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Three Tier Architecture for IoT Driven Health Monitoring System Using Raspberry Pi

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***Abstract*—Wireless sensor networks (WSNs) have witnessed advancement in medical services from real-time tracking and computer-assisted machine to alert response systems. Due to a tremendous shortage of trained manpower and a huge cost for setting up state-of-the-art facilities, it is often not possible to deliver proper health care services in the rural and remote areas. Lack of accurate and timely information further adds complexity and challenges to the problem. The proposed system uses a three-tier architecture that can be generally applied to WSN based healthcare systems. The proposed model monitors the patient body temperature, heartbeat, and body position movements constantly, and sends this information to site pages and crisis centres/services from the remote location. WSNs are composed of low power consuming sensors. Raspberry pi is a credit card sized board that uses 5V power supply. The proposed and implemented system prototype uses raspberry pi that is driven by Internet of Things (IoT) connected through different sensors DS18B20, ADXL345, ADC1015 and heartbeat sensor. The framework additionally gives crisis warning to a specialist and sends the information on a web server. The framework utilizes DS18B20, heartbeat sensor, and accelerometer. The system is designed secured by providing a mechanism to authenticate the user to get access to patient data. Implemented system hardware prototype consists of two controllers that provide a mechanism to bring personal health status in the normal range in case of emergency.**

***Index Terms*—IoT, Health monitoring system, Raspberry Pi and IoT, Architecture.**

I. Introduction

In India, nearly three quarters of 1.2 billion population live in rural areas. Providing efficient health care services is a significant challenge for them. Due to tremendous shortage of trained manpower and huge cost for setting up state-of-the-art facilities, it is often not possible to deliver proper health care services in the rural and remote areas. Lack of accurate and timely information further adds to the complexity of the problem. The efficient use of technology can improve the overall performance of the health care system and its reach ability amid the citizens of India.

A survey was conducted by NCBI to observe the functionality and working conditions of different types of health care delivery to observe the improvement in health care services with the introduction of information technology in health care field. The survey revealed that the data related to patient are not kept properly and were maintained manually that leads to duplication of data of patients and inconsistency in data.

A. Novel Contributions of the Paper

The paper provides the details of a proposed system efficient to continuously monitor and generate different reports of the patient. The developed system is robust and economical. The system can inform the wellness status of the inhabitant to the health service provider in advance. The system provides real time monitoring of the patient. The system processes various samples of data and extracts the information through probabilistic analysis according to the proposed decision model. The system generates predictive decision in the implemented hardware prototype depending upon several monitoring health parameters.

B. Overall Organization of the Paper

The remainder of the paper is organized in the following manner. Section II discusses related research work and motivation for the paper. Section III provides overview for proposed system having three tier architecture. Section IV describes the mechanism of decision making model for hardware prototype. Section V gives brief description on hardware prototype consisting of stepper motor. Results are discussed in section VI. Finally section VII consists of conclusion and future work.

II. Related Research and Motivation

Implementation of IoT (Internet-of-things) in healthcare services provides data consistency and reduces duplication of data related to patient [1][3]. Electronic Health care system provides tracking, tracing and monitoring of patients with accuracy where a traditional health care system falls short [5] [10]. IoT technologies are incorporated with various sensors connected to processors through various open sources like AWS (Amazon Web Services) [7] [14]. The use of fog computing in IoT provides time sensitive health care applications [11]. Fog computing brings cloud closer to cease-customers and records sources by allowing computation at the side of the network. Low latency is the essential gain [6]. IoT applications are often latency-sensitive [9]. Such applications can also be provisioned as factor-based totally in a hybrid cloud/fog surroundings with elements spanning cloud and fog [4] [13]. This permits placing some of its additives in the fog region closer to the IoT devices, and therefore reduces the latency [6]. Healthcare utility development in FIWARE FI-superstar utilizes cloud computing and net of things (IoT) idea to assemble innovative future net services for healthcare provisions in the information and conversation era [2]. This encompasses quite

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a number of use instances such as monitoring, rehabilitation and others of sufferers making use of cloud offerings [12] [8].

III. Proposed System

The proposed system provides continuous monitoring of a patient. The system uses raspberry pi and various sensors like DS18B20, ADC1015, ADXL345 and heart beat sensor. The system provides assistance that includes automation in systematic monitoring of patients, transmission of medical data at real-time, saving those data in database, and manipulation data for future use. The proposed system operates in two modes. The mode depends upon number of samples collected that is 50 samples (fast mode) and 200 samples (high precision mode). The system uses a web page that requires authentication to access patient data. The proposed system consists of three tier architecture. The tier one consists of wired sensor network that have low power consumption to collect various samples of patient. Tier two consists of processing unit that includes processing model, probabilistic model and decision model. The system generates live graph of various samples of data that are collected through GPIO. Tier three consists of web page for remote access for patient condition and hardware prototype that provides mechanism to control body temperature and heart beat of patient in case of emergency. This is shown in Figure 1.

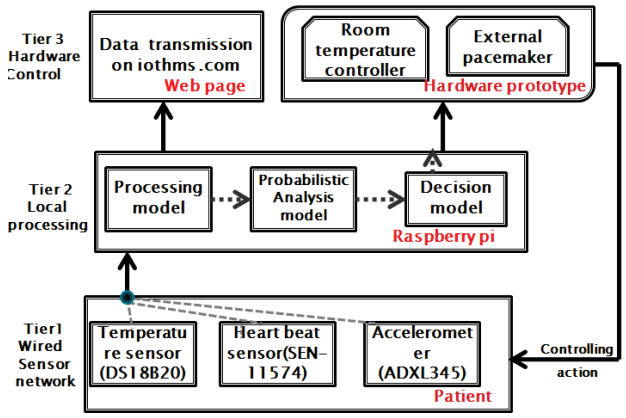

Fig. 1. Three Tier Architecture of proposed system.

The system does processing on data received from sensor to determine whether data is in normal range or unusual range to determine various cases like heatstroke, hypothermia, bradycardia and tachycardia. The system does probabilistic analysis of data collected from sensor through GPIO. Hardware prototype consists of two controllers that provides a mechanism to bring person health status in normal range in case of emergency condition. Decision making model makes decision regarding hardware prototype that are room temperature controller and external pace maker (in emergency case) consisting of stepper motor.

IV. Details of Decision Making Model

Detailed description of the decision making process in the proposed three tier architecture may be provided as follows (shown in Figure 2).

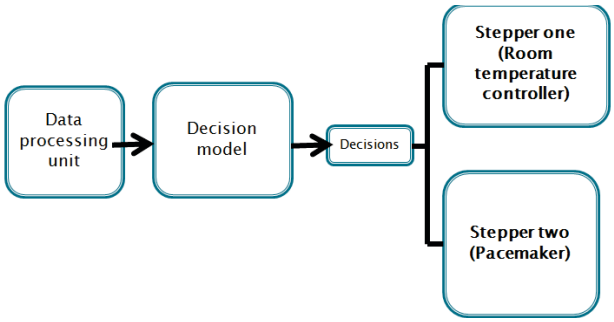

Fig. 2. Decision model.

A. Data processing

The tier one consists of group of sensors connected from various GPIO (gpio4, SDA and SCL) to collect the samples of body temperature, heart beat and body position of patient. These are carried to the processing model. The system collects various samples from patient and processes these samples through various models to convert a raw data to information, maintaining the Integrity of the Specifications.

B. Decision making model

Decision making model with its two controllers at tier three provides a mechanism to bring person health status in normal range. Decision making model makes decision regarding hardware prototype that are room temperature controller and external pace maker consisting of stepper motor. Stepper motor used is Model 28BYJ-48 and they are driven by ULN2003 that provides required current to drive steppers. Hardware prototype consists of two controllers that provide a mechanism to bring person health status in normal range in case of emergency condition.

C. Protocols used in proposed system

The proposed system uses various protocols at different tiers of three tier architecture. Tier one consists group of wired sensors having interfaces with raspberry pi using protocols one wire protocol for temperature sensor and I2C for accelerometer and ADC. I2C can communicate with one controller and total 127 slaves at same time having 7 bit address. Tier two does the processing of data and visualization of data using mat plot. Tier three does the wireless communication between system and web page (iothms.com) using get and post method and IEEE802.11 and provides decision to hardware prototype.

D. Process flow of system

Raspberry Pi communicates with sensors through GPIO. The system Controls the devices and sensors from GPIO by using raspbian OS. Raspberry pi is connected by laptop using Ethernet port and uses PUTTY to make connection between laptop and raspberry pi. Each system has a unique user name and password. The samples are collected and processed by processing model. The data are stored in buffer for probabilistic analysis and live graphs. The output of probabilistic model is input to decision making model to take decisions for the hardware in case of emergency.

V. Hardware Prototype

Stepper one (room temperature controller) module controls the temperature of surroundings according to normal body temperature. It moves in clockwise direction to increase the temperature of surrounding in case person body temperature falls below the normal temperature. Similarly it moves anti-clockwise to increase the temperature of surroundings in case the person body temperature goes above the normal temperature. Stepper two (pacemaker) module controls the heart beat. Stepper two moves in clockwise direction to increase the heart beat in case person heart beat falls below the normal heart beat rate and moves anticlockwise to increase the heart beat in case person body heart beat becomes more than the normal range.

VI. Experiments and Result Discussion

This section consists of detailed description of the interfacing done for the experimental purpose, experiments performed, and discussion on results obtained thereby. Figure 3 shows interfacing of heart beat sensor(along with ADC) and figure 4 shows interfacing od ADXL345 and temperature sensor with raspberry pi using SDA, SCL and GPIO 4 . The result of body temperature is (shown in Figure 5).The result of heartbeat and unexpected body movement is (shown in Figure 6) and data visualization of heart beat, body temperature and unexpected body movement is (shown in figure 7).

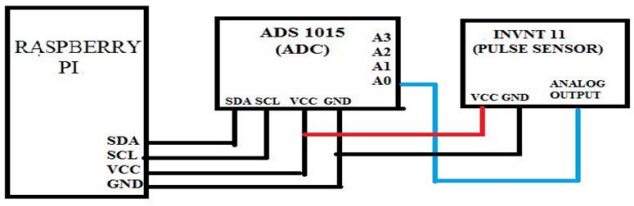

Fig. 3. Interfacing diagram of ADC1015 with heartbeat sensor.

A. Results and Discussion

The proposed system works more efficient way as compared to previous work. The previous proposed system does not provide any processing of data or any kind of authentication access. The proposed system does processing on data received from sensor to determine whether data is in normal range or unusual range to determine various cases like heatstroke, hypothermia, bradycardia, and tachycardia. The system does probabilistic analysis of data collected from sensor through GPIO. The previous work does not provide any mechanism to control patient condition in case of emergency. Detailed comparisons have been presented in Table I.

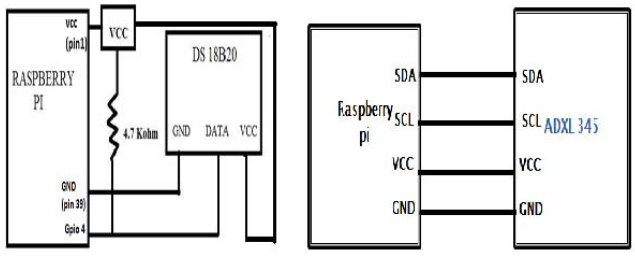

Fig. 4. Interfacing diagram of DS18B20 and ADXL345.

Fig. 5. Screen shots of result for body temperature of patient.

Fig. 6. Screen shots of result for heartbeat and unexpected body movement of patient.

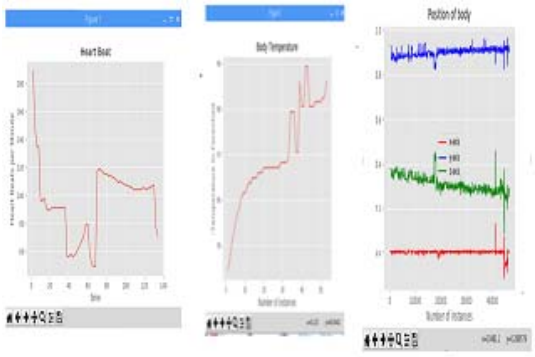

Fig. 7. Data visualization of body temperature , heart beat and body position.

TABLE I
COMPARISON WITH PREVIOUS WORK

	Paper [5] ICCSP 2015	Paper [1] ICICT 2016	Proposed System
Heart Beat	YES	YES	YES
Body Temperature Sensor	YES	YES	YES
Unexpected Motion of Body	NO	NO	YES
Detection of Abnormal Conditions in Body Temperature	NO	NO	YES
Detection of Abnormal Conditions in Heart Beat	NO	NO	YES
Processing of Data Locally	NO	NO	YES
Data Available on Web page	YES	NO	YES
Authenticated Access	NO	NO	YES
Live Streaming of Samples	NO	NO	YES
Hardware Prototype	NO	NO	YES

VII. CONCLUSION AND FUTURE WORKS

The proposed system is efficient to generate different reports in different modes i.e. precision mode (200 samples) and fast mode (50 samples). The system does the processing of data locally before transmission of data to web page. System does detection of hypothermia, heatstroke, bradycardia of patient by analyzing (200 samples/sec) of body temperature and heart beat. System provides the Authentication mechanism to get access of patient health data from health care provider. The system provides continuous monitoring and takes proper actions through controllers. The developed system is robust and is possible to develop at a very low cost. The system can inform the wellness status of the inhabitant to the caregiver in advance. The proposed system generate real time graph of data that are body temperature, heart beat and body position that are collected through GPIO for better visualization of patient data. The system provides cost effective and real time monitoring of a person. The system does processing of various group of samples and extracts the information through probabilistic analysis. The system generates decision for hardware prototype that are room temperature controller (stepper one) and external pacemaker (stepper two) in case of emergency. Future works may be extended to consider and analyze more numbers of health parameters and making the decision engine more accurate to analyze and predict real time health conditions and suggesting proper necessary precautionary measures in case of emergency.

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