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IoT: Smart Pulse Monitoring and Emergency Alert System using Artificial Intelligence

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ABSTRACT
This paper represents a smart IoT-based pulse monitoring and emergency alert system proposed to support continuous health observation and time to time assistance. A wearable device is built using ESP32 platform that measures vital signs such as heart rate and body temperature, where an integrated GPS module tracks the user's location in real time. Here, the sensed data is safely uploaded to a Firebase Realtime Database, that enables quick and dependable cloud synchronization. Coming to backend part, incoming readings are evaluated using predefined threshold values to categorize the user's condition as normal, warning, or critical. Whenever abnormal values are detected, the application immediately notify and pre-register the contacts by sending the alert messages which include both location details and necessary readings through Telegram. Additionally, the system incorporates an AI-based health support feature that helps users better understand unusual readings by offering simple explanations, basic symptom insights, and general guidance related to wellness, nutrition, and medication precautions.
Keywords— *IoT · Health Monitoring · ESP32 · Emergency Alert System · AI-Assisted Decision Support · Cloud-Based Healthcare*

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I. INTRODUCTION

Internet of Things (IoT) has gained momentum in today's society due to rapid developments and it has been significantly improving today's health monitoring systems with its abilities of real-time and remote monitoring. The increasing prevalence of chronic, cardiovascular diseases and old people have driven the rapid development of intelligent healthcare systems which could detect anomaly at earlier stages and could provide medical attention at the first opportunity [1], [4]. Continuous physiological monitoring can increase the safety and reduce risks.

Periodic checking of medical records at the healthcare facility or at a medical check-up visit to a doctor constitutes current monitoring systems. Under such situations, instantaneous and short-lived variation of the vital sign, for example fluctuation of the heartbeat rate and body temperature might go undetected [2]. Acute cardiovascular events occur without medical response until the damage is irreversible, leading to increases in the mortality rate, delays in health care response and greater healthcare cost.

Researchers have started using IoT enabled wearables with cloud computing platform to implement automated health monitoring system with alerting services [5], [9]. The wearable system measures the physiological parameters, namely heart rate, body temperature, body oxygen level and body motion. All the physiological data is collected and sent to a cloud based server which would store and analyze it for its viewing in a human interface display, either by the patients themselves or by healthcare providers. By integrating artificial intelligence (AI), it is possible to improve the precision of anomaly detection and the reducing false alarms as well as improving prediction for healthcare [6], [12], [18].

There are several drawbacks in existing monitoring systems. Many health monitoring systems are either statically designed or too costly to compute, leading to low scalability and deployment in real world [1], [2], [9], [12]. Moreover, the following features like real-time medical emergency assistant with location tracking, automated contact via electronic messages when emergency is encountered and real time interactive medical guide haven't been thoroughly investigated [5], [7]. It shows that the world is in need for lightweight, cost-effective and scalable healthcare monitoring systems which should be performant under low resource environment and especially in developing countries.

This paper proposes a lightweight cloud based IoT health monitoring system providing personalized health monitoring and automated emergency alert services. A light weight wearable device with an ESP32 microcontroller is embedded with some physiological sensors and GPS. The physiological sensors can measure body heart rate and body temperature. GPS is added to track the user's real-time location at the time of emergency.

The sensor readings obtained from the physiological sensors are transferred to a cloud based back end. In this system, the sensor readings are stored in a Firebase Realtime Database to guarantee safe access for data monitoring at any point in time and remotely. A backend monitoring program will evaluate physiological data according to configured threshold to determine the state of the user as "normal", "warning" or "critical".

Furthermore, the system utilizes AI to provide a general medical explanation and advice on fitness and wellness. At time of medical emergencies, the system automatically sends notification with current condition (heart rate and body temperature) and real-time location to designated contacts via Telegram application.

II. RELATED WORK

The widespread implementation of IoT in healthcare has enhanced the remote patient monitoring, the early detection of diseases, and the medical emergency detection system. Wearable IoT devices integrated with cloud computing and AI systems have been utilized to monitor vital physiological information and provide immediate medical assistance.

Some works have focused on the design of IoT-based healthcare monitoring system. Gubbi et al. [1] discussed the vision and architectural framework of the IoT systems and their various applications including healthcare. The application of IoT for health monitoring and the use of connected medical devices for patient diagnosis and tracking of patient vital information was studied by Islam et al. [2]. Alam et al. [3] also explained the application of the IoT in the smart health care system with an additional cloud for storing the enormous number of medical data. Li et al. [4] carried out a review on various healthcare application of IoT technology.

Wearable IoT devices have been used extensively in health monitoring. Wan et al. [5] had proposed a wearable IoT based real time health monitoring system and transmitted the sensor data to the cloud. The proposal was found to be viable for the real time monitoring but it lacked automatic alerting and position based warning messages. A wearable IoT health monitoring device has been proposed by Wu et al. [6] but it mainly focuses on device based monitoring system. A wearable IoT based system for health monitoring has been proposed in [7] with collection of various physiological signals but lacked the automatic emergency alert mechanism.

Some of the research works focusing on cloud based IoT healthcare system include the proposal of a remote patient monitoring system with cloud based IoT framework by Ahmed et al. [11] and the integration of IoT devices and cloud computing for healthcare framework, health monitoring and prediction by Bhatia and Sood [12]. Similarly, Verma and Sood [13] presented a cloud centric IoT architecture for disease prediction using real time data from the wearable health monitoring devices. An IoT based elderly care system that uses cloud service such as Firebase to store the information was introduced by Efendi et al. [14].

The integration of Artificial Intelligence with IoT has been one of the trending research areas in healthcare. Machine learning approaches for enhancing clinical decision making and diagnosis accuracy was discussed by Rajkomar et al. [20]. The evolution of AI applications in healthcare has been thoroughly discussed by Jiang et al. [21]. Nayab et al. [23] proposed an Artificial Intelligence of Thing for monitoring cardiac healthcare.

To reduce the response time in IoT healthcare systems, the concept of Edge computing has been proposed. An edge-based IoT framework was proposed by Pathinarupothi et al. [16] which helps in detection of abnormal health states and real time data transmission. An edge aware architecture was proposed by Alshuhail et al. [15] which balances the computation power between the edge nodes and the cloud servers so as to enable faster response. However, the edge architecture increases the system complexity and requires greater computing power.

Emergency healthcare monitoring system. In [17] Rathore et al. Introduced a system for real time medical emergency using IoT and big data technologies. Chavan et al. [18] proposed an IoT based health monitoring system designed for emergency. Damaeviius et al. [19] introduced the concept of Internet of Emergency Services to ensure faster emergency response.

Another area of research is in health monitoring for elderly people. An IoT based wearable system was proposed for elderly care by Jaradat and Ishaq [24]. AI and IoT based fall detection and prevention in elderly is discussed by Mohan et al. [25]. A comprehensive survey on next-generation IoT systems was published by Bollineni et al. [26] including smart sensors, intelligent health analysis, reliable storage with the aid of cloud, security features and automated alert systems.

Many of the existing IoT based health monitoring systems do not provide the automated classification of health state, the automated alert message with location tracking feature and AI based health recommendation to the user. Hence a lightweight and a scalable IoT based health monitoring framework with a blend of wearable sensor data, cloud based monitoring, intelligent analysis, and automated emergency alert mechanism are required.

III. METHODOLOGY

3.1 Approach for System Design

We propose an IoT based health monitoring and alerting framework designed and tested using a system-oriented experimental design approach. The system has a combination of wearable sensors and cloud based services, that enable real-time acquisition of physiological signals and health status evaluation, and automatic alert notification to caregiver upon condition failure.

Existing health monitoring systems fail to accurately determine the state of a patient by primarily focusing on assessment based on periodic checkups in clinic, when it is difficult to identify critical but rapid changes in physiological status such as Tachycardia, hypothermia or unusual body temperature shifts. Unlike the normal fitness monitoring devices which primarily focuses on a normal health state, this system provides the personal health monitoring service that automatically sends an alert.

The system will be experimentally validated on simulated normal and abnormal physiol al-time
health

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heart rate and body temperature and the alert notification. User interface will also be able to track past history of physiological data, and to set specific thresholds and user-related details, as well as Artificial Intelligence (AI) capabilities in forecasting and early disease detection.

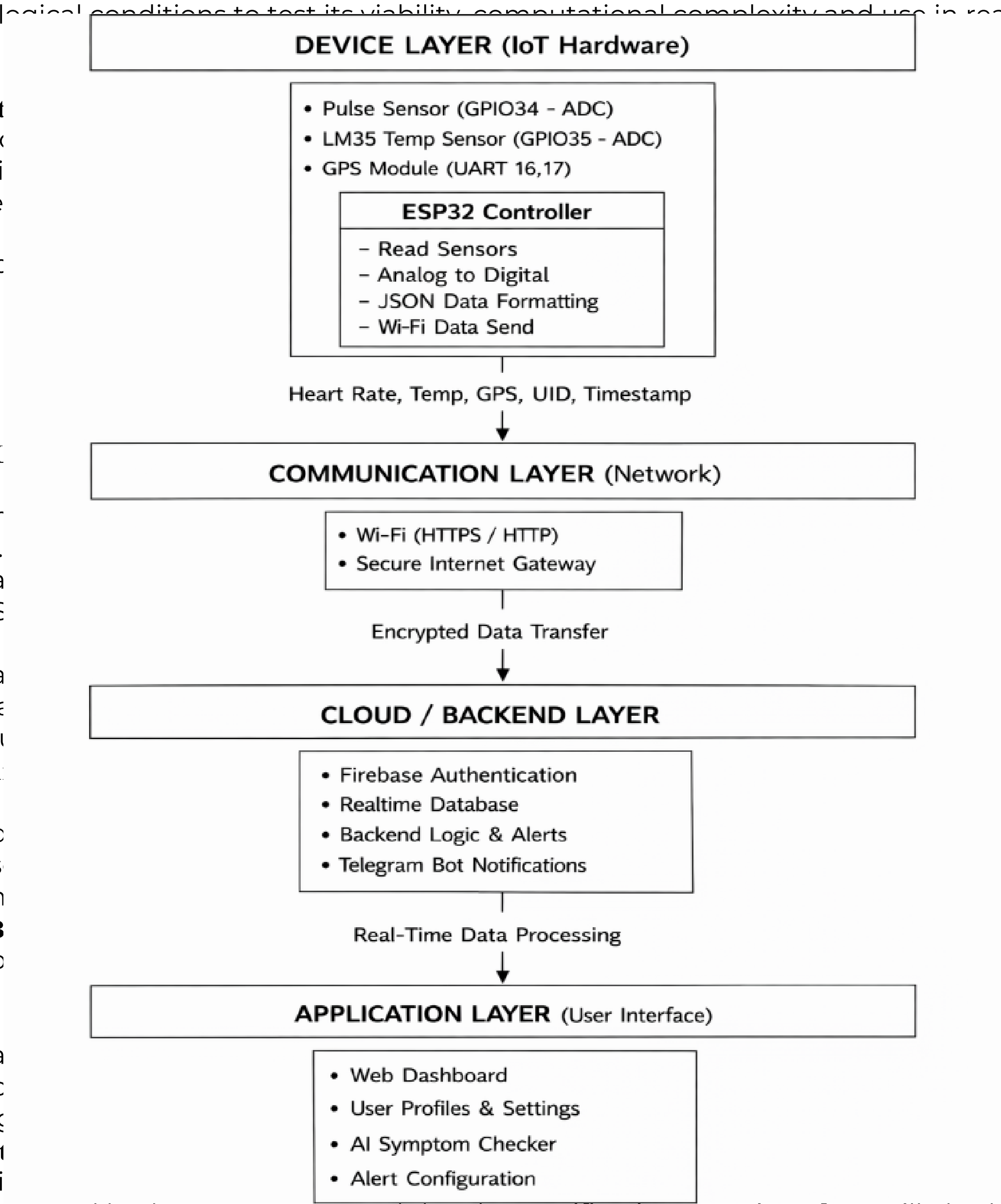
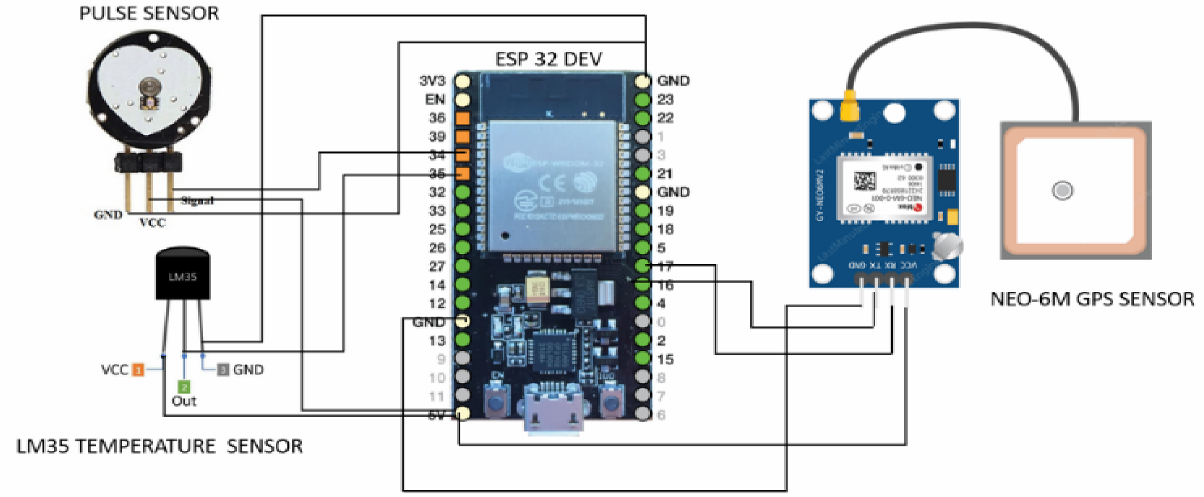


Fig. 1. System architecture of the proposed IoT based health monitoring system

3.3 Implementation Details

The health monitoring system that is presented is implemented as a unified system with the involvement of embedded hardware, cloud technologies and web-technologies. In the embedded hardware, a microcontroller called ESP32 is considered as a main processing part that acquires and transfers physiological signals. ESP32 is programmed with Embedded C/C++ via Arduino IDE in order to obtain the sensor reading from inputs and to wirelessly transfer via Wi-Fi connection. In the hardware, pulse sensor that measures heartbeat of the person, LM35 that measures body temperature and GPS that tracks geographical location are installed and the data from all these sensors is constantly transferred to the main board ESP32 where it will acquire the value and do pre-processing. Physiological data such as heart rate, body temperature and GPS location is transferred to the cloud via JSON formatting which helps in reducing transmission overhead and ensures uniform data format while the transfer will be done via secured Http/Https. The web platform uses ReactJS combined with HTML5, CSS3 and JavaScript for an interactive interface and it contains an overview page which shows the readings



symptoms and physiological signal is also implemented via the OpenAI API.

Fig. 2. Hardware implementation and pin configuration of the proposed IoT-based health monitoring system

IV. RESULTS AND DISCUSSIONS

This section elaborates the experiments carried out for the proposed health monitoring system utilizing IoT technology. This system was tested to assess its performance in real time physiological monitoring, sensor accuracy, emergency alerting, and cloud communication.

4.1 Real-Time Monitoring Performance

The real time monitoring performance of the proposed health monitoring system was tested utilizing an ESP32 micro-controller and physiological sensors. The system was designed to monitor heart rate and body temperature of a user in real-time and send data to a cloud platform via Wi-Fi. A web based dashboard was implemented in order to present these vital signs. This dashboard displays real time values for heart rate and temperature. Alerts which are triggered by the system are also displayed. The data presented by this dashboard are updated constantly to maintain continuous monitoring of user's health condition

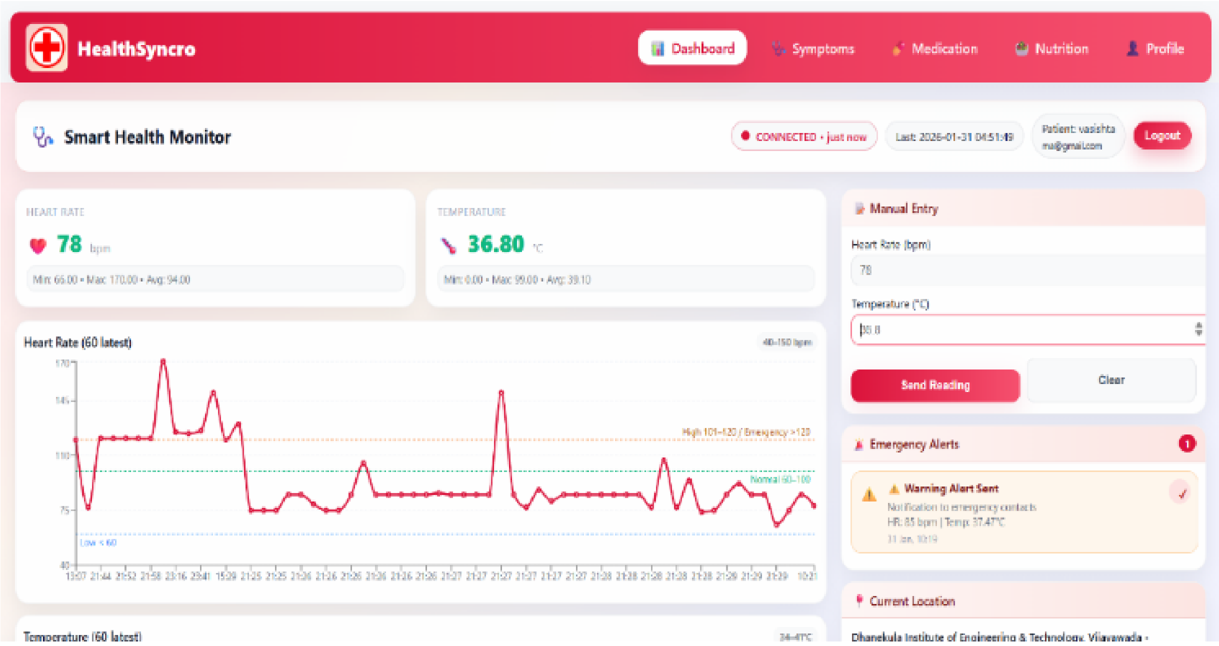


Fig. 3. Web-based dashboard for real-time heart rate and temperature monitoring, along with the alerts.

It was observed that data displayed on the dashboard was being updated roughly in the range of 2-4 seconds making the monitoring of physiological signal almost in real-time. The wave graph display on the dashboard exhibits continuous acquisition and sending of sensor readings thus confirming that the system is ideal for continuous real-time health monitoring.

4.2 Sensor Accuracy Evaluation

The sensor accuracy of the physiological sensors was compared with standard medical instruments to ascertain that they work correctly for this system. The readings were taken several times and recorded under constant conditions to evaluate the reliability of the wearable sensing module.

Table 1. Proposed system and standard medical devices accuracy comparison

Parameter	Proposed System	Standard Device	Accuracy (%)
Heart Rate (BPM)	110	112	96.2
Temperature (°C)	38.3	38.5	95.4

The tests revealed that the accuracy of this system is around 95-96% for physiological parameters. These variations can be due to motion artifacts, error in calibration of wearable sensors and environmental noise. However, it is believed to be good enough for real-time health monitoring application.

4.3 Emergency Alert Response Analysis

In order to check the system's emergency alerting capabilities, tests were conducted under varying physiological conditions where heart rate and body temperature were made to exceed the threshold values set. The moment threshold value is reached an emergency alert notification is sent.

The emergency alert system takes between 2-3 seconds to trigger after detection of abnormal physiological conditions and another 3-4 seconds to send the message notification to the caregivers using the Telegram messaging application.

The success rate for message notification system was found to be 100% over several tests, indicating that the system's notification is very reliable. The alert notification consists of the user's vital signs (heart rate and temperature), GPS coordinates of the user and the explanation regarding the medical condition of the user generated by the AI system which enables immediate and effective reaction by the caregiver to the situation.

Fig. 4. Telegram based emergency notification including vital readings, GPS coordinates and explanation

4.4 Network Latency and Cloud Synchronization

The network communication capabilities were tested and analysis was done of latency time between the sensors to cloud. All the tests were conducted with the Wi-Fi signal constant to determine the delay incurred during data transmission and processing.

Table 2. Network latency and cloud synchronization performance

Metric	Observed Value
Average Transmission Delay	1.8 seconds

Cloud Processing Time	1.2 seconds
End-to-End Alert Time	~3 seconds

The system was found to exhibit low network latency with efficient cloud synchronization, and an end-to-end alert notification time of nearly 3 seconds can be determined which confirms the effectiveness of the real-time health monitoring system.

4.5 System Reliability and Stability

Long duration testing was performed on the system in order to measure the system reliability and stability. It was observed that the Wi-Fi connectivity between the sensors to cloud to web server was reliable throughout the tests. No errors were found in the communication between IoT device, cloud service and web interface and there was no system crash in any scenario.

4.6 Comparison with Existing Systems

In order to measure the efficiency and capability of the proposed system compared with other IoT based health monitoring systems, it was compared with those mentioned in research articles.

Table 3. Comparison of proposed system with existing healthcare monitoring system

System	Real Time	Alert	GPS	AI
Wan et al. [5]	Yes	No	No	No
Wu et al. [6]	Yes	Yes	No	No
Taştan [7]	Yes	No	No	No
Pathinarupothi et al. [16]	Yes	Yes	No	No
Jaradat & Ishaq [24]	Yes	Partial	No	No
Alebeisat et al. [22]	No	No	No	Yes
Proposed System	Yes	Yes	Yes	Yes

Compared with the mentioned systems, the proposed health monitoring system possesses real-time monitoring of vital signals, automated alerts, GPS positioning and AI based analysis. Thus, the system enhances the efficiency and capabilities of health monitoring framework.

To summarize, the experimental evaluation of the proposed health monitoring system using IoT technologies has resulted in promising performance with real time monitoring capabilities. The system provided high sensor accuracy for vital sign monitoring and low latency cloud communication to transmit data. The system's automatic alerts provide an effective mechanism for emergency response while the integration of GPS location tracking and AI based health analysis can assist the care givers and health professionals to promptly and effectively address critical health issues.

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