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ORIGINAL RESEARCH

Route Planning Service for Emergency Vehicles with Increased Accuracy and Efficiency for Online Platforms

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Abstract

There are a range of route-planning solutions available in daily use. When it comes to emergency circumstances, speed and efficiency are more important than luxury. The vast majority of these vehicles fall short of delivering swift and efficient transportation services. Our research resulted in the creation of a functional route-planning system for emergency services that may be used in a range of applications of electronic driver assistance, including those supplied by online emergency service providers. Real-Time Vehicle Navigation Systems most often employ a base map in combination with technologies, such as Global Positioning System (GPS), Vehicular Ad Hoc Network (VANET), Mobile Ad Hoc Network (MANET), and several sensors, to determine the location of a transport on the road. A real-time mechanism is crucial in an emergency; nevertheless, it is also necessary to have a time and energy-efficient route plan that varies according to geographic location, such as urban or rural regions. In this paper, we have researched with the effectiveness and applicability of the proposed solution on simulation which is based on maps provided by Google Maps for going from location A to B on different geographic situations. These findings indicate that the proposed strategy may be beneficial.

Keywords Driving assistance · Emergency vehicle · Global positioning · Route planning · Vehicle navigation

Introduction

Emergency vehicles are heart of all the contingency plans against any kind of danger or disastrous situation against mankind. To save lives and minimize damage to property, emergency services include ambulances, fire engines, police cars, and other vehicles. They are expected to arrive to the scene of the event as quickly as they can. 80% of seriously injured patients survive when rescued in 30 min, but that percentage drops to 40% and 10% when saved in 60 min and 80 min, respectively [1]. The goal of this study is to design a time and energy-efficient route-planning system that can be used on many internet platforms, exactly as the most recent online taxi services. These services can be implemented on current infrastructure with little or no additional changes to the workflow of existing emergency services. In this paper, we have put an emphasis on the ambulance sector. Another major goal of this research project is that there is a very narrow window of time in which emergency transportation requests are submitted and the process needs to be adaptive and reliable enough to send vehicles quickly to the situation. As a result, locating and dispersing idling vehicles within the target area are essential if we are to quickly serve people in need. As the number of cars on the road grows, traffic congestion and delays on urban arterials deteriorate; it is imperative to improve transportation safety and efficiency to reduce congestion and delays. All emergency vehicles are permitted to break the rules of the road to get to any critical locations as fast as possible, such as running through a red light at an intersection. To improve transportation safety and efficiency, emergency vehicle priority and signal preemption have to become mandatory features for every emergency vehicle. Response times to incidents are mostly determined by how quickly emergency responders can get at the location. It is the responsibility of the emergency service providers to locate ambulances so that patients may be rapidly reached in the case of an emergency.

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To accomplish these aims, we began using the vast infrastructure of the global positioning system (GPS) as the primary technology for determining the vehicle's real-time location. Second, we chose dispersed ad hoc networking over fixed networking infrastructure due to the high cost and extensive modifications required to the current workflow. We have used MANET and a subset of MANET called VANET for the road environment. Both of these networks are decentralized and can be utilized extremely effectively on the road since they need a little number of data packets to operate. By averaging the GPS and these networks' coordinates, we can determine the cars' present position on a real-time base map. We can determine the shortest route between the vehicle and the destination using proposed solution, a modified Dijkstra's method [2], and A* algorithm. Not only that, as we are now exclusively focusing on ambulance services, we can exchange critical information with online cloud service providers instead of using just a ping command to get precise position and traffic statistics from surrounding nodes. These information packets may include the vehicle's current position and direction, as well as the vital signs of the passengers, which could be critical for hospital preparedness. Additionally, our support service methodology will be self-calibrating depending on the sent or waiting location's geolocation. This calibration will ensure that the accuracy thresholds for the location determination technology being utilized satisfy the requirements and will eliminate false readings, because ad hoc nodes and GPS signals might differ depending on whether driver is in an urban or rural region. This will ensure the service's maximum applicability.

Materials and Methods

To offer the best possible driving assistance to an emergency vehicle, the system must be real-time and very precise. We examined current systems for general route-planning and the technology that underpins them for this study. We analyzed their study findings and determined the disadvantages and how other alternative services or algorithms may address them for our present application. Utilizing three distinct types of technology to support the process, such as GPS, MANET, and VANET, we will be able to determine the vehicle's location and position on the road, and utilizing their real-time location data we will be able to utilize well-documented efficient path finding algorithms, such as modified Dijkstra's and A*, to find the shortest path to the destination.

Global Positioning System (GPS)

A satellite constellation, ground stations, and satellite control stations make up the Global Positioning System (GPS). As shown in Fig. 1, it is a radio navigation system based in space. 31 GPS satellites now in the orbit of the Earth at an altitude of about 11,000 miles. They are delivering exact information on the user's coordinates, speed, and time under all weather conditions.

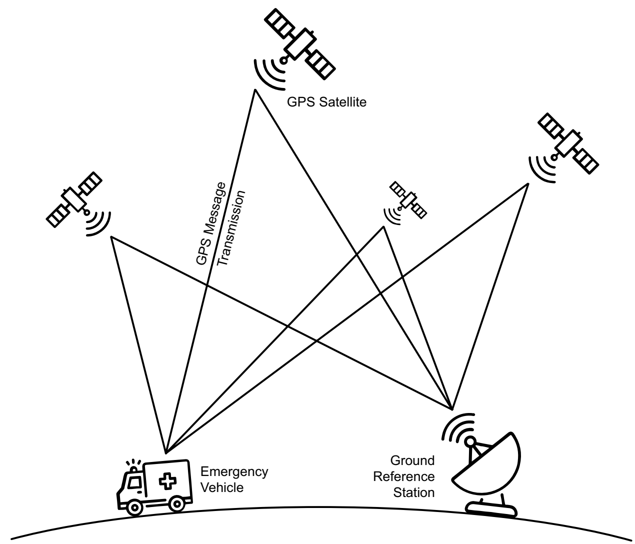


Fig. 1 Simple GPS Infrastructure

The GPS satellites in orbit around the Earth provide timed signals that a GPS receiver uses to pinpoint its exact position [3]. Each of these GPS satellites broadcasts signals continuously, which contains the time of the message was sent and the satellite's location at the moment the data packet was transmitted. The receiver receives and analyzes these messages to estimate the transit time of each message and utilizes the speed of light to calculate the distance from each satellite [4]. Each of these distances and the placements of the satellites constitutes a sphere. When the distances and satellite placements are accurate, the receiver is on the surface of each of these spheres. These distances and the positions of the satellites are utilized to determine the receiver's location using navigation equations based on the parameters extracted from GPS signal and a base sphered map. This position is then presented, maybe using a moving map or latitude and longitude coordinates; elevation data may also be added. Numerous GPS systems provide derived data, such as heading and speed, based on location changes.

Reference [5] developed a mobile navigation system capable of executing map searches and delivering local orientation using the Google Maps API. This solution is compatible with the vast majority of popular mobile phones as well as built-in car infotainment system.

Mobile Ad Hoc Network (MANET)

A mobile ad hoc network, also known as a wireless ad hoc network or an ad hoc wireless network, is a kind of ad hoc network that often has a routable networking environment on top of a Link Layer ad hoc network. They are made up of a collection of wirelessly linked mobile nodes that form a self-configuring, self-healing network without the need for a permanent infrastructure as shown in Fig. 2. MANET nodes are allowed to migrate freely due to the frequent changes in the network structure. Each node acts as a router, routing traffic to other nodes designated in the network.

Mobile devices may create a mobile ad hoc network by spontaneously connecting across a wireless channel. These could be through existing technologies like Bluetooth or Wireless LAN (WIFI) 802.11 standards. This eliminates the need for a centralized organization. While conventional networks are harder to build and maintain, MANETs offer significant benefits over them. This multi-hopping minimizes the risk of bottlenecks since routing is conducted independently by nodes utilizing other intermediary network nodes to forward the network packets [6]. However, the primary advantage of MANETs over wired solutions is their increased mobility. Although devices may interact directly over the wireless spectrum and route messages via intermediary nodes, the nature of wireless shared communication and mobile devices creates several routing and security concerns that must be solved prior to launching a MANET. Reference [7] conducted a study of the literature on the security of the AODV protocol, one of the most widely used MANET implementation protocols, and suggested Security-aware Ad Hoc On-demand Distance (SAODV) to solve the security concerns.

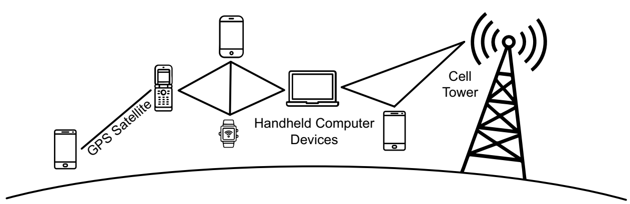


Fig. 2 Simple MANET Infrastructure

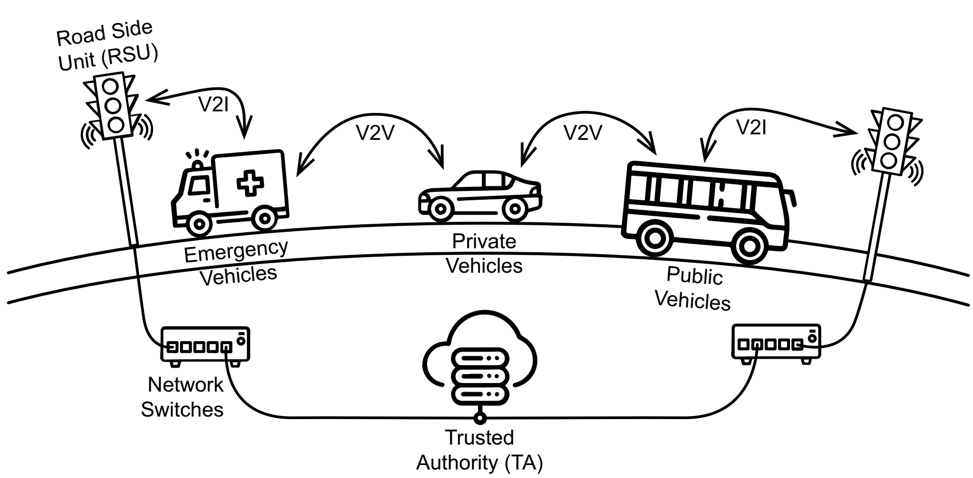
Wireless systems are simple and quick to install, need no wiring through walls or ceilings, and may be expanded to places that are not connected. It is more adaptable to changes in network configuration and provides greater flexibility. The need for quick deployment of autonomous mobile users inspired the development of Mobile Ad Hoc Networks.

Vehicular Ad Hoc Network (VANET)

The term "Vehicular Ad Hoc Network" is derived from the term "Mobile Ad Hoc Network" (MANET) for implementation on road transport. It may be characterized as an intelligent component of the transportation system since vehicles can interact with one another (V2V) and with roadside base stations (V2I) positioned at strategic spots along the route. It is a relatively new technology that has a crucial role to play in the Intelligent Transportation System (ITS) as shown in Fig. 3. The conventional mode of transportation has several flaws, including traffic congestion, accidents, delays, time wasting, and a lack of communication between cars and roadside equipment. Intelligent transportation systems have the potential to address these shortcomings using contemporary wireless communication technology with the goal of delivering important advantages, such as decreased accidents, reduced traffic congestion, and much safer and more comfortable travel [8].

Reference [9] suggested a VANET-based A* (VBA*) route-planning algorithm based on two real-time traffic information sources that are not used by conventional GPS navigation systems. The first source of traffic data is the route traveled by the vehicle. It is then sent wirelessly between automobiles through IEEE 802.11p. The second traffic data source is Google Maps. The VBA* application is then installed on Android using a GPS navigation app. The simulation results demonstrate that, as compared to

Fig. 3 Architecture of VANET with both V2V and V2I Communications



conventional route-planning algorithms, VBA* lowers average journey time and fuel usage. Reference [10] demonstrated a peer-to-peer traffic detection and avoidance system based on a VANET. This application makes use of a simple data collection and dissemination protocol to facilitate the exchange of information concerning traffic congestion. Running cars use the data to choose the optimal routes to their destinations based on traffic congestion. The program makes use of a dissemination-aware request-response geocast protocol to locate autos through GPS.

The high-speed dynamics of nodes and the quick change in network architecture provide substantial issues for the design of routing protocols in vehicular ad hoc networks (VANETs). Reference [11] presented a unique technique for location-based routing called Greedy Perimeter Coordinator Routing (GPCR). This strategy is capable of overcoming the restrictions inherent in metropolitan areas, where objects often block radio signals. By not needing external information such as a static street map, their solution circumvented the limitations that traditional position-based systems confront in this kind of situation. The AUTOPIA technique described in Ref. [12] is a V2I-based intelligent traffic management system. To avoid crashes and enhance traffic flow, a fuzzy-based control system has been developed that considers each vehicle's safe and comfortable distance and speed adjustment. To demonstrate its use, [13] developed a simulation for emergency vehicle route guidance and navigation using cooperative communication based on V2I. The goal of this system is to assist emergency vehicles in reaching their destination by coordinating traffic information over wireless networks. To create a realistic mobility model, the simulation makes use of the Federated Mobility Model. The mobility model allows the traffic generator and network simulator to be integrated concurrently.

Efficient Pathfinding Algorithms

Map-matching algorithms are critical components of land vehicle navigation systems because they improve the precision of vehicle location solutions. As previously described, a map-matching process is a technique for merging digital map data with data from a positioning system. Geometric, topological, and sophisticated algorithms are used to classify map-matching methods. Geometric map-matching algorithms make use of just geometric data, such as the geometry of line segments. A topological map-matching technique makes use of topological information, such as road segment connection, bearing, and road features. Advanced map-matching algorithms make use of sophisticated statistical, mathematical, and artificial intelligence approaches, such as the Kalman Filter or fuzzy logic [14].

Dijkstra's method is a greedy algorithm for optimizing and determining the shortest route between two hops in a network. Edsger W. Dijkstra proposed the Dijkstra's algorithm, which is an extremely efficient algorithm [15]. There are several variations of this algorithm. In the original approach, the shortest path between two nodes was identified. To do this, a single node is established as the source and the shortest way to all other nodes is calculated. As well, this is the principle upon which Google Maps is built, calculating and displaying the quickest route between two places [16]. The approach provided by [2] makes use of the nearby list data structure and the concept of restricted searching area; it also makes use of the spatial distribution characteristic of the real road network to confine the searching zone appropriately. Finally, it is shown that this technique outperforms the standard Dijkstra algorithm when used to Real-Time Vehicle Navigation Systems (RTVNS).

However, this algorithm has one flaw. Owing to the near-infinite or uncountable number of nodes in Google Maps, the increasing complexity of time and space makes this approach vulnerable to failure. To solve this problem, we may use the A* algorithm. The A* graph method is one of the most efficient graph traversal and path search algorithms available, having been designed specifically for weighted graphs. Due to its completeness, optimality, and efficiency, this approach is chosen. Similar to the Dijkstra algorithm, but A* applies heuristics to determine the most efficient path while Dijkstra just goes in search of every available route. Unlike Dijkstra's method, the A* algorithm concentrates on just the target nodes and ignores all other nodes. Consequently, this approach is more efficient. Additionally, it considers characteristics, such as time constraints, distance, and so on, optimizing and selecting the best nodes. As a result of the algorithm's excellent accuracy and capacity to cope with massive amounts of data and vast graphs, Google Maps now employs it to find the quickest route. VBA* is a route-planning algorithm that utilizes two different sources of real-time traffic information [9]. The trip data of an individual vehicle are the main source of traffic information for that vehicle. IEEE 802.11p is used to transmit data wirelessly between cars. And the second source of traffic is Google Maps. Kalman filters are used to account for imperfections in the multiple identified likely states that an automobile may be in [3]. The KFs are then linked into a system called an Integrated Management Module (IMM) that forecasts the vehicle's future location. To reduce the IMM prediction error, this study employs an iterated geometrical error detection technique based on GIS data.

From all of these methods, we may choose the one that is most suited for our use case and is quick enough to discover the shortest route to the destination utilizing the finest real-time geolocation data available through GPS and ad hoc networking for an always-running distributed road network system.

Proposed System Design and Architecture Design

We have presented a new network architecture that incorporates all of the technologies mentioned previously. As illustrated in Fig. 4, the GPS receiving service will be installed on both the emergency vehicle's on-board system and the driver's phone. Through switches, traffic light poles will be connected to the internet via a trusted authority, such as a mobile network service provider or local ISP. On these traffic light poles, a proper radio transistor can be placed, converting them into RSUs. Additionally, MANET can be established using a driver's phone that is connected to the vehicle via a cable or Bluetooth connection. As illustrated in the Fig. 4, all of these networks will communicate with one another via a communication channel. The suggested design ensures that the whole system operates in perfect synchrony from cold boot to fully operational state. The following is a step-by-step description of the process flow.

Step 1: Calibrate the sensors for connection.

This procedure begins with the first installation of the service on a vehicle. The vehicle's on-board technology will establish a connection with the driver's phone and self-calibrate. Generally, it is a one-time configuration, but if the driver deviates considerably from the original geolocation of the setup or if one or more sensor services fall below the threshold or are turned off, it will self-calibrate to the best settings.

Step a: GPS: After successfully receiving GPS satellite transmissions on both the phone and the on-board system, the phone's and on-board system's current coordinates will be computed and averaged out for increased accuracy.

Step b: MANET: The MANET transceiver (the driver's phone) will attempt to connect to the closest mobile nodes and determine their availability and signal quality.

Step c: VANET: On board VANET transceiver will try to connect the nearest vehicle node or road side unit (RSU) and also calculate its availability along with signal strength.

Step 2: Calculate the sensor's threshold.

This procedure determines the most appropriate threshold value for each sensor reading. While running, this determines whether the signal strength or node count is sufficient to evaluate a viable choice. This threshold value will be maintained in the system along with the

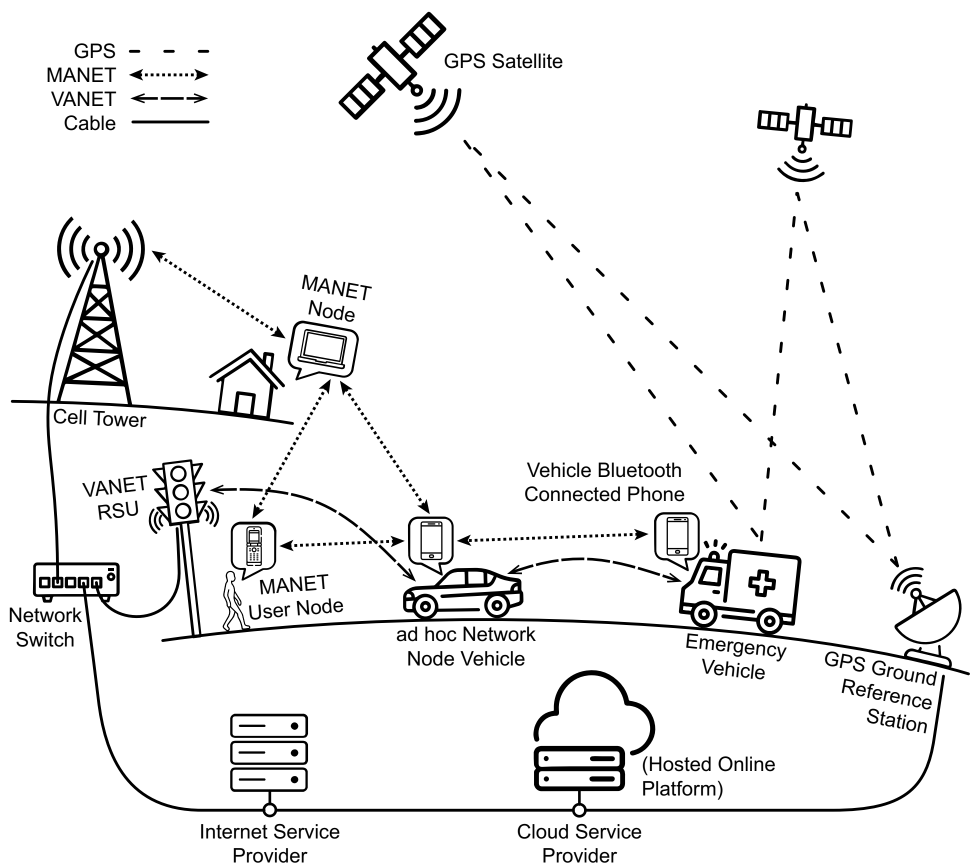


Fig. 4 Proposed Architecture of Emergency Vehicles Route Planning System for Driver Assistance via Online Platforms utilizing GPS & MANET on the driver's phone, and on-board VANET of the vehicle

geolocation associated with it, thus allowing it to self-calibrate in the event of a change in the overall location.

Step 3: Establish connection and real-time location.

This procedure initiates the system's primary functions. It will attempt to connect via all three technologies and will evaluate the reading quality. If the sensors' thresholds are met, declare them accessible and run the following commands.

Step a: Using the GPS receivers on board and on the driver's Bluetooth-connected phone, obtain an average value and a fixed location on the Google Maps API-provided base map.

Step b: Based on signal strength use MANET or VANET transceiver, establish a solid Internet connection and connect to the online emergency service provider's server platform. Through that network, the navigation data generated in subsequent phases are shared with the appropriate parties, such as service providers, patients, and hospitals.

Step c: If MANET is available, then connect to adjacent mobile nodes and exchange current positions, traffic information, and emergency status. Adjust self-position on the map after receiving the positions of neighboring nodes, as well as their own location and signal strength.

Step d: If VANET is available, then check for availability of vehicle-to-vehicle communication (V2V) as well as vehicle-to-infrastructure communication (V2I).

Step i: If V2V is available, then connect to nearby vehicle nodes and share current positions, traffic information and emergency status too. Upon receiving the positions of nearby nodes along with their own location and signal strength, fine-tune self-position on the map.

Step ii: If V2I is discovered, then check the intersections or road segments information from the road side unit (RSU) and determine more accurate position on the map.

Step 4: Find shortest path and finish the mission.

After securing real-time position monitoring on the base map, use a modified Dijkstra's algorithm along with A* over VANET to determine the shortest and most efficient path from start to destination utilizing real-time traffic data from the RSU and the current location as primary parameter. Share the current location and heading of the vehicle with the specified user and server of online emergency service providers via the on-board internet connection. Additionally, share these data with the hospital for treatment preparation, including emergency information such as risky patients' vitals.

Implementation and Analysis

It is quite simple to implement the project over existing emergency services provided by specific institutions, such as ambulance services provided by multiple hospitals. When an online platform wishes to incorporate 'route-planning driving help' into their services, they must first acquire a base map supplier that provides GPS access. Access to the base map and GPS data will require either Google Maps or the MAPBOX API. They must develop their own mobile application for accessing MANET and VANET data. While car connection features, such as Android Auto or Car Play, make life easier, they are not required for vehicles. Although decentralized ad hoc networking has not got any large implementation at the time of authoring this article, MANET will be required to maximize the performance of this concept. However, mobile internet is practically universally available at this time via cell towers. Given the little quantity of data necessary to operate this system, in this age of centralized infrastructure, this decentralized network architecture will function adequately well with the assistance of a mobile hotspot. Finally, to construct a good VANET with highest availability, RSU must be installed. The majority of traffic light posts currently have network connectivity for CCTV and a central traffic control system. This will be more efficient if a dedicated port with a VANET transceiver is installed on these poles.

Results and Discussion

In reality, it is quite difficult to execute a huge scale decentralized project of this kind and track all relevant data like as journey distance, speed, energy consumption, and speed. To evaluate and demonstrate the practicality and efficiency of our suggested solution, we can simulate our architecture using "Simulation of Urban MObility (SUMO)", "Network Simulator 3 (NS-3)", and "OpenStreetMap (OSM)". We have built a SUMO configuration file, osm.sumocfg, using OSM to later generate a trace file for simulation on NS-3. We ran SUMO on both the Dijkstra and the A* algorithms. Then, for 50 min, we ran the trace files on NS-3 for eight total nodes and obtained our performance results for eight of those nodes, including total traveled distance and time, as well as all fuel and emission metrics. These results have been put on a Time-Fuel chart as Fig. 5. Throughout the experiment, eight cars were dispatched in a variety of time intervals, including one gap as non-peak hour to cut the local ad hoc connection and use standalone GPS and V2I communications. By

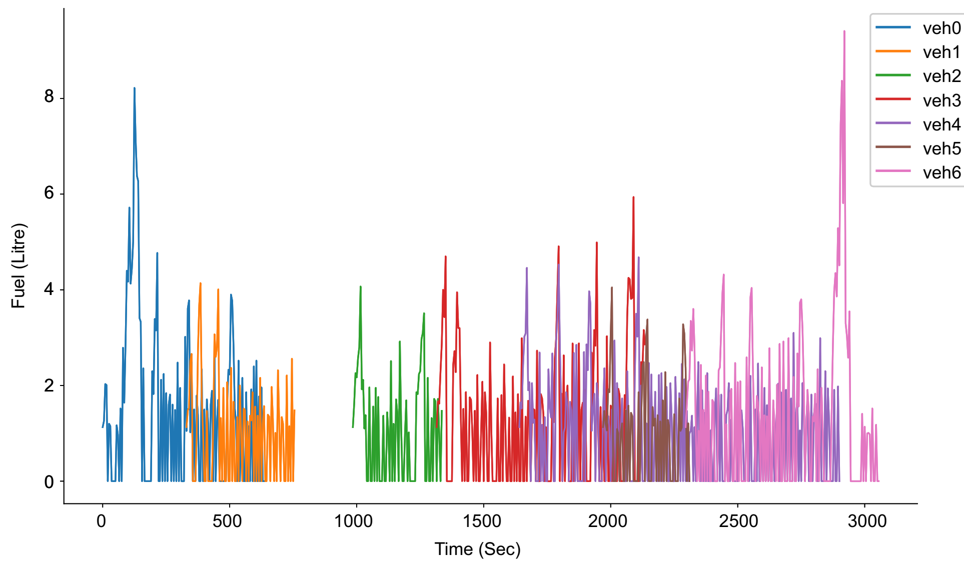


Fig. 5 Simulation Result Plot of proposed network architecture ran on our Institution Map

comparing these results to previous efforts, we can see that our performance was nearly as efficient as [9], despite the fact that we used three distinct technologies to determine accurate real-time location along with the default navigation algorithms used by major navigation services [16].

We can see the effect of adjusting the degree of traffic congestion on travel time and the average speed of cars based on these assessment and analysis results. It is demonstrated that our proposed model can be used to effectively and efficiently to manage emergency vehicle route-planning. Even if one or more connectivity options are disabled, the service remains operational, making it more acceptable and applicable for emergency scenarios.

Conclusion

In this study, we offer a comprehensive system architecture for route-planning for emergency vehicles on the road by connecting and synchronizing disparate technologies and services for improved performance, accuracy, and efficiency. We have blended age old GPS technology with modern decentralized ad hoc network concepts. To avoid bottlenecking, we developed a step-by-step procedure for the system from boot to operation for multiple hardware interfaces such as the on-board infotainment system on the dash to the diver's phone. As we know faster accuracy takes precedence over all other parameters during an emergency. MANET and its road-applicable component VANET were included to provide dual channel connectivity and accuracy. In contrast to other existing systems, our entire service can be deployed as a cloud-based or decentralized system. Additionally, it features self-calibrating capabilities, which can be extremely beneficial when traveling long distances or relocating to a completely new geographic region where GPS or other networking signal threshold values must be adjusted for optimal operation. These findings imply that the proposed technique is highly practicable in a situation where emergency vehicle services are delivered online via cloud or decentralized infrastructure.

Although great effort has been made to address issues related to emergency vehicle planning and operation, topics for further research remain. To begin, we leveraged existing traffic light systems as VANET RSUs, to upgrade this could interact directly with the vehicle's urgency level and control congested traffic conditions to improve response time. Second, these decentralized algorithms must be applied in some real-world test settings to mitigate deployment uncertainty. Third, as a result of these real-world test results, a large amount of data can be evaluated and the resulting dataset utilized to train some deep learning models that have the potential to radically scale the future direction of this study subject. This architecture should be considered in future for developing a successful interconnected autonomous vehicle technology.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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