Fog Enabled Framework for Patient Health Monitoring Systems Using Internet of Things and Wireless Body Area Networks

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Abstract. WBANs (Wireless Body Area Networks) has a significant role in the automation of remote patient monitoring systems (via over the Internet) for large hospitals, potentially reducing paramedic staff responsibilities. These systems, on the contrary, create a large volume of sensed data, necessitating time-bounded services, dependability, data preparation, and effective communication technology. One of the acceptable choices to improve patient monitoring systems is the Internet of Things (IoTs) with the notion of Fog computing. In this scenario, this paper is focused on the needs of patient monitoring systems before proposing and implementing a hierarchical layer-based IoT architecture that incorporates WBANs, fog computing, and cloud services. In addition, the suggested architecture is tested using an embedded system and an open-source prototyping platform. Results are tracked, saved, and evaluated after testing. The findings demonstrate that by delivering reliable communication, this architecture meets the stringent criteria of medical applications.

Keywords: Fog computing, WBAN, IoT, Patient Health Monitoring Systems, Wearable Devices

1 Introduction

For everyone to remain fit and solid, early detection and treatment is essential. Different illnesses are caused by a fast-paced lifestyle and the consumption of unhealthy foods, as well as high-pressure jobs. In today's medical services environment, the IoT is receiving a lot of attention. In general, an IoT-based framework is capable of connecting numerous products, sensors via the internet, with each linked gadget having its own unique identity, allowing them to communicate information without requiring human intervention intervention. In terms of efficacy, rationality, and accessibility, the Internet of Things (IoT) integration in the medical services sector has resulted in a revolutionary advance in a health-monitoring system. Organization of IoT has become a lot easier because to the availability of free IDE (Integrated development environment) and SDK (programming development kits) programming [1] [10].

The IoT idea may be applied to remote health monitoring, which is commonly known as Wireless Body Area Sensor Networks (WBASNs), but first it is necessary to comprehend WBASNs. A WBASN is made up of sensor nodes that have properties such as low power, miniaturisation, wearability, and lightweight. Electrocardiography (ECG), electromyography (EMG) EEG, accelerometer, gyroscope, pulse oximeter, blood pressure, temperature, barometer, and heart rate monitoring are all utilised in medical applications. These sensor nodes are reliable and can monitor continuously with a little amount of memory [5, 6]. These wearable sensor nodes continually monitor physiological data and transfer it to a coordinator node (PDA or any other appropriate node) for preprocessing utilising RF signals before memory fills (Radio Frequency). The coordinator node is connected to the human body or close to the body. The Central Server (CS) is used to maintain track of data for various patients so that emergency assistance and feedback may be provided. The WBASN architecture is broken into three sections tiers: on-body wearable sensors, coordinator, and control system. Communication occurs at two levels in the three-tier architecture: between the sensor node and the coordinator, and between the coordinator and the CS. The major pushing element for WBASN development is user requirements. Usability, security, privacy, interoperability, availability, and safety are just a few of the criteria. WBASN employs physiological, environmental, and bio-kinetics sensors to meet these needs. The majority of these sensors, such as EMG, ECG, temperature, humidity, blood pressure, blood glucose, and motion sensors, are now commercially accessible. The industry was forced to explore possible applications because to the range of WBASN sensors (Medical and Non-Medical applications). Wearable WBAN (wearable health monitoring, Asthma and Sleep Staging, etc.), Implant WBAN (Cancer detection, etc.), and Remote Control WBAN (Ambient Assisted Living (AAL), Patient Monitoring and Tele-medicine system [7, 8], etc.) are examples of medical applications, whereas non-medical applications include entertainment and video streaming apps. Because communication between sensor nodes includes channel access methods, choosing a suitable and efficient MAC protocol is critical [9, 10].

The IoTs is a forward-thinking concept for communication advancements. The IoT is a collection of entities that are tangible been embedded with various components such as sensors, hardware, and programming. These actual implanted objects are capable of communicating with other like articles, much like the Internet. Each transmitting object is easily identified by its physical characteristics (UID or MAC or IP and so on) By 2020, it is estimated that IoTs would consist of 50 billion objects [6]. The IoT concept may be used to remote health monitoring territories, which is commonly referred to as WBASNs, however it is required to first understand WBASNs. Sensor hubs make up a WBASN, which indicate qualities such as low force, scaled down, wearable, and lightweight, among others. ECG, EMG, accelerometer, spinner, beat oximeter, circulatory strain, temperature, indicator, and pulse watching are all used in clinical applications. These sensor hubs are robust and well-equipped for continuous monitoring with limited memory [5, 6]. These wearable sensor hubs continuously monitor physiological data and send it to a facilitator hub (PDA or other suitable hub) for preprocessing using RF signals before memory fills (Radio Frequency). IoT-based medical care is characterised by a few persistent illness and continuous area monitoring [6]. The modernisation of the applied sciences spurred by continuing advancements in data and correspondence innovation. The Wireless Body Area Network (WBAN) [1] enhanced the applications in medical care by reducing the number of distant sensors and other electronic devices. The extra options created by technological advancements have also reduced health-care costs and treatment delays. WBANs are smarter, have a smaller size, have a shorter battery life, have higher quality of service (QoS) requirements, and handle diverse organisation traffic [2]. The Web of Things (IoT) is a unique innovation that connects any item to a company, and this approach is ideal for WBAN engineering of medical care administrations [3], [4]. The constant advancement of innovation that prepares for the expansion of relationships over the internet and the development of the capacity to deal with data has created more significant chances for the global health business, specifically telemedicine. Data sharing, information analysis, the IoT, wearables, cloud innovation, and mechanical technology are all on the rise as development drivers for the next decade. With these perspectives pointing to responses to the a huge volume of information used in medical care, the requirement for predictable exactness in complex methodology, and growing demand in medical care administration, it's clear that artificial intelligence (AI) plays a prominent role in technological activity and application. Computerizing clinic logistics is needed to increase productivity in scheduling time and transmitting medical care demands and activities [1] [6].

Fog computing is used to distribute the load of a basic network's information exchange and administration. It improves the cloud administrators' performance by providing more detailed information. Fog computing is a virtualized platform that provides processing, programming interface, systems management, and capacity among other services. The business administration facilitates communication between an IoT and cloud connection. Fog computing is commonly used in circumstances where applications and administrations are sent for greater range in a circulating environment. Fog computing is used in consumer electronics, such as wrist watches, to indicate not only in terms of time, but also in terms of the user's route, such as how far they walked and how many calories they ingested. The device can detect a person's heartbeat and provide them a hard or soft rest. The most modern cells nowadays come with built-in sensors, such as the Samsung Note 4 with heartbeat sensors, a gyro metre, and an accelerometer integrated into PDAs. Fog processing is an all-encompassing aspect of distributed computing in which both registration phases have comparable admissions, which benefits fog computing by reducing cloud worker idleness. Distributed computing creates a complete package that benefits customers, but it also has flaws. One of the advantages of the IoT has the ability to quickly enormous volumes of data created to process and analyse and managed efficiently in various applications. Smart care frameworks are especially important in the fast-paced movement of human life. The competence of the activities in such medical care frameworks can be increased when fog processing and IoT are incorporated in machines relevant to clinical sector applications [11][15].

Users need monitor their health parameters on a regular basis to reduce the risk of various ailments, which is impossible to do manually without visiting hospitals and clinics. As a result, a fog-enabled IoT-based health-monitoring system is required to provide real-time healthcare services to remote sites. In comparison to existing cloud-based solutions, the proposed Fog enabled architecture promises lower latency, faster reaction time, increased security, and lower power consumption. The planned IoT framework also attempts to enhance inhabitants' overall quality of life.

2 Related Work

The adaptability and adaptability of both AI and telemedicine gave the unlimited opportunities for advancement and these can be found in the writing inspected [1]. Kallipolitis A. et. al. [2] presents the plan and usage of a feeling examination module incorporated in a current telemedicine stage. The current examination expects to present a novel engineering (SENET) [3], which depends on AI methods and comprises of three principle layers. It is pointed toward bringing the calculations near information sources from medical care habitats [4]. A structure introduced [5] that utilizes, fog computing alongside IoT and AI to give a superior and more intelligent medical services insight. Author presents deal with coordinating electroencephalography [6] based AI components in our eHealth IoT framework by utilizing the TensorFlow open source stage. Author presents a consistent home telemonitoring framework [7] for constant respiratory patients by utilizing 5G network. M. S. Ashapkina et.al. has considered an errand [8] to create quantitative measurements for programmed acknowledgment of activity types in the form of the framework for far off checking of the actual restoration measure. A progressive structure of the framework under investigation is proposed [9] based on the OSI reference model and the degrees of information introduction are portrayed. They actualized a framework [10] for the continual transmission and show of information from numerous subtle frameworks and approved that there were no issues related with sending and accepting information. The point of the AIR CARDIO venture is to assess [11] the effect, productivity and viability of a home telemonitoring framework for youngsters with inherent coronary illness. Creator use IoT to build up the availability between the apparatuses [12], the client and his/her organization. D. Gračanin et. al. [13] investigate how innovation used to give wellbeing administrations while securing and saving protection, all things considered.

A devoted clinical Decision Support System (DSS) and a clinical specialist UI upheld the framework [14] in giving computerized location of anomalies/illness weakenings. The creators set an objective to dissect [15] the condition of utilization of the accomplishments of current Internet advancements corresponding to the assignments of telemedicine screening of patients' condition and to examine the chance of deciding approaches to improve the nature of telemedicine benefits by making present day telemedicine buildings. Author research work [16] depends on the exploration subject of the insight IoT telemedicine medical services for the old living alone framework.

An e-Health model [17] for taking the systolic weight, diastolic weight and pulse of the patient, communicates the information to a Bluetooth preparing card and furthermore sends them progressively to the distant worker through the phone organization. Md. shahiduzzaman et.al. proposes [18] a cloud-network edge engineering to improve fall identification, anticipation and security which comprises of the clinical cloud, edge organizations and end gadgets, such shrewd protective cap. An epic IoT framework is proposed [19] and was made with the help of oxygen immersion (SpO2) estimation sensor, Temperature sensor, Blood Pressure sensor, Bluetooth, Arduino, and APP innovations or strategies. Ajaya and Mohapatra et.al. presents [20] a savvy customer hardware answer for encourage protected and steady opening after stay-at-home limitations are lifted. Texture cathodes are utilized to remove human bio impedance signals, discrete Fourier change calculation is utilized to recognize human respiratory signs, and respiratory rate is identified dependent on unique differential edge top discovery innovation. X. Zhao et.al. presents [21] a wearable framework utilizing accelerometers and AI for programmed observing of fetal development.

3 Material and Method

The proposed system as appeared in figure 1, which has been presented to accomplish WBANs, depends on the technologies IoT devices, and the wearable or embedded WBANs.

In this framework, WBSNs data collection and transmission of it to them toward their programmable devices, which can encourage interpreting the information received. The devices are customized by various strategies in which every one of them can be viewed as a diagnostic framework. These devices are programmable and They are also capable of being associated with the Internet. Unlike sensor network, they have no energy impediments and they are associated directly to the power. To this end, proficient intelligent techniques and computational hardware will utilize. Besides, for accomplishing appropriate analysis models, doctors screen the frameworks. All in all, the proposed design uses supervised machine learning techniques. The programmable devices likewise report anonym’s events to the connected experts. Primarily framework categorize into three layers described below:

3.1 Sensor Layer

It includes mobile wireless body sensors node which is mostly depend on diseases, also can categorize into embedded or wearable body sensors. It consists of various wearable sensors. A WBAN is a collection of miniaturized wireless nodes coordinating with each other and including sensors and actuators in order to supervise the human body functions and its environment. Body Area Network consists of nodes, each acquiring a specific biological parameter from human body, processing it and communicating for processing to the fog nodes. Wireless sensor nodes worn by the patient enables him to carry out his routine work while he is being monitored. Short range wireless communication technologies utilizing license free ISM band (2.4 GHz to

2.4835GHz) like Zigbee and Bluetooth are practiced nowadays for the implementation of WBAN. Also for long range distance WiFi or using IoT will an options. These standard technologies define a specific protocol to implement the network functionalities. However there are other non-standard wireless communication technologies utilizing the same frequency spectrum to do the same operations.

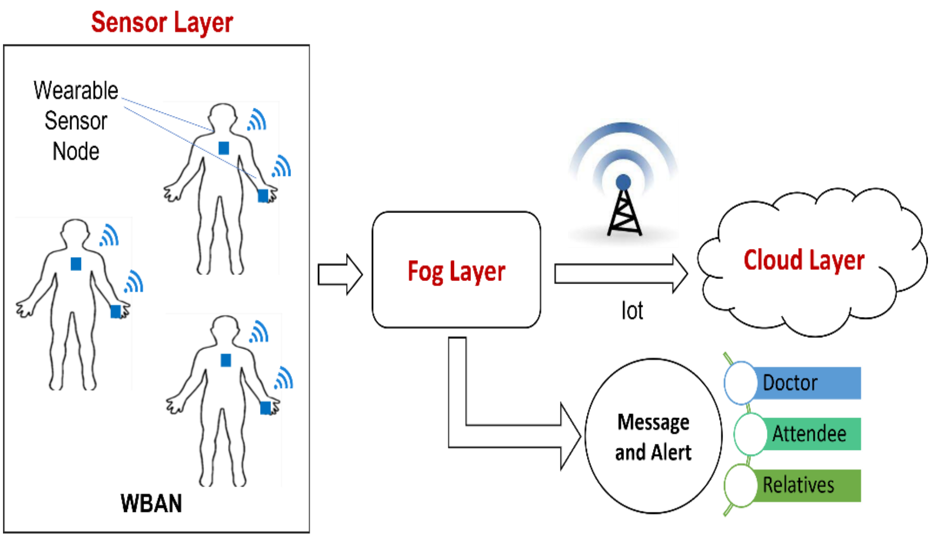

Fig. 1. Proposed framework

3.2 Fog Layer

It includes fog nodes which has capability of data processing and analyzing it which helps in diagnosing or predicting the nature of disease. The analytics system will develop under supervision of experts which generates alerts message and data to doctors or attendant who take cares of the patient. Fog computing performs the data analysis to aggregate the resultant factors that are controlled by a sensor layer device. It is also used to share the load of underlying network in term of data processing and management. Most importantly, this layer is represented as the server to distribute the process across devices i.e. fog-node. Data Classification using analytics system allows to predict the value of a categorical variable by constructing a model based on one numerical and/or categorical variables.

3.3 Cloud Layer

It belongs to cloud storage in which data will be kept as a medical health record data for further use and it help to create monitoring system application for real time data to doctors or patients or attendant. Data processed and managed by fog nodes will receive at cloud layer for application or user case scenario for UI based data software or app. Our main purpose is to study the recognition system based on Machine Learning techniques, as such awareness is quite beneficial for assisting the medical stuff to make a better interpretation for patient state and its vital signs measurements.

4 Results And Discussion

4.1 Experimental Setup

Sensor layer, fog layer, and cloud layer components are used to implement the proposed architecture framework. Sensors such as a breathing sensor, a body temperature sensor, and a heart rate sensor are used to monitor parameters in the sensor layer, which is attached to the Node MCU open source platform. The sensor nodes are mounted on a shield that is linked to the microcontroller. The Arduino IDE is used to develop embedded C programmes for reading sensor data. This data is wirelessly sent using IEEE 802.11 wifi. Through a WiFi network, the coordinator is attached to the Fog server, which is running on a Raspberry Pi. For processing, the coordinator delivers data (sensor data) to the Fog server. Fog server first processes sensor data and temporarily stores it in a database before continuing to transfer data to the Ubidots Cloud account using MQTT protocol. A dashboard with a user interface (UI) is used to show data on a mobile phone, tablet, or monitoring screen.

4.2 Experimental Results

Wearable sensor parameters are monitored, deliberated and analyzed in order to assess the system's efficacy in a variety of human activities. The values of each sensor parameter are observed for two sensor nodes connected to to healthy people, and the distributions were statistically significant display on the cloud. As per anomaly found in values as per threshold assigned, alert will be sent to doctor or caretaker.

Following figure shows respiratory rate, body temperature, air quality,SpO_2 and heart rate person under various test environment extracting from protype device in real time recorded for 30 different events at interval of 1. It has been noted that when person is healthy, in case of monitoring respiratory rate, its value is discovered to be 16 to 20 breath per min and in other case, it is discovered to be unhealthy. In case of body temperature, healthy person temperature value is discovered to be 36.5 to 38.5 °C and in case of heart rate measurement, healthy person value is discovered to be 60-100 beats per min, similarly for SpO_2, healthy person value is discovered to be above 95%. For false case determination, air quality index is measured, and it is found to be below 100 PPM for healthy environment should be below. In case of unhealthy person, the anomaly or abnormality is found in measure value based on threshold and alert signal is generated and referred it to the doctor, patient, or caretaker as per priority given to individuals.

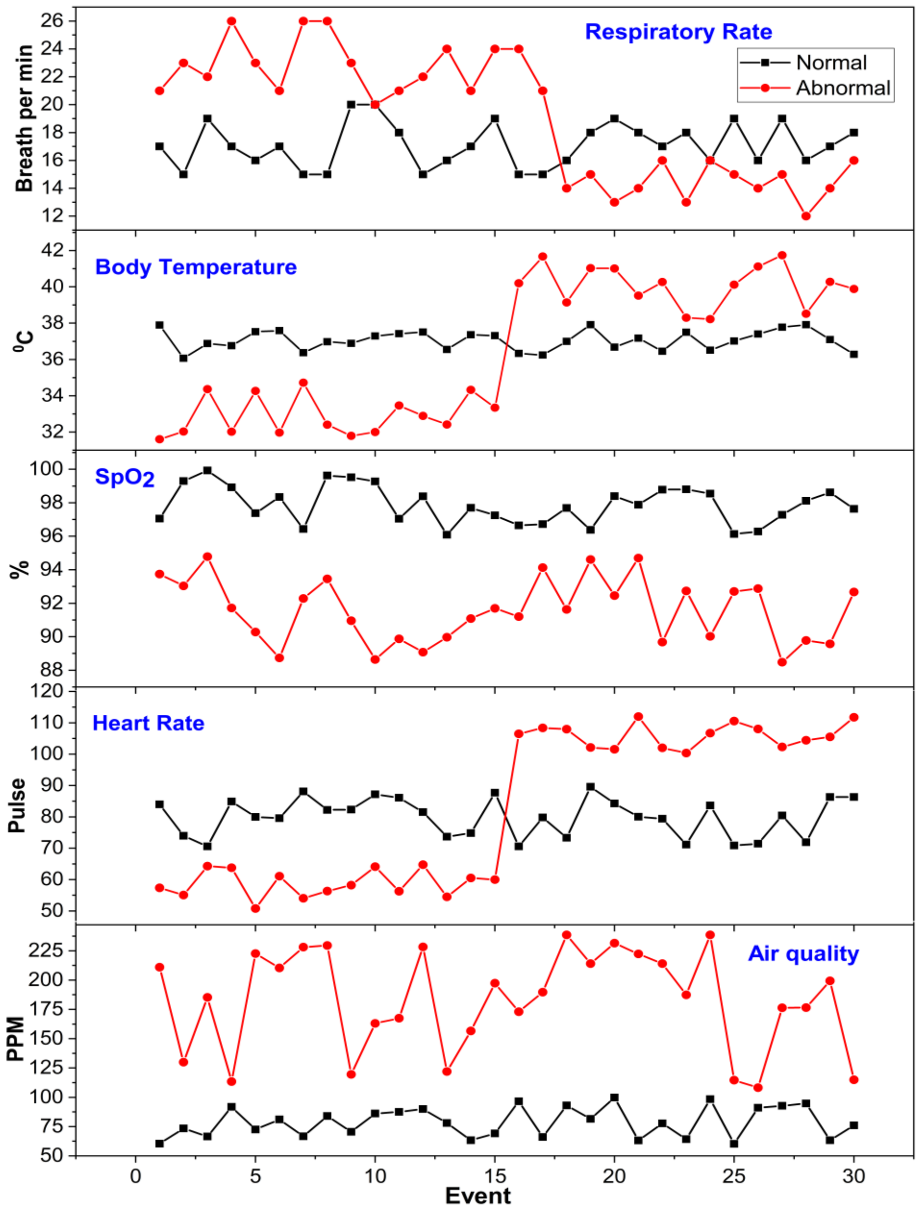

Fig. 2.

5 Conclusion

WBANs deliver novel possibilities for a variety of healthcare applications, such as activity identification and patient monitoring. To fully utilize network in a remote setting, It's vital to summarize their needs and combine them with an effective computation and communication architecture. We adopted the notion of fog computing for computing, which works as an intermediary layer between the network and perception layer of IoTs. Besides, the Fog server includes data acquisition and processing, data storage, and data transmission capabilities. Overall, the system architecture is based on IoTs, with WBAN sending data to the Fog server, After that, the data is processed and sent to the network layer. The network layer uses a trustworthy model to offer effective routing. The data is received by the application layer, which then sends it to the appropriate interface. The suggested architecture is prototyped utilizing the Node MCU open source prototyping platform. The findings demonstrate that architecture helps to minimize WBAN load and deliver time-bounded services. We want to expand the system in the future by adding more sensors on a big scale. In order to figure out whether the given telemedicine system can be implemented in practice, more technological enhancements and the collecting of clinical data are required. However, this proposed methodology has a number of flaws that can be rectified in the future. One of them is the security and privacy of data created by multiple layers.

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