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SMART AUTOPILOT FOR AMBULANCE NAVIGATION SYSTEM: AN AI AND IOT-BASED FRAMEWORK FOR REAL-TIME EMERGENCY NAVIGATION SYSTEM

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Abstract

Emergency ambulance services can face serious delays due to traffic congestion, unsuitable route selection, waiting at traffic signals, and limited communication with hospitals. This paper presents a Smart Autopilot for Ambulance Navigation System that uses IoT, GPS, and web technologies to improve ambulance movement and emergency coordination. The proposed system combines realtime ambulance tracking, route selection, smart traffic management, patient monitoring, and hospital communication in a single platform. An ESP32 DevKit V1 is used as the main controller, while a NEO-6M GPS module provides the ambulance location. A* and Dijkstra algorithms are used to support suitable route selection. A smart traffic model using traffic-light LEDs, a 4-channel relay module, and an active 5V buzzer demonstrates a Green Corridor for the ambulance at traffic intersections. The system also monitors the patient's heart rate, SpO_2, and ECG using MAX30100 and AD8232 sensors. The vital information is displayed on a 16×2 I2C LCD inside the ambulance and can be shared with the hospital before arrival. system also monitors the patient's heart rate, SpO_2, and ECG using MAX30100 and AD8232 sensors. The vital information is displayed on a 16×2 I2C LCD inside the ambulance and can be shared with the hospital before arrival. A

web application developed using Next.js 15, Node.js, and Express provides ambulance and hospital monitoring, while SQLite with Prisma ORM stores the required records. The proposed system aims to reduce avoidable delays, improve emergency coordination, support continuous patient monitoring, and help hospitals prepare for incoming patients.

Keywords: Intelligent Ambulance Autopilot, Dynamic Green Corridor, Real-Time Vital Telemetry, Emergency Route Coordination, Hospital Pre-Arrival Notification, Embedded Traffic Control, Smart Emergency Response

Introduction

Emergency ambulance services are important for providing quick medical support to patients during critical situations. However, reaching the patient on time can be difficult due to traffic congestion, route-selection issues, and delays at traffic signals. there problem can increase the time taken by an ambulance to reach the patient and transport the patient to a suitable hospital .

Choosing the right route is also an important part of emergency ambulance transportation. The route selected under normal conditions may not always be suitable when traffic condition change. Road congestion and unexpected traffic conditions may require the ambulance to change its route while travelling. In addition, waiting at traffic signals can cause further delays, especially during peak traffic conditions.

Patient monitoring during transportation is another important concern. Vital information such as heart rate, SpO2 , and ECG signals needs to be monitored so that changes in the patient's condition can be identified during the journey. This information can also be useful for hospital staff in preparing for the patient's arrival. However, without proper communication between the ambulance and hospital , it may be difficult to share patient

information and prepare required resources such as beds, ICU facilities, and medical staff in advance.

These challenges show the need for a system that can bring different emergency operations together in one platform. The proposed Smart Autopilot Ambulance Navigation System integrates GPS-based ambulance tracking ,IOT-based patient monitoring, route selection using A* and Dijkstra algorithms, green corridor traffic coordination, and web based hospital communication. The system is developed to provide real-time information and improve coordination between the ambulance and hospital during emergency transportation.

Problem Statement

Emergency ambulance may face delays due to traffic congestion, unsuitable routes, and waiting at traffic signals. During transportation, patient vital information may also not be continuously available to the hospital, making it difficult for medical staff to prepare before the patient arrives. Existing ambulance systems may address individual aspects such as GPS tracking or patient monitoring, but these functions are not always integrated into a single platform. Therefore, there is a need for an integrated system that can support ambulance tracking, efficient route selection, traffic signal priority, real-time patient monitoring, and communication with the hospital to improve coordination during emergency transportation

The major problem addressed by the proposed system are :

- Traffic congestion: Ambulances may face delays due to heavy traffic, especially in busy urban areas.
- Route selection: selecting a suitable route during changing traffic conditions can be difficult for ambulance drivers
- Traffic signal delays: ambulance may have to wait at traffic signals, increasing the overall travel time.

- Patient monitoring: continuous monitoring of the patient vital signs during transportation is important but may not always be available.
- Hospital communication: patient information and ambulance status may not reach hospital staff in the time for proper preparation.
- Lack of integration: ambulance tracking, route navigation, traffic priority, patient monitoring, and hospital communication are often not combined into a single system.

Literature Review

Recent research has explored the use of GPS, IoT, artificial intelligence, and intelligent traffic management to improve emergency ambulance services. Prajwal et al. (2024) proposed a smart GPS and IoT-based approach for ambulance optimization. The study uses real-time traffic information, GPS navigation, IoT-based traffic-signal communication, and route optimization to provide priority for ambulances at intersections. From this study, the importance of real-time ambulance tracking, traffic-signal coordination, and dynamic route selection was identified.

Srikanteswara et al. (2023) developed an automated smart traffic manager for emergency vehicles. The system uses YOLOv8-based vehicle detection and dynamic traffic-signal control to identify emergency vehicles and provide priority at junctions. This work provided an understanding of emergency vehicle detection, traffic-density analysis, and adaptive signal control for reducing delays at intersections.

Pavan Teja et al. (2024) proposed an IoT-enabled dynamic traffic management system that considers vehicle density and provides priority to emergency vehicles. The system uses sensors, image processing, IoT communication, and ESP32-based control to adjust signal timings according to traffic conditions. This study helped identify the role of IoT and

microcontroller-based traffic control in developing a smart green corridor for emergency vehicles.

Nahata et al. (2024) presented an ML-driven approach for ambulance placement and routing using real-time data, Google Maps integration, predictive analytics, and dynamic route calculation. The study also considers ambulance distribution and hospital resource allocation. From this work, the importance of predictive routing, real-time road information, and efficient ambulance deployment was identified.

Dev et al. (2025) proposed an AI-based emergency assist system that monitors patient conditions using sensors and transmits patient information through an IoT cloud platform. The system also incorporates an AI-based voice assistant and emergency communication with hospitals and authorities. This study provided the basis for integrating patient monitoring, emergency alerts, IoT communication, and hospital preparedness into an ambulance system.

From the above studies, it was observed that existing research addresses different aspects of emergency ambulance management, including navigation, traffic prioritization, routing, patient monitoring, and emergency communication. These studies helped identify the key technologies required for the proposed system. Based on these findings, the proposed Smart Autopilot for Ambulance Navigation System integrates GPS tracking, route selection, traffic-signal priority, IoT-based patient monitoring, emergency alerts, and hospital communication within a single system.

Proposed System Architecture

The proposed system architecture consists of four main parts: the ambulance unit, traffic control unit, web-based platform, and hospital module. These components communicate with each other to support emergency ambulance transportation.

The ambulance unit contains the ESP32 DevKit V1, NEO-6M GPS module, MAX30100 sensor, AD8232 ECG sensor, 16×2 I2C LCD, and active 5V buzzer. The ESP32 collects the ambulance location and patient vital information and manages communication with the other system components.

The web-based platform receives and displays ambulance location, route, and patient information. The hospital module allows authorized hospital staff to view the information received from the ambulance and prepare required resources such as beds, ICU facilities, and medical staff.

The overall architecture connects the ambulance, traffic control, web platform, and hospital into a single system. This enables real-time information exchange and improves coordination during emergency transportation.

Figure 1: Proposed System Architecture

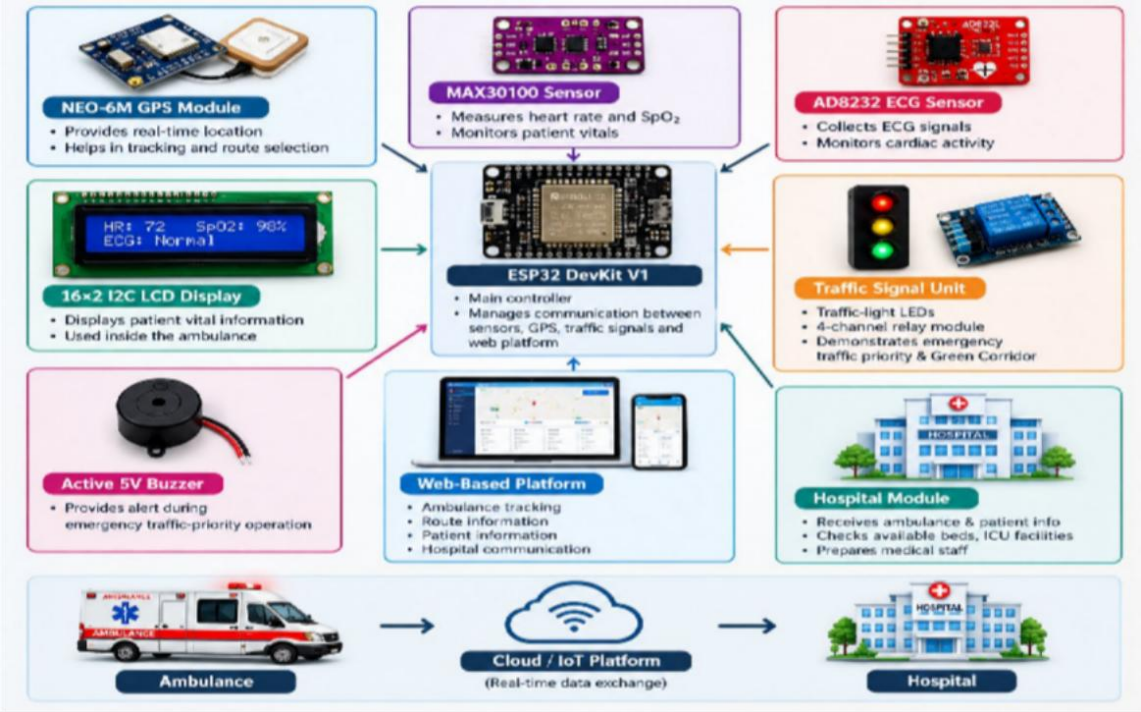


System Components

The system comprises of the following components:

1. ESP32 DevKit V1:This is the primary controller of the system responsible for controlling the communication among the sensors, GPS module, traffic lights and web based platform.
2. NEO-6M GPS Module: This component provides the real-time location of the ambulance.
3. MAX30100 Sensor: It measures the heart beat rate and SpO_2 level of the patient during ambulance transportation.
4. AD8232 ECG Sensor: It records the electrocardiogram (ECG) of the patient.
5. 16×2 I2C LCD Display: It displays the information about the patient's vital signs inside the ambulance.
6. Traffic Signal Unit: Traffic-light LED along with relay module will be used for demonstrating emergency traffic-priority and Green Corridor.
7. Active 5V Buzzer: It works as an alarm during the process of emergency traffic-priority operation.
8. Web Based Platform: It provides ambulance tracking, routes, patient information, and communication with hospital.
9. Hospital Module: It provides authorized hospital personnel access to ambulance and patient information and allows to check hospital resources like bed and ICU availability.

Figure 2: System Components



Methodology

The proposed system follows a step-by-step methodology integrating ambulance location tracking, intelligent route selection, emergency traffic-signal coordination, IoT-based patient monitoring, emergency classification, and hospital communication. The system uses an ESP32 DevKit V1 as the primary controller for integrating GPS, communication, traffic-control, and patient-monitoring components.

Research Gap

Recent research has investigated individual components of intelligent emergency response systems, including GPS-based ambulance navigation, IoT-enabled traffic management, machine-learning-based ambulance routing, and AI-based patient assistance. GPS and IoT have been used to provide emergency-vehicle priority and dynamic route optimization, while other systems have concentrated on predictive ambulance deployment or patient monitoring and hospital notification.

However, these approaches primarily emphasize specific parts of the emergency-response process. A need remains for an integrated system that combines ambulance tracking, route selection, traffic-signal coordination, real-time patient monitoring, emergency-condition classification, and hospital communication within a single prototype.

Table 1: *Patient Vitals Monitor*

Case	**Emergency Type**	**HR (BPM)**	**SpO_2 (%)**	**Status**
1	Heart Attack	131	89	Critical
2	Road Accident	140	89	Critical
3	Road Accident	131	89	Critical
4	Fire Accident	76	96	Stable
5	Trauma / Injury	86	97	Stable
6	Seizure / Epilepsy	75	98	Stable
7	Fire Accident	81	95	Stable

The proposed system was evaluated using 25 recorded emergency cases covering different emergency conditions. Among the 25 cases, 7 were categorized as critical and 18 as stable, representing 28.00% and 72.00%, respectively. The average recorded heart rate was 96.10 BPM, while the average SpO_2 was 94.71%. The ambulance travel distance ranged from 1.65 km to 13.04 km, with an average distance of 4.64 km. These results demonstrate the application of the proposed system for monitoring patient vital parameters and emergency-case information during ambulance transportation.

Table 2: *Analysis Report Summary*

Parameter	**Result**
Total cases	25
Critical cases	7
Stable cases	18
Critical cases percentage	28.00%
Stable cases percentage	72.00%
Average Heart Rate (HR)	96.10 BPM
Average Oxygen Saturation (SpO_2)	94.71%
Average ambulance distance	4.64 km
Minimum distance	1.65 km
Maximum distance	13.04 km

Challenges

The development of a smart ambulance navigation system involves several challenges, including accurate real-time GPS tracking, dynamic traffic management, reliable network connectivity, and efficient traffic signal coordination. Integrating multiple hardware components such as GPS, GSM, patient monitoring sensors, and ESP32 also requires reliable communication and synchronization. In addition, patient movement may affect sensor readings, while unexpected road conditions such as accidents, congestion, and roadblocks may require rapid route updates. Ensuring system reliability and safety during emergency operations remains an important challenge

- Real-Time Traffic Management: Processing continuously changing traffic conditions and selecting an appropriate route during emergencies is challenging.

- Accurate GPS Tracking: Maintaining accurate ambulance location tracking in areas with poor GPS signals, tunnels, or dense buildings can be difficult.
- Reliable Network Connectivity: Continuous communication between the ambulance, control center, and hospital requires stable internet or GSM connectivity.
- Traffic Signal Coordination: Coordinating traffic signals to create a green corridor while considering normal traffic flow and other emergency vehicles is challenging.
- Patient Monitoring: Collecting reliable ECG, heart-rate, and SpO_2 readings while the ambulance is moving can be affected by patient movement and sensor placement.
- Hardware Integration: Integrating GPS, GSM, sensors, traffic lights, buzzer, LCD, and ESP32 into a single system while maintaining reliable communication is technically challenging.
- Emergency Route Changes: Accidents, roadblocks, construction, or sudden traffic changes may require the system to update the route quickly.
- System Reliability and Safety: Since the system operates in emergency situations, failures in navigation, communication, or hardware can have serious consequences, making reliability and safety important challenges.

Outcomes

Expected Outcomes: The proposed system is expected to provide efficient navigation of the ambulance through real-time GPS tracking and route selection. The objective is to coordinate traffic lights in order to make it fast during emergency transportation. IoT-based patient monitoring can help in observing ECG, heart rate, and SpO_2. Moreover, coordination with the hospital will allow sending information about the patient and ambulance to the hospital before arrival. In other words, the hospital can be informed in advance

Quick Ambulance Navigation: The system is expected to find good routes and avoid delays during emergency transportation of patients.

Ambulance Real-Time Tracking: The ambulance can be tracked in real-time using GPS technology, which helps in tracking the ambulance's movement from the control center as well as the hospital.

Traffic Signal Coordination: Traffic signals can be coordinated in a way that they offer green passage to the coming ambulance.

Patient Monitoring: Continuous monitoring of ECG, heart rate, and SpO_2 can be done using IoT-based sensors, which will show vital data inside the ambulance.

Coordination at the Hospital: Information about patient and ambulance will be available to the hospital before the arrival of the ambulance.

Route Update: The selected route can be updated based on changing traffic conditions and emergencies.

Emergency Alerts: The system will give emergency alerts using a buzzer and notifications during emergencies and traffic signal coordination.

Monitoring of All Information: The proposed platform will give information about the ambulance, traffic, patients, and hospitals through a centralized dashboard.

Future Enhancements

The ambulance control system may be upgraded further through advanced artificial intelligence and communication techniques to enhance emergency ambulance activities. Future systems will include the prediction of traffic conditions through AI techniques and alternate route selection based on predictions. V2X communication is one such feature that can be included in future systems to allow direct communication between ambulances, traffic signals, and other nearby vehicles. Additionally, autonomous driving support through the

navigation system may include lane detection, obstacle detection, and collision avoidance with human intervention.

Advanced IoT-based patient monitoring is another upgrade that may include the tracking of more vital parameters to continuously update medical staff about patient health. AI-based health prediction may help identify any anomalies in the patient's condition during transit. Moreover, integration with hospital systems can be upgraded to allow real-time data regarding bed, ICU, and emergency room availability at hospitals. Further, drone-based emergency support may be introduced to provide necessary medicines or medical equipment in case of heavy traffic or poor road access. Large-scale real-world experiments including multiple ambulances, hospitals, and traffic networks may be performed to test the efficiency of the proposed system.

Conclusion

The developed Smart Autopilot for Ambulance Navigation System** serves as an integral solution for enhancing the process of emergency ambulance transportation through intelligent navigation, real-time ambulance tracking, traffic signals coordination, IoT-based patient monitoring and communication with hospitals. For the purpose of obtaining the ambulance location, GPS technology is used, while the choice of the route depends on current traffic conditions. Through traffic signals coordination, a smooth passage of the ambulance is ensured, eliminating all unnecessary delays in the process of emergency transportation.

The use of IoT-based sensors allows for continuous monitoring of critical parameters like ECG, heart rate, and SpO_2. The collected information about patients may be transmitted to the hospital in advance, so that necessary resources could be prepared for the arrival of the ambulance. The central monitoring platform gives information regarding ambulance, traffic, patients' and hospitals' status, increasing the level of coordination between different parties involved in emergency response.

Thus, the developed project demonstrates the possibility of using the artificial intelligence, IoT, GPS, communication technologies and smart transportation infrastructure for the purpose of supporting the process of providing emergency healthcare services. Though currently the solution was implemented and tested with the help of prototype environment, it lays the foundation for further improvements and implementation. The use of AI-based traffic prediction, V2X communication, more advanced patient monitoring and autonomous driving assistance will increase the effectiveness of the system in the future.

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