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GPS Based Shortest Path for Ambulances using VANETs

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Abstract. Cities and traffic go hand in hand drawing inhabitants to congregate in large urban areas which lead to intolerable levels of traffic congestion. Effective urban governance requires a compromise between agglomeration and excessive congestion. Congestion poses challenge for transporting lifesaving drugs and equipments, patients, accident victims, defence equipments, immunation, currency chest etc. In this paper, VANET based efficient navigation system for ambulances in real time traffic congestion is estimated through a centralized dispatch centre to avoid unexpected congestion and follow the shortest path to the destination (hospital) based on historical data and the updates of real time traffic information. A dynamic routing system has been developed which includes the metro rail network along with road transport system to guide ambulances in real time scenarios. IEEE 802.11p has been implemented at the Physical and Medium Access Control(MAC) layers of the WAVE protocol stack which was considered for a metropolitan city over an unpredictable high density of vehicles and Dijkstra's algorithm has been employed to compute the shortest path using the time variable considering non-recurring congestion as a result of unexpected incidents, thereby arriving at the shortest path in minimum time to the destination. Results show that inclusion of metro reduces the travel time by a good margin, decreasing the response time of ambulances.

Keywords: Dynamic routing system, Metro transportation, VANETs, ITS, WAVE, IEEE802.11p, Dijkstra's Algorithm.

1. Introduction

Transportation has always been a crucial aspect due to the rapid increase in the number of vehicles and in the transportation demand in virtually all transportation modes leading to congestion in an attempt to use a common transportation infrastructure in limited capacity. The vehicles themselves must be able to communicate with each other to tackle congestion through Intelligent Transport Systems with the involvement of VANETS to achieve intelligent inter-vehicle communications, seamless Internet connectivity resulting in improved road safety, essential alerts and accessing entertainment and news. IEEE 802.11p WAVE protocol provides accurate and efficient networks in dynamically mobile nodes which is utilized in the proposed work.

Equipping vehicles with communication devices turns them into efficient data collectors. Distributed applications can be implemented over this infrastructure to detect congestion and propagate congestion information to future vehicles enroute to the congestion area making it possible for the driver to seek alternate routes to avoid the congestion. Congestion detection algorithms are designed to detect areas of high traffic density and low speeds. Each node captures and disseminates information such as location and speed and processes the information received from other nodes in the network.

Traffic congestion is a major reason that affects the travel time of emergency vehicles and increases the response time of medical services. Dynamic routing for the ambulance is necessary in coordination with metro rail to reach the victims and shift them to the nearest hospital. Effective routing of ambulance will thus minimize its response time and improve the performance during emergency.

The method proposed in Performance Evaluation of IEEE 802.11p for Vehicular Traffic Congestion Control for congestion detection is extended to determine the shortest path for ambulances in this paper.

1.1. VEHICULAR AD-HOC NETWORKS (VANETs)

VANETs are a class of Mobile Ad-Hoc Networks (MANETs). They can provide communication between the vehicles (nodes) i.e. Vehicle-to-vehicle (V2V) communication and/or communication between vehicles and the roadside infrastructure i.e. Vehicle-to-infrastructure(V2I) communication. The vehicles and the associated infrastructure (all nodes) are equipped to gather data, process it to determine present traffic conditions and disseminate it over longer distances and provide other traffic related services related to toll ticketing, monitoring, collision warning, road signal alarms and so on. VANETs help provide safety and comfort for passengers through intelligent use of networking. Recent research efforts have placed a strong emphasis on novel VANET design architectures and implementations. Emphasis has been laid on areas like broadcasting, routing, security and quality of service (QoS).

Characteristics of VANETs:

•Highly Dynamic Topology:-The highly dynamic topology of a VANET is defined by the speed of the vehicles and their path.

• Frequently Disconnected Network:-The consequence of the above property is that the link has to be re-established with other nodes as soon as possible for seamless connectivity to be maintained.

• Mobility Model and Prediction:-Maintaining connectivity ensues that the positions of the nodes and their movements are to be predicted. A mobility model and node prediction based on study of predefined roadways model and vehicle speed is of paramount importance for an effective network design.

•Communication Environment:-The node prediction design and routing algorithm need to adapt depending on the different mobility scenarios.

•Hard Delay Constraints:-The safety aspect (such as accidents, brake event) of VANET application warrants on time delivery of message to relevant nodes. High data rates are not as important an issue for VANET as overcoming the issues of hard delay constraints.

• Interaction with on-board sensors:-Sensors help in providing information such as node location, nature of movement, system status information and are used for effective communication and routing.

1.2. INTELLIGENT TRANSPORT SYSTEMS (ITS)

An Intelligent Transport System (ITS) deploys communication systems in the form of satellite location (used in GPS), mobile telephony or wireless networks. Interest in ITS comes from the problems caused by traffic congestion and a synergy of new information technology for simulation, real-time control and communications networks. Congestion reduce efficiency of transportation infrastructure and increases travel time, air pollution, and fuel consumption. VANETs are a meaningful component of ITS system, which provides an infrastructure based frame work and all related applications taking full advantage of the Vehicle-2-Vehicle (V2V) communications. Development of VANETS can further enhance driving safety and support the traditional traffic management concerned with activity on the road ahead and not behind. The intelligent transport applications offers service which helps in getting instant accident information, alert at dead crossing, location of nearby motel and gas stations etc. Besides the analysis of traffic congestion and mobility, data could help develop optimum traffic signal system for efficient traffic flow while comfort applications offered are internet connectivity, multimedia access etc.

1.3. WIRELESS ACCESS IN VEHICULAR ENVIRONMENT (WAVE)

Vehicular traffic scenarios have greater challenges than fixed wireless networks, caused by varying driving speeds, traffic patterns, and driving environments. To address challenging requirements of IEEE MAC operations for vehicular communication scenario, IEEE802.11p Wireless Access in Vehicular Environments (WAVE) was introduced. 802.11p is an IEEE standard that supports Intelligent Transportation Systems (ITS)applications in the context of vehicle to-vehicle(V2V) and vehicle to infrastructure communications(V2I) that are being developed, namely the DSRC(Dedicated Short Range Communications) operating in 5.9 GHz band. WAVE has become a standard that can be universally adopted across the world compared to the regional standards of DSRC. At present DSRC based on the Wi-Fi standard is widely used in VANETs as it connects infrastructure to vehicles and also vehicles-to-vehicles using two way short range radio which is of lower costs compared to other wireless standards available. DSRC/WAVE systems fill a niche in the wireless infrastructure by facilitating low latency, geographically local, high data rate, and high mobility communications.

1.4. DIJKSTRA'S ALGORITHM

Dijkstra's algorithm is a graph search algorithm that solves the single-source shortest path problem for a graph with nonnegative edge path costs, producing a shortest path tree. This algorithm is used in routing and as a subroutine in other graph algorithms. For a given source vertex (node) in the graph, the algorithm finds the path with lowest cost(i.e. the shortest path) between that vertex and every other vertex. It can also be used for finding costs of shortest paths from a single vertex to a single destination vertex by stopping the algorithm once the shortest path to the destination vertex has been determined. For example, if the vertices of the graph represent cities and edge path costs represent driving distances between pairs of cities connected by a direct road, Dijkstra's algorithm can be used to find the shortest route between one city and all other cities. As a result, the shortest path first is widely used in network routing protocols, most notably IS-IS and OSPF(Open Shortest Path First).This is asymptotically the shortest known single-source shortest-path algorithm for arbitrary directed graphs with unbounded nonnegative weights.

2. IMPLEMENTATION

2.1. ASSUMPTION

- Existence of a widespread metro transport system that connects all parts of the city.
- Availability of sufficient VANET modules in the routes in order to detect traffic pile up.
- Infrastructure such as GPS, communication link and two way radio is provided, Fig.1.
- Presence of a Dispatch Centre (DC) that serves the purpose of information exchange.
- Existence of an updated database of the arrival and departure of all metros and accessible to the dispatch centre.
- Existence of Road side units (RSU) at suitable locations which might be inaccessible due to restrictions for propagation of signal.
- Availability of a separate medical compartment in the metro to transport patients.

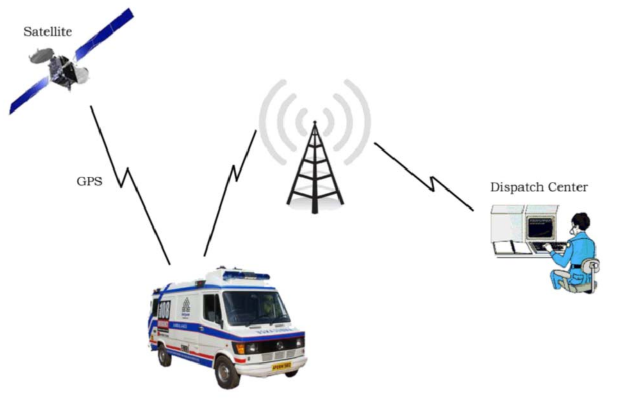

Fig.1. Proposed system network

2.2. OVERALL VIEW

In this study, Dijkstra's algorithm is used with certain modifications. Instead of using the distance, time taken to cover the distance between the nodes is considered as the node weight making this a dynamic model. The time taken is calculated using the speed and distance variables. The speed considered is the average speed with which the vehicles are traversing the path that can be obtained from the vehicles dynamically with the help of VANETS. Since distance is time-invariant, the time taken is calculated by taking the ratio of the distance and speed between the nodes. The Dijkstra's algorithm is run at the centralized DC to obtain the shortest path between the source and the destination. Once the shortest path is obtained, the DC checks for presence of metro at that instant in the path, else the Dijkstra's algorithm is rerun to obtain the new shortest path between the source and the destination to determine the final shortest path and communicated to the ambulance, Fig.2.

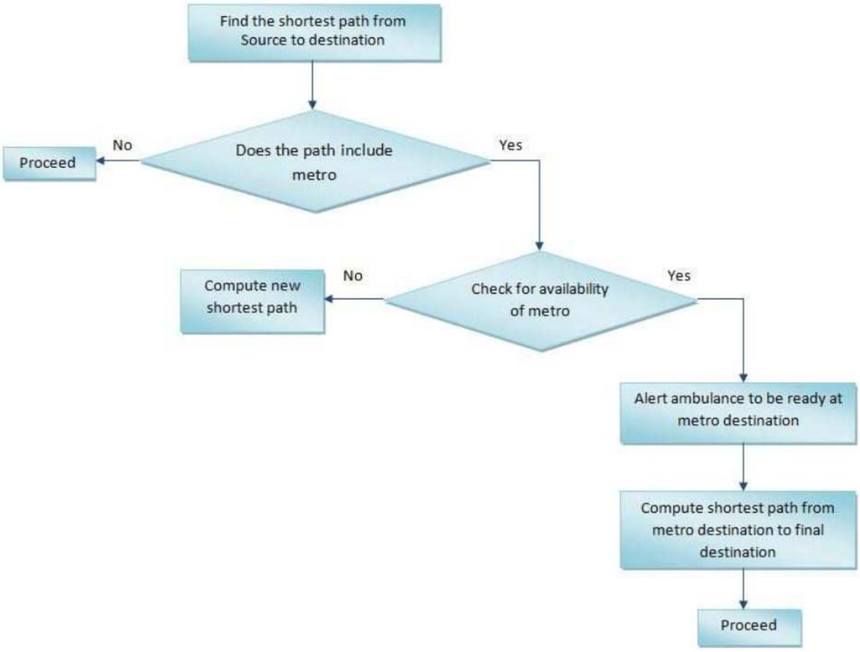

Fig.2. Determing the shortest path for ambulance

Once the final path is obtained, it is sent to the ambulance. Any congestion between nodes along the source and destination is reported to the dispatch centre. The DC checks the location of the ambulance using GPS to determine congestion ahead else ignored so as to determine alternate route, Fig.3.

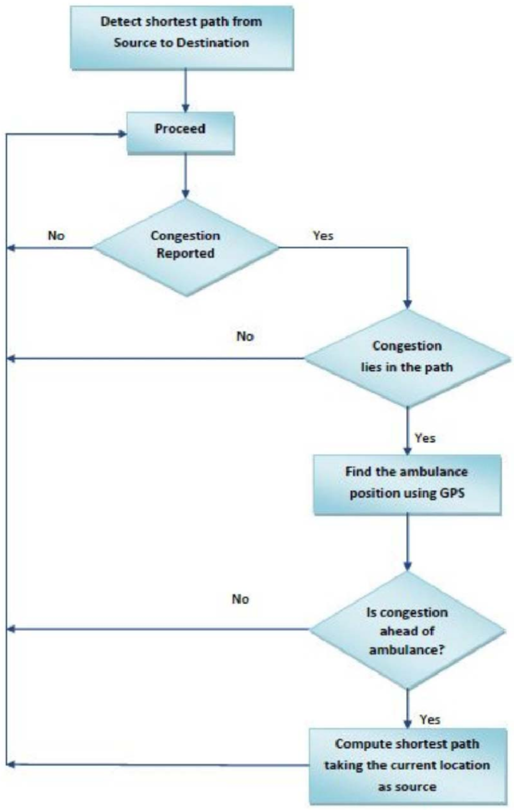

Fig. 3. Congestion detection and avoidance

3. CONGESTION DETECTION

The congestion detection algorithm works with vehicle parameters derived from a Global Positioning System (GPS) device. The congestion is said to be existing when large clusters of slow moving nodes are present. This information may be stored and retrieved from a centralized system or passed on normally from vehicle to vehicle. Road-Side Unit (RSU), the Passive unit (repeater) is deployed to transmit data during blind spots along which vehicles would not traverse or obstacles being present restricting propagation of signal where in there is a demand from the centralised location at any instant to perform other intelligent operations.

The information thus obtained is then presented to the dispatch centre on the existing On-Board Units (OBUs) or via text messages. The main parameters used are the speed of the vehicle, location of the vehicle, direction, type of road or junction, time of the day and allowable vehicular density of the roads in the algorithm. All vehicles (vehicular nodes) are GPS enabled to read the parameters and broadcast to the neighbouring vehicles (vehicular nodes). Periodically the vehicular node updates the speed of its neighbouring vehicular nodes to predict a possible congestion and transfers this information. If the vehicular nodes around these are not moving at a slower speed than this vehicular node, they increment a counter to indicate the number of vehicles moving normally. In case the neighbouring vehicle agrees with the congestion state of the initializing vehicle, a congestion counter is incremented and as the value exceeds the normal moving vehicles values by a certain predefined limit, then congestion is confirmed. Vehicle receiving any information checks its own status for congestion and proceeds; else it updates and transmits congestion information into the geographical map with a flag indicating modified information by the immediate sender.

4. SIMULATION AND RESULTS

A topology of traffic network of Bengaluru (India) which includes metro, Fig.4, was chosen for the real time simulation with 39 nodes considered where each node represents a junction. The connectivity between nodes can be via road or metro, each connection is assigned a line weight which is an estimation of travel time between the nodes connected. In Turbo C simulation, the shortest path is highlighted in red and the metro path is highlighted in magenta in both cases.

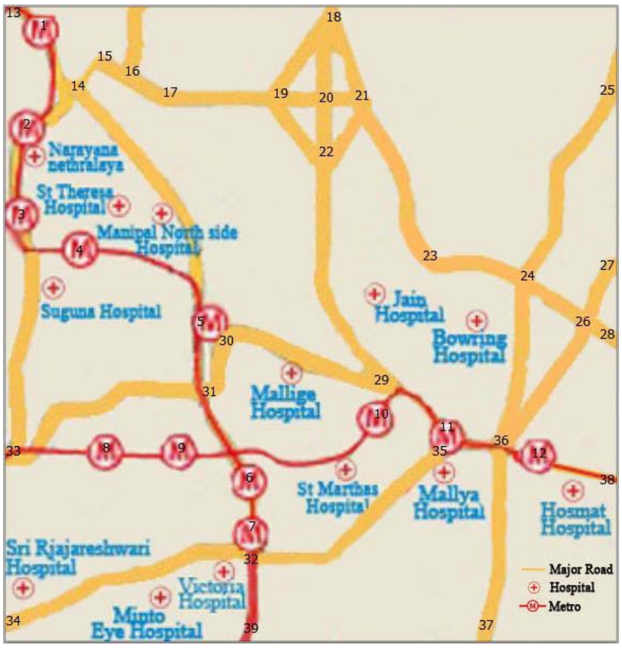

Fig. 4. Topology considered

CASE 1: This case simulates the shortest path from source to destination without inclusion of metro in the path. Node 14 is the source and node 39 as the destination. The simulator uses Dijkstra's algorithm to determine the shortest path, Fig.6, which is highlighted in red, Fig.5 and the total travel time is also calculated.

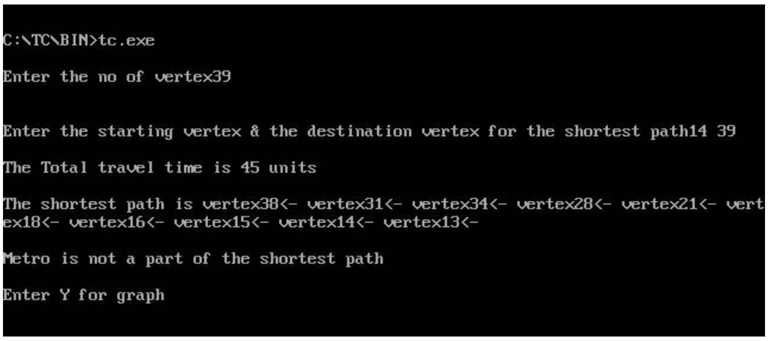

Fig. 5. Simulated path for case 1

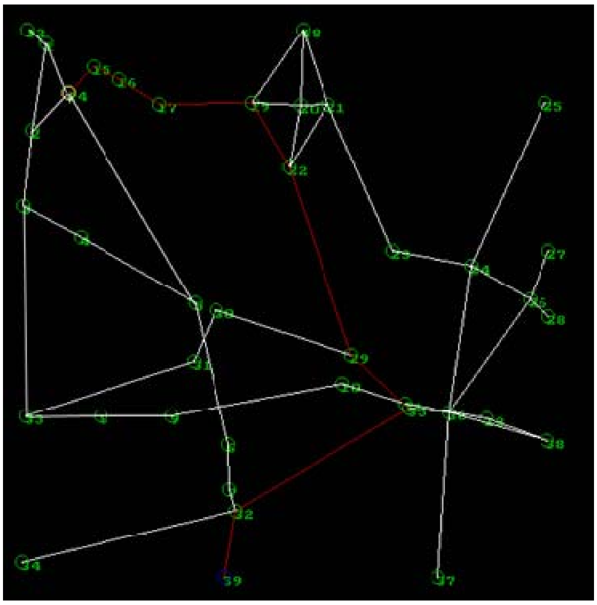

Fig. 6. Screen shot for case 1

CASE 2: In the second case simulation of the shortest path from source to destination with the inclusion of metro in its path with Node 14 as the source and node 39 as the destination is obtained, Fig.7, and is highlighted in red, Fig.8.

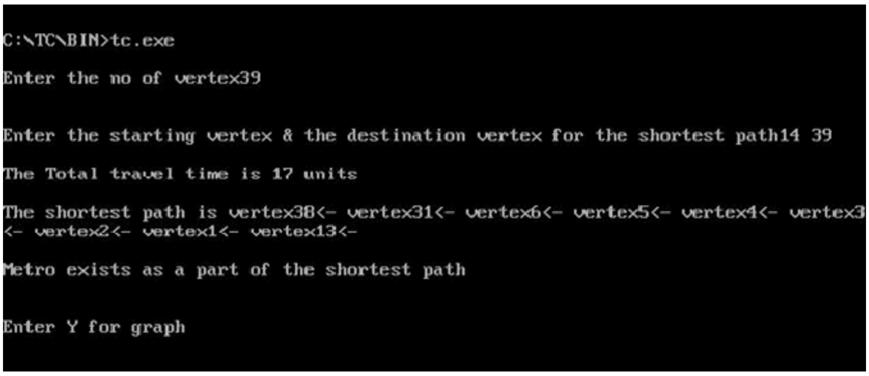

Fig. 7. Screen shot for case 2

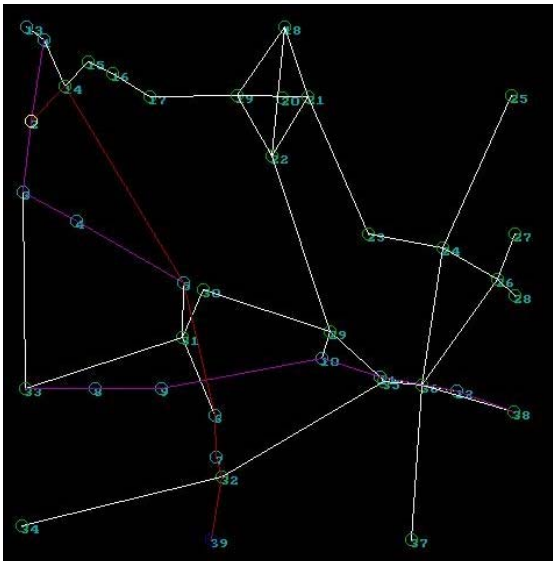

Fig. 8. Simulated path for case 2

Comparing Case 1 and 2 shows that inclusion of Metro reduces the travel time by a good margin, increasing the response time of ambulances which helps to transport the patients faster.

5. CONCLUSION AND FUTURE WORK

This study addresses the problem of determining dynamic shortest path in traffic networks, where travel times vary over time. This study proposes a dynamic routing system which is based on the integration of GPS and real-time traffic conditions. It uses GPS for determining the position of the emergency vehicle and helps in obtaining the shortest path to the destination. This is used as a powerful functionality for planning optimal routes based on online travel time information. The results of this study illustrate that dynamic routing of emergency vehicle compared with static solution is much more efficient. This efficiency will be most important when unwanted incident takes place in roads and serious traffic congestion is occurred. In this study, the initial planned route is saved since when real-time data is received only portion of the planned path may be changed. This improves the computational performance than re-computing from scratch which is the main idea of dynamic shortest path algorithm. This study also involves integration of the road transport system with Metro which leads to a well-developed transport system for emergency vehicles. Developing a dynamic routing system for not just emergency vehicles, but all vehicles using urban road and rail network in the case of accidents or other mishaps has some special considerations which can be the subject of future work.

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