International Journal of Scientific Research and Engineering Development-– Volume 9 Issue 2, Mar-Apr 2026
Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

A Smart Ambulance System for Real-Time Emergency Response and Inclusive Healthcare Support

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Abstract:

In situations where people need immediate medical intervention (such as an incident, medical emergency, or some sort of disaster) an emergency medical response is essential to save lives. Unfortunately, many traditional emergency service providers (e.g., ambulance services) experience delays caused by factors including traffic congestion, inefficient routing, lack of coordination among hospitals and other emergency responders, and no real-time monitoring systems. Such delays can have a negative impact on patient survival rates and increase the likelihood of complications.

This paper proposes the Smart Ambulance System for Real-Time Emergency Response and Inclusive Healthcare Support (referred to as Smart Ambulance System) as an innovative platform that combines a number of technologies (i.e., GPS tracking, real-time traffic/route analysis, cloud computing, mobile communication systems) to automate the ambulance dispatch process, determine the nearest available ambulance, identify the quickest route using live traffic data, and notify hospitals of a patient's arrival before they arrive there.

The system is composed of multiple modules (e.g., Admin, Dispatcher, Ambulance Crew, and Hospital Staff) to facilitate operations within the emergency response process. The system also provides real-time tracking of ambulances, facilitating efficient coordination between emergency responders and healthcare providers.

Ultimately, the Smart Ambulance System is expected to provide improved efficiency in emergency response, decreased arrival time of ambulances at hospitals, increased preparedness of hospitals for receiving patients, and increased inclusiveness of healthcare by providing faster access to emergency medical care.

Keywords: Emergency Medical Services, Smart Ambulance System, Real Time Monitoring, GPS Tracking, Intelligent Ambulance System, Route Optimization, Healthcare Technology.

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I. INTRODUCTION

Emergency Medical Services (EMS) provide emergency health care services to people with critical health problems that could result in death if not treated quickly. Emergency medical care is greatly affected by how quickly an ambulance arrives to respond to an emergency call and how quickly that ambulance arrives to take the patient to a suitable hospital for diagnosis/treatment of their health problem. Traditional emergency medical services have many of the same challenges that

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keep them from providing emergency medical care quickly, so they can be very effective in doing so. The following factors are regularly stated by many members of the EMS community as problems that usually impede the ability of EMS to provide timely and quality emergency medical care:

• Traffic delay and other factors that impact response time

• Poor traffic management resulting in inefficient routing and long response times for ambulances

• No real-time ability to monitor, locate, and respond to an ambulance

• Coordination of emergency responders (police, fire, EMS) and hospital staff prior to the ambulances arriving at the hospital (i.e. no advance notice).

In many situations, ambulances are dispatched by staff who are not thoroughly trained to do so. Consequently, delays occur with the dispatching of the ambulance or providing them with incorrect instructions regarding where they should respond. In addition to these delays, in many cases, when an ambulance arrives at a hospital with a patient there is no prior notice to the hospital regarding the patient's status and/or any preparation (diagnosis) that would be needed in order to receive the patient.

To address these issues, we have developed a Smart Ambulance System that will provide emergency response systems for both the dispatching and real-time tracking of ambulances based on the real-time transmission of data (using cellular, satellite, etc.) and cloud-based technologies.

Smart Ambulance Systems will improve the efficiency and response time of emergency services by ensuring that the ambulance is routed to the closest medical facility, allowing for optimal care for the patient being transported via ambulance. The four major objectives of the Smart Ambulance System are to:

• Decrease the amount of time it takes to respond to a request for an ambulance;

• Allow for the real-time tracking of ambulances;

• Provide the hospitals with adequate notice and preparation to receive an emergency patient;

• Provide the necessary technology to allow for improved coordination between emergency service providers.

II. PROBLEM STATEMENT

Emergency medical services have been delayed as a result of different operational problems. Some examples include:

• Ambulance delay caused by traffic congestion

• Lack of an efficient route planning system

• Manual dispatching system that has errors

• The ability to track ambulances is not available in real time

• Poor communication between dispatch centers and hospitals

• Emergency management systems are unrelated to each other.

These problems significantly decrease the ability of emergency healthcare services to operate effectively and may result in delayed patient treatment.

The Smart Ambulance System is designed to provide a smart, automated emergency response platform that will solve these types of issues.

III. EXISTING SYSTEM

In the current emergency response system, ambulance dispatch and routing is done mostly manually or by using basic GPS navigation or geographical location tools.

Dispatchers assign ambulances based on where they know they are approximately located, and ambulance drivers use the standard navigation applications they would find on their mobile device, which do not always account for traffic conditions at that particular moment.

Emergency requests, ambulance availability, and hospital bed availability are typically monitored/manually maintained on a different system (not integrated), resulting in delayed response time, underutilization of ambulances, and poor coordination between the healthcare provider and the emergency response system.

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IV. LIMITATIONS OF THE CURRENT SYSTEM

The conventional ambulance operation system has many problems that should be taken into consideration:

- Manual dispatch of ambulances creates more room for human error.
- The routes used by the ambulances are not optimized for traffic conditions, which means that there will be delays because of traffic jams or detours due to accidents.
- Emergency response time is taking longer than necessary because the ambulance dispatch process usually involves two different organizations who are not always in communication with each other.
- The ambulance service does not have any real-time tracking capabilities of the ambulance.
- The data regarding calls for assistance and their respective responses are inconsistent, thus creating duplicate records.
- In large-scale emergency response situations, the operation of the ambulance service may not be able to scale accordingly.

V. SMART AMBULANCE SYSTEM

The Smart Ambulance System is a web and mobile-based platform that uses intelligent algorithms to automate dispatch and routing of the ambulance. The Smart Ambulance System automatically determines the nearest ambulance when the emergency request is received by using GPS coordinates of the caller. It will also determine the most efficient route based on real-time traffic conditions. In addition, it will determine which hospital is closest to the emergency site by measuring distance and what resources (i.e., ambulances with specific capabilities) are available at the hospital.

The system will provide real-time tracking of the ambulance and will inform the hospital in advance of an incoming emergency patient.

This will enable the medical care team to have necessary equipment available and to begin preparations for treatment prior to the arrival of the patient.

VI. ADVANTAGES OF PROPOSED SOLUTION

The proposed system offers numerous benefits over existing systems for responding to emergencies. These advantages include:

- Quicker or shorter time for ambulances to arrive at an emergency scene.
- Computerized dispatch of ambulances.
- Ambulances tracked in real time.
- Routes taking into account traffic congestion to speed up ambulance response.
- Shared access to emergency data among numerous suppliers and providers with a total system for sharing that data.
- Additional benefits to wounded people, hospitals and emergency service providers through better coordination and care between hospitals and emergency service providers.
- Ability to handle multiple emergency scenarios at the same time.

VII. REQUIREMENTS TO USE THE PROPOSED SOLUTION

A. Software

In order to implement and operate the proposed solution, the following types of software must be present:

- Operating System (either Linux or windows)
- Back End Technology (either Node.js or FastAPI)
- front end application (either React Native or Web Dashboard)
- Database System (PostgreSQL with support for PostGIS).
- Application Programming Interface (API): OpenStreetMap and Traffic Data
- Development Tools: Visual Studio Code and Postman

B. Hardware

In order to implement and operate the proposed solution, the following types of hardware must be present:

- Server with a minimum of 8 GB of RAM;
- An Internet-connected smartphone or tracking device equipped with GPS;

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• Reliable access to the internet;
• Access to the cloud computing infrastructures of the organization on which the proposed solution will be installed

VIII. SYSTEM ARCHITECTURE

Components of the Smart Ambulance System.

1. Patient/User App: Allow patients or bystanders to request an ambulance for an emergency. Includes registering an emergency, transmitting current location, providing emergency details, and an ambulance tracking function.

2. Dispatcher System: The dispatcher system manages the emergency requests, assigns ambulances to these requests and is responsible for monitoring whether the ambulance is available, when an alert has been received, whether there is an available unit closest to the request and monitoring how the emergency operation is going.

3. Cloud Server / Central System: Main Processing Unit for Smart Ambulance System. Responsible for processing the emergency response requests; system data is stored; calculates the best routes for ambulances to travel; oversees all system component communication.

4. GPS Tracking System: GPS Tracking ambulances during travel in order to provide real-time tracking of the ambulance's location, monitor progress along the way, provide navigation updates, and keep the dispatcher; hospitals are informed of the current location of the ambulance.

5. Traffic Management Interface: The Smart Ambulance System interfaces with traffic data services for the ability to provide the fastest routes available. The functionality includes real-time traffic data monitoring static/dynamic route optimization by avoiding congested areas to improve response time to emergencies.

6. Ambulance Unit: The Ambulance Unit operated via a driver device that interfaces with the Smart Ambulance System; responsible for communicating to the dispatcher by utilizing prescribed communication devices. The ambulance unit is used to navigate the best routes provided by the dispatcher and keeping the dispatcher informed of its condition.

7. The emergency departments of hospitals receive advanced notice of incoming emergency patients.

This allows hospitals to prepare:

- Emergency medical teams for response;
- A bed (if available);
- Medical equipment that will be used by the medical team;
- Provide emergency medical care as soon as the patient arrives.

Workflow of the Smart Ambulance System (System Architecture):

The Smart Ambulance System (SAS) consists of several components and operates in the following manner: The patient sends a request for an ambulance via a mobile application, and the request is forwarded to the ambulance dispatcher through the cloud server. The dispatcher determines the closest available ambulance to the patient based on GPS location. The dispatcher also determines the fastest route to the patient based on real-time traffic conditions. The dispatcher then sends a dispatch notification to the ambulance. The ambulance navigates to the patient; and the hospital where the patient is to be transported has been notified in advance so that emergency care will be available upon the patient's arrival. This architecture allows for improved coordination among the organizations, as well as faster response time and improved access to health services for the patient.

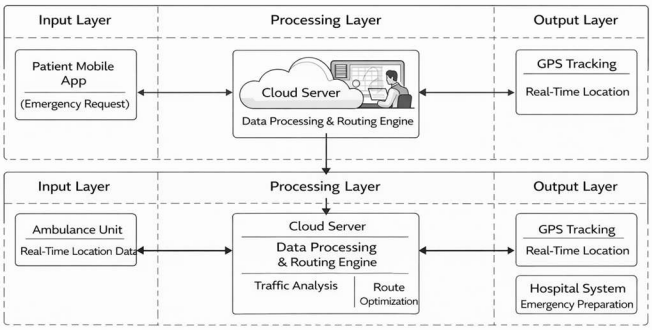

Fig. 1: System Architecture of Smart Ambulance System

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IX. MODULES IN THE SYSTEM

The Smart Ambulance System contains a number of separate modules that may do distinct and varied activities within the system.

A. *ADMIN MODULE*

The administration module of the system oversees the configuration of the system, user accounts, information for each ambulance, and information for each hospital.

B. *DISPATCHER MODULE*

The dispatcher module receives emergency requests and dispatches ambulances based on their distance from the emergency.

C. *AMBULANCE CREW MODULE*

This module permits the ambulance driver and crew to receive notifications of dispatch and to navigate the most efficient route.

D. *HOSPITAL MODULE*

The hospital module is used by hospitals to receive notification of incoming emergencies so that hospitals can prepare for the patient before they arrive.

X. SYSTEM FUNCTIONALITY

The Smart Ambulance System has several functions that provide better emergency medical care.

1. ***Registration Of Emergency Requests:*** The user registers an emergency request via the mobile device application, which contains the user's address and type of emergency.
2. ***Identification Of Nearest Ambulance:*** The system determines which available ambulance is nearest to the user using GPS data in real time.

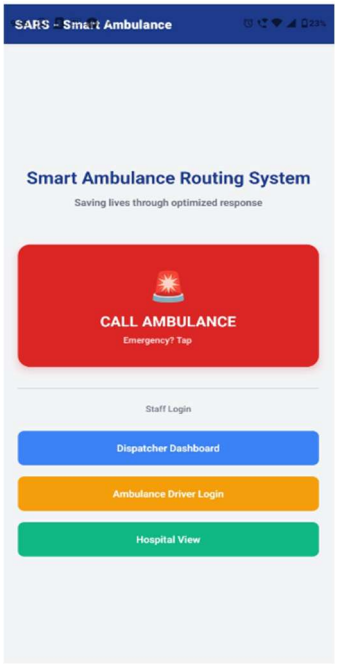
3. Dispatch, Assignment, And Monitoring of Ambulance and Emergency Operations: The ambulance dispatcher automatically assigns an ambulance to the emergency and monitors all emergency operations.

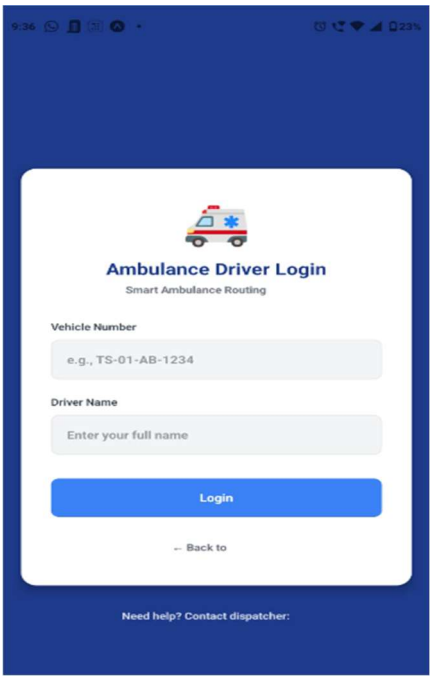
4. Route Optimization: The fastest route is selected in real time based on the latest available traffic information.

5. Real Time Monitoring of Ambulance Location: The ambulance location is GPS tracked in real time.

6. Hospital Notification: The hospital is notified in advance of a patient arriving by ambulance, so the hospital can have medical treatment for the patient ready for when the ambulance arrives.

XI. RESULT





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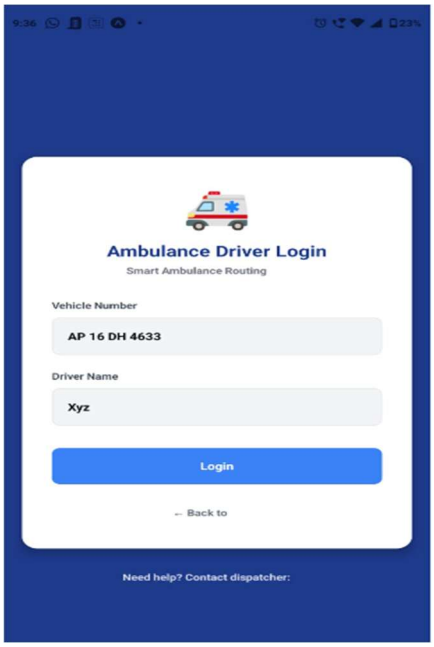

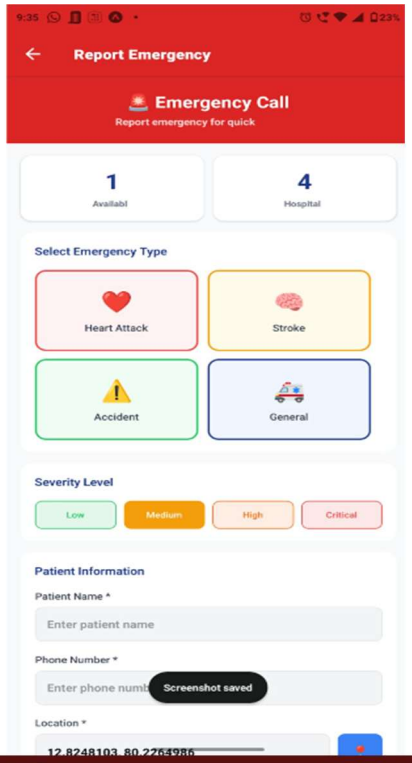

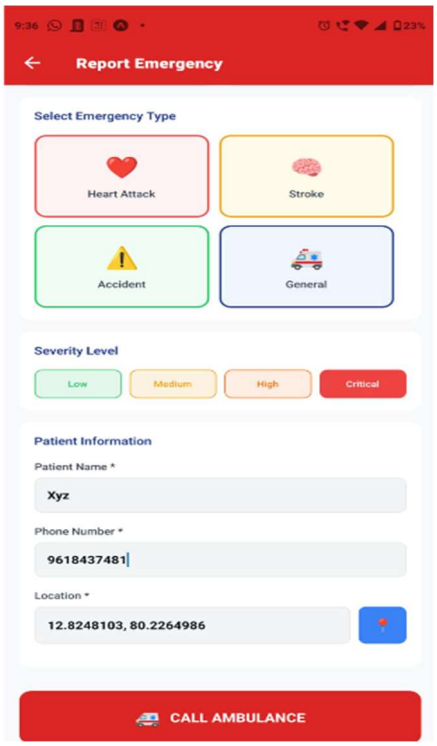

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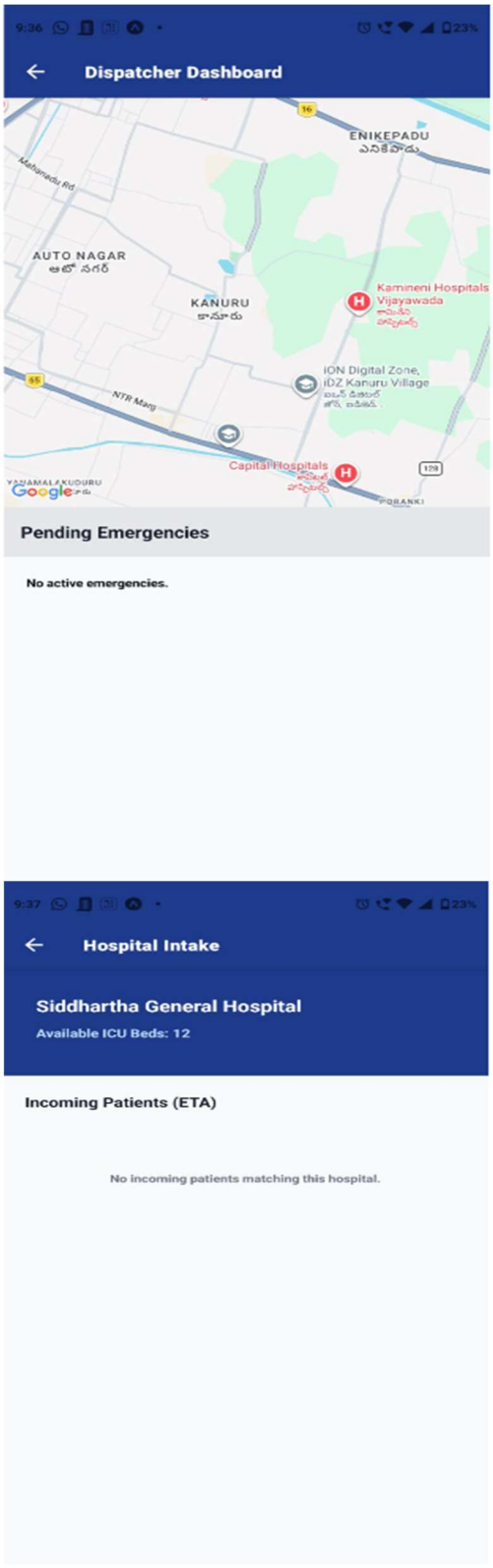

XII. CONCLUSION

Smart ambulance systems will facilitate and ultimately improve emergency medical services by using technology to minimize delays associated with traditional ambulance service providers who have to respond to emergency calls and transport patients under the restrictions of heavily congested roadways, difficulty tracking where an ambulance is at any given moment, and insufficient coordination between hospital facilities and first responders at the time of the emergency call.

This new smart ambulance service will utilize technologies such as GPS tracking on ambulances, as well as real-time routing analysis to provide the closest ambulance to respond to the emergency call in the quickest possible manner, in order to provide for rapid delivery of patients to the hospital.

Smart ambulances will provide ambulance tracking in real-time, therefore allowing hospitals to receive real-time notifications of arriving ambulances, which will help to better coordinate the work of dispatch centers, ambulance crews, and hospitals, thereby reducing response and transfer times, leading to improved patient outcomes and greater access to emergency medical services.

ACKNOWLEDGMENT

The authors wish to extend their thanks to the faculty and staff of the Department of Information Technology for their guidance throughout this research effort. We are especially grateful to our project supervisor for his consistent support and insightful input throughout this research project.

In addition, we wish to thank our institution (Prasad V Potluri Siddhartha Institute of Technology) for providing us with access to the resources and facilities needed to successfully conduct this research.

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