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Leveraging real-time data: A location-based ambulance booking and tracking system with geofencing

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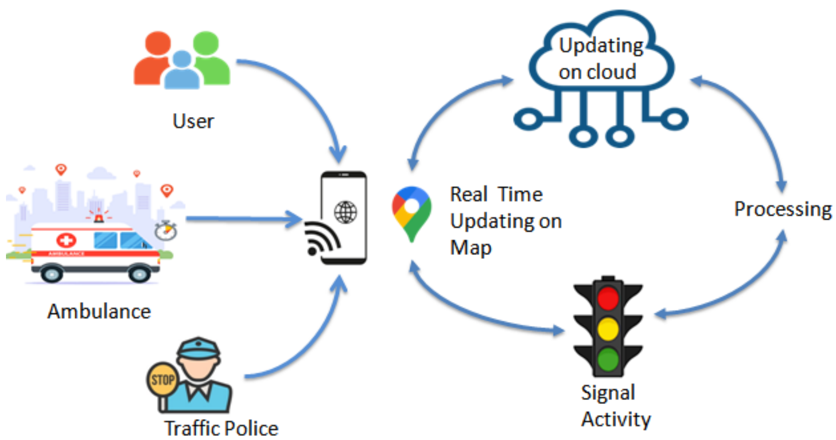
Article

ABSTRACT



Delayed ambulance arrival is a critical issue in emergency medical care, impacting patient outcomes. This research addresses the challenge of slow response times in India's ambulance services. Our proposed system aims to significantly improve response times and patient transportation efficiency. To provide rapid medical assistance, the technology allows dynamic ambulance reservations depending on the severity of the accident, deploys competent drivers, and transmits real-time traffic data. The paper details the system's architecture and approach, including the use of Firebase Authentication and AWS Amplify for user management and backend development. Integration of various APIs (Google Maps API, Google Places Auto Complete, and Distance Matrix API) enhances user experience and functionality. This research presents a real-time ambulance booking and tracking system with the potential to revolutionize emergency medical response in India.

Keywords: Real-time ambulance booking, Geofencing technology, AWS Amplify, GraphQL, Google Places Auto Complete.

INTRODUCTION

Ambulances are of paramount importance in medical urgency, as they offer an array of indispensable services, but the problem of ambulance response time is quite concerning since it might endanger the lives of those who require urgent emergency medical care.[1] But for patients, not getting an ambulance to their desired location and in the desired time can be a frustrating problem as this report suggests that in India, 24,012 persons lose their lives every day because of the delay in receiving medical care because ambulances are backed up in traffic and ill-equipped to treat critically ill patients. The report published in 2020 by the prestigious All India Institute of Medical Sciences presents a concerning reality of the ambulance services in India. The report highlights that a staggering 98.5% of ambulances in the country end up transporting dead bodies due to their failure to reach the site of the emergency on time. About 28% of all monthly calls are rejected by Centralised Accident and Trauma Services (CATS), largely because the ambulance is not available.[2] In India the ambulance response time from March to June 2020 in a medical emergency can be as high as 12 hours.[3]

In India, out of the total calls received for emergency vehicles, 64% were ineffectual, with no response and disconnected calls accounting for 42 and 34%, respectively. Only 3% of the callers received a call-back. 1.75 lakh ambulance hours were wasted due to delays in patient transfer that lasted more than 15 minutes in 18% of the cases. In addition to the difficulties that ambulances have in reaching their destinations, there are several other issues that might make the situation worse. The prompt arrival of ambulances can also be hampered by poor communication between emergency services, dispatchers, and the public as well as by topographical

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obstacles like distant or difficult-to-reach places.[4] Considering the challenges and obstacles experienced by ambulances in reaching their intended destinations promptly, and the predicaments encountered by patients in securing emergency ambulance services to their preferred location, a dynamic and immediate ambulance reservation system is deemed indispensable, with the aim of optimizing response times and minimizing the time taken to transport patients to medical facilities.

The presented system will facilitate the booking of ambulances on the basis of the severity of the accident and dispatch the nearest available ambulance driver who is qualified to handle the situation, ensuring that patients receive prompt medical attention. Moreover, system will automatically send the driver's location to the on-duty traffic police officer, who can promptly manage the traffic, accordingly, thus ensuring a seamless passage for the ambulance and reducing the time taken to transport the patient to the medical facility. The proposed system is comprised of three components: 1. Application for patients, 2. Application for ambulance drivers, 3. Application for traffic police inspectors. The mobile application integrates with the ambulance system, allowing drivers to input their destination and receive real-time traffic updates and optimized routes. Geofences can be created around traffic police officer locations for real-time notifications. This proposed system enhance ambulance routing, response times, and coordination between drivers and traffic police for efficient traffic management.

Following are the key contributions of proposed research work,

1. Real-time ambulance booking: Location-based booking allows for faster dispatch based on urgency and geofencing.
2. Dynamic ambulance allocation: The system assigns the most suitable ambulance based on real-time traffic data and driver availability.
3. Improved coordination: Proposed system integrates traffic management and ambulance routing for optimized emergency response.
4. Aims to explore minimizing hardware and leverage Google Maps API for a more scalable solution.
5. System leverages a mobile network for communication, offering potential advantages over RF in terms of range and scalability.

LITERATURE SURVEY

A significant amount of work has been done and is still being done on this issue. Some of them provide solutions via software while others operate with physical hardware.

A study by Alendra et al. proposes a Vehicle Monitoring System that tracks cars using GPS and geofencing. Users define zones on a map (geofences) and receive alerts (email/SMS) when a car enters or leaves them.[5] The Blynk App displays real-time vehicle locations. Seeing the value of geofencing, the authors propose extending it to warn traffic authorities about ambulance movements for improved traffic management.Ramya et al. propose an emergency vehicle routing system using an SDSS. It offers a dynamic shortest path based on real-time traffic data (GIS) and locates patients and ambulances via GPS and Google Maps. User requests reach ambulance drivers through a dedicated app, and the server assigns the closest available ambulance. To further improve real-time location tracking, the authors plan to integrate device permission for precise location access and Google Maps for all parties involved (patients, ambulance drivers, and traffic police).

Noei et al. propose a system to prioritize emergency vehicles at congested locations.[6] Geo-fences are created around critical areas (junctions, highway ramps) using GPS. Emergency vehicles with GPS transmit location data, triggering green lights at smart traffic lights upon detection. This research highlights the potential of geofencing for our system. Sasipriya et al. propose a smartphone-based accident detection system that triggers alerts to family, police, and emergency services upon impact.[7] The system uses GPS to locate the accident scene and send real-time updates to relevant parties. We plan to implement a cloud-based version using AWS Amplify and GraphQL for improved scalability.

Nellore et al. propose an ambulance prioritization system using the Euclidean algorithm to calculate distance and visual sensing to assess traffic conditions.[8] However, this method is susceptible to weather limitations. This presented system will leverage geofencing technology for improved reliability. Another approach with Stroboscopic Lights & Sensors: Emergency vehicles with strobe lights are detected by traffic light sensors, enabling quicker green lights. Prinsloo et al. propose an RFID-based vehicle tracking system with limited range and needing clear line of sight.[9] The system consists of an RFID reader unit and an RFID transponder put on the vehicle. The transponder receives a signal from the RFID reader unit and responds with a signal conveying information about the identity of the vehicle andthe data from the response signal is then processed by the RFID reader unit to determine the location of the vehicle. The RFID reader unit and the RFID transponder interact via electromagnetic waves. This system has some potential drawbacks such as the reader unit and transponder have a limited communication range, require a clear line of sight for reliable operation, and are subject to signal interference from many environmental variables.

A complete hardware-based solution have proposed by A. Chowdhury et al.[10] The system, which employs an Arduino UNO, a GSM SIM 900A, and a GPS Neo 6M, is a hardware-based solution for ambulance monitoring. Position information from GPS satellites is collected using the GPS Neo 6M module.The Arduino UNO determines the location of the ambulance by analysing the position data obtained from the GPS Neo 6M module and then it transmits the position information to the GSM SIM 900A module, which then transmits it to the central monitoring centre. Chakraborty et al. propose a system that utilizes radio frequency (RF) technology to prioritize emergency vehicles at traffic junctions.[11] The system employs a 434 MHz RF module to detect approaching emergency vehicles. Upon detection, the traffic light controller automatically switches to an emergency mode, adjusting traffic light timings to allow the emergency vehicle to pass safely. Once the emergency vehicle clears the intersection, the system reverts to the regular traffic light sequence. This approach helps ensure smooth passage for emergency vehicles while minimizing disruptions to regular traffic flow.

Table 1 shows summary of research papers compared for systems advantages, disadvantages, underlined algorithm and technologies used.

Table 1. Comparative Summary of literaure research

Ref. No.	System	Advantages	Disadvantages	Algorithms Used	Technologies Used
5	Vehicle Monitoring System with Geofencing Capability	- Real-time monitoring of vehicle location	- Hardware cost for components like FONA808 shield and Arduino Mega 2560	Geofencing	GPS, GSM, Arduino Mega 2560, FONA808 shield
	Emergency ambulance tracking system using GPS android application	- Real-time tracking of ambulances	- Dependence on technology - Limited coverage - Cost	Dijkstra's algorithm, A* algorithm, K-means clustering algorithm, Naive Bayes classifier	Mobile technology, GIS, GPS, Google Maps, Cloud computing, Android operating system, XML, MySQL, JSON
6	Reducing Traffic Congestion Using Geo-Fence Technology	- Improved emergency response time - Efficient traffic management - Enhanced safety - Optimized resource allocation	- Cost of implementation and maintenance - Technical challenges and compatibility - Potential for misuse or abuse	Geo-Fencing Algorithm, Vehicle Identification/Verification Algorithm, Traffic Light Control Algorithm, Location Tracking Algorithm	Geo-fencing, Gimbal Geo-fence Cloud, Google Cloud
7	Accident Alert and Ambulance Tracking System	- Real-time tracking and monitoring capabilities for emergency ambulance services - Accident alert system - shortest distance calculation for ambulance drivers	- Accuracy and reliability of accident detection	Accident Detection Algorithm, Route Optimization Algorithm, Alert Message Delivery Algorithm	Cassine server, MySQL server, GPS, Google API
8	Traffic management for emergency vehicle priority based on visual sensing	- Improved response times for emergency services. - Optimized traffic flow. - Reduced emissions. - Cost-effective. - Scalable.	- Visual sensing technology affected by weather conditions. - Cost of implementation and maintenance.	- Distance-based emergency vehicle dispatching algorithm. - Traffic signal control algorithm. - PE-MAC protocol. - Image processing algorithms.	- Visual sensing technology. - Ultrasonic sensors. - Wireless communication protocols.
9	Accurate vehicle location system using RFID, an internet of things approach	- Real-time bus tracking. - Improved passenger experience. - Efficient resource allocation. - Integration of technologies. - Centralized monitoring.	- Dependency on technology. - Initial infrastructure investment. - Privacy concerns.	- GPS-based tracking algorithm. - GSM data transmission algorithm. - RFID-based tracking algorithm. - Data processing and update algorithm.	- GPS. - GSM. - RFID.
10	IoT Based Traffic Management System for Ambulances Mansaf Alam Jamia Millia Islamia IoT-Based Traffic Management System for Ambulances	- Real-time Tracking - Improved Response Times - Efficient Route Optimization - Enhanced Safety - Integration Potential	- Dependence on Technology - Limited Coverage - Privacy and Security Concerns	- Real-time Traffic Analysis - Route Optimization - Communication Protocol - Data Processing and Decision Making	Arduino UNO microcontroller board, GPS module NEO 6M, SIM 900A GSM Modem, IoT technology
11	Traffic Light Control System for Emergency Vehicles Using Radio Frequency	- Real-time Traffic Control - Efficient Routing. - Increased Safety - Minimal Infrastructure Requirements	- Limited Range - Interference Risks - Coordination with Other Systems - Error in Emergency Vehicle Identification	- Radio Frequency Transmission - Traffic Light Pre-emption - Traffic Pattern Optimization - Vehicle Identification	Wireless communication, Radio frequency transmission

PROPOSED METHODOLOGY

The exposition begins with a thorough description of the architectural layout of the suggested real time ambulance booking and traffic management system,[12] followed by a thorough explanation of the system's structural elements and operating procedures.

A. Architecture Overview:

The proposed system goal is to guarantee that patients receive rapid medical care, which is essential in circumstances where life is at stake.[13] A patient application, an application for ambulance drivers, and an application for traffic police inspectors are all included in the system's three-tiered design.

B. Technologies and Algorithms used

The system has implemented Firebase Authentication for users, ambulance driver, and traffic police inspector authentication. This proposed application is designed using React Native and Expo. This work uses AWS Amplify, a cloud-based development platform, for the backend development. This platform supports the GraphQL API, which is used to collect and modify data from the backend.

This system has incorporated several APIs, including the Google Maps API, Google Places Auto Complete, the Distance Matrix API, the Places API, and the Directions API. We have also used algorithms like the Dijkstra algorithm, ETA (Estimated Time of Arrival), and GPS through API to locate all users, drivers, and traffic enforcement officers in real-time.

1.Patient/User Side Application Working Flow

Patients can use the patient-specific application to make

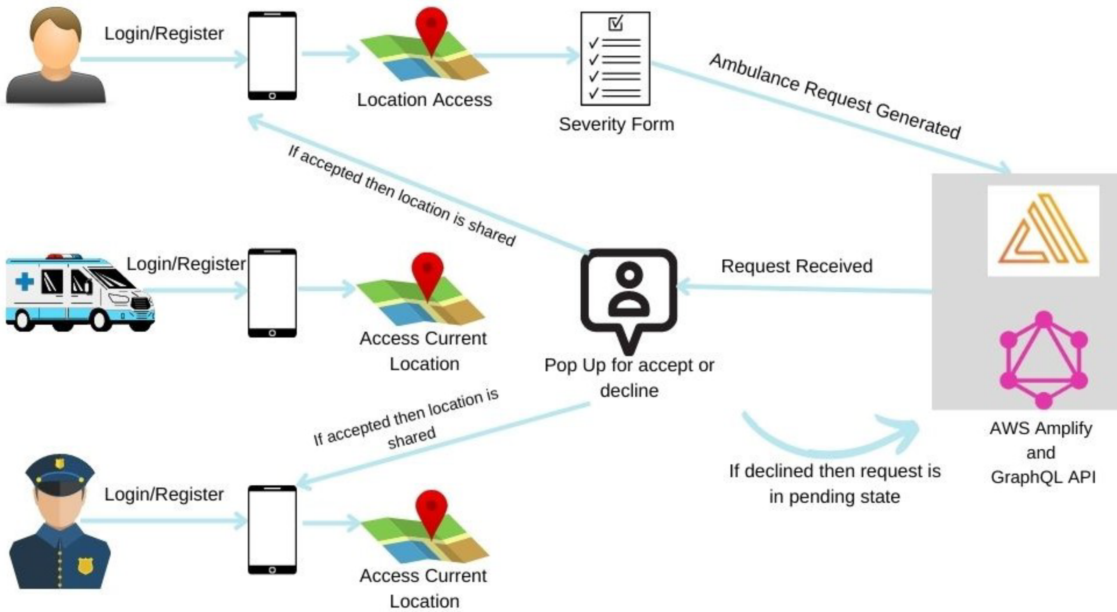

Figure 1. Architecture diagram of Proposed Methodology showing internal APIs and Outflow

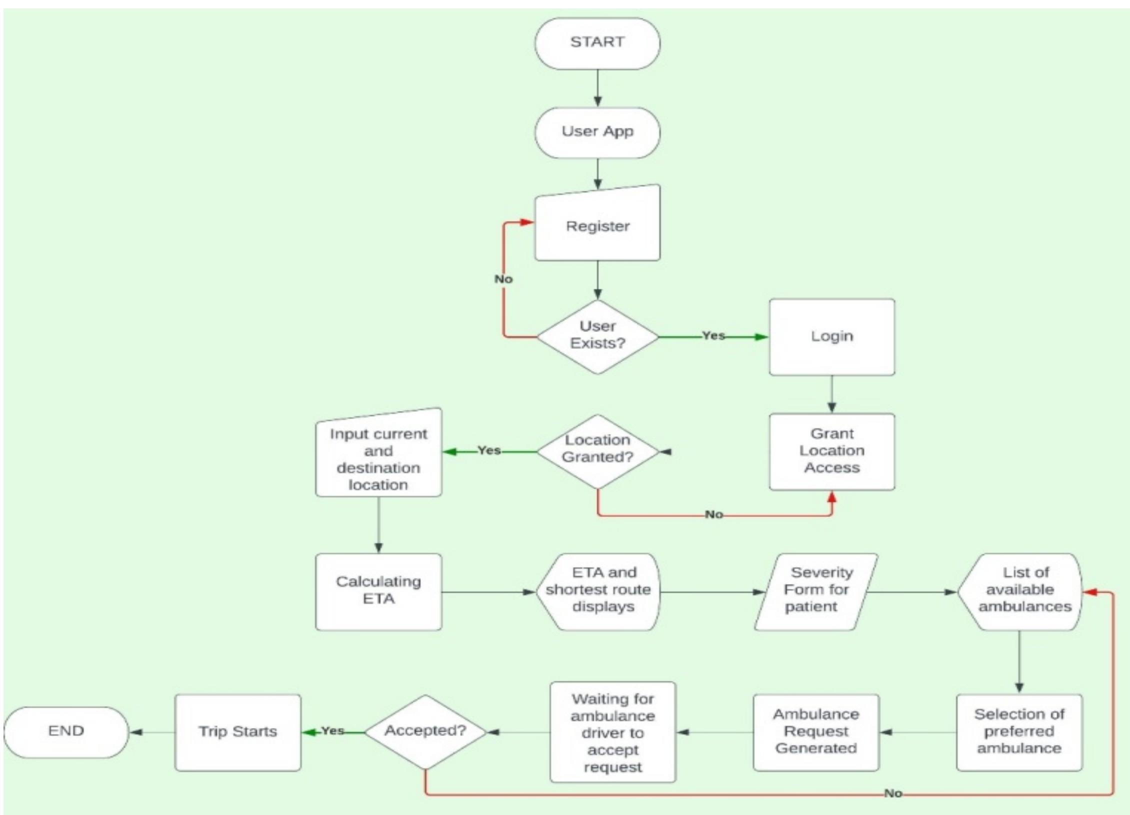

Figure 2. Patient/User Side Application Working Flow

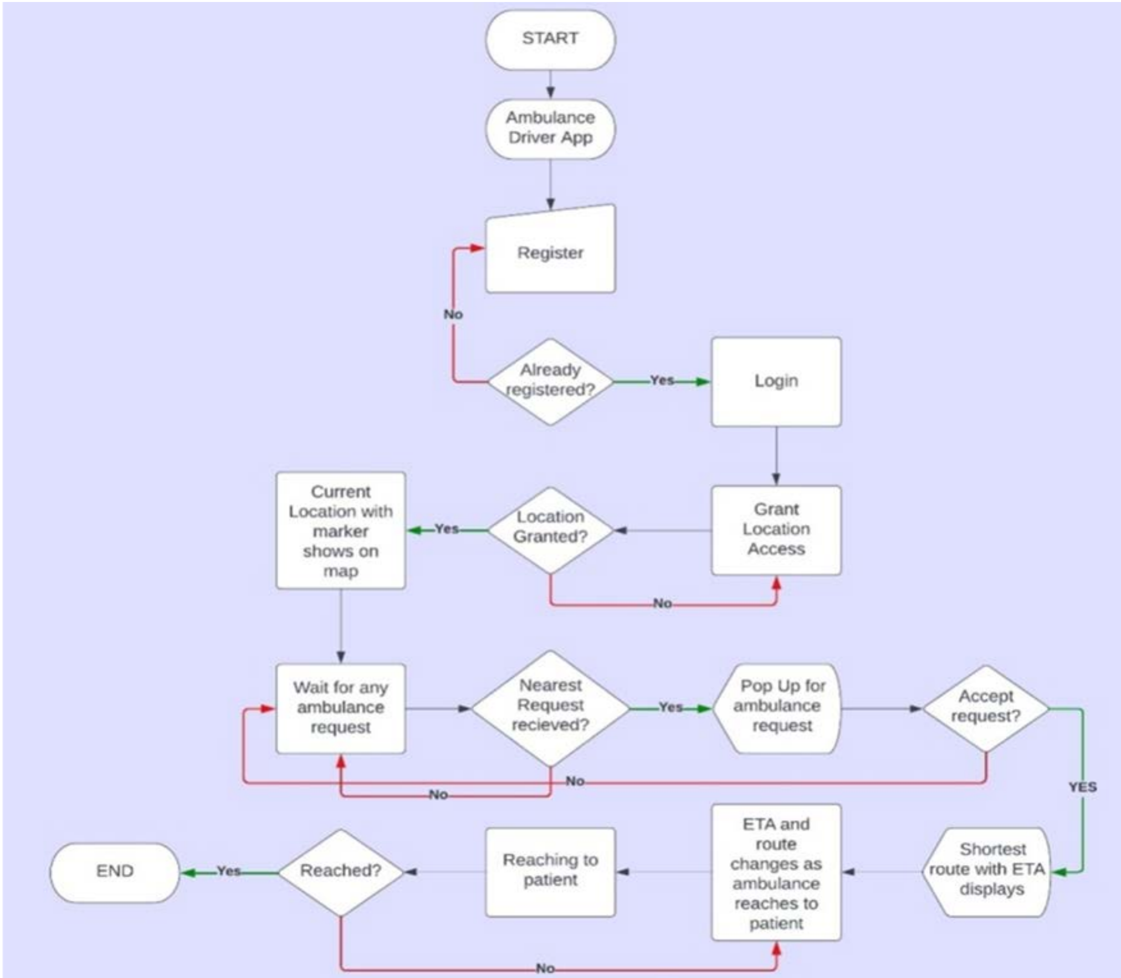

Figure 3. Ambulance Driver's Application Working Flow

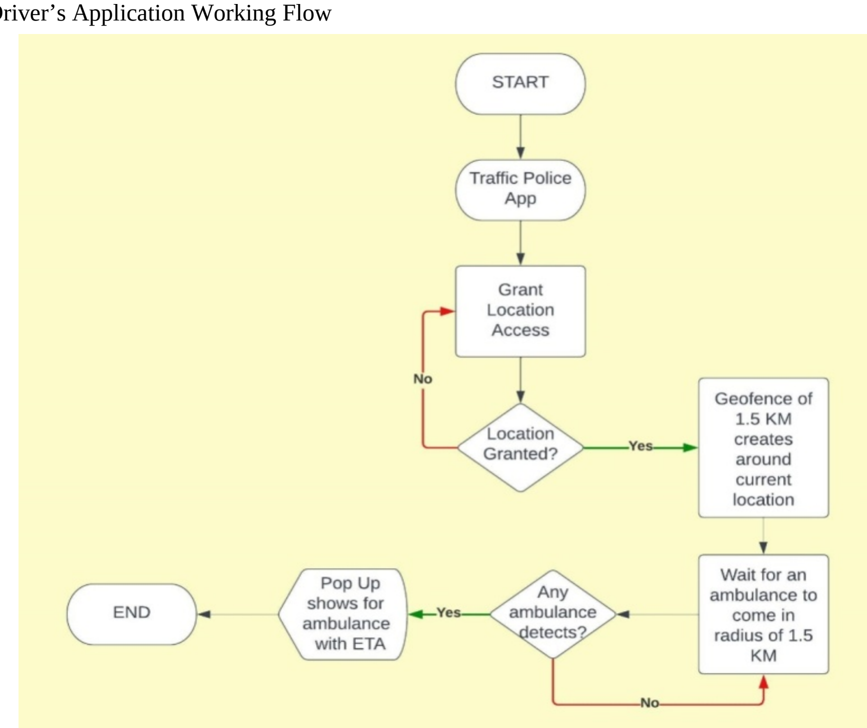

Figure 4. Traffic Police Officer's Application Working Flow

information about their location and ailment severity and request an ambulance based on the urgency of their situation when they need one.

The app then delivers the request to the backend system created with the help of GraphQL API and AWS Amplify. The backend system receives the request and processes it to locate the closest available and most capable ambulance driver. Once a driver is assigned, their real-time location is sent to the patient application using GraphQL API.

The patient can track the driver's location and estimated time of arrival (ETA) using Google Maps API and Distance Matrix API. The application also provides updates on the status of the ambulance and the driver's contact information.

2. Ambulance Driver’s Application Working

An ambulance driver receives the request for ambulance and according to their location they get real-time traffic information and optimized routes to get there as fast as possible

The Google Maps API and Directions API are used to provide the app with optimized routes and real-time traffic updates. Ambulance drivers have two options, either they can accept the request, or they can deny the request based on their availability. Once they accept the request, the user application receives their position and notifies them that an ambulance is in route. The app may then be used by the driver to find the patient's position. The driver may utilize the app to update the patient's status and transfer them to the medical Centre once they arrive at the patient's location

The backend server also updates the incident's status and the ambulance driver's availability. Using the mentioned API’s, the patient may follow the driver's whereabouts and estimated arrival time (ETA).

All registered ambulances in the inspector’s area are shown on a dashboard in the application for traffic police officers. Additionally, it enables traffic police inspectors to get notifications when an ambulance is nearby The dashboard has a database with the locations of traffic police officers and allows to receive instant alerts when an ambulance approaches them Every officer has a 1.5 km geofence radius defined by us. Police officer immediately receives an in-app notification whenever an ambulance approaches within the geofence's radius.

1. Traffic Police Officer’s Application Working
2. Working of Dijkstra Algorithm

The Dijkstra algorithm is utilized in our ambulance booking and dispatching system to identify the quickest route between the patient's location and the ambulance driver's present position. We must first comprehend the idea of a network to comprehend how the Dijkstra algorithm functions A graph is made up of vertices, also known as nodes, and edges, which bind the nodes together. Each vertex in our system corresponds to a specific position, such as the patient's or the ambulance driver's present location. The pathways between these places are shown by the edges, backend server to set up geofences around each traffic police officer

Table 2 Algorithm Steps Dijkstra's algorithm

Steps of Dijkstra's algorithm applied to smart routing of an ambulance in real-time:
Step 1. Model the City as a Graph
Step 2. Set Starting and Ending Points
Step 3. Initialize Distances and Priority Queue:
Use a priority queue to efficiently explore the graph. The priority queue prioritizes nodes with potentially shorter distances. Each element in the queue is a tuple containing (distance, node).
Step 4. Iterative Exploration:
While the priority queue is not empty:
Dequeue the node with the minimum distance (considered the "most promising" candidate for the shortest path).
If the dequeued node is the destination, stop the loop (shortest path found).
For each neighbor of the dequeued node:
Calculate the tentative distance to the neighbor by adding the edge weight between them to the current distance of the dequeued node.
If the tentative distance is less than the currently stored distance for the neighbor:
Update the neighbor's distance in the data structure.
Add the neighbor (along with its updated distance) to the priority queue.
Step 5. Shortest Path Reconstruction:
Once the destination node is found in step 4, backtrack through the "previous node" information stored during the exploration to reconstruct the actual shortest path from the ambulance's location to the destination.

This method operates by repeatedly travelling between the present location of the ambulance and the patient's location, starting at each vertex in the graph The method determines the distance between the present position of the ambulance and each vertex. The distance between each neighboring vertex that may be reached from the present vertex is then updated. This procedure continues until the algorithm locates the patient.

Google Maps API automatically implements a priority queue data structure to keep track of the unvisited vertices in order to improve the algorithm's speed. This makes it possible for us to choose the vertex with the minimum distance at each iteration, ensuring that we are constantly travelling in the direction of the patient along the shortest path.

In the proposed system, the fastest path for the ambulance driver to travel is determined using the Dijkstra algorithm, and GPS data. This reduces the travel time to the patient, which is crucial in an emergency where every second counts.

Working of ETA

Our system's ETA (Estimated Time of Arrival) feature is essential since it determines how long it will take to transfer a patient from the scene of the accident to the hospital. The distance between the accident scene and the medical institution, as well as the speed of the ambulance, are all considered when calculating the

ETA. The Distance Matrix API and Google Maps API's real-time traffic updates are used to get the ETA. These APIs deliver precise data on traffic conditions, including the current volume of traffic and the anticipated journey time. The Dijkstra algorithm is used by the app to determine the shortest and fastest route to the destination based on real-time traffic changes once the driver has entered the destination. The distance to the destination and the current traffic on the chosen route is then considered to determine the ETA.

As the ambulance moves closer to the destination, the ETA is updated continuously, and the app gives the driver up-to-the-second information on any traffic jams or delays that could have an impact on the ETA. Additionally, the app makes use of GPS technology to continuously track the ambulance's location and modify the ETA if necessary. As a result, the user will always receive an accurate and trustworthy ETA.

In conclusion, ETA is an essential part of the proposed system since it enables the prompt and effective evacuation of patients during emergencies. In order to offer precise and current information about the anticipated arrival time, the Dijkstra algorithm, real-time traffic updates, and GPS technology are combined.

Figure 5 depicts the User interface for user or patient side booking. Figure 6 is the accident report form where user can add location manually or automatically. Users can fill in the details such as name, type of accident; can also upload the image or video. Figure 7 shows ambulance driver side user interface where he can view the location. Figure 8 is the picture of location tracking from venue to nearby hospital. It also shows the distance and time to reach. Figures 9 and 10 are traffic police application user interface where police can nearby coming ambulances, its distance and time taken to reach.

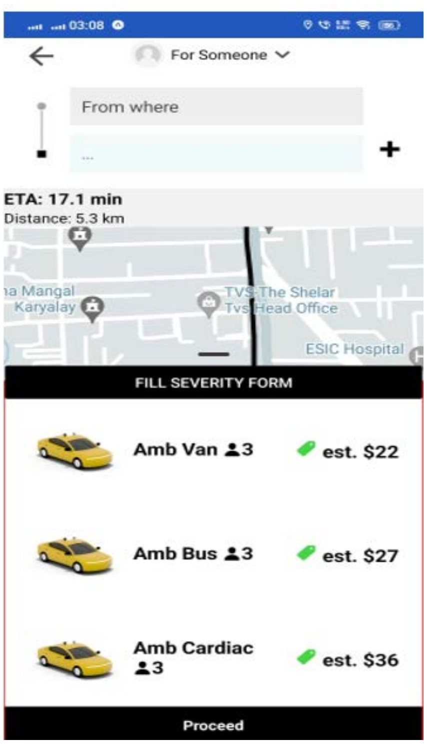

Figure 5. User Side UI

Challenges or Limitations of proposed approach:

1) Factors like weather conditions, vehicle type (ambulance may have different speed limits), or specific traffic regulations for emergency vehicles cannot be easily incorporated into the algorithm.
2) The routing algorithm considers only distance and no other potential factors like hospital capacity, availability of specialists, and potential delays at intersections.

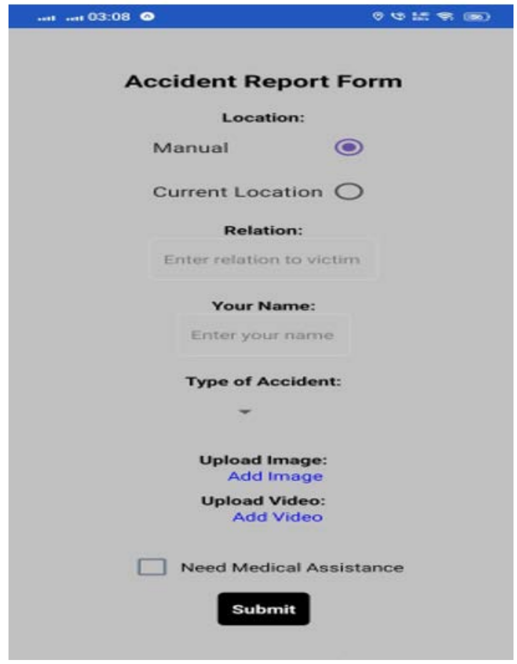

Figure 6. Accident Report Form

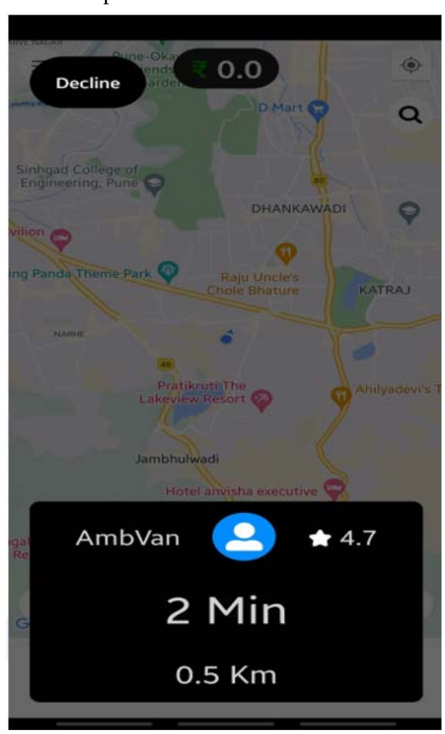

Figure 7. Ambulance Driver Side UI

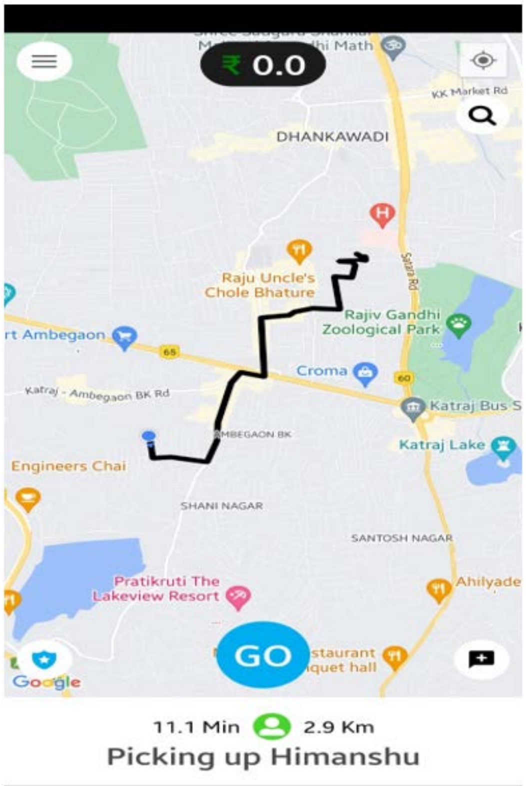

Figure 8. Driver side UI showing track

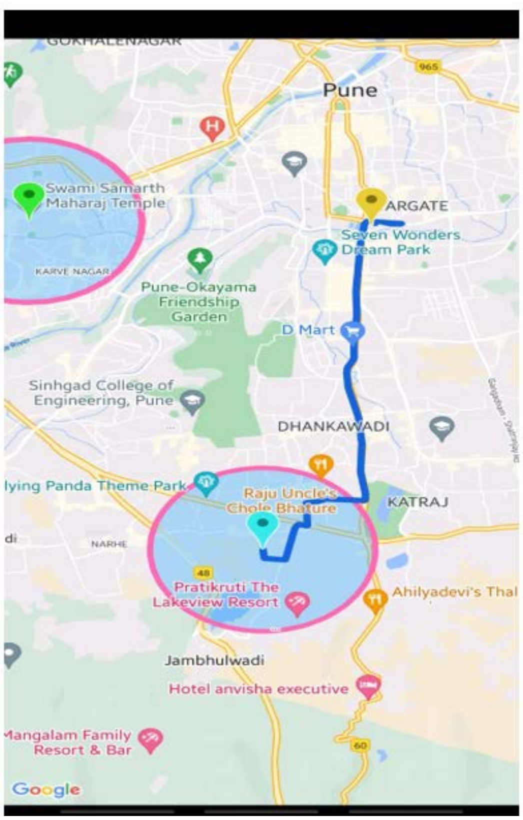

Figure 9. Police side UI showing real time ambulance location

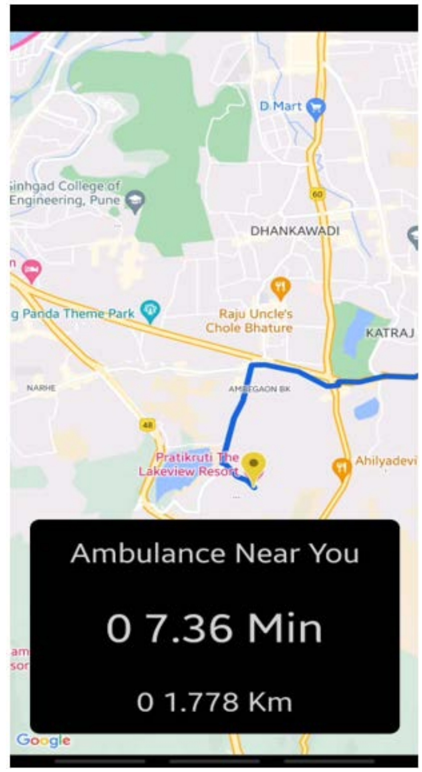

Figure 10. Police side UI ambulance near you

FUTURE SCOPE

The proposed system, which is created to alleviate ambulance service difficulties and improve emergency medical response, has enormous future development and enhancement potential.[14] Integrating the system with healthcare institutions is one area of future scope. Real-time exchange of patient information, medical data, and bed availability can be eased by creating seamless connections between ambulance services and hospitals. The whole process, from emergency response through hospital admission and treatment, would be streamlined, guaranteeing a smooth transfer and continuity of care. Artificial Intelligence (AI) and Machine Learning (ML) algorithms can significantly improve the system's capabilities. AI and ML systems can estimate demand, optimize resource allocation, and recommend the most effective routes in real-time by analyzing past ambulance data, traffic patterns, and emergency scenarios. Furthermore, AI-powered chatbots may give patients with immediate medical information and assistance before the ambulance comes, increasing the system's efficacy. Finally, the approach may be customized and used in other locations having comparable ambulance service issues. It may be customized to diverse healthcare systems and infrastructures by customizing the system according to local requirements and laws, expanding its reach beyond India.

CONCLUSION

This proposed work throws light on the essential problem of ambulance response time in emergency medical circumstances, especially in India. The worrisome figures and reports given show the critical need for an effective solution to enhance ambulance service timeliness and efficiency. The proposed system is a real-time ambulance reservation system and traffic management system. This solution makes use of technologies such as Firebase Authentication, React Native, and AWS Amplify to provide a unified user experience and secure authentication for patients, ambulance drivers, and traffic cops. This solution optimizes ambulance routing, response times, and coordination between drivers and traffic cops by integrating multiple APIs such as the Google Maps API, Google Places Auto Complete, and the Distance Matrix API, as well as Dijkstra algorithm, ETA, and GPS through Google Maps API. This not only allows for faster medical care for patients, but it also improves traffic management by immediately informing traffic cops of the ambulance's location for effective traffic clearance. The proposed system's multi-tiered architecture, which includes patient, driver, and inspector apps, tackles the issues faced by each participant in the ambulance service process. The results promise to reduce delays and optimize ambulance resource utilization by delivering real-time updates, optimized routes, and continuous communication.

Conflict of Interest Statement

Authors declare that there is no conflict of interest. The study's design, data collection and analysis, and manuscript writing were all done independently of the funders.

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