Design and Development of IoT Based Intravenous Infusion System

Kanchi Raghavendra Rao and Koluthuri Evangili Supriya

Abstract Health care organizations are adopting IoT Cloud with wireless sensor networks that is beneficial, especially when administering the condition of a greater number of patients and their resulting data storage are taken into account. Considering the case of patients fed with Intravenous [IV] fluids in Intensive Care Unit [ICU], it is essential to administer the flow rate and fluid level of gravity fed bottles in real-time, either by an attendant or duty nurse allotted to that bed. Manual negligence in such a scenario may lead to the death of patient, in the worst case. In this paper, a new design for IV bottle is suggested and a wireless sensor network [WSN]-based liquid level and drop count measuring system is developed. The system is built around the Texas Instruments CC3200, Ultrasonic sensor HC-SR04, LM35 temperature sensor, and GSM SIM900A. The proposed system can also be used to track the status anywhere wirelessly by Wi-Fi and Cellular systems. Thus, possible danger to the patient such as blood loss, back flow of blood due to negligence of nursing can be overcome by monitoring to fluid level and flow-rate. Whole day, 24 h. It is possible to extend the work for private cloud of a nursing home or hospital to maintain secrecy.

Keywords Intravenous system · IoT · Ultrasonic sensor HC-SR04 · GSM SIM900A

1 Introduction

Development in the fields: Information and Communication Technology [ICT], Nano sensors fab [NEMS] and Internet of Things [IoT] have brought in tremendous development in the fields of health care and bio-medical engineering. It is this which paved way to the development of wearable health care parameters such as blood pressure, heart rate, sugar levels etc. Besides this, such parameters can be displayed

K. R. Rao (✉) · K. E. Supriya (✉)
Department of Physics, Sri Krishnadevaraya University, Anantapuram 515003, India
e-mail: kanchiraghavendrarao@gmail.com

K. E. Supriya
e-mail: evangilisupriya.k@gmail.com

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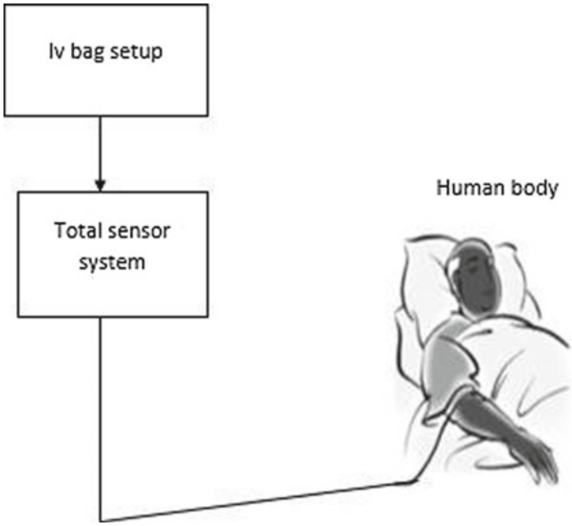

Fig. 1 Intravenous setup

and transmitted using Wi-Fi and cellular technologies. Considering the health industry, nothing is more precious than the patient's life. In such a scenario, it is not the number of patients or money turn over that counts but it is the quality of treatment that is important. Thus, the instruments used in administering any ailment should be self-sufficient and should be in a position to communicate to the hospital's dashboard in general and nursing staff in particular, so there is a need to develop the E-fluid monitoring in the present situation. Keeping view in this point, the total sensor setup is developed as shown in Fig. 1, where the setup detects the drop count, measures the fluid level and sends an alert signal to the attendant when the fluid reaches the threshold level. Pharmacology activities that are involved in the treatment of diseases include the medical administration by oral, intramuscular, subcutaneous, intra-arterial and intravenous [IV].

2 Literature Review

Huang and Lin [1] developed a warning system based on radio frequency identification [RFID]. This RFID technology acts like a triggering device for the developed system. The specially fabricated RF tag can be attached to any kind of IV liquid package available on the market. Zhang et al. [2] developed a novel RFID-Based intravenous infusion monitoring based on fork type light barrier as a sensor with Zigbee protocol, which helps in monitoring the velocity of IV system with high accuracy and reliability. Bhavasaar et al. [3] developed intravenous fluid monitoring system where load cell checks the level of the fluid by weighing the IV bag. Amanu et al. [4] suggested a drip infusion monitoring system using Bluetooth technology where it consists of various infusion monitoring devices that helps in detecting the infusion rate and the collected data is send to the central monitor placed at the nurse station so that required action can be taken. Yanan et al. [5] developed a health information alarm system using Bluetooth and GPRS technologies in which the system monitors, collects data and sends information to analysing counter using artificial intelligence [AI]. Ogawa et al. [6] developed a drip monitoring system based on electrical impedance. The electrodes used are in non-contact with the system which determines parameters of each fluid drop. Ahouandjinou et al. [7] developed a Smart and Pervasive ICU system using Automatic Detection of risk situation and alert [ADSA] method consists of multi camera system and collaborative sensor Network which helps in real-time monitoring to the patients especially facing danger and chronic conditions. Rachman [8] developed a monitoring system regarding patient infusion where laser photodiode is used. This sensor kit collects, process and further sends data to Zigbee transmission device to display them in the form of GUI. Yadav and Jain [9] developed real-time E-saline monitoring system where IR sensor used to detect drop rate, infusion capacity and servo meter used to control drip rate mechanism.

From the above literature survey, it is clear that various workers have used technologies like RFID, Zigbee, GPRS etc. for IV infusion monitoring. Further, IoT-based IV infusion monitoring and alerting system is very rarely seen in the literature. Keeping this in view point, IoT-based IV infusion monitoring and alerting system is designed.

3 Salient Features of the Developed System Include

- The liquid [drug] level and drop rate are constantly monitored and its level is sent to the dashboard of the monitoring system and also to the mobile of the nursery staff.
- When the drug level reaches a threshold value or the set drop rate changes then an alert signal goes to both dash board and nursing staff.

4 General Description of the Hardware Components

The present developed system consists of Texas Instrument CC3200 microcontroller, HC-SR04 Ultrasonic sensor, LM35 temperature sensor, IR senor consists of IR transmitter-receive pair, GSM SIM 900A module.

4.1 CC3200-XL Launchpad

The CC3200 launchpad is the industry's first single chip microcontroller with built in Wi-Fi connectivity. It has an arm cortex core at 80 MHz and contains two on-chip sensors, Thermopile sensor and Accelerometer [BMA222]. It has an embedded memory up to 256 KB. It has an integrated DC-DC converter which operates with wide-voltage mode of 2.1–3.6 V. The board has built in USB-to-JTAG for debugging, flash memory of 8 MB for programming. It has input peripherals like 4-ADC channels and 20 pin headers that provides general purpose input and output pins, three LED's. It has multiple protocols like SPI, I^2C, UART, TCP/IP and TLS/SSL status and HTTP server [10]. The hardware overview of the CC3200 launchpad is shown in Fig. 2.

HC-SR04 Ultrasonic Sensor:

Ultrasonic sensor is now a days recognized as being as simple and cheap answer to many typical demands [11]. The human ear can hear sound frequency around 20 Hz–20 kHz and ultrasonic is the sound wave beyond 20 kHz. Ultrasonic sensors are often used in applications like distance measurement, level measuring etc. It provides excellent non-contact measurement with high accuracy. It has a resolution of 0.3 cm and the ranging distance is from 2 to 400 cm. It has measuring angle of 15° and works with 5 V. It has features like stable performance and accurate distance

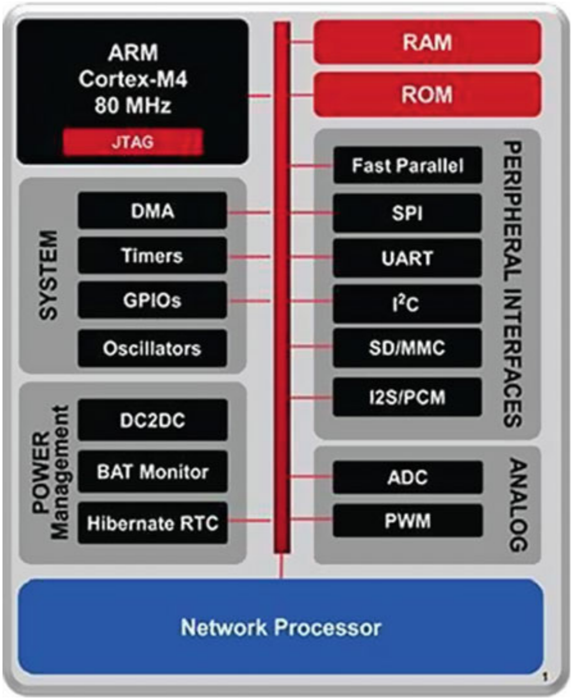

Fig. 2 Hardware overview of CC3200 launchpad (*source* CC3200 datasheet from Texas instruments)

measurement. In the developed system ultrasonic senor is used as a level sensor. The block diagram of HC-SR04 is shown in Fig. 3.

Working Principle:

Ultrasonic transmitter emits an ultrasonic wave in one direction and started timing when it launched. Ultrasonic spread in the air and would return immediately when it encountered obstacles on the way. At last, the ultrasonic receiver would stop timing when it received the reflected wave. The working principle of ultrasonic sensor is shown in Fig. 4.

Timing Diagram:

By applying a short 10 μs pulse to the trigger input will start ranging, then the module raises its echo by sending out an 8-cycle burst of ultrasound at 40 kHz. The range can be calculated through the time interval between trigger signal and echo signal. The timing diagram of ultrasonic sensor is shown in Fig. 5. The two basic blocks of ultrasonic sensor are transmitter and receiver [12].

Fig. 3 Block diagram of HC-SR04 ultrasonic sensor (*source* HC-SR04 datasheet)

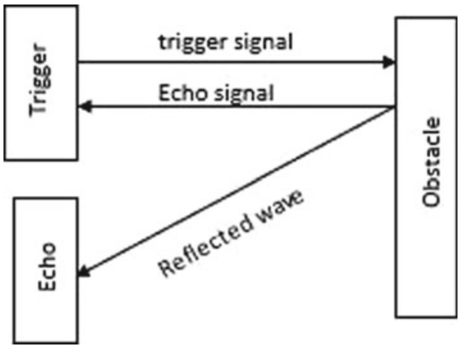

Fig. 4 Ultrasonic sensor working principle

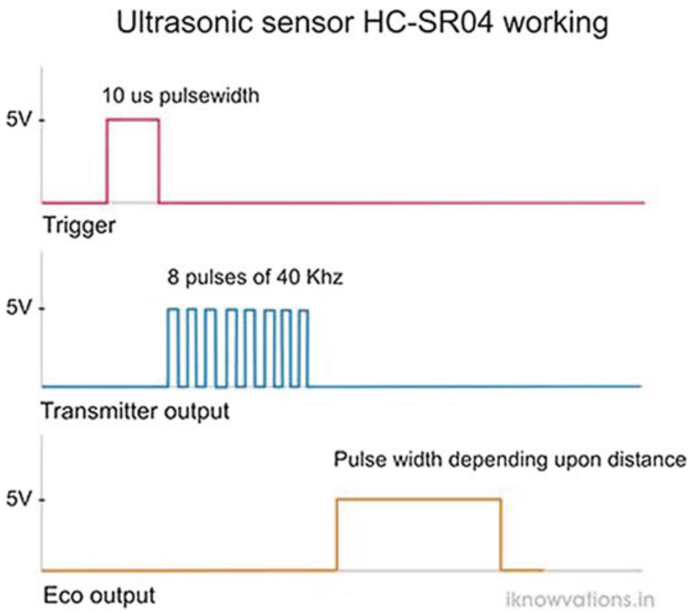

Fig. 5 Timing diagram of ultrasonic sensor (*source* ultrasonic sensor HC-SR04 datasheet)

4.2 LM35 Temperature Sensor

LM35 sensor is used for measuring temperature. These are specially designed sensors whose output voltage is linearly proportional to the Celsius. It has a 0.5 °C accuracy. It has three terminals namely Vs, Vout and Ground as shown in Fig. 6.

It is a low-cost sensor used for many typical applications due to water level trimming and it can operate at 5 V. The low output impedance, linear output and

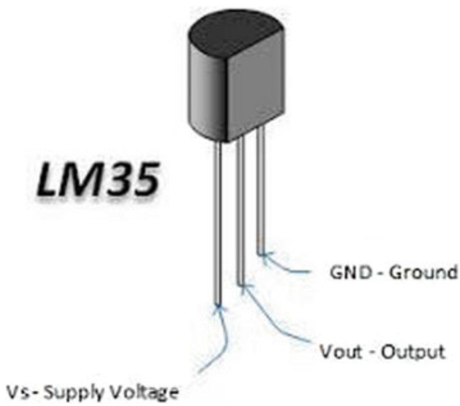

Fig. 6 Pin diagram of the LM35 Temperature sensor (*source* LM35 datasheet)

Fig. 7 Photograph of the IR sensor [IR transmitter-receiver pair]

precise inherent calibration of the LM35 sensor makes interfacing to read out or control circuitry especially easy. LM35 temperature sensor has an advantage over linear temperature sensor which can calibrate in kelvin as the user is not required to subtract a large constant voltage from the output [13].

4.3 Infrared Sensor

Infrared sensor is used to detect the drop count. This sensor is low-cost, small in size and having good precision. Infrared [IR] Sensor consists of an IR emitting diode which acts as an emitter and IR phototransistor which acts as a detector. It works in low-voltage mode [3–5 V]. The photograph of the IR transmitter receiver pair which is used in the present work is shown in Fig. 7.

It has the advantage of fast response time and high sensitivity. IR sensor is having a feature of non-contact measurement [14]. Thus, IR sensor is used in various applications like embedded fields, distance measurement, medical and engineering field for obstacle detection.

4.4 GSM SIM900A Module

GSM SIM 900A [global system for mobile communication subscriber identity module] built with SIMCOM makes SIM900 works on frequencies 900/1800 MHz. It is very compact in size and easy to use as plug in GSM modem. The baud rate is between 9600 and 115,200 through AT command. The built in low-drop linear voltage regulator allows you to connect wide range of unregulated power supply [4.2–13 V]. It has features like sending and receiving SMS, making audio calls and receiving calls. It has built in SIM card holder and network status LED [15]. The AT commands of GSM module used in the system are shown in Table 1.

Table 1 AT commands of GSM module used in the present study

Instructions	Meaning
AT	Attention
AT + CMGF	Set module in message mode
AT + CMGS	Set module in call mode

5 System Architecture

The block diagram of the system (Fig. 8) developed in the present work consists of:

- US senor: Ultrasonic sensor HC-SR04
- V: +5 V
- G: ground
- E: Echo Output US senor: Ultrasonic sensor HC-SR04
- T: Trigger Input
- LM35 TS: LM35 Temperature sensor

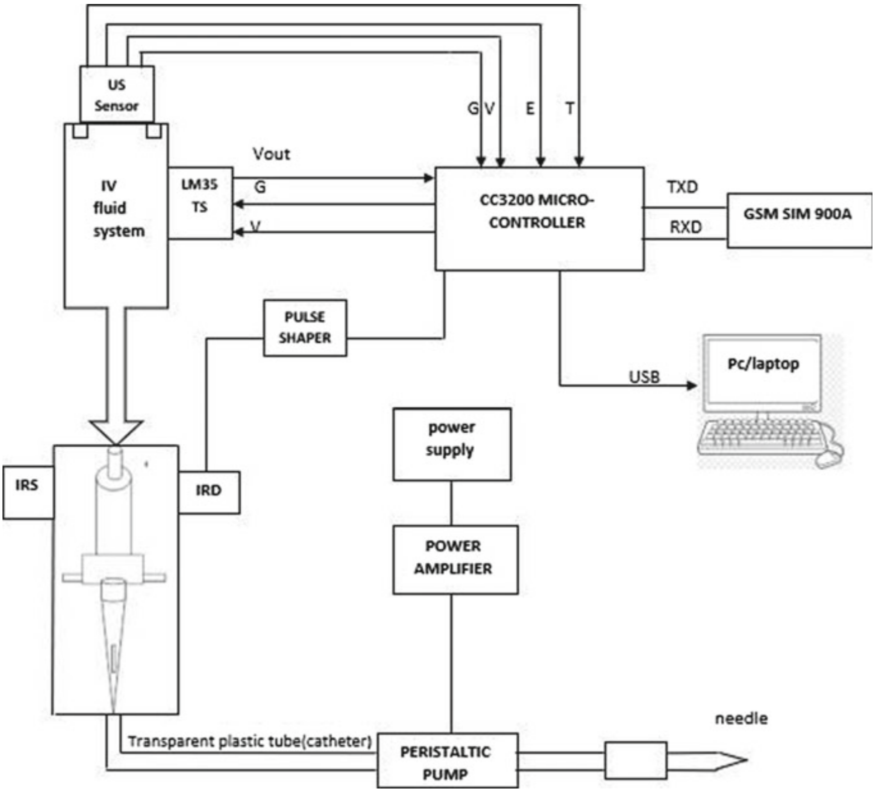

Fig. 8 Block diagram of the developed system

- GSM SIM900A: Global System for Mobile Communication Subscriber Identity module
- IRS: Infrared source, IRD: Infrared detector
- TXD: Transmit data, RXD: Receive data.

6 Working Principle

In the developed system as shown in Fig. 8. ultrasonic sensor is used as a level sensor to the check the fluid level of the system. The sensed level of the fluid is converted into electrical signal and is send to the CC3200 microcontroller. The level of the fluid is sensed by the ultrasonic sensor, by applying a short pulse 10 μs pulse to the trigger input, then the echo is a distance object that is pulse width and range in proportion. And also, temperature sensor LM35 is used to measure the temperature, which can operate with low voltage that is 5 V.

In the above intravenous setup where the Infrared [IR] sensor is kept in the drip chamber. The main blocks of the IR sensor are IR Emitter and IR emitter which is used to emit the light and the IR photodiode which acts as a detector used to detect the light of same wavelength. Normally, in IR senor, the phototransistor does not receive any radiation from IR LED but when it detects an object and the object becomes closer then the photo transistor which is acting as a detector reflects and receiver radiation [16]. The IR detector and IR source/emitter are placed side by side in the drip chamber. Suppose, if the droplet blocks in the drip chamber then the light emitted by the LED of IR and the detector automatically receives the radiation from the object. Thus, each drop can be counted by IR sensor.

7 Power Amplifier LM393

Lower power dual voltage comparator consists of two independent low voltage comparators designed especially over a wide range of voltages [17]. In the developed system, LM393 is used to amplify the generated signal. Suppose when there is a droplet going through infrared emitting diode, the phototransistor receives radiation and the receiver of the IR sensor will generate a signal, then that signal will be sent to the microcontroller. Also, there is an LED connected to signal output interface, indicating that infrared emitting diode is working properly.

8 Software Description

In the present work, the software is developed using Energia IDE. It works with windows, Linux and Mac operating systems. The program is developed in embedded C. It's very easy for the user to program in this IDE. The flowchart of the related firmware is shown in Fig. 9.

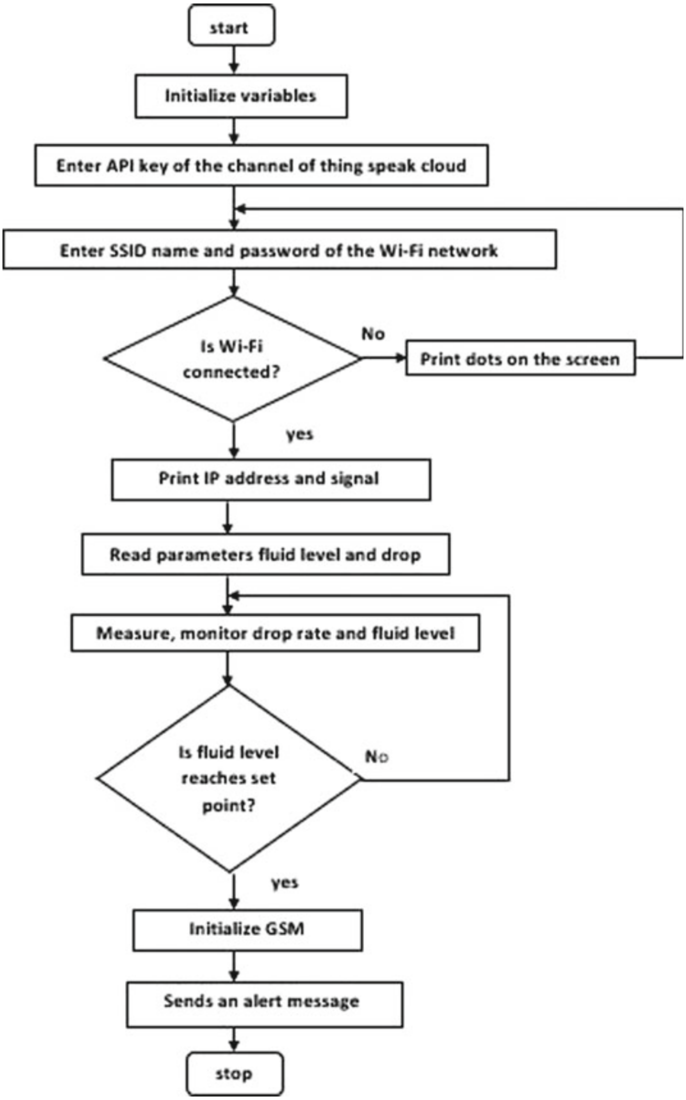

Fig. 9 Flowchart of the program developed in the work

9 Message Transmission

After the liquid level and drop rate are monitored, collected, if the value reaches the set point then an alert signal sends to the concerned nurse through GSM. The block diagram of the message transmission is shown in Figs. 10 and 11 and the screen shot of getting alert message is shown in Fig. 12.

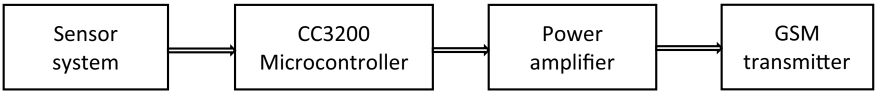

Fig. 10 Signal generation from sensor system to GSM module

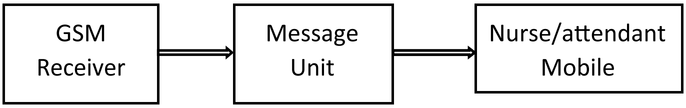

Fig. 11 Signal generation from GSM to nurse mobile

Result:

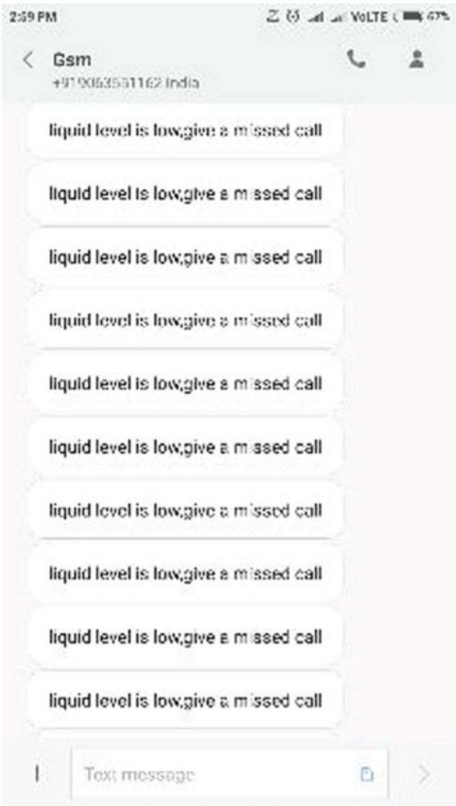

Fig. 12 Screenshot of getting message to the registered mobile number

10 Conclusion

The developed Intravenous Infusion system determines the fluid level and drop rate which are continuously monitored and display to the dashboard and to the mobile of the nurse/attendant. And also, if the drug level reaches the set point and the drop rate changes then the alert signal goes to monitoring system and to the nurse/attendant. The performance of the developed system was found to be much superior and better performance when compared to the other types of similar developed systems in the market. The system has been composed of with minimum hardware components and in minimum power consumption.

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