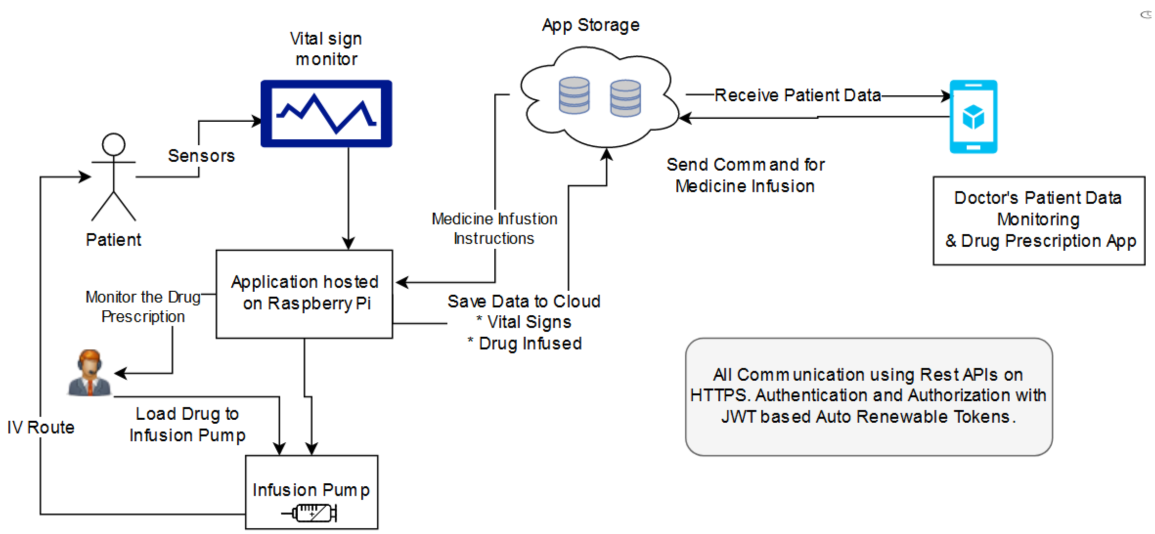

Figure 1: Working model

We have also designed an Android application which will enable doctors to receive the patient's physiological data after the successful authentications. In clinical practice it is necessary to secure the patient data to maintain the privacy. Therefore, It is essential to provide end to end security, confidentiality and integrity of patient data while the information is processed, stored and shared [(11)(12)]. The authentication and authorization are based upon JWT (JSON Web Token) auto renewable tokens. After seeing the vital parameters of the patient the doctor can suggest and prescribe the drug to the medical staff in the ambulance. Information like syringe number, the amount of the drug to be infused, syringe motion is sent in the form of a secure packet to the cloud as shown in figure-2. This packet is further received by the interface.

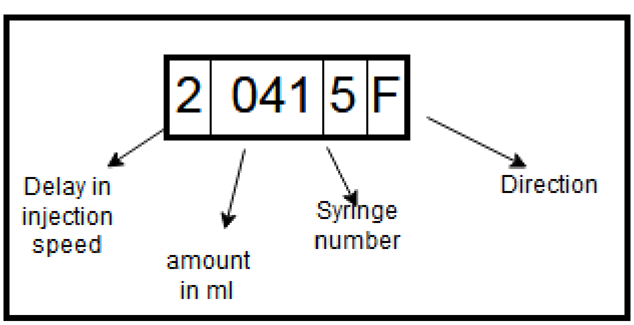

Figure 2: Packet information for cloud

The operator receives a signal and fills the syringe as per the drug prescribed by the doctor and the interface application sends a command to the infusion pump. The three layer architecture for the patient monitoring is shown in figure-3. The middle layer consists of two applications (user interface and android), which interacts with the hardware and cloud layer respectively. The user interface is hosted on the raspberry pi controller which acts as a middleware between top and bottom layer.

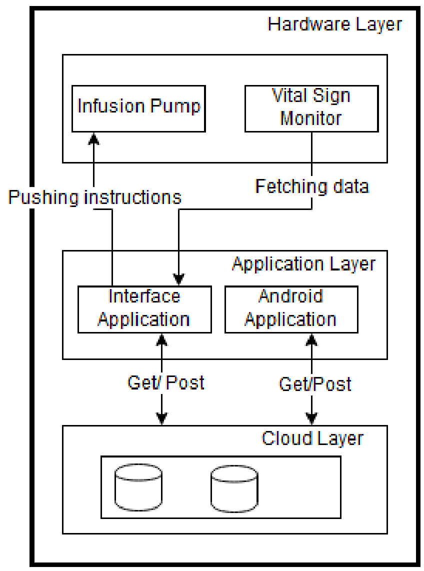

Figure 3: Three layer architecture model for patient moniroring

FINDINGS

Patient safety is one of the important challenges which is faced by healthcare professionals worldwide. The medication errors are increasing due to wrong infusion/drug, workload of the nursing staff, lack of mathematical skills/ pharmacological knowledge [(13)(14)(15)(16)]. Therefore, with a computer controlled drug delivery system we can reduce the adverse effects due to drug. As shown if figure-3 user interacts with the application layer. At the application layer we have developed user interface in python programming language to fetch the vital parameters of the patients from the sensors connected with the vital sign monitor. For our study, we have used data set provided by[(17)], who provided vital sign data recorded from patients undergoing anaesthesia at the Royal Adelaide Hospital. We have also developed an android application which will help the doctors to fetch the patient data using an android phone. The sensors are installed in the infusion pump to detect the status of a syringe (installed, empty and filled). Figure-4 shows the mechanical control of infusion pump that uses a lead screw to position the plunger and to manage the liquid movement. This whole process is controlled by a stepper motor which moves the syringe plunger. Microcontroller attached with the stepper motor generates the pulses to control the direction of the motor. Formula to generate the pulses is derived to control the speed of motor.

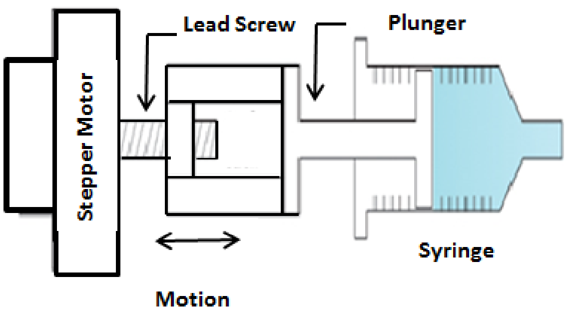

Figure-4 Mechanical Control of Infusion Pump

Pulse Generation Formula

To perform the whole experiment different parameters are taken into consideration. Supposing f is the frequency, Td is the time delay for the generation of frequency, Ts is the time taken, q is the quantity of drug to be dispensed, x is taken as a constant. Since frequency cannot be controlled so we control Td. As Td is inversely proportional to frequency so $\mathbf{f} \propto \frac{\mathbf{1}}{\mathbf{Td}}$

Therefore, as Td increased the speed decreases, this helps in maintaining the precision of the device.

$$Td \propto Ts$$

$$Td \propto \frac{1}{q}$$

$$Td = \frac{Ts}{(q * x)}$$

$$x = \frac{Ts}{Td * q}$$

Therefore, from the above calculation value of constant x can be determined, i.e. x= .00324

$$Td = \frac{Ts}{q * 0.00324}$$

Thus, in order to make the device work properly the quantity of the drug to be delivered and the time for drug delivery should be provided to the system which will produce time delay and in turn provides pulses to the controller. The syringe sensors, which are installed with the pump help to detect the status of a syringe. The syringe sensor reads the status of syringe before the start of infusion e.g. if the syringe is not installed by the user, it will not start the infusion. The syringe sensor available at the pump can also detect if the syringe is empty and thus can immediately stop the infusion. A switch is also installed on the infusion pump which is to be pressed by the operator if command for the infusion is received at the pump.

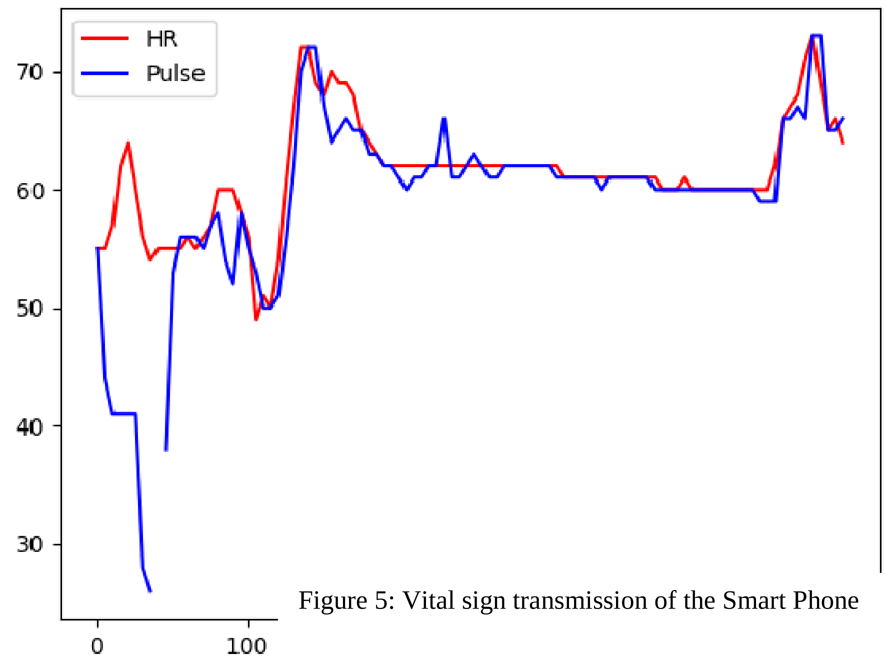

Figure 5: Vital sign transmission of the Smart Phone

Conclusion

The present invention discloses a cloud computing based interface that involves a remote access diagnostic unit to monitor the patient from a remote location. With respect to the remote monitoring of a patient from the remote location, many researchers have demonstrated the transmission of the physiological data of the patient in real time. The proposed model is not only helping a doctor to view the vital parameters, but also facilitates a doctor to prescribe name, rate and amount of the drug. Portability is one of the important features of the model which enables to install the system from one place to another place. Therefore, it can be installed in ambulances so is to provide virtual presence of the doctor inside the ambulance.

Financial Support and sponsorship

The proposed model (Smart Portable Intensive Care Unit) is awarded and funded by Millennium Alliance (MA) at stage-1.

Conflict of interest

There are no conflicts of interests.

Ethical Clearance

This project is sanctioned by Millenium Alliance, Govt. of India, USAID, UKAID, World Bank. Testing phase is undergoing.

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