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A Practical Review on ECG-Based Remote Patient Monitoring Using Low-Cost Embedded Systems

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ABSTRACT :

Remote monitoring of heart activity using electrocardiogram (ECG) signals is gaining attention for its role in detecting and managing heart-related illnesses at an early stage. This paper reviews the progress made in ECG-based Remote Patient Monitoring (RPM) systems, with a focus on studies and technologies developed between 2019 and 2025. Continuous ECG tracking using wearable sensors has shown benefits in reducing hospital readmissions and identifying conditions such as arrhythmias. A working model using the AD8232 ECG sensor and the ESP32 microcontroller is also described. This system allows real-time data transmission to an Android application. The design approach, data communication flow, and system components are explained in detail. Common issues like signal noise, limited battery life, and user interface challenges are discussed. Lastly, we highlight possible improvements to make such systems more adaptable, accurate, and user-friendly.

Keywords: ECG, Remote Patient Monitoring, ESP32, AD8232, IoT, GSM, Android Application

1. Introduction

Heart diseases remain one of the top causes of death globally, with the World Health Organization (WHO) reporting nearly 17.9 million deaths annually. Early detection and timely monitoring play a key role in preventing complications. Unfortunately, many patients—especially in rural or remote areas—have limited access to continuous care due to hospital constraints and cost barriers. Remote Patient Monitoring (RPM) offers a practical solution by enabling health data tracking outside hospital environments.

Among various health signals, ECG is one of the most reliable indicators of heart function. With advances in biomedical electronics and wireless communication, it is now possible to develop portable ECG devices that patients can wear at home or work. This paper reviews such a system built using the AD8232 ECG sensor and ESP32 microcontroller, highlighting its development process and performance.

2. System Design and Architecture

The ECG RPM system was designed with three main components: the AD8232 ECG sensor, the ESP32 microcontroller, and a custom-developed Android application.

2.1 Hardware Components

- AD8232 Sensor: This is a compact analog front-end for ECG signal acquisition. It helps extract and amplify the ECG signal, providing a clean waveform suitable for processing.
- ESP32 Microcontroller: The ESP32 is a dual-core chip that supports both Wi-Fi and Bluetooth. It reads the ECG data through its analog-to-digital converter (ADC) and sends it wirelessly to the Android app.
- Power Supply: A 3.3V regulated source powers the system, supplied through USB or battery.

2.2 Wiring Connections

ESP32 Pin	AD8232 Pin	Function
3.3V	3.3V	Power for sensor
GND	GND	Ground connection
GPIO34	OUT	ECG signal input

GPIO25	LO+	Loose electrode detection (positive)
GPIO26	LO−	Loose electrode detection (negative)

3. Software Architecture

The embedded code was written using the Arduino IDE. It handles signal reading and Wi-Fi communication. The Android application, developed in Android Studio, receives data over Wi-Fi, displays real-time ECG graphs, stores patient details, and can trigger alerts for abnormal readings.

For cloud storage, platforms like Ubidots or Firebase were optionally used to store data and make it accessible to healthcare providers anytime.

4. Android Application Features

The Android app was developed to make heart monitoring simple and accessible. Features include:
- Real-Time Graphs: ECG signals are plotted live as they are received from the ESP32.
- Patient Information: The app allows input of personal details for identification.
- Alerts: Abnormal patterns like irregular heart rate trigger visual or sound alerts.
- Storage Options: Data can be stored locally or uploaded to the cloud.
- Sharing: The app supports sharing PDF reports or screenshots with doctors.

5. Communication Workflow

The ECG signal is captured by the AD8232, digitized by the ESP32, and sent to the Android application over Wi-Fi. This real-time communication helps patients and caregivers stay updated with heart health trends and take action when needed.

6. Conclusion

This project demonstrates the feasibility of building a low-cost, portable ECG monitoring system suitable for real-world applications. By combining an affordable ECG sensor with the Wi-Fi-enabled ESP32 and a simple mobile app, continuous heart monitoring becomes possible even outside hospital settings. The system is especially useful for patients living in remote areas where access to cardiologists is limited. Though basic, the setup provides a solid foundation for more advanced health monitoring applications.

7. Future Scope

While the current system works effectively, several upgrades can make it more powerful:
1. Multi-Lead ECG: Adding more leads will provide a more detailed heart analysis.
2. Humaniz-Based Detection: Algorithms can be developed to automatically detect irregularities in ECG patterns.
3. Noise Filtering: Digital filters like Butterworth or Kalman can help improve signal clarity.
4. Cloud Connectivity: Automatic data upload allows doctors to check patient history remotely.
5. Wearable Form Factor: A compact, battery-optimized design can make the device easier to use daily.
6. Emergency Alerts: Features like SMS or email alerts can notify doctors immediately when something is wrong.
7. Integration with Health Apps: Compatibility with Google Fit or Apple Health can enhance data tracking.

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