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# Smart Ambulance Navigation System Based on Real – Time Patient Condition and Hospital Availability

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*KEYWORDS*

**ABSTRACT**

*This research paper focuses on developing a Smart Ambulance Navigation System that improves emergency medical response through real-time patient monitoring and intelligent hospital selection. In emergency situations, delays caused by traffic congestion, improper hospital choice, and lack of coordination between ambulances and hospitals can significantly reduce patient survival rates. The proposed system addresses these challenges by integrating Internet of Things (IoT) based biomedical sensors to continuously monitor vital parameters such as heart rate, body temperature, ECG signals inside the ambulance. The collected data is processed using an embedded controller and transmitted to a cloud platform for real-time analysis. Simultaneously, hospitals update their availability status including emergency beds, ICU capacity, and critical medical resources. Based on the severity of the patient's condition, hospital resource availability, the system automatically identifies the most suitable hospital and provides optimized GPS navigation for the ambulance. This approach reduces manual intervention and response time while improving coordination between emergency services and healthcare facilities. The proposed system offers a scalable and cost-effective solution that can enhance emergency healthcare services in urban and semi-urban environments. Keywords: ECG Sensor, Biomedical Sensors, Vital Parameters, IoT.*

## 1. INTRODUCTION

Emergency medical services play a crucial role in saving human lives, particularly during critical situations where immediate medical intervention required. Rapid transportation of patients to appropriate medical facilities is essential during the golden hour, the time period in which medical treatment prompts significantly increase survival chances. However, traditional ambulance systems often suffer from delays due to traffic congestion, lack of communication between ambulances and hospitals, and absence of real-time patient monitoring. These limitations may lead to situations where ambulances reach hospitals. That are not adequately equipped to handle critical patients, resulting in further treatment delays.

Recent advancements in the Internet of Things and embedded systems have enabled the development of intelligent healthcare solutions capable of improving emergency response efficiency. By integrating biomedical sensors, communication technologies, and real-time data processing, it is possible to continuously monitor patient health conditions and transmit critical information to medical facilities during transportation. Such systems enable better coordination between ambulance staff and hospitals, allowing hospitals to prepare necessary medical resources before the patient arrives.

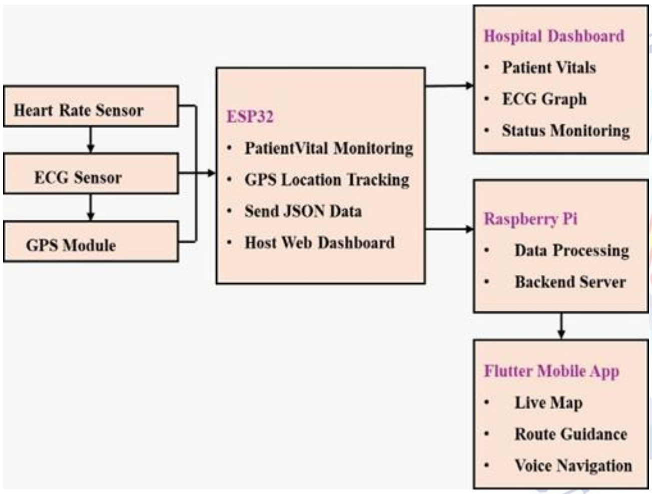


Fig .1. Block Diagram of Proposed System

This project proposes a Smart Ambulance Navigation System that integrates real-time patient monitoring, GPS-based location tracking, and intelligent hospitals. Biomedical sensors such as ECG modules and heartbeat sensors continuously monitor the patient's vital parameters. The collected data processed using an ESP32 microcontroller and a Raspberry Pi 4 processor, which analyzes the patient's condition and determines the severity level. Simultaneously, a GPS module provides real-time ambulance location information, allowing the system to identify nearby hospitals and evaluate their resource.

Based on patient condition severity, drivers select the most suitable hospital in mobile apps and hospitals receive alerts hospital web dashboard containing patient information. This approach reduces manual decision-making, improves coordination between emergency services and hospitals, and minimizes delays in treatment.

### *1.1. Objectives*

・The system continuously monitors the patient' s health in real time using ECG and heartbeat sensors, allowing immediate detection of critical conditions. This helps medical staff and hospitals respond quickly with appropriate treatment during transit. To analyze patient condition using embedded systems and to track ambulance location using GPS.

・To identify the most suitable hospital based on availability, to reduce emergency response time and to send patient data to hospitals in advance.

・The system helps increase patient survival rates by reducing delays in treatment and ensuring timely medical intervention. Real-time monitoring and early data transmission allow hospitals to prepare in advance, improving the chances of saving lives.

### 1.2. Principles of Smart Ambulance System

- Real-Time Monitoring:

The system continuously monitors vital signs like ECG and heart rate during transit, allowing immediate detection of any critical changes in the patient's condition.

- Embedded Processing:

The ESP32 microcontroller collects sensor data and sends it to Raspberry Pi, where it processed and analyzed to make timely decisions.

- Condition-Based Decision Making

Based on predefined thresholds, the system classifies the patient's condition as critical, stable, or normal, helping prioritize care and hospital selection.

- GPS-Based Tracking

The GPS module provides real-time ambulance location, enabling accurate navigation, distance calculation, and monitoring for emergency coordinators.

- Hospital Availability Analysis

The system checks hospital databases to determine ICU bed availability, specialist doctors on duty, and emergency facility readiness.

• Intelligent Hospital Selection

Using patient condition and hospital resources, the system automatically selects the most suitable hospital to minimize treatment delays.

• Pre-Arrival Communication

Patient health data and estimated arrival time (ETA) sent to the hospital, allowing medical staff to prepare for immediate treatment.

• Voice Assistance for Route Guidance

The system provides real-time voice instructions to the ambulance driver, guiding them along the optimized route. This ensures hands-free navigation, reduces the risk of errors, and allows the driver to focus entirely on driving safely while still following the fastest path to the selected hospital.

1.3. Processes Involved

Emergency Request Initiation:

The process begins when a patient or caregiver requests an ambulance via an app or call. The system captures the location and basic details of the patient.

1) Real-Time Patient Monitoring

ECG, heart rate, and other vital sensors attached to the patient continuously collect health data during transit.

2) Data Acquisition and Processing

The ESP32 microcontroller collects sensor data and transmits it to the Raspberry Pi, which analyzes patient condition using predefined thresholds.

3) Real-Time Patient Monitoring

ECG, heart rate, and other vital sensors attached to the patient continuously collect health data during transit.

4) Data Acquisition and Processing

The ESP32 microcontroller collects sensor data and transmits it to the Raspberry Pi, which analyzes patient condition using predefined thresholds.

5) Condition Classification

The system classifies the patient's condition as critical, stable, or normal to prioritize hospital selection and route urgency.

6) Ambulance Tracking via GPS

The ambulance's real-time location is tracked, and distance to nearby hospitals is calculated for optimal routing.

7) Hospital Availability Check

The system accesses the hospital database to verify ICU bed availability, doctor presence, and emergency facility readiness.

8) Intelligent Hospital Selection

Based on patient condition and hospital resources, the system selects the most suitable hospital for immediate treatment.

9) Pre-Arrival Communication

Patient data and estimated time of arrival (ETA) and transmitted to the selected hospital so that medical staff can prepare in advance.

10) Route Optimization and Voice Guidance

The system calculates the fastest route considering traffic conditions and provides real-time voice instructions to the driver for safe navigation.

11) Continuous Monitoring and Updates

During transit, patient health and ambulance location is continuously monitoring, and updates sent to the hospital dashboard until the patient arrives.

1.4. Operating Conditions

• Power Supply: The system requires a stable power supply (5V–12V) to operate components like ESP32, Raspberry Pi, sensors, and GPS module without interruption.

• Network Connectivity: Continuous internet connection (Wi- Fi or mobile data) required for real-time data transmission, hospital communication, and cloud updates.

• Temperature: The system operates efficiently within a temperature range of 0°C to 50°C inside the ambulance environment.

• Sensor Conditions: ECG and heartbeat sensors must properly attach to the patient to ensure accurate and noise- free reading.

• GPS Signal Availability: The GPS module requires open signal access for accurate real-time location tracking and navigation.

• Processing Conditions: Proper synchronization between ESP32 and Raspberry Pi required for smooth data acquisition and processing.

• Environmental Conditions: The system should be protected from excessive vibrations, dust, and electromagnetic interference for reliable performance.

1.5. Materials & Methods

The materials and methods of the Smart Ambulance Navigation System include sensors, embedded systems, GPS modules, and communication technologies to ensure efficient operation. ECG and heartbeat sensors collect real-time patient data, which processed using ESP32 and Raspberry Pi. The system uses GPS for tracking and selects the most suitable hospital based on availability. It also transmits patient data in advance and provides optimized route guidance with voice assistance for faster emergency response.

a) Materials:

- ESP32 Microcontroller: Used for collecting sensor data and transmitting it wirelessly.
- Raspberry Pi: Acts as the main processing unit for analyzing patient condition and decision-making.
- ECG Sensor: Measures the electrical activity of the heart to monitor patient condition.
- Heartbeat Sensor: Detects heart rate in real time.
- GPS Module: Provides real-time location of the ambulance for tracking and navigation.
- Wi-Fi Module / Internet Connectivity: Enables communication between ambulance, cloud, and hospital systems.
- Mobile Application: Displays patient status, hospital options, and route guidance for the driver.
- Hospital Dashboard: Used by hospitals to receive patient data and prepare for emergency treatment.
- Power Supply Unit: Provides required voltage to all system components.

b) Methods:

- Data Acquisition: Sensors collect real-time patient health data such as ECG and heart rate.
- Data Transmission: ESP32 sends collected data to Raspberry Pi and cloud/server via wireless communication.
- Data Processing: Raspberry Pi analyzes the patient's condition based on predefined thresholds.
- Condition Classification: The system categorizes the patient as critical, stable, or normal.
- Location Tracking: GPS module tracks the ambulance position continuously.
- Hospital Selection: The system checks hospital availability and selects the most suitable one.
- Pre-Arrival Communication: Patient data sent to the hospital before arrival for preparation.
- Route Optimization: The system determines the fastest route considering traffic conditions.
- Voice Guidance: Provides real-time voice instructions to the driver for navigation.
- Continuous Monitoring: Patient condition and system updates maintained until hospital arrival.

## 2. EXPERIMENTAL METHODOLOGY

2.1Working principle Smart Ambulance Navigation System:

The architecture of the Smart Ambulance Navigation System consists of multiple interconnected modules that work together to monitor patient health, analyse medical conditions, and provide intelligent navigation to the nearest suitable hospital. The system integrates biomedical sensors, embedded processors, GPS tracking, and communication technologies to ensure efficient emergency response.

The working flow begins with the patient monitoring module, where biomedical sensors such as the ECG module and heartbeat sensor continuously measure the patient's vital parameters. These sensors detect heart activity and pulse rate and generate analog signals representing the patient's health condition.

Then the sensor data transmitted to the ESP32 microcontroller, which acts as the data acquisition unit. The ESP32 converts the analog signals into digital data using its internal analog-to-digital converter and performs preliminary processing. After processing, the data are sent to the Raspberry Pi 4 processor, which acts as the central processing and decision-making unit.

The Raspberry Pi analyzes the received patient data by comparing the values with predefined medical thresholds to determine the severity of the patient's condition. At the same time, the NEO-6M GPS module continuously provides the real-time location of the ambulance. Using this location information, the system calculates the distance to nearby hospitals.

The Raspberry Pi then accesses the hospital availability database, which contains information about emergency beds, ICU facilities, and medical resources. Based on the patient's condition, hospital resource availability, and travel distance, the system automatically selects the most suitable hospital.

Once the hospital is selected, the system sends an alert message containing patient details and estimated arrival time to the hospital. Finally, the system provides GPS-based navigation guidance to the ambulance driver, ensuring the fastest route to the selected hospital while continuously monitoring the patient's condition during transportation.

### 3. RESULTS

The implementation of the Smart Ambulance Navigation System based on real-time patient condition and hospital availability demonstrates improved efficiency in emergency response, patient monitoring, and coordination between ambulances and hospitals. The system integrates IoT-enabled biomedical sensors, GPS-based lo- cation tracking, and embedded processing to support decision-making during emergency transportation.

The experimental setup evaluated under different simulated patient conditions, including normal, moderate, and critical heart rate levels. Biomedical sensors such as the ECG module and heartbeat sensor successfully monitored the patient's vital parameters continuously. The ESP32 microcontroller accurately acquired analog signals from the sensors and transmitted the processed data to the Raspberry Pi 4 processor without noticeable delay. Wireless data transmission using Wi-Fi ensured near real- time communication with minimal latency.

The navigation module used real-time location information obtained from the NEO-6M GPS module through the Global Positioning System. Based on this location data, the mobile interface displayed nearby hospitals along with their ICU availability status. Hospitals without ICU facilities were clearly indicated, enabling the ambulance drivers quickly identify suitable medical centers.

In the current implementation, the driver performed the final hospital selection manually to maintain flexibility in real-world scenarios. After selecting a hospital, the system provided optimized route navigation using the Google Maps API with real-time voice guidance, allowing hands-free navigation, and reducing driver distraction. Simultaneously, the hospital dashboard displayed live patient information including heart rate values, ECG waveform, and patient condition status. This allowed medical staff to monitor the patient before arrival and prepare required medical facilities in advance.

Experimental observations confirmed that the integrated modules patient monitoring, hospital availability display, and navigation system functioned effectively as a unified platform. However, system performance depends on network availability for real-time communication and map services. In areas with limited connectivity, minor delays in data transmission observed.

Overall, the results indicate that the proposed system enhances emergency coordination, reduces response time, and improves hospital preparation, thereby increasing the chances of timely medical intervention.

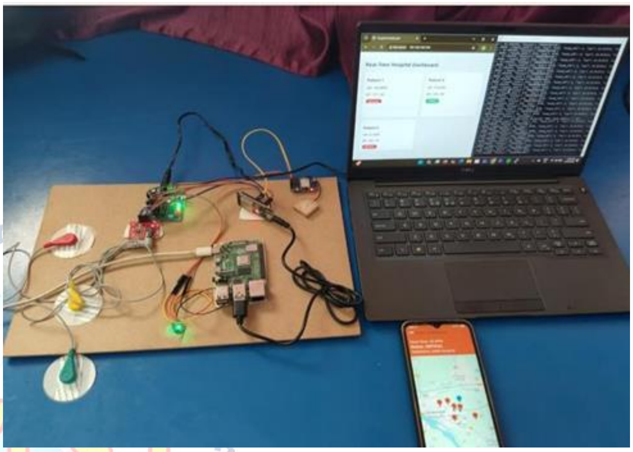

Fig. 2. Proposed System

### 4. CONCLUSION

The Smart Ambulance Navigation System provides an advanced approach to emergency medical services by integrating real-time patient monitoring, intelligent hospital selection, and optimized navigation. In this study, ECG and heartbeat sensors were used to continuously monitor patient health during transit, and the ESP32 microcontroller along with Raspberry Pi processed and analyzed the data to classify patient condition. GPS-based tracking and hospital database analysis enabled the selection of the most suitable hospital, while voice-assisted route guidance reduced response time and improved driver efficiency.

Pre-arrival transmission of patient data allowed hospitals to prepare for immediate treatment. The system successfully reduced emergency response delays, improved coordination between ambulances and hospitals, and increased the likelihood of patient survival. Implementation of continuous monitoring and optimized navigation demonstrated the effectiveness of integrating embedded systems, IoT, and communication technologies for modern emergency services. This study concludes that smart ambulance systems are significantly superior to conventional methods, offering faster, safer, and more reliable patient care, while providing a solid foundation for future enhancements such as AI-based decision support and telemedicine integration.

## 5. FUTURE WORK

Future work will focus on integrating Artificial Intelligence to predict patient deterioration and optimize hospital selection. Additional sensors for comprehensive health monitoring, cloud-based analytics for large-scale data, and smart city traffic integration for improved routing will be implemented. Telemedicine support for remote doctor guidance, multilingual voice assistance, and enhanced cybersecurity will also be explored to ensure reliability, efficiency, and wider deployment in real-world emergency scenarios.

## Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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