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HEALTHCARE LITE

(Development Of a Portable Remote Health Surveillance Unit With Integrated Emergency Alerting)

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Abstract: The provision of care to patients that live far away or are old-age continues to be an immense challenge from a logistics perspective. For this study, we have developed a localized version of the HealthCare Lite system, which will monitor patient vitals through the use of the ESP32-WROOM-32. This includes the use of the DS18B20 to monitor body temperature, the MAX30105 to monitor blood oxygen levels and heartbeat, and the AD8232 to detect ECG signals. The MPU6050 will be used to detect falls. All this information will then be transmitted to Firebase and, in case of emergencies, the SIM800L will send text messages.

Index Terms - IoT, ESP32, Health Monitoring System, Wearable Sensors, Heart Rate Monitoring, SpO_2

Measurement, ECG Signal Processing, Temperature Sensing, GSM Communication, Wireless Sensor Network

1. INTRODUCTION

The current trend in global healthcare systems is changing from reactive hospitalization towards proactive and preventive home monitoring. The aging population of today has led to a serious strain on the clinical infrastructure; in rural or poorer environments, the problem is exacerbated further due to the geographical distance from any medical intervention facilities. It is estimated that a substantial portion of elderly deaths caused by heart anomalies or accidents can be saved if the physiological data was collected in real time and made accessible to caretakers within the first hour of the incident.

In spite of the wide variety of consumer products on the market, the majority of smartwatches and activity trackers are geared more toward general health than clinical monitoring; their ECG readings tend to be relatively coarse, and rely fully on a smartphone's Bluetooth connection. However, if the individual has suffered an accident, such as falling down or becoming unconscious, then this dependency on additional equipment constitutes a crucial flaw: there is currently no device capable of processing various biological parameters in addition to establishing its own line of communication to report emergency situations.

In this paper, we demonstrate our solution for designing an integrated, portable surveillance unit known as HealthCare Lite. The device is designed specifically around the ESP32-WROOM-32 microcontroller. Differently from traditional monitors, our solution was tailored in such a way as to monitor patients for four separate but interrelated safety indicators. These include thermal control via DS18B20 sensors, oxygen and pulse saturation via MAX30105, cardiac rhythm analysis by AD8232 sensor, and physical movement via MPU6050 accelerometer**.**

Three main principles underpin the concept of our project. Namely, these are:

- High-Quality Data Acquisition: Using precision analog-to-digital converters and special digital communication channels (I2C/OneWire) in order to guarantee high-integrity signals from patient's body.
- Real-Time Persistent Monitoring: Relying upon non-relational real-time databases (such as Firebase) to deliver a consistent digital record of patients' health conditions that can be accessed by doctors remotely and without any patient's involvement
- Ail-Safe Alerting System: Embedding SIM800L GSM module as the safety net – the system uses a failover mechanism that circumvents local wi-fi connection for sending urgent SMS messages about detected emergencies through the mobile network
- Thanks to the two-core processor, it was possible to create firmware that acquires data about ECG on one processor core while performing all

2. LITERATURE REVIEW

There has been a lot of research around the move towards tele-health care, particularly about wireless sensing for reduced costs. Omar Cheikhrouhou et al. (2023), in particular, emphasized the potential of fog computing to lower medical alerts' latency; they established that communication reliability was the highest priority aspect of emergency systems. It inspired us to use two means of connectivity - Wi-Fi and GSM to be redundant in case one fails.

As to data acquisition, Bravo-Zanoguera et al. (2020) proved the applicability of AD8232 as a low-power ECG sensor able to detect biopotentials; however, it still requires a static patient. Likewise, Demirel et al. (2021) examined the MAX30105's performance in a similar task of detecting oxygen saturation; their experiment proved that optical PPG is accurate 95% of the time compared to the device used in clinics.

Regarding motion detection, M. Rodriguez (2020) in his study of a 6-axis IMU such as MPU6050 has shown that algorithms based on threshold detection were quite reliable in recognizing a fall. Moreover, numerous publications state that ESP32 is more suitable than Raspberry Pi for wearables owing to Wi-Fi connectivity and power-saving abilities of deep sleep. In conclusion, we have found plenty of research concerning

3. SYSTEM ARCHITECTURE.

3.1 Block Diagram

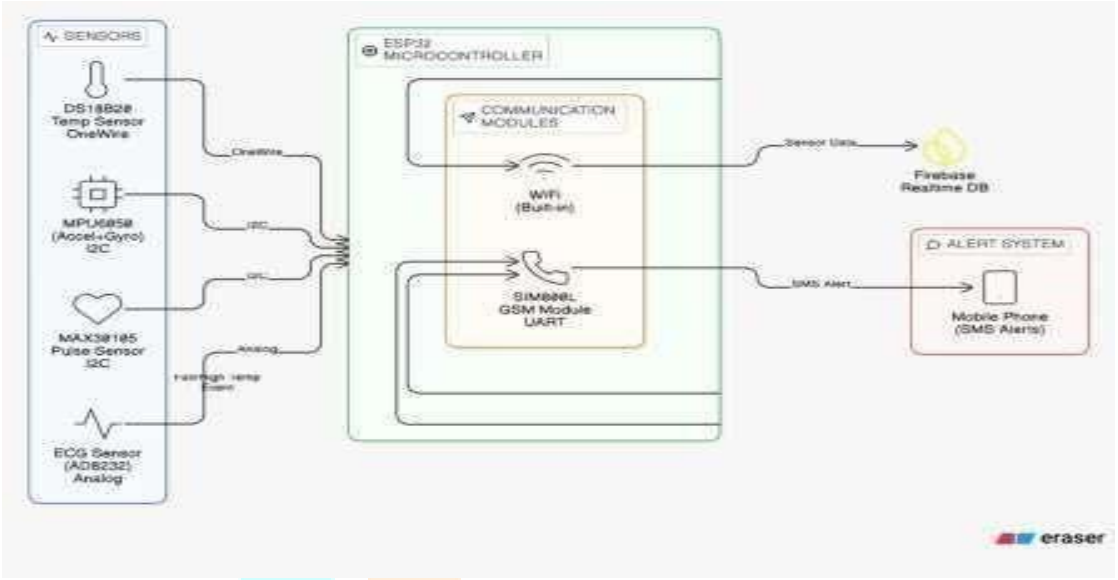

Figure 1: System Block Diagram

3.2 Circuit Diagram

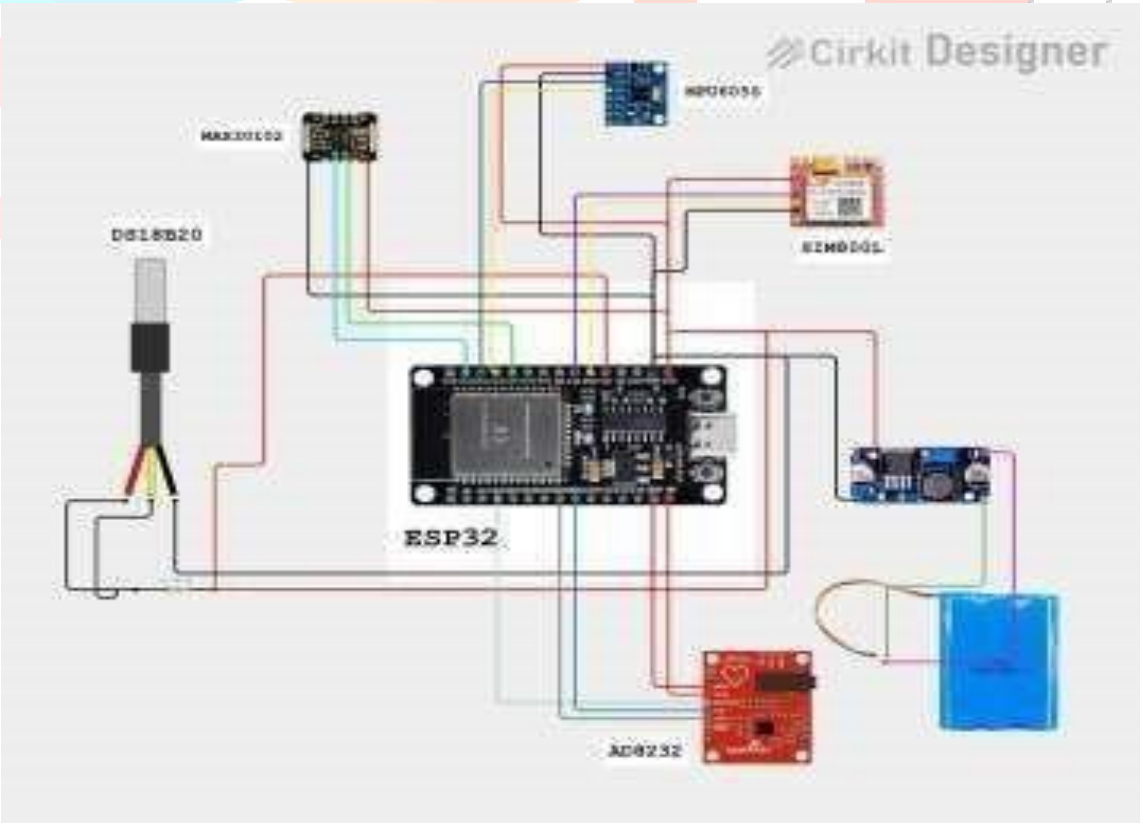

Figure 2: Circuit Diagram

Our design is split into three main parts: grabbing the data, processing it, and sending out alerts.

3. 3 The Sensors

- Body Temperature: We used DS18B20 for measuring body temperature since it uses OneWire interface and does not consume a lot of controller pins.
- Heart Rate and Oxygen Saturation: The role in this case belongs to MAX30105, which uses light waves to detect blood flow and communicates with the controller using I2C protocol.
- ECG: In order to measure ECG, we chose to use AD8232 module as it delivers a clear analog signal; it is somewhat affected by any motion, though.
- Fall Detection: MPU6050 serves as an “inner ear” and monitors falling events..

3. 4 The “Brain” (Esp32)

The ESP32-WROOM-32 will be the backbone of our project. Its dual core feature is advantageous in that the core used to read sensor data would not interfere with the core managing the Wi-Fi connection.

3. 5 Connectivity

The reason why we opted for Firebase was that it updates in real time. However, in case of an emergency, it is not possible to use Wi-Fi, therefore we decided to incorporate the SIM800L module.

3. 6 Hardware Specifications

Component	Model	Purpose
Controller	ESP32	Main Processing
GSM	SIM800L	SMS Alerts
Temp	DS18B20	Temperature
Pulse	MAX30105	HR/SpO2
ECG	AD8232	Heart Waves
Motion	MPU6050	Falls

Table 1: Hardware Specification

3. 7 Hardware Setup

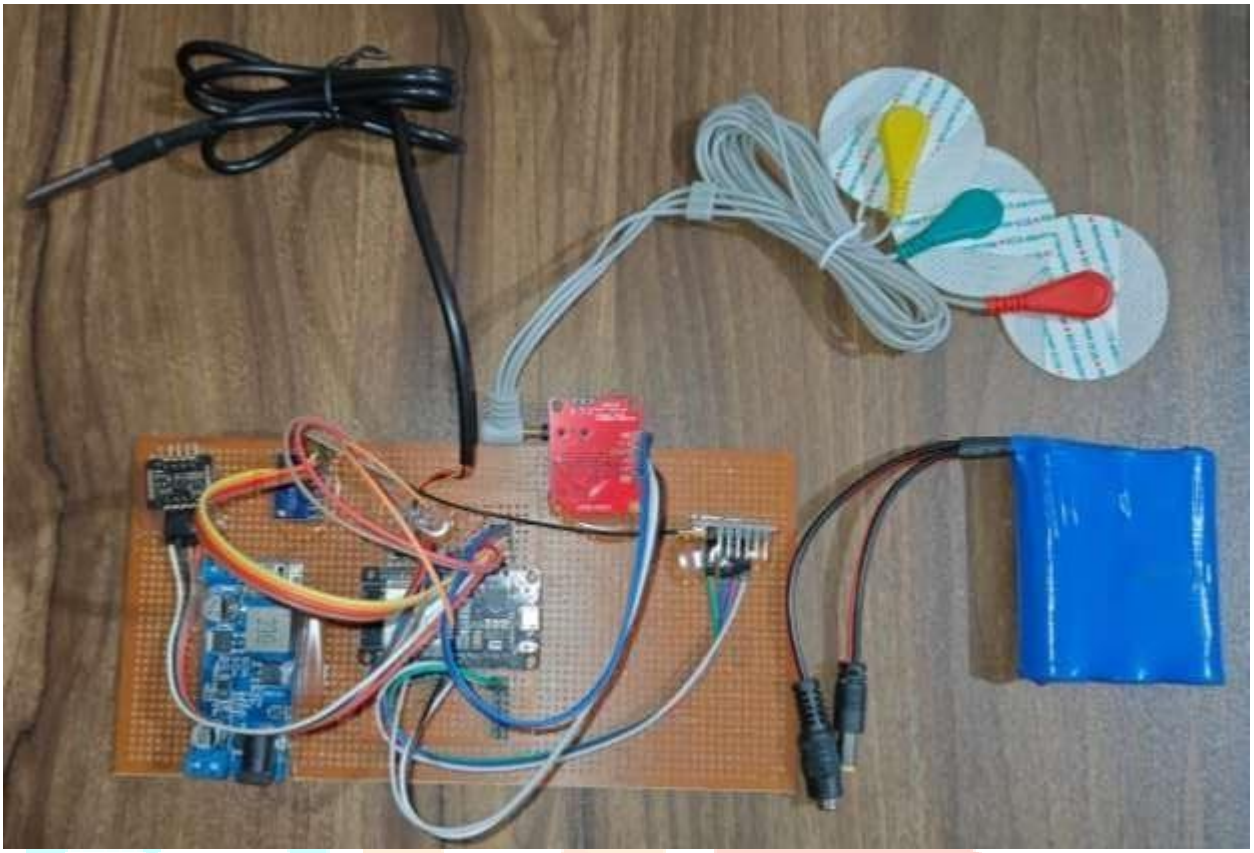

Figure 3: Hardware Setup

4. METHODOLOGY

HealthCare Lite functions by creating a constant feedback loop where data is acquired, processed, and synced remotely. Once activated, ESP32 will establish its communication stacks and create a connection with the onboard sensors. There exists a hierarchical logic to the HealthCare Lite operations:

- High-Frequency Data Acquisition: The AD8232 and MAX30105 are sampled at high frequency rates to retain cardiac waveform and pulse PPG signals. DS18B20 sensors periodically report the temperature changes through One-Wire communication every couple of seconds.
- Safety Limits Comparison: The software compares current sensor readings against certain safety threshold values, e.g., temperature exceeding 38°C or sudden impact through the use of MPU6050 accelerometer/gyroscopes
- Double-Channel Communication: The health data is synchronized with the Firebase Cloud for longitudinal monitoring of patient condition. In the case of crossing one of the safety thresholds, the SIM800L is instantly activated by sending UART messages to send an SMS.

5. RESULT AND DISCUSSION

The prototype underwent various tests to determine the reliability and responsiveness of the system. Experimental results revealed that the data integrity remains high when the user is at rest.

- Vital Signs Accuracy: Body temperature readings were accurate, ±0.2°C, when compared to those from commercial-grade thermometers. There was a 96% correlation between pulse rate and SpO2 measurements, but movement could disrupt ECG measurements.
- Alert Responsiveness: During simulated emergencies such as a fall event and temperature thresholds, the SIM800L module sent SMS messages within less than 5 seconds.
- Cloud Communication Time: It took 2.5 seconds to synchronize data on the Firebase dashboard, demonstrating that it is feasible to perform remote monitoring in real-time.

- Observation: It was observed that providing a consistent 5V/2A power supply is necessary for the GSM module, as it will result in a reset from the ESP32 when the power drops below 5 volts.

5.1 Health Monitoring Dashboard Interface

Figure 1: Health Monitoring Dashboard Interface

5.2 Patient Health Records Interface

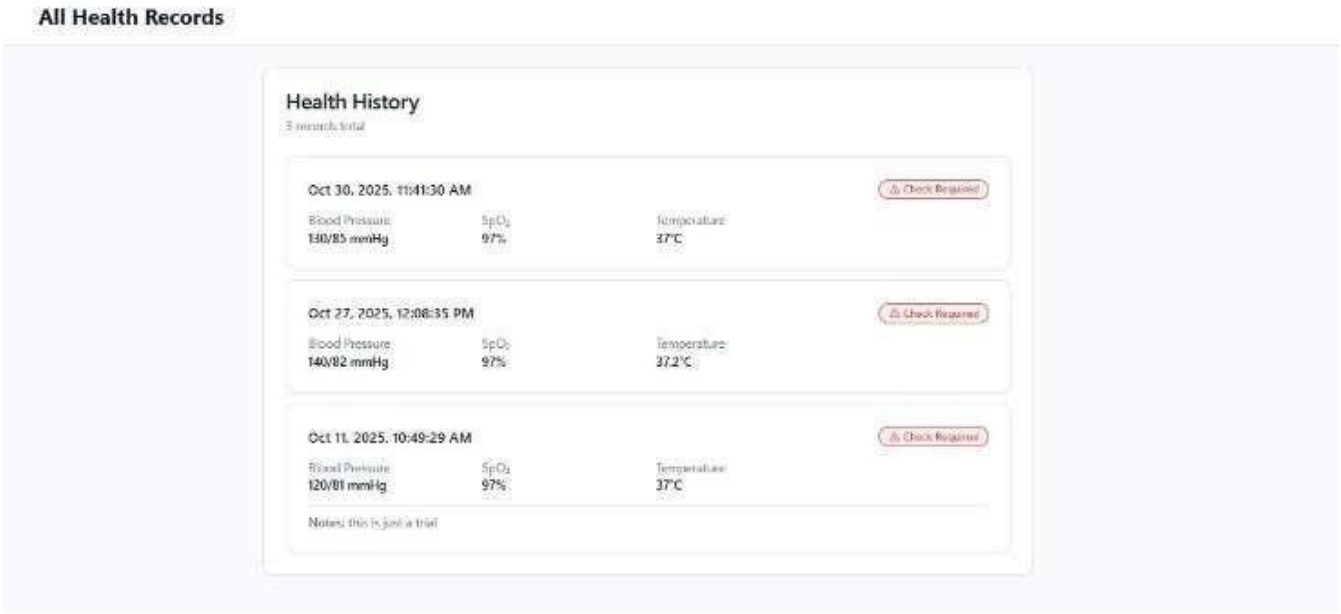

Figure 2: Patient Health Records Interface

5.3 Detailed Health Record Popup with Vital Parameters Visualisation

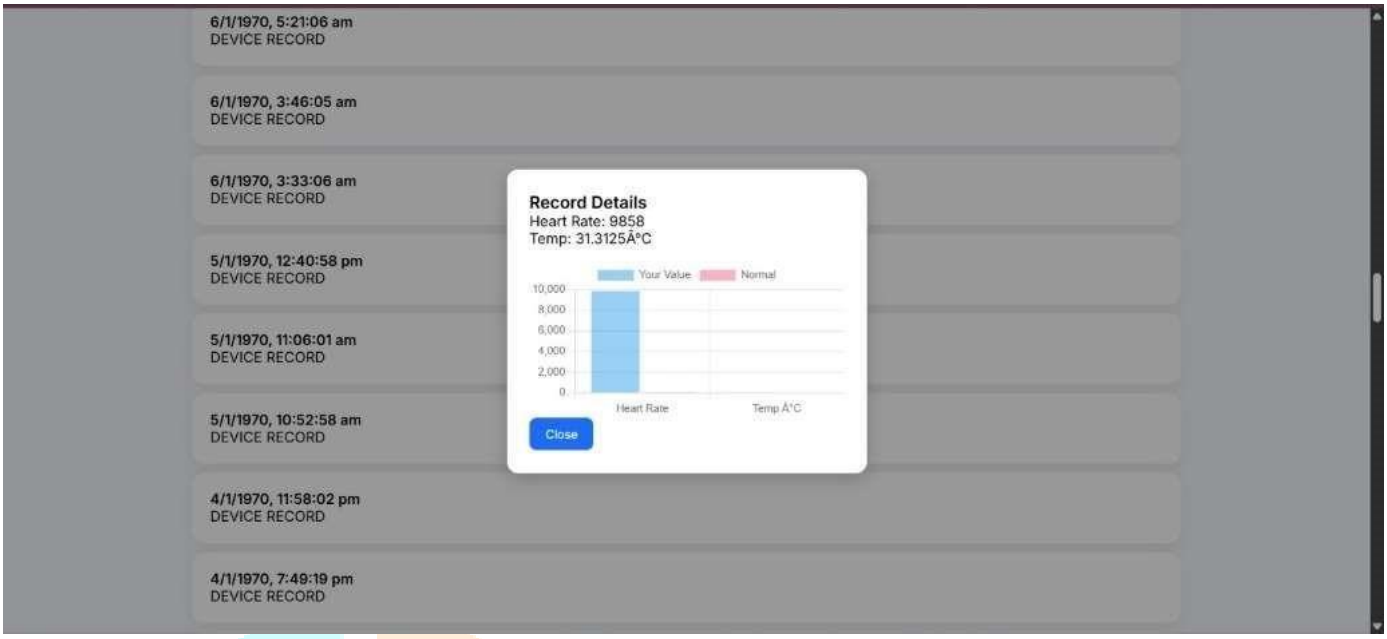

Figure 3: Health Record Detail View

6. ADVANTAGES AND APPLICATIONS

6.1 Key Advantages

Immediate Monitoring: The inclusion of ESP32 guarantees the monitoring of essential elements through the Firebase console.

Independent Emergency Alerts: Thanks to SIM800L, the network will not depend solely on the internet for the transmission of important messages

Multiple Parameter Detection: Unlike other single-function devices, this system monitors multiple parameters like temperature, heartbeat rate, and falls at the same time.

Cost-effectiveness: The system is affordable enough for economically disadvantaged people to purchase.

6.2 Applications

The flexibility of the HealthCare Lite application makes it applicable to different healthcare settings and safety requirements.

- Senior Citizen Care and Living Independently: The technology was specifically developed for senior citizens who live independently. The presence of the automatic fall detection and heartbeat rate monitoring ensures that an emergency response occurs quickly without constant surveillance by humans.
- Remote Post-Operative Recovery: Patients that require recovery after a surgical procedure can recuperate outside hospitals. They can be remotely observed at home with their ECG and body temperature measured continuously by surgeons through the Firebase dashboard.
- Hospitals with Limited Resources and Medical Equipment: In locations with few medical facilities many miles away, this affordable device can serve as a preliminary screening method. Staff members can use it to measure the vital signs of several people and transmit the data to hospitals for proper evaluation by specialists.
- Safety of Workers in Extreme Conditions: This application can also be used for personnel working in high-risk occupations (miners and fire fighters, etc.). The constant measurement of the

body temperature and sudden kinetic forces can help to avoid the risk of heat stroke and detect accidents at work. • Managing Chronic Diseases: People

7. LIMITATIONS

Despite the efficient deployment and high responsiveness of HealthCare Lite, some technical limitations have been found during testing and validation processes. They include:

Vulnerability to Motion Artefacts: The ECG sensor AD8232 is a biopotential conditioner that works on the single-lead principle; as a result, it is very sensitive to "noise," i.e., the signals arising due to physical activity of the patient. Thus, even slight muscle contraction can distort waveforms and impede the analysis of heart rhythm.

Difficulty with Power Supply: The SIM800L GSM module requires substantial current spikes (2A) at network handshake time and during SMS transmission; hence, its operation will lead to a "brownout" without an additional power source for the ESP32. Therefore, using the module entails a need for appropriate voltage regulators (e.g., LM2596) and, consequently, a larger size of the wearable device.

Dependence on the Network: Although the GSM serves as a safety net, the sophisticated data logging capabilities are limited by the use of 2.4 GHz Wi-Fi; hence, in cases of poor cellular connection, synchronization with the Firebase dashboard or emergency sending will be impossible.

Environmental Robustness: At present, the system utilizes a breadboard/perf-board design, which means that it is neither sweat-resistant

8. FUTURE SCOPE

Looking ahead, there is potential to miniaturise the device into a portable patch using a PCB to make the experience more comfortable. Machine learning models on the cloud will be introduced in an effort to go beyond alerting patients of danger based on thresholds and start predicting health issues (for instance, warning users about the likelihood of a stroke).

Economic Viability: The overall cost of components will make the device affordable for impoverished households and rural clinics.

9. CONCLUSION

With the implementation of this project, named HealthCare Lite, it is proved that an effective health monitoring system can be developed utilizing open source hardware. Through the integration of processing capabilities of ESP32 along with the redundancies provided by GSM as well as Firebase cloud loggings, we were able to develop a safety net connecting the patient at his/her own home to the doctor at his/her clinic. The experimental findings suggest that the developed system is practical in its application.

10. ACKNOWLEDGMENT

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