Sensor-Driven Smart Healthcare Ecosystem for Critical Diagnostics

Latha H N[1], Gayathri M. S.[2], Kiran Bailey[3]
[1,3]Department of E & C Engg, BMS College of Engineering, Bangalore
[2]Department of Mathematics, BMS College of Engineering, Bangalore

Abstract- **This paper proposes a model which monitors various health parameters like heart rate (BPM), body temperature, blood pressure monitor (mm Hg) and ECG (Electrocardiogram) of an individual. The collected data through the system is then transferred over the internet to a smartphone application of the patient. This data is transferred to the registered doctors on to their smartphone application as well as standalone computers. The doctor can then prescribe the medication based on the data results shown by the system. The designed prototype will reduce the burden on patients to visit the doctor every time for monitoring of these health parameters.**

Index Terms— **Electrocardiogram, Wireless sensor network, BPM, IoT, ARM.**

I. INTRODUCTION

Wireless Sensor Network technologies have become a latest research area in health care [1] industries due to rapid maturity in improving the quality of life of a patient. Wireless Sensor Networks when work in medical field provide continuous monitoring of vital health parameters which over a long period of time provide doctors much needed help to make accurate diagnosis [2] and giving better treatment.

WSN can be considered as a network consisting of independent sensor devices. These are deployed in locations which are known for the intention of monitoring and data collection such as radio signals, sound, pressure, temperature etc. WSN can be utilized in various civilian and industrial applications, including healthcare applications, industrial process monitoring and control, home automation, habitat monitoring and many others.
Nowadays, the complexity of healthcare systems is very high. The needs of continuous health care for the people are increasing by the day. Medical staffs are faced with advancing challenges. Thus, there are questions being raised with regards to the medical domain and these must be answered in the most effective way possible. Current state must be analyzed ardently so that a functional system which can resolve a considerable number of issues can be formed. An appropriate solution can be provided by WSNs in the medical domain [4].

Driven by technological innovations in low-power networked systems and sensors in medical science, the emergence of WSNs is being witnessed. WSNs aid in the building of intelligent Medical Sensor System.

The primary goal of the system is to collect the information of individual health parameters based on WSN to provide physicians with concise data and readings [5] which can be used to monitor the diagnosis of health parameters through mobile communication. This can be utilized for individual investigation to help with rolling out conduct improvements, and to share with parental figures for early detection and treatment. Such systems are successful and monetary methods for observing ailments.

II. LITERATURE SURVEY (BACKGROUND OVERVIEW)

Wireless sensor network (WSN) [4] [6] is a network comprised of autonomous sensor devices which are usually deployed in known locations for the purpose of monitoring and collecting data [7], [8] such as radio signals, sound, temperature, etc. Becoming mature enough to be used for improving the quality of life, wireless sensor network technologies are considered as one of the key research areas in computer science and healthcare application industries. The pervasive healthcare systems provide rich contextual information and alerting mechanisms against odd conditions with continuous monitoring. This minimizes the need for caregivers and helps the chronically ill and elderly to survive an independent life. Currently, wireless sensor networks deployment is starting to be deployed at an accelerated pace. It is reasonable to expect that the world will benefit from services of Wireless sensor networks with technological access.

While considering Health care application using wireless sensor networks several challenges also needs to be considered such as low power, limited computation [9], material constraints, and continuous operation, robustness and fault tolerance, scalability, security and interference and regulatory requirements. Our system would try to overcome these performance metrics which needs to be overcome in implementation health care systems using WSN. Health care monitoring systems using Wireless Sensor Networks consists of physiological monitors, which are custom-built sensors [10], patient worn motes that sample, and pass the data through a wireless network. Moreover, there is also one backend server which stores the data medical data and presents them to authenticated GUI clients only. The main challenge here is mobile communication where clients don't have the flexibility to communicate through smart hand-held devices and have to be location dependent for gaining treatment from doctor thereby visiting him every time for medication.
Hereby a system is proposed which overcomes this drawback [11], [12] and allows clients to send their data to doctors through mobile communication and by using system insights two major factors of such as time and location dependencies are saved.

III. PROBLEM STATEMENT AND PROPOSED SOLUTION

Drawbacks of Existing System are that it has the problems of using single functionality specific machines to monitor various health parameters of the user. These machines are huge and bulky in size as well as it is also not able to communicate the sensed or captured data to other devices using mobile communication.

Proposed System presents a distributed set of sensors which will mimic the work of individual elements by sensing the data captured by them.

This system shown in Fig 01, focuses on the use of various wireless sensors to determine the process of checking various parameters of health of the patient using different sensors namely blood pressure sensor, pulse sensor, ECG sensor and temperature sensor which will be used to supervise the heart rate of a person. All the sensors are connected to a Raspberry Pi which features an ARM compatible CPU and on chip GPU with the CPU speed ranging from 700 MHz to 1.2 GHz along with an onboard memory of 1GB RAM. It also features an RJ 45 Ethernet Port and Pi 3 also has onboard WIFI 802.11n and Bluetooth.

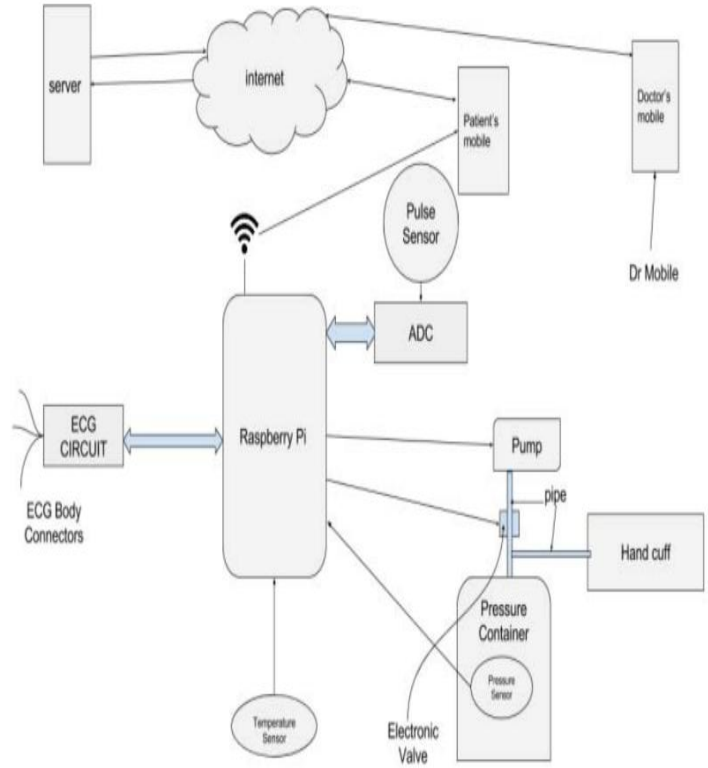

Fig 01: Block diagram of proposed solution

The system also includes other components namely ADC to obtain a digital pulse from an analog pulse. AD 8232 Heart Monitor is used to produce ECG [16] of an individual. To calculate Blood Pressure[17] of an individual system uses BMP 180 Barometric Pressure Sensor along with its handcuff, pipe attachments and Electronic Valve which is used to control the air flow to the pressure sensor which resides inside the pressure container. M513 MLX90615 Temperature Sensor is used to measure an individual's temperature. All the sensors collect their individual data and give to Pi 3 for processing.

Health parameter ranges are defined in advance to determine if the data collected is correct or not. Channel bandwidth that the system provides is dependent on the speed of the mobile node connected to the internet [13]. The mobile node is made as the WIFI router [14] and send data to both the android applications using the mobile node data which is provided by telecommunication partner.

System Overview

1. Press the button on the device
2. Red light glowing indicates the processing

of the report, checking body and generating numbers for the report.

3. Green light glows when data is uploaded to the server.
4. We can open the patient's side of the mobile application to check the report.
5. Patient can view report and wait for the doctor's feedback.
6. The list of submitted report is received by the doctor when he/she opens the app.
7. Prescription is sent by the doctor.
8. The patient gets the prescription when he opens the app.

1. Pulse Sensor

The proposed system uses a pulse sensor.
It is an effectively designed plug and play heart rate sensor for the Pi. The sensor clips onto the earlobe or fingertip and some jumper cables are used to plug it into the Pi 3. The front of the sensor is the pretty side with the Heart logo. This side makes the contact with the skin. A small round hole is seen on the front side, which is where the LED shines through from the back. There is also a small square under the LED which is an ambient light sensor similar to the one used in tablets and cellphones to adjust the brightness of the screen in various light conditions. The LED shines light into the fingertip or earlobe, or other capillary tissue, and sensor reads the light that bounces back. The back of the sensor is where the rest of the parts are mounted.

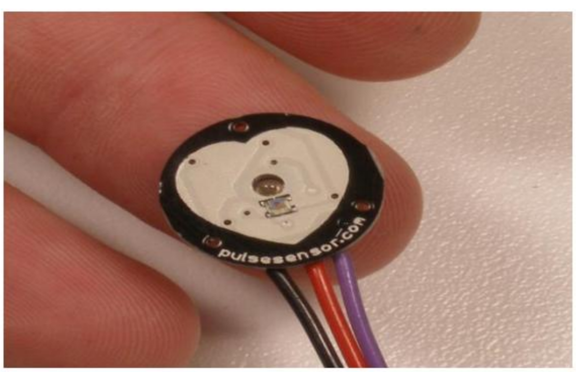

Fig 02: Pulse Sensor cables connected to Pi 3

Once the code is run, the pin 13 is seen to blink on Arduino in time with one's heartbeat when the user holds the sensor on her/his fingertip. Clean and nice data and signals is given to the Pi 3 by spot pressure on the pulse sensor. Here, a normal resting heart rate in the range 60 to 100BM is defined for adults. Collected data through the pulse sensor is provided to Arduino which is used as ADC since the pulse sensor generates waveform for heartbeats. Arduino is utilized here as it possesses the ability to generate digital value from analog waveform and then processed into BPM algorithm to produce values for heartbeats for every user. Pi's OS then stores this heartbeat and transfers to a remote server over the internet and transfers directly to user smartphone app so that they can view their heartbeats in real time. If this data isn't in the aforementioned resting range, it will automatically get transferred to registered physicians for diagnosis and subsequent treatment.

2. BPM algorithm

I. Fill the data from sensor in an array for T seconds.
II. Find minimum value and maximum in that array suppose A and B.
III. Map values in array A to some negative value (–x) and B equivalent positive value (+x) and all middle value directly proportional.
IV. Increment counter C for every time the value in array changes from negative to positive.
V. BMP = (C/T) * 60.

3. Temperature Sensing Unit

This module integrates M513 MLX90615 Digital Infrared Temperature sensor [7] sensor and other required components on Pi 3. The DHT 11 sensor includes a resistive-type humidity measurement component, an NTC (Negative Temperature Coefficient) temperature measurement component and a high-performance 8-bit microcontroller inside, and provides calibrated digital output when connected to Pi 3. This sensor has high reliability and long-term stability. The system accepts data from MLX90615 sensor through Pi 3 and gives it to user's smartphone application for diagnosis. The average normal body temperature is 98.6°F (37°C). The range defined in our system for the body temperature to be normal is from 97°F (36.1°C) to 99°F (37.2°C). The temperature over 100.4°F (38°C) is the quoted abnormal human body temperature for the system; it means the user is suffering from fever caused by infection or illness.

4. Pressure Sensing Unit

In this proposed system, user's blood pressure is measured using the BMP 180 Breakout barometric pressure sensor with an I2C interface. This unit comprises of different other components responsible for the calculation of the systolic (maximum) and diastolic (minimum) blood pressure of the user.

This unit consists of a pressure container which has pressure sensor which is used in the system to monitor pressure. Air pump is the second component which is utilized to fill the handcuff (an inflatable strip tied around the patient's hand for the calculation of blood pressure. When wrapped around the hand and inflated, the blood flow is stopped in the hand)

Pressure from handcuff will be induced inside the pressure container and the pressure inside the pressure container and handcuff will be said that will be calculated by bmp180 sensor inside the pressure container. Third component is air pump, it consists of centrifugal pump which forces air inside the handcuff to inflate it. Fourth component is pulse sensor (heart rate sensor), just like doctor uses his stethoscope to listen the beats from hand's veins; we are using this sensor which will digitally detect beats. We will fill air inside the handcuff till a point when the pulse sensor doesn't show pulse in its output, this is when we get the Systolic pressure by reading value from BMP180 sensor inside the pressure container. When we get the pressure reading, we have to deflate the handcuff. Fifth component is a solenoid valve, it will open the air flow hole by which air will escape and the handcuff will deflate and blood flows normally again and we get the pulse from pulse sensor. We will continue to deflate the handcuff by turning on solenoid valve, till we don't get pulse reading and stop that is when we read Diastolic pressure from pressure sensor BMP180. These readings are then transferred to user smartphone application via Pi 3. If the blood pressure of the user is above or below the normal resting range of approximately 120/80 mm Hg then necessary action can be taken by the doctor as this data will be sent to doctor's smartphone from user application after getting the alert to the user.

5. ECG Sensing Unit

In the system, a heart graph of the user is generated using ADS1292R ECG/Respiration Breakout kit. The kit comprises of breakout board for the TI ADS1292R Analog front-end IC for ECG and respiration measurement will help measure both; ECG patterns and respiration. The kit, when connected to Pi 3 adheres to these following steps of execution: The probes are connected to the body in 3 places as shown in Fig 04.

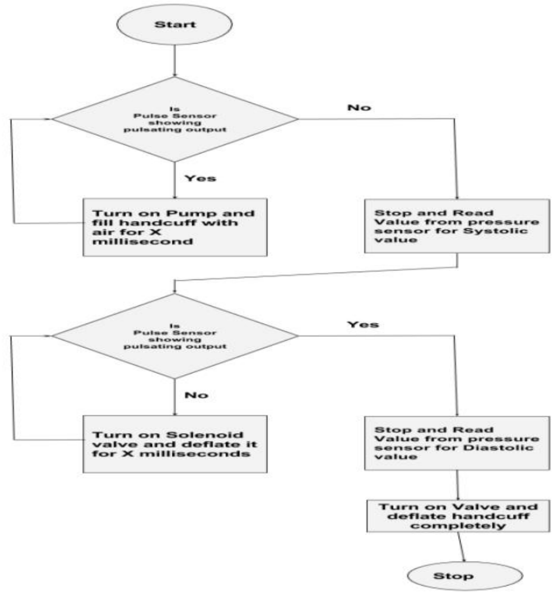

Fig 03: Blood Pressure Calculation flowchart

Analog values are read by the program from the probes that are minute fluctuations in one's body's electric current. IC is used for amplification and digitally sample the readings. Data is sampled and normalized by the IC; filters out all the outlier from the digital values. An array stores all the values which is displayed as image and saved in an .png image. Array values are directly equivalent to the ECG graph pulses; program stores the image in a directory which is later uploaded to the server using HTTP request.

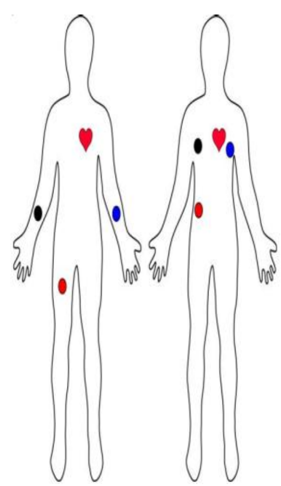

Fig 04: Connectors for ECG Circuit

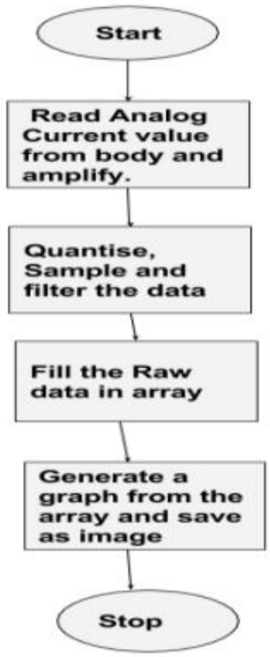

Fig 05. ECG Sensing unit flow chart

V. RESULTS AND DISCUSSIONS

Two perspectives are offered with the use of this proposed system:

1. User side android application
   Here, the application collects data from different sensors altogether and shows it on the smart health application specially designed to view the measured parameters.
   If any of the measured parameters lies in an abnormal range defined earlier, then it will automatically be displayed as an alert and will be sent to the registered doctors in the area. (Fig: User side android application)

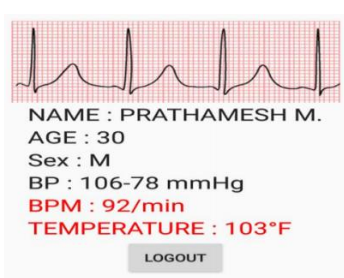

Fig 06: Doctor side android application

2. Doctor side android application
   On logging in to his/her application, the doctor will be able to directly view the reports and data sent by individual patients along with their previous and current statistics. The doctor can also view the medical history of every patient on their smartphone application. Therefore, based on the current diagnosis as well as previous medical records, a prescription can be immediately generated by the doctor which contains the medication with respect to the patient's data. Subsequently, the prescription is available the patient to view along with the doctor's registration number and other important credentials.

(Fig: Doctor side android application)

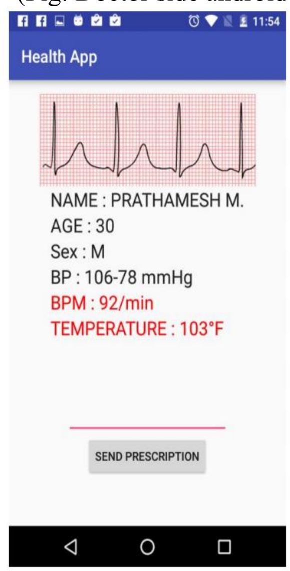

Fig07: Doctor side android application

VI. CONCLUSION AND FUTURE WORK

The idea of using WSNs for the calculation of medical health parameters is not new, but this paper rather focuses on calculating different parameters namely ECG, heartbeats and blood pressure monitoring altogether in a in a single calibrated kit which poses to the user as a single system when interfaced with android smart phone application providing higher usability both to doctors as well as patients. The system will eliminate the problems observed in the manual and conventional machine-based monitoring system as the real time data monitoring demand increases because of rise of chronic diseases which will vary person to person. Given the right time and right information, the sensor based medical system can assist patients to easily monitor and track their health records. This system will eliminate the need to visit the doctor every time for a diagnosis and will help registered patients of a doctor to receive an effective treatment.

REFERENCES

[1]. M. C. Vuran and I. F. Akyildiz, *Wireless Sensor Networks*. Hoboken, NJ, USA: John Wiley & Sons, 2010.

[2]. C. Schmitt and G. Carle, "Applications for Wireless Sensor Networks," in *Handbook of Research on P2P and Grid Systems for Service-Oriented Computing: Models, Methodologies and Applications*, N. Antonopoulos, Ed. Hershey, PA, USA: Information Science Publishing, Jan. 2010.

[3]. S. Sahaa and S. K. Tomar, "Issues in transmitting physical health information in m-healthcare," *Int. J. Curr. Eng. Technol.*, vol. 3, no. 2, pp. 411–413, Jun. 2013.

[4]. V. Shnayder, B. Chen, K. Lorincz, T. R. F. Fulford-Jones, and M. Welsh, "Sensor networks for medical care," Harvard Univ., Cambridge, MA, USA, Tech. Rep. TR-08-05, 2005.

[5]. S. Smys and G. J. Bala, "Efficient self-organized backbone formation in mobile ad hoc networks (MANETs)," *Comput. Electr. Eng.*, vol. 38, no. 3, pp. 522–532, May 2012.

[6]. J. Chauhan and S. Bojewar, "Sensor networks based healthcare monitoring system," in *Proc. Int. Conf. Inventive Comput. Technol. (ICICT)*, Coimbatore, India, 2016, pp. 1–6, doi: 10.1109/INVENTIVE.2016.7824814.

[7]. J. Chauhan and S. Bojewar, "Sensor networks based healthcare monitoring system," *IEEE*, 2016.

[8]. M. Dhanvijay and S. C. Patil, "Internet of Things based patient monitoring system," *IEEE Internet of Things Journal*, vol. 7, no. 6, pp. 5001–5008, June 2020, doi: 10.1109/JIOT.2020.2971956.

[9]. S. Izza, M. Benssalah and K. Drouiche, "An enhanced scalable and secure RFID authentication protocol for WBAN within an IoT environment," *IEEE Transactions on Information Forensics and Security*, vol. 16, pp. 102705, 2021, doi: 10.1109/TIFS.2021.3056789.

[10]. S. S. Sen, M. Cicioglu and A. Çalhan, "IoT-based GPS assisted surveillance system with inter-WEAN geographic routing for pandemic situations," *IEEE Sensors Journal*, vol. 21, no. 5, pp. 103731, Mar. 2021, doi: 10.1109/JSEN.2021.3057312.

[11]. A. A. Hassan, K. Tutuncu, H. O. Abdullahi and A. F. Ali, "IoT-Based Smart Health Monitoring System: Investigating the Role of Temperature, Blood Pressure and Sleep Data," *IEEE Access*, vol. 9, pp. 231–240, Dec. 2023, doi: 10.1109/ACCESS.2023.3270602.

[12]. S. Sasikala et al., "Wireless Sensor Network Application for IoT Based Healthcare System," *2023 IEEE International Conference on IoT and Healthcare Technologies*, pp. 1–6, May 2023, doi: 10.1109/ICHT.2023.1005044.

[13]. A. Gutte and R. Vadali, "IoT Based Health Monitoring System Using Raspberry Pi," *2021 IEEE International Conference on Computing, Communication, Control and Automation (ICCUBEA)*, Pune, India, pp. 1–5, doi: 10.1109/ICCUBEA.2021.8697343.

[14]. P. Gope and T. Hwang, "BSN-Care: A Secure IoT-Based Modern Healthcare System Using Body Sensor Network," *IEEE Sensors Journal*, vol. 20, no. 5, pp. 1368–1376, Mar. 2021, doi: 10.1109/JSEN.2021.2502401.

[15]. A. Ben Abdallah and Y. Bouteraa, "Optimized stimulation control for upper limb exoskeleton using fuzzy logic-based pain detection," *IEEE Transactions on Biomedical Engineering*, vol. 71, no. 2, pp. 1047–1055, Feb. 2024, doi: 10.1109/TBME.2024.31241047.

[16]. U. Gogate and J. Bakal, "Healthcare Monitoring System Based on Wireless Sensor Network for Cardiac Patients," *IEEE Instrumentation and Measurement*, vol. 70, pp. 1–6, 2022, doi: 10.1109/TIM.2022.1537.

[17]. A. Ghosh, S. Misra and A. Mukherjee, "Sensor Network-Based Healthcare Monitoring System," *2020 IEEE International Conference on Computational Intelligence and Communication Technology (CICT)*, Ghaziabad, India, pp. 1–6, doi: 10.1109/CICT.2020.12.