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Real Time Patient Monitoring System based on Internet of Things

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***Abstract*— The popularity of Internet of Things is increasing day by day in the area of remote monitoring system. The remote monitoring systems include, vehicle or assets monitoring, kids/pets monitoring, fleet management, parking management, water and oil leakage, energy grid monitoring etc. In this paper, we have proposed an intelligent patient monitoring system for monitoring the patients' health condition automatically through sensors based connected networks. Several sensors are used for gathering the biological behaviors of a patient. The meaningful biological information are then forwarded to the IoT cloud. The system is more intelligent that can able to detect the critical condition of a patient by processing sensors data and instantly provides push notification to doctors/nurses as well as hospital in-charge personal. The doctors and nurses get benefited from this system by observing their corresponding patients remotely without visiting in person. Patients' relatives can also get benefited from this system with limited access.**

Keywords*— *Intensive Care Unit, Real time patient monitoring, Health monitoring system, Intensive care, IoT device, Sensors, Mobile apps, sensors networks.

I. INTRODUCTION

A. Intensive Care Unit

The similar name of ***Intensive Care Unit*** (ICU) is ***Critical Care Unit*** (CCU). It is also familiar with some others name such as intensive treatment unit. ICU is a distinct sector of a clinic/hospital that delivers rigorous treatment. Not all the patients need intensive care. Medical scientist categorized them (patients) who needs special treatment. Such categories include:

- If the physiological regulatory systems of a patients are not stable because of drug overdose.
- Patients with Cardiovascular or organ failure disease.
- After critical surgery such as open-heart surgery, single or multiple organ replacement etc. Those patients are directly transfer to the ICU unit.
- If a patient suffering malfunction in several organs such as trauma or septic shock.
- Mother and baby throughout the childbirth process.

B. Internet of Things

The Internet of Things is the connected network between devices (wearable, portable and house-held devices etc.), which was first proposed by Prof. Aston while performing the research related to ***Radio-frequency identification (RFID)*** in 1999. The service composition is fully supported by IoT with various applications. The communication among millions of devices (any type of internet connected) are possible through IoT. The Three Layer Architecture (most popular) is illustrated in Fig. 2. The layers are: ***Perception, Network*** *and* ***Application Layer***. Sensors, Actuators, Proximity tags (***RFID, NFC*** etc.) and other embedded devices such as microcontrollers/microprocessors are connected to the IoT system via ***Perception layer***. ***Network layer*** establish the communications between ***Things*** and ***users*** (human or consumers). User interfaces/applications are demanded by ***Application layer***. More details specifications and applications domain of Internet of Things (IoT) are nicely elaborated in [2–6].

Fig. 1: A Typical ICU unit [1].

Terms and Basic Definitions:

- **Internet of Things (IoT):** A network of Internet connected devices (electrical) able to interchange data between them using sensors and actuators.
- **IoT device:** Any type of electrical Internet connected device/s that can be monitored and/or controlled through Internet from anywhere(remote location).
- **IoT ecosystem:** All the components that enable consumers, governments and businesses to connect with their IoT devices, including remotes, networks, dashboards, gateways, storage, analytics and security.
- **Entity:** Mainly includes the users of IoT system such as consumers, governments and businesses etc.

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- **The Physical layer:** The physical components (hardware) that makes an Internet of Things (IoT) device which includes sensors, actuators and networking gear.
- **The Network layer:** The main duty of network layer is transmitting the data collected from physical layer to IoT devices.
- **The Application layer:** All the protocols and interfaces used by the connected devices for identification and communication.
- **Dashboard:** The dashboard is used for visualizing the information about the Internet of Things ecosystem. It also used for controlling the IoT ecosystem. It acts as a special type of remote control for IoT.
- **Analytics:** Software systems that analyze the data generated by IoT connected devices. The analysis can be used for a different purposes, such as predictive maintenance.
- **Storage for IoT:** The cloud storage/data bucket, where data from IoT devices are stored temporary or permanently.
- **The Networks:** The Internet communication layer that enables the entity to communicate with their embedded devices, and enables devices to communicate with each other.

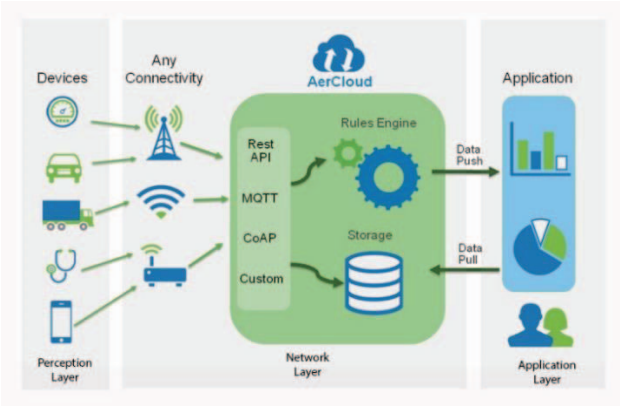

Fig. 2: Architecture of Internet of things (most popular).

II. State of the Art

The popularity of Internet of Things are increasing day by day in the area of remote monitoring system. The remote monitoring systems include, vehicle or assets monitoring, kids/pets monitoring, fleet management, parking management, water and oil leakage, energy grid monitoring etc.

A fixed route, simple bus tracking system has been proposed by Lau in [7]. The system used a smartphone application and LED display panel for displaying the location after a specific time interval. The system is very useful for college/university students who attend classes in big campuses. As a result, they (students) can spend more time in studying, sleeping or relaxing rather than wasting time through waiting for a bus. Nowadays, almost all the European countries are using similar type of tracking system for public transportation.

Rohit in [8] proposed a smart home with real time e metering system based on IoT for building the automated intelligent home. The system reduces the power consumption by remotely controlled the electrical equipment. Another IoT based energy efficient smart home concept has presented by Laila in [9], where the different type of sensors are used for controlling the electronic equipment.

Water pollution detection system is very useful for pollution management. A real-time water monitoring system is discussed in [10]. The system consists of several sensors such as ***pH level***, humidity/temperature etc. Sensors data are directly transmitted to the base station for monitoring the pollution level of water. The experimental setup was took place in lake Toba, Indonesia.

IoT is also popular in health care field. Nowadays, various health monitoring devices are getting wearable/portable, including body temperature monitors, glucose monitors, ECG monitors, pulse oximeters, and blood pressure monitoring system are described in [11–19]. A prototype of ICU monitoring application was introduced in [20] without satisfactory details. A hardware design for monitoring patient through embedded computer raspberry pi was shown in [21] without use of the proper sensors and cloud connectivity left for future work. Another solution was proposed in [22-23], without following proper IoT structure. Human fall detection system is very helpful for monitoring the older people who lives in alone. A prototype fall detection system based in Internet of Things is presented in [24-25].

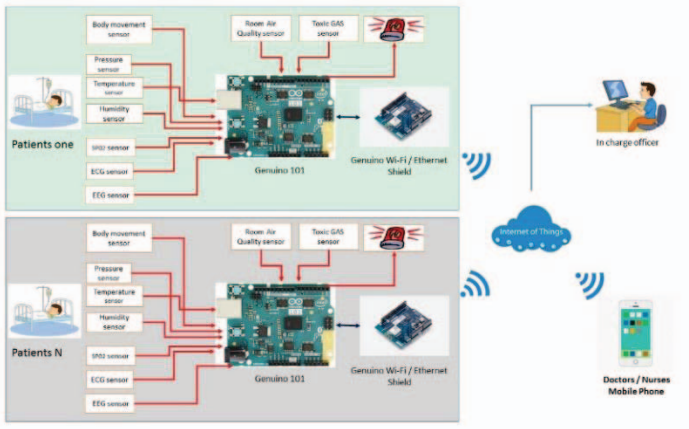

Fig. 3: The block diagram of proposed patient monitoring system.

III. Proposed System

We have used an ***Arduino 101*** (IoT development board) as a principle controller of our proposed monitoring system. The details technical specifications of Arduino 101 development board are listed in (see [34]). The Arduino board collected the information about patient health parameter from various sensors (described in Table-I), which were directly connected with principle controller. The ***thinger.io*** [35] IoT cloud platform is used as a IoT cloud for our proposed system. The emergency condition of a patient is determined through the simple mathematical Equation-I, where the details mathematical notation about threshold level is elaborated in Table-II.

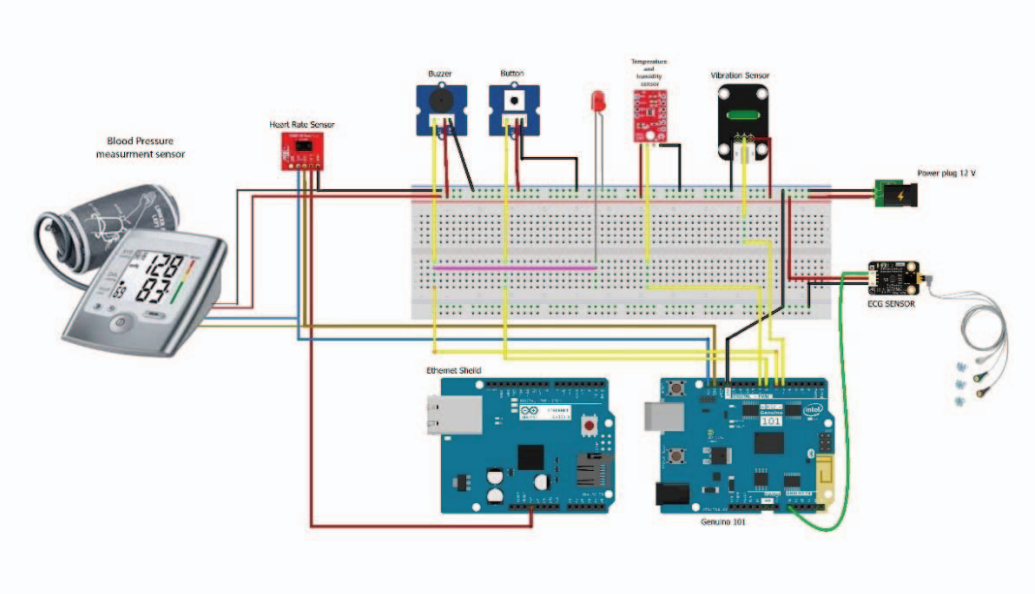

Figure 4: Hardware design of the system.

TABLE 1: HARDWARE COMPONENT LIST

Name of the components	Purpose
Arduino/Genuino 101	*The main controller board*
Arduino Ethernet Shield [26]	*Connection bridge between cloud and controller*
Temperature and Humidity sensor [27]	*For body temperature and humidity measurement*
Heart rate sensor (MAX30100 [28])	*Measure the pulse*
ECG sensor [29]	*Measure the ECG data*
Buzzer [30]	*Emergency Alarm*
LED	*Emergency indicator*
Push button [31]	*call for assistance*
Movement sensor [32]	*Detect the unexpected movement*
Blood pressure sensor [33]	*Measure the blood pressure*
360 Camera, Optional	*Optionally streams the video*
Others sensors	*Air quality sensor and room temperature sensor are used for measuring room environment*
12volt DC power supply	*Power source*

TABLE 2: MATHEMATICAL NOTATION OF SENSORS READINGS

Sensor (notation)	*Threshold*	*Threshold level [1]*
Heart rate, h_r	$T_{heartrate}$	less than 50 and greater than 120
Temperature, $temp_{body}$	$T_{temperature}$	less than 35 and greater than 39 in Celsius
Humidity, $humidity_{body}$	$T_{humidity}$	less than 40% and greater than 55%
Movements, $move_{body}$	$T_{movements}$	Unexpected
SPO2, $spo2_{blood}$	T_{SPO2}	Under 90 %
Upper blood pressure, $upper_{blood}$	$T_{upperblood}$	less than 120 and greater than180
Lower blood pressure, $lower_{blood}$	$T_{lowerblood}$	less than 80 and greater than 110
Push button, $button_{call}$	T_{button}	On
ECG, ecg_{heart}	T_{ECG}	N/A

$$T_{temperature} \vee T_{humidity} \vee T_{heartrate} \vee T_{movement} \vee T_{SPO2} \vee T_{upperblood} \vee T_{lowerblood} \vee T_{button} \quad \text{..... (1)}$$

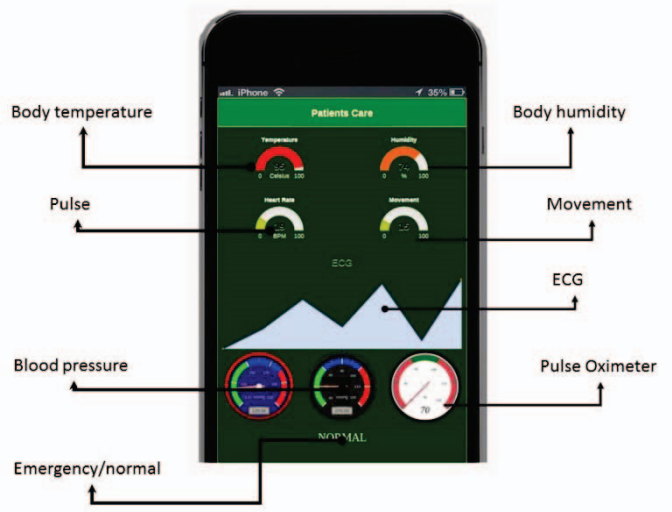

Fig. 5: Mobile application of patient monitoring system for doctors and nurses. The device continuously streams the sensors data to the IoT cloud and the application is directly connected to the cloud and visualize the real time using different type of charts.

A. *Software and Apps*

We have developed a Mobile application (shown in Fig.5 and Fig.6). Various charts and gauges have used for displaying the real-time sensors data, which contains present health parameters (present health condition) of a patient. Through this application, doctors or nurses can monitor their patients remotely without visiting the ICU unit. Due to the nature of intelligence, the system sent the push notification to corresponding doctors or nurses about the emergency situation of the patient, where the Equation -I determines the emergency condition of a patient by processing the sensors data. The hospital-in charge personal (ICU in-charge person) also constantly monitored more than one patient at a time through our web based cloud connected desktop application (shown in Figure-7), which improves the efficiency of ICU unit. All the application were connected to the IoT cloud and visualized the real-time data using different type of charts such gauge, spark-line, Text etc.

IV. System Testing

We used some existing medical devices listed in Fig.10, that are available in the market for measuring health parameter of a person. The ***Blood Pressure*** monitor device is already medically certified and the validation of this device is available in [36]. Others sensors such as ***Humidity*** and ***ECG*** are not tested since we do not have enough medical device support. Detecting the patient body movements is an important task. In this regard, ***Computer Vision*** based human body movement system is more accurate than measuring the body movements using low cost sensors like (accelerometers). On the other hand, integration of vison based system with low cost microcontroller is more complex than sensors based system. A sensors (accelerometers) based human body movements measurement system is described in [37], which can be easily integrable with our proposed system.

Fig. 6: The Mobile Application with Normal and Emergency condition.

Fig. 7: The Desktop application for monitoring the patient.

V. Conclusion and Future Plan

Many patients died in ICU unit due to the careless of in-charge personal. In traditional system is not able to provides constant monitoring facilities. Our proposed system described in this paper allows doctors or nurses, as well as hospital in-charge personal allows them to monitor the patient in ICU unit in real time, which improves the efficiency and service quality. There is a huge opportunity to modify this system as a wearable device, that allows us to monitor the older people or babies remotely from any place.

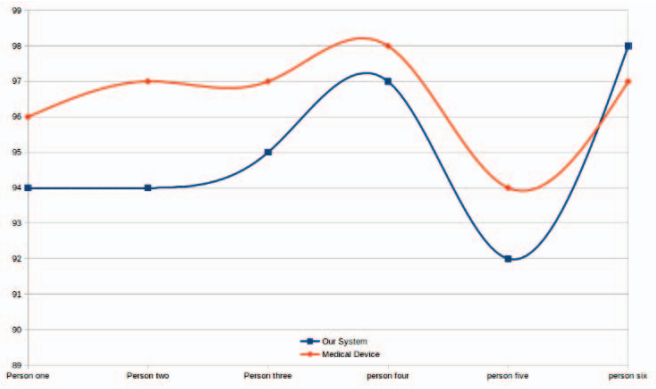

Fig. 8: Blood Oxygen -Level(SPO2) measurement data.

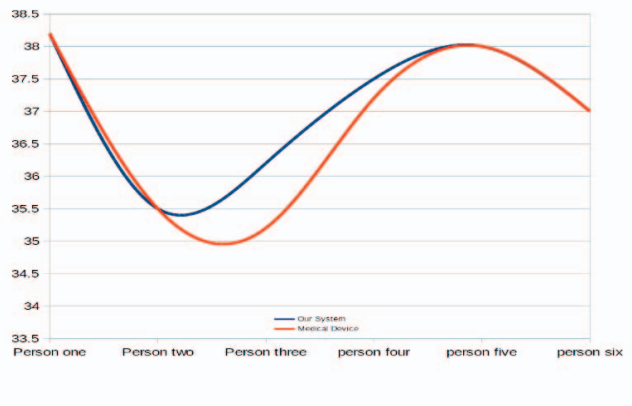

Fig. 9: Body temperature measurement data.

APPENDIX

- The shortest form of Peripheral Capillary Oxygen Saturation is known as SPO2, which measures the oxygen level of humans' blood.
- Electrocardiography (ECG or EKG*) is the way to detect and determine the electrical phenomenon of humans' heart. It is also known as electrogram. It is used for determining hearts activity rate.

Fig. 10: Medical devices used for testing pulse oximeter(left) and thermometer(right).

TABLE 3: COMPARISON OF TRADITIONAL PATIENT MONITORING SYSTEM AND OUR PROPOSED SYSTEM.

Our System	Traditional System
Fully Automatic	Semi-Automatic
Remote Monitoring System	Not Applicable
Real Time Monitoring	Not Real time
Low maintenance	Maintenance is high
Cheaper	More expensive
Automated	Need skilled operator
Less Error	More Error

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