IOT based Smart-Portable Intensive Care Unit for Patient in Medical Emergency/Critical Conditions

Surya Narayan Panda[1*], G. Arun Kumar[2], Antony Judice[3], Sanjeev Verma[4]

Abstract

In COVID-19 pandemic situations or in critical/emergency conditions patients experience a great problem because of the non-availability of doctors. A person in a medical emergency needs an immediate doctor to monitor and diagnose his/her medical problem and prescribe the medicine. In these types of critical conditions, there is a demand for some smart portable intensive care unit that can transmit the patient's vital parameters and provide this information to the doctor so that the patient gets lifesaving drugs as per the doctor's prescription. This work proposed a low-cost and Internet of Things (IoT) based smart-portable intensive care unit (S-PICU) that is capable of transmitting the vital parameters of a patient to doctors' mobile applications when the patient is in a remote location or transit because of a medical emergency. Patients in intensive care units (ICUs) with severe or life-threatening illnesses and injuries demand round-the-clock treatment, so this portable unit fulfils the medical requirement during emergency conditions. The android based mobile application fetches the patient's data in real-time from the IoT cloud database system. A doctor can receive the patient's data in digital and analog form on mobile and can easily set the drug infusion flow from their location. The proposed device helps the patient in critical/emergency conditions save a life because it can easily communicate with doctors through a smart mobile application and get prescribed drugs remotely. This device reduces doctors' movement and better utilization of medical diagnoses. The automation feature of this device improves patient safety and features of this device improve the safety of patients and also the quality of medical treatment.

Key Words: Internet of Things, Remote Drug Delivery, Vital Parameters Data, S-PICU.

DOI Number: 10.14704/nq.2022.20.8.NQ44515 **NeuroQuantology 2022; 20(8): 4904-4912**

Introduction

An effective and advance technology is required for healthcare industries. Mobile telecommunication system impacts a revolution in the field of healthcare sector. Android/IOS applications on smart phones help a lot in medical field. Modern intensive care unit equipped with smart phone applications monitor and diagnose the patient effectively. In COVID-19 pandemic situations or in emergency medical conditions patients need an immediate treatment for their medical problems. In these types of severe conditions there is a demand of smart medical equipment that can transfer the patient's medical reports to the doctor quickly so that his/her life can be saved.

The Internet of Things (IoT) is a phrase coined by the fields of electronics and computer science. The Internet of Things (IoT) allows all things with an IP address to communicate via a network. Any social development's ultimate purpose is to increase human health. The Internet of Things (IoT) is a new technology that greatly improves patient quality of life while simultaneously lowering healthcare costs. In the realm of healthcare, IoT has a significant impact on the collection and processing of patient-related data [5].

Corresponding author: Surya Narayan Panda

Address: [1*,4]CURIN, Chitkara University Institute of Engineering and Technology; [2]Department of ECE, JSS Academy of Technical Education, Noida; [3]Department of Engineering, University of Technology and Applied Sciences-IBRI, Oman.

E-mail: [1*]snpanda@chitkara.edu.in; [2]arunkumarg@jssaten.ac.in; [3]Judice.av@ibrict.edu.om; [4]sanjeev.verma@chitkara.edu.in

IoT-enabled patient monitoring enables healthcare providers to make diagnostic judgments. The goal of this project is to use a hybrid computing technique to create a feedback controlled dynamic drug delivery interface. The quantity and duration of the medicine in the patient's body are important considerations in drug delivery. As a result, medications have been utilized to improve a critically ill patient's health and extend his or her life.

In this process, vital signs of the patient play a vital role to know the exact status of a patient. Recent technological advancement in the field of sensor area network allows the researchers to transmit the physiological data of the patient to a doctor at a remote location. Therefore many patients can be benefited from continuous monitoring. The bedside monitors help to view the physiological data of the patients locally. The technology like body sensor network helps the researchers to transmit the vital information of a patient to the doctor at a remote location. Concerning the remote monitoring of a patient from a remote location, many researchers have demonstrated the transmission of the physiological data of the patient in real time. Thus, continuous monitoring in real view not only improves the life quality of a patient, but also helps the family member of a patient to monitor the physiological signals from the remote location. In the proposed model a hybrid model is proposed to access the vital parameters of the patient from local and remote locations.

Related Work

It has been concluded in a fair number of previous articles that drugs have been used to improve the health of a patient; therefore, drug delivery is an essential factor for an admitted patient. Drug delivery is a route to control the therapeutic effects of human beings [1]. The essential task of the drug delivery system is to calculate the exact amount of drug and deliver it to the target area in the body. Therefore, the precise amount of drug must efficiently reach to the target area. Drugs can be delivered to the body through multiple paths. Each route has its pros and cons. Finding a suitable path through which a drug is to be delivered to a target area is known as drug administration. The drug can be administered through either enteral routes or parenteral routes. Drug administration through enteral route is a slow process as it takes time to reach to the destination. On the other side drug delivery through parenteral route is quick, e.g. through intravenous, intramuscular, ointment, inhalation, etc.

In a relevant previous work, it has been shown that drug delivery system ensures that drug must reach into the destined area; therefore, the rate and the amount of dose in the body must be carefully calculated. In the traditional drug delivery methods where the dose rate is calculated and delivered manually any mishandling can lead to certain complications in a patient [2]. As both overdosing and under- dosing may be harmful to the patient. So, it is necessary to administer an accurate amount of the drug. Another research work related to traditional methods, the drug is delivered through oral route or intravenous routes in the form of injections, where the drug is distributed through the blood circulation system. However, only a small portion of the drug reaches the destined area in the body, which results in the slow recovery of the patient. Drug delivery system ensures that drugs reach to the area, where they are needed. The clinician must take care of the amount of the dose to be delivered so that the body can effectively use the drug, which [3] thus requires a drug system that allows for accurate dosing. In this process, the computer- controlled drug delivery system is playing a vital role to deliver precise amounts of the drug. In many of the cases in today's medical world, due to non-possibility of providing physical presence of doctor to the patient on on-spot site and even the people who are present have no authority to administer the patient medically. As a result, the patient may reach critical condition or even he may lose his life. This concludes that a qualified doctor is needed at the spot which is not possible at immediate instant of time. However, the communication between the ambulance attendant monitoring vital body parameters such as blood sugar, anxiety etc. is communicated telephonically without the physical interaction of the patient in ambulance or site. This verbal communication may not solve the problem of patient and hence, an efficient way of communication with immediate drug delivery to patient in the ambulance is necessary.

In the other research this has been concluded that Oral medication delivery [4] is the most common and favorable method of delivering pharmaceuticals and it has proven to be effective in treating a wide range of ailments. The advantages of this mode of distribution include patient friendliness, cost effectiveness, a well-established delivery system, noninvasiveness, and convenience,

eISSN 1303-5150

and it is the most used drug delivery system in the pharmaceutical industry. Based on the mechanism of drug release, oral drug delivery systems, as well as other effective and prospective delivery system types are described in this study. Patient safety depends on several parameters and one of the main problems is medication error [6]. There are many reasons for the occurrence of dosing errors such as transcription, dispensing, and administration steps of drug therapy [7]. There is a risk of dosing due to the increasing number of such errors in public and hospital pharmacies around the world [8]. A traditional method of manual drug delivery has caused errors due to lack of math skills. This can lead to drug under or overdose [9]. In 2001, substance abuse complications killed about 1,200 people in England and Wales, an increase of 500% over the last decade [10]. According to one study, adverse drug events due to dosing mistakes were detected at a rate of 6.5 per 100 patients [11]. Therefore, it affects patients with a view to staying in the hospital for a longer period of time. A study was conducted in which 82 nurses participated in the study at the Felege Hiwot Referral Hospital (Inpatient Division). The author analyzed the data using SPSS and found that the dose error was 23.1% due to incorrect drug calculations [12]. In one of the related work described tele-monitoring was defined as the use of remote (Bluetooth-enabled) monitoring technology that collects information (blood pressure and weight), sends information electronically to caregivers, and allows for caregiver-patient communication [16].Another research work related to manual drug delivery is a form of conventional drug delivery in which the drug is given orally or intravenously in the form of an injection and the drug is circulated through the bloodstream. The potential for dosing errors in a manual drug delivery system is similar to a computer controlled drug delivery system. As chances of miscalculation in the manual drug delivery system are more; so the critically ill patients admitted in the ICUs are susceptible to higher risks of the adverse effects of drugs [13]. Therefore, the chances of medication errors are more. Drug errors in case of pediatric patients are increasing due to wrong calculation of the drug because a drug is calculated based upon the weight of the patient [14].

The telemedicine which is one of the latest technology used in delivering of the drug has emerged as one of the lifesaving technique. On the other hand, this technology of interaction between the patient and doctor do have de-merits such as requirement of the hardware including high end camera which is not possible all the time. India being a moderate economical country and only very less percentage of the people can afford this facility, this system may not be preferred over the patients due to very costly equipment's involved. In many of the cases, the patient may need the facility of Intensive-Care-Unit (ICU) on the spot or in ambulance which is not available in today's scenario. Hence, need arises for smart with portable facilities of ICU which can be rendered immediately to the patient with online monitoring and interaction. The ICU [15] or Critical-Care-Unit (CCU) can be defined with super-speciality equipment's monitoring the vital parameters of the patient in need at real time scenario which can be also life threatening. This situation demands expert doctors and nurses to handle such critical situation including trauma in patient, multiple organ failure etc. In general at present, in any multi-speciality hospital, the concerned specialist doctor visit the hospital and gives his expert advice with important medical prescription. However, this methodology of monitoring the patient in ICU do suffers drawbacks which are given below

a) The technicians available immediately are not trained to give the medicine immediately.
b) Due to the invisibility of the patient parameter to the doctor, the actual medication cannot be rendered.

In this work, S-PICU is reported which includes the following novel features.

a) RADU: This is a digital assistant device known as Remote-Access-Diagnosis-Unit which is used to transfer the real-time vital parameters noted from the patient on to the device like smart phones, tablets or any other hand-held devices transmitted wirelessly from the remote location. This communication will help the doctor receiving the vital parameter of the patient and will instruct the attendant present on-site with the patient. This communication will also help the doctor to monitor external injuries to the patient if any and correspondingly can be treated.

b) RAMDU: This is also a wireless device or system known as Remote-Access-Dispensing-Unit which will be controlled by the doctor and inject the important medicines needed immediately to patient at the remote location. This setup comprises of several number of syringes and as per the doctor instruction with the app present on his device, can be injected to the patient remotely.

One of the related works has revealed that medicine delivery devices that can operate in both closed and open loops and relay important patient characteristics to a remote expert are necessary [17]. Yet another study investigated the useful feature of the developed model is the ability to control the drug infusion rate from a distance. Every 10 seconds, the patient's physiological data is sent to the cloud database. This information has been encrypted and saved in the cloud's Real Time Clinical Database (RTCDB), which can be accessed at any time following proper authentication [18].

Objective

Objective of present work is to explore various types of drug delivery system and make the comparative analysis and also to design and develop the architecture of dynamic drug delivery interface system that will be able to deliver accurately calculated drug(s) as per the vital sign based interface system with least human intervention by using hybrid technique. In this work we merge of expert system facility and analyzer database within dynamic drug delivery interface for future reference. Finally implementation the dynamic drug delivery interface.

The reported work offers very unique features including online monitoring of the vital parameter of the patient. This is a real time monitoring of the patient, who is in the remote location ad between the doctors who is monitoring from the different location. This feature not only include the real time-monitoring of the patient but according to the condition of the patient, the vital medicines in the injections are injected by the instructions sent by the doctor.

Methodology

A drug delivery system model has been proposed that can deliver required medical drugs to the patient during critical/emergency conditions from a remote location. S-PICU is an IoT based health monitoring medical drug delivery unit which can easily fulfill the requirement. Five important medical investigated parameters (Body Temperature, Heart Rate, Blood Saturation, Non-Invasive Blood Pressure and ECG) of patient are transmitted to the doctor. This system enables the doctor to view vital signs of patient on its mobile. JSON (JavaScript Object Notation) is used to transmit vital signs of patient to cloud-based server. A mobile application is used to fetch patient data from cloud based server and with this mobile application doctor can easily view patient data in real-time. Doctor can easily control the infusion pump from remote location and give command to release medicine. The schematic illustration of S-PICU is shown in figure 1.

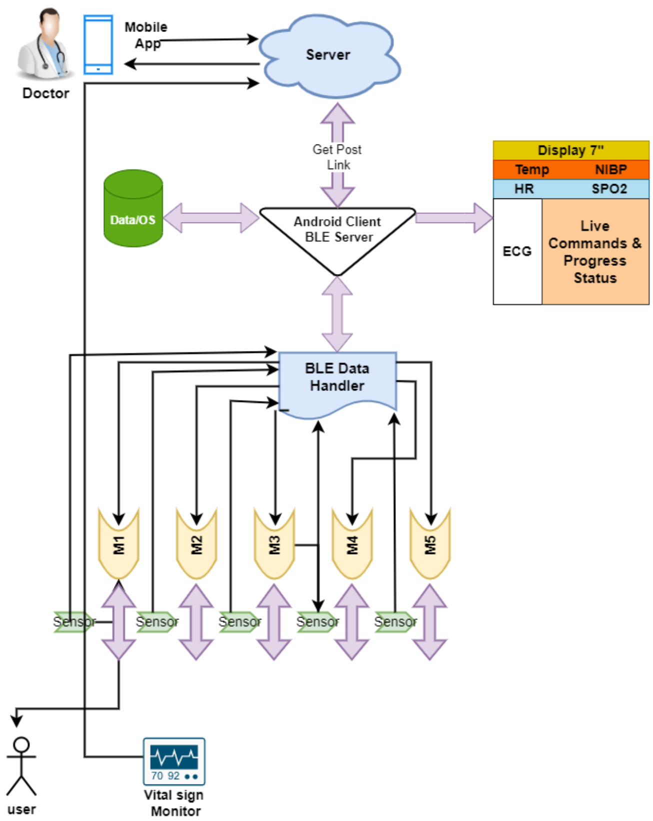

Fig. 1. Schematic diagram of S-PICU

S-PICU can be easily use in ambulance, when patient is in emergency condition. A notification is send to the doctor's mobile, through IoT based S-PICU system. The role of S-PICU in ambulance is illustrated in figure 2. It can transfer patient vital signs to doctor' mobile immediately using cloud server. An additional feature of S-PICU is drug delivery. After analysis of patient vital information doctor provide command for delivering drug.

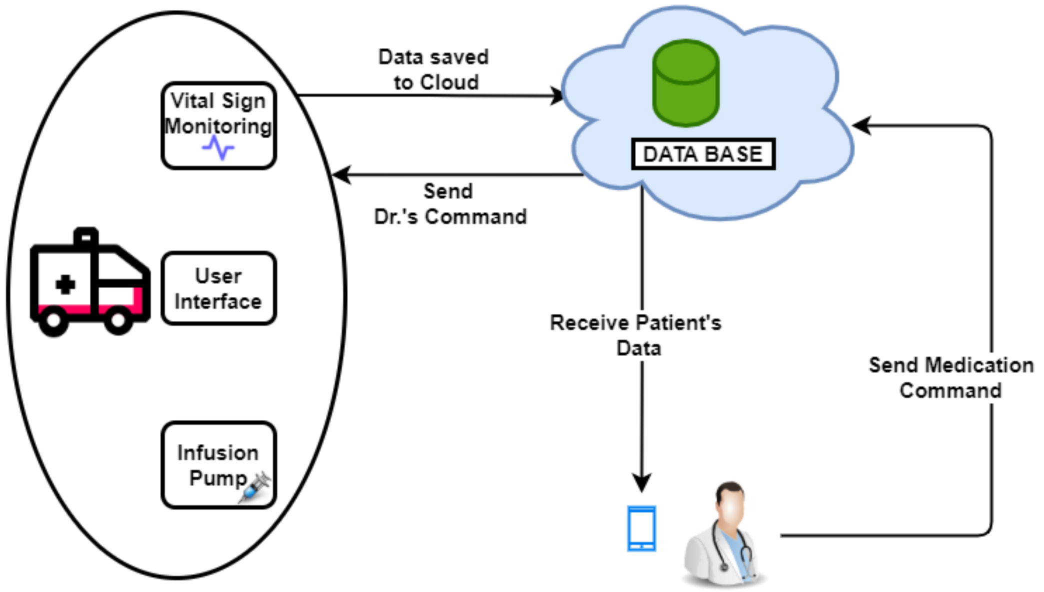

Fig. 2. Role of S-PICU (inside ambulance)

The lifesaving drugs can be injected in the patient by means of four-different routes and this proposed work, infusion pump connected to five-syringes can be injected into patient as per the instructions of the doctor. Also, the authenticity of the pump is calibrated by NABL, India. The doctor information from their phone is sent to infusion pump in the form of secure pocket.

The name of drug, amount of drug, rate of infusion and infuse time of drug is highlighted in the form of packet. Doctor information is sent to RTCDB in cloud through mobile application. The web based application send packet to python application, that de-capsulate the frame and deliver information to infusion pump. The vital parameters sign with technical values in table no. 1

Table I. Technical Specifications of Vital Sign Monitor

Model-Specification	**Ulterius$_{501}$**
ECG Standard	Standard 12 Leads
SPO2 Saturation range	0-100%
Pulse range	20.0-250.0 bpm
NIBP	40.0-280.0mmHg (SYS) 10.0-225.0 mmHg (DIA) 10.0-240.0 mmHg (MAP)
Temp.	0-50.0° C
Display	Display 320×420 Pixels TFT Screen
Power Supply	220.0-240.0 V, 50Hz
Network	LAN/ Wi-Fi (802.11n)
Battery	12V/1.2 AH (Lead Acid)
Weight	Weight 1.8 kg

For dispensing the drug to patient, a drug dispensing formula is used. Formula used for drug dispensing is as follow:

$$N \propto V \quad \text{.......(i)}$$

$$N = \frac{1}{K} V \quad \text{.......(ii)}$$

$$T_S = \frac{T}{N} = \frac{T}{V/K} \quad \text{.......(iii)}$$

$$T_S = T_o + T_d \quad \text{.......(iv)}$$

$$T_d = \frac{KT}{V} - T_0 \quad \text{.......(v)}$$

V = Volume of drug
N = Total steps
T_o = Delay between two steps
T_s = Single step timing
K =56 µL/ per step

Working Model

The present invention is generally related to the healthcare sector, especially the SMART AND PRTABLE INTENSIVE UNIT used for critically ill patients. Along with that is the combination of a real-time multi-node telemedicine network with an integrated computerized drug management system.

Fig. 3. Designed model of S-PICU

We frequently see patients die because there is no doctor on site or because the person on site is unable to provide any drug without the approval of a medical professional. To acquire a doctor's prescription, either the doctor is approached by telephone or the readings of vital sign monitors, if any, either in the ambulance or at the patient's location, are relayed to the doctor by the person caring for the patient. The disadvantage of telephonic communication is that the doctor is unable to see the monitor and must rely on the attendant for information and, ultimately, drug administration. In such case, the patient may suffer loss due to communication errors between the doctor and the attendant. In this case, the patient could take a loss due to an error in communication between the doctor and the attendant. The suggested model will allow clinicians to remotely monitor the patient's physiological data (HR, NIBP, Temp, ECG, and SPO2) as well as prescribe medication. This system will assist in providing a virtual presence of the doctor inside the ambulance as well as providing lifesaving medications to the patient while in transit [16].

Features of S-PICU.

- Planning and drug-delivery remotely.
- Alarm indication for pain management for both in-site and within doctor smart-phone.
- Video-online monitoring facility with real time-view of the body of patient.
- Alarm for VSE (Vital-Sign-Exception).
- High security transmission of data related to vital parameters of patient.
- Lower investment.

System consists of two mobile applications.

- One for the doctor (Dr Infusion)
- Second for the Attendant (Infusion pump)

Dr Infusion - This app is used at the doctor end to schedule the doses; it communicates with the attendant app directly with the device.

Infusion pump: - This app is used on the attendant's phone to receive the information from the Dr Infusion app and communicating with the hardware.

Fig. 4. Dr Infusion app icon

Fig. 5. Attendant's app icon

Following Steps are used to operate the system (S-PICU):

1. Install the apps Infusion Pump & Dr Infusion on the Tab and Physician's phone respectively.
2. Switch on the Power Supply.
3. LED inside the cabinet will glow red (If not glowing, toggle the red switch on the right side).
4. Open the app (Infusion Pump) on the tab.
5. The connectivity of the tab with S-PICU will be via Bluetooth. (Please ensure the bluetooth and location service is active on the tab).
6. Upon successful connection, Syringes will appear on the tab screen.

Scheduling of new dose:

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Following steps to be followed to schedule a new dose are:

1. Open the Dr Infusion app that is shown as below.

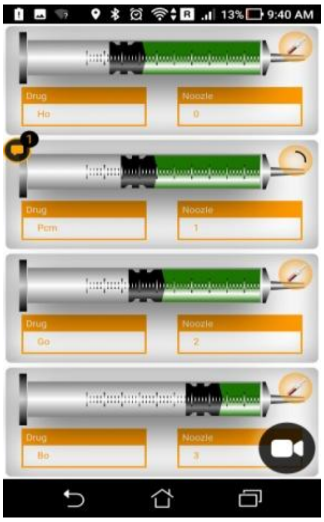
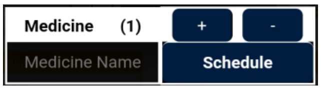


Fig. 6. Dr Infusion app launching screen

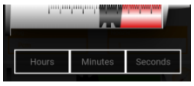
2. Click on injection bubble  corresponding to the nozzle to be used.

Fig. 7. Injection bulb indication

3. Sliding on the syringe body, left or right will adjust the dose volume according to the requirement.

4. 

Use + and - to make the necessary adjustment in the volume of injection.

5. 

Set the duration of the dose.

6. 

Click on schedule option to start.

Note:

If you want to save the dose information for future uses, click on 

Save Dose button. Stop button will be used only in emergency situation.

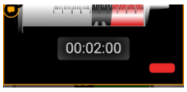
Injecting the scheduled dose:

1. Make sure that the Infusion Pump app is connected with the device.

Fig. 8. Launching screen

2. By clicking , a screen as shown below will appear which will be containing information about the dose to be given to the patient.

This dialog contain the name of the dose (here PCM) and number of nozzle (here 1).
Note: Numbering of the nozzle will be from right to left (0 => 3).

3. 

Wait for the right bottom red button to turn Green as shown here 

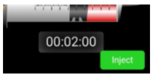
.

4. Click on back button and come back to the main screen.
5. Swipe left on the selected dose, below given screen will appear.

6. Make the contact between slider and the syringe piston by clicking Tare button. In every single tare, the slider will move approximately 1mm. Keep Tarring until the separation finishes as shown below.

Fig. 9. The adjustment of syringe piston with the slider

7. Click  open injection dialog.

8. Click on inject to 

start the dose.

Figure 10. Red block will indicate the left out amount. (Injection of dose is completed).

Conclusions

The interface of a feedback-driven hybrid drug delivery system is shown in this work. The interface is a real-time remote patient monitoring technology that allows clinicians to see physiological data from patients in real time. Clinicians will find it easier to use the system in open or closed loops due to the hybrid nature of the interface. Many researchers have shown that the real-time transmission of patient physiological data for remote monitoring of patients from remote facilities. The proposed model is a hybrid drug delivery system based on the Internet of Things that allows physicians to dispense drugs remotely. One of the important elements of the proposed model that helps clinicians to make diagnostic recommendations is the feedback system. Even after a case has been concluded; doctors can access patient data through the analytic database. The current research reveals a feedback-controlled hybrid drug delivery systems interface. The interface includes a remote patient monitoring system that allows clinicians to see the patient's physiological data in real time.

The interface's hybrid nature will make it easier for doctors to use the device in open or closed loop. Many studies have proved the transfer of the patient's physiological information in real time when monitoring a patient from a remote location. The suggested model is a hybrid IoT-based medicine delivery system that allows a physician to provide medication from a remote location. One of the key characteristics of the suggested model that allows a doctor to make a diagnosis is the feedback system. The doctors will be able to access the patient records even after the case has been ended.

Future Scope and Limitation

Sensors create vast volumes of data, which renders standard software difficult to manage. Since 2011, the US healthcare system is said to have created 150 hexa-bytes of patient-related data. As a result, big data can be used to evaluate and manage massive amounts of data. Data mining technology can also help to uncover hidden information in your data. These trends could aid healthcare providers in reducing drug adverse effects and finding cheaper alternatives. In a nutshell, data mining can help doctors make better clinical decisions. Over the Internet, the model's application interface communicates with the cloud interface. As a result, excellent internet connectivity is required to communicate with cloud apps at both the end users. For an example, it works well in the 3G band. Cross-layer design protocols can be implemented to improve communication dependability (low power, low latency communication). In the future, the proposed model could be enhanced to work successfully in the 2G spectrum as well.

Acknowledgment

This study has been conducted under the Project "SMART AND PORTABLE INTENSIVE CARE UNIT" funded by Millennium Alliance FICCI, USAID, UKAID, Facebook, World Bank, TDB, DST.

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