STUDY OF LOCALIZATION TECHNIQUES IN VEHICULAR AD-HOC NETWORKS

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ABSTRACT

In VANET, vehicle communicates with each other and also with roadside unit which provides various applications such as traffic safety, driver assistance, and internet access. Most of these applications need to know the precise current location of vehicle in real time. Most common technique for knowing the location of vehicle is with the help GPS. In this technique, GPS receiver embedded into the vehicle receives signal from satellite. But this technique will not work in the tunnels, undergrounds or near tall buildings. In this paper, there will be discussion about various localization techniques based on GPS, RFID as well as clustering.

Keywords: Localization, RFID, Vehicular Ad-hoc Network

1. INTRODUCTION

Vehicular Ad-hoc Network (VANET) comprises of vehicles moving at very high speed [1]. In VANET, communication takes place either between two vehicles or between vehicle and infrastructure. For some of the applications of VANET, protocol needs knowledge of real time position of nodes that are moving with variable speed. One way to obtain position of nodes is to use Global Positioning System (GPS). In this, each vehicle has GPS receiver mounted on it which will give position of vehicle by receiving signal from satellite. But this technique will not work in the environment such as tunnel, underground or near tall buildings.

VANET is capable of providing various services like safety application, Convenience application. Further, safety application contains application like, vehicular collision warning system, security distance warning, and cooperative cruise control. On the other side, convenience application contains application like driver assistance, cooperative driving, automatic parking, driverless vehicles, Map location, etc. [2].

In Intelligent Transport System (ITS), vehicles are having communication equipment that is used to exchange messages with each other in Vehicle-to-Vehicle (V2V) communication and also
used to exchange messages with roadside network infrastructure i.e. Vehicle-to-Roadside infrastructure communication (V2R).

The organization of this paper is as follows: In the next section, there will be discussion about various location-aware VANET applications. Section III shows various existing localization techniques available in VANET. Finally, section IV contains some concluding remarks.

2. LOCATION AWARE VANET APPLICATIONS

There are many VANET applications which require real-time updated position information of vehicles. This requirement can be fulfilled with the help of GPS (Global Positioning System) as GPS can be easily installed in vehicles. Out of all VANET applications, some applications can still be able to work although they have inaccurate localization information in that position of a vehicle may have errors between 10 to 20 m or 30 meters, while some other application like critical safety application require more accurate position of a vehicle. VANET applications can be divided into three main groups: Vehicle communication, Driver Assistance and Cooperative Driving [3].

![Several VANET Applications](image)

**Figure – 1** Several VANET Applications [2, 3]

2.1 Vehicle Communication

These applications can be able to work with inaccurate localization information. Vehicle communication provides various services such as data dissemination of road congestion, incidents and information routing between vehicles. In fact, this is the main goal of vehicle communication. Performance of various routing protocols used for VANET can be improved by using position information related to vehicle, for example, dynamic topology changes and frequent network fragmentation.

A simple and classical example of vehicle communication is greedy forwarding. In this technique, location information about the nearest destination node is wrapped into packet and sent it to the nearest neighbor of that node. Some routing protocols designed specifically for VANET uses the geographical information such as maps or movement information of vehicles. Routing protocols which uses internet connection to access the local infrastructure network can assist the routing with the help of position information of node or future trajectory knowledge as shown in Fig. 1 (A). Information, like road flow, traffic congestion, can be communicated between vehicles by various
data dissemination methods specially designed for VANETs. Having knowledge about location, these protocols ensure that this information can be passed to only those vehicles that are interested in receiving this information. As shown in Fig. 1 (B), interested vehicle is able to receive the road information about the dangerous situation disseminated by some vehicles in the network. With respect to location requirement, these algorithms will accept errors about location within a few meters only. Localization inaccuracy can be resolved to some extent by increasing the range of transmission for the vehicle.

2.2 Driver Assistance

In this application, while driving the vehicle, driver is informed about surrounding environment information that will help him to avoid collision.

A simple and widely used driver assistance application is Map localization which also works with inaccurate localization information. In this application, current position of a vehicle can be derived from the map in which path direction is given between the two points of the city. When driver lost his path in some unknown region of the city, this application is used to assist the driver to find the correct path. With respect to the localization requirement, map localization can be used to overcome inaccuracy of GPS localization scheme.

Second useful application in this category is vehicle collision warning system [2, 3]. The main component of this application is security distance warning, which will give alert message to the vehicle when minimum distance to another vehicle is reached. Alternative implementation approach of this application is when distance between two vehicles is decreasing too quickly; it can apply an emergency break to avoid the collision, as shown in Fig. 1 (D). With respect to the localization requirement, this application uses multi-hop communication to disseminate collision information. This kind of application will get accurate position of vehicles using robust and reliable local distance estimation which can be obtained from sensors and cameras.

Another driver assistance application is vision enhancement which helps driver by giving clear view of vehicles and obstacles in foggy days and also provide information about vehicle that is hidden by obstacles, building and other vehicle. This application requires high-accurate position of vehicle. With respect to localization, vehicle position can be obtained from GPS, but this information may be inaccurate. Information obtained from GPS can be combined with map knowledge to locate distant and/or hidden vehicles. Accurate estimate distance to near vehicles can be obtained from sensors.

Automatic parking is another driver assistance application which requires highly accurate position of vehicles. This application is used to park a vehicle in the parking lot without the need of driver intervention. With respect to localization requirement, sensors will be needed on vehicle in order to estimate the distance and/or video/image processing.

2.3 Cooperative Driving

In this kind of application, vehicles in VANET exchange messages in order to avoid collision and to share road space cooperatively. The main feature of this application is that there will be cooperation between each vehicle in order to achieve the common goal and vehicle is assumed to be partial or total control over driving. In these applications, localization error of 1m to 5m is acceptable. Certain degree of confidence and accuracy is required to compute the position and/or to estimate the distance between two vehicles. The following paragraph contains detail description of such applications.

Cooperative adaptive cruise control is the application that is used by driver to maintain the constant speed while travelling up or down hill, without driver intervention. This application must require accurate position of vehicles because the driver sets the speed of vehicle and then system will
take over while vehicle can cooperate with other vehicle to set the speed adaptively, as shown in Fig. 1 (F). With respect to localization requirement, in this application, vehicle should have certain kind of confidence in itself because GPS receiver has correlated errors. To increase the accuracy and confidence of the system, sensors can also be used to compute the distance between two vehicles or between vehicle and infrastructure.

Another interesting and popular application of VANET is cooperative intersection safety which also requires accurate position of vehicle in the VANET. In this application, vehicle exchange messages with other vehicles at a road intersection to provide safety while crossing the roads as shown in Fig. 1 (G). Another application called blind crossroads can also be implemented in which the vehicles cooperate with each other when there is no street light control in order to make a cooperative crossroads as shown in Fig. 1 (H). With respect to localization requirement, position information can be obtained from decision making process and also application must be allowed to differentiate between street sides and lanes.

Vehicle following or platooning is the technique in which all vehicles will follow the leader vehicle to form a train like system as shown in Fig. 1 (I). This application is mainly used in a system where two or more vehicles are travelling into the same direction. With respect to localization requirement, application must ensure the minimum distance between two vehicles and also each vehicle must keep the track of vehicles having position in front of that vehicle. Position of vehicles in this technique can be obtained from video/image processing or from GPS receivers.

3. LOCALIZATION IN VEHICULAR AD-HOC NETWORKS

A number of localization techniques have been proposed to calculate the location of vehicle in VANET. Some of them are shown in Fig. 2. Various localization techniques that are used for the estimation of position by vehicles are Global Positioning System (GPS) / Differentiated Global Positioning System (DGPS), Map Matching, Dead Reckoning, RFID Assisted Localization, Cellular Localization, Image/Video Processing, Relative Distributed Ad-hoc Localization and Localization services. In this section, I have explained each technique in detail and also I have discussed pros and cons of each technique.

![Localization Techniques applied in VANET](image-url)
3.1 Global Positioning System (GPS)

In this technique, there are 24 satellites which together compose global positioning system and operate in orbit around earth as shown in Fig. 2 (A). Each satellite makes two complete circles every day and form a circle around the earth at a height of 20,200 km. The orbits for satellite have been defined in such a manner that at least four satellites can be seen in the sky by each region in the sky. The technique used to estimate the location of vehicle is called Time of Arrival (TOA) in which GPS receiver is constantly receiving the information being sent by the four satellites and finally another technique called trilateration is used to compute the position of vehicle. Using Time of Arrival technique, receiver is also able to know its latitude, longitude and altitude.

This technique is less expensive, as mostly all vehicles are equipped with GPS receiver. But, this technique leads to some undesirable problems such as not always available, or not being robust for critical applications.

In order to calculate the location of vehicle, GPS receiver needs to access at least three satellite signals for 2D positioning and at least four satellite signals for 3D positioning. The signals generated by satellite can easily be disturbed or blocked which in turn cause position inaccuracy or unavailability in urban dense environments. Also not all GPS receivers will give accurate result because GPS receiver can have localization error of ± 10 to 30m. So this position value is not useful in the application which requires accurate localization information. This kind of error can be minimized with the help of Differential GPS (DGPS) method. In this method, GPS receiver can compute its position with reference to already known physical location. Then, the broadcasting of this difference is done in the network and all nearby GPS receiver correct their computed position information based on the differential information broadcasted by any one GPS receiver. The disadvantage of this method is it requires some fixed ground-based reference station for information broadcasting.

For critical application, position information received from GPS needs to be combined with different source of positional information, and / or geographic knowledge. This will lead to more accurate positioning of vehicle in the network.

Sometimes long delay can occur while locating a mobile device using GPS. This delay can be minimized by Assisted Global Positioning System (A-GPS) [4] which operates on GSM, GPRS and UMTS networks. A-GPS is also using satellite reference points to determine location and can be accurate up to 10 meters.

RF-GPS [7] is improving the accuracy in position obtained from GPS receiver by designating moving vehicle as a reference node. The vehicle that passes by the roadside unit receives vehicle’s position within 3m error range and calculates error rate using its own GPS coords and received Abs coords. Then, using Diff coords, GPS error is broadcasted to neighbor for correcting the GPS position.

3.2 Map Matching

By using Geographic Information System (GIS), one can easily collect, access and store very accurate geographic data although available device is less powerful. Using map matching [6], one can easily store information related to city map in order to provide localization system in vehicle navigation as shown in Fig. 2 (B). This technique can be used to improve the performance of GPS based system as estimated vehicle position is limited by roads or other places, it is possible to reduce the error in estimated position. In this technique, estimated trajectory is to be obtained by receiving various positions over some time interval. Then, obtained estimated trajectory is mapped with known digital map data to best suited path geometry on the map that matches with trajectory. Position information obtained from GPS can be accurately depicted on the map.
3.3 Dead Reckoning

By using dead reckoning [4, 6] method as shown in Fig. 2 (C), the current position of vehicle is calculated based on its last known location and using some movement information such as direction, speed, acceleration, distance, time, etc. The last known position (also known as fix) can be obtained from GPS receiver or by locating some known reference point from digital map. Practically this technique can only be used at the place where GPS is not available. So this technique is only used over short period. For long time period, it accumulates errors easily.

3.4 RFID Assisted Localization

In this technique, vehicle communicates with each other with the help of both IEEE 802.11 and RFID. Vehicle broadcasts packet to its neighbor having distance of only one hop using IEEE 802.11 radio channel. Simultaneously, it exchanges the data with neighbor using mobile RFID tag / reader set [7]. Eun-Kyu Lee et al. has assumed that only few vehicles have GPS receiver and remaining have an RFID tag / reader set. The width of lane is assumed to be 3m. Some selected roadside unit contains RFID tags e.g. speed advisory signs. There were different tags used in this technique. One of them is Stationary RFID tag which stores the accurate position data and transmits it to passing vehicles. Another tag is called Mobile RFID tag is semi passive tag which stores and send vehicle’s ID to neighbors in response to their interrogations. One component is used as an interrogator on a vehicle that extracts data from either a stationary or mobile RFID tag. Some vehicles are acting as a GPS vehicle that is used to obtain the accurate position from a stationary RFID tag. Once GPS error has been calculated, then it is broadcasted using IEEE 802.11 radio. Coordination between the data obtained from GPS receiver and vehicle is done by GPS coords. Absolute RFID tag data is coordinated with exact position is done by Abs (olute) coords. Accurate coords contains vehicle’s position data within 3m error range. GPS coords and accurate coords difference is given by Diff (erential) coords which represents a GPS error at the point. Information about vehicle’s movement, vehicle ID, Accurate coords, speed and orientation is called travel data.

3.5 Cellular Localization

In cellular localization [3, 4] technique, existing mobile cellular infrastructure is used for the localization of vehicles as shown in Fig. 2 (D). In order to work properly, installation of communication infrastructure is required which is composed of number of cellular base stations distributed in the covered area. Mobile phone is continuously communicating with the base station and when the received signal strength of one base station is greater than another, at that time, mobile phone start communication with new base station. This phenomenon is called hand-off.

At the same time, it is possible that more than one base station can listen to and communicate with mobile phones. So number of different localization technique can be used to measure the accurate location of vehicle. One such technique is called RSSI (Received Signal Strength Indicator) which uses the strength of received signal for finding the distance to the base station. Another techniques is called TOA (Time of Arrival) in which distance will be estimated based on the times it takes for single signal to leave the sender and arrive at the base station. One more approach is possible which uses directive antennas or antenna arrays at the base station which estimates the position based on the angle at which the signal arrives at the base station.

Another technique for cellular localization is called Finger Printing in which signal characteristics of base stations are recorded at each station. After this, from the current signal characteristics, a mobile node can find its position from the database by matching with the best stored signal characteristics. Cellular localization technique is less precise than the GPS. Average localization error may vary between 90m and 250m [3].
3.6 Image/Video Processing

For the localization purpose, in some cases, cameras that are already installed in parking lot are used. These image / video processing techniques together with some data fusion techniques are used to estimate the position of vehicle. For instance, detection of sides of lanes in video image is detected based on some vision algorithm which precisely estimates the vehicle’s geometrical parameters in a local reference system which includes distance of the vehicle from the left side of the lane, road lateral curvature, lane width, vehicle’s direction angle and the camera inclination angle.

3.7 Localization Services

In some places, like tunnels, urban canyons, parking lot, GPS is not available. In that case, some infrastructure is needed in order to communicate with vehicles when GPS is not available. One such system called VETRAC [4], which uses Wi-Fi access point as an infrastructure and also as landmark when positioning vehicles. Sometimes other localization technique such as Image/Video processing or laser scanners can also be used to compute the position of vehicle. The main challenge is to setup the infrastructure required for communication inside tunnels because inside tunnel, access is limited so at that time emergency rescue operation is very difficult and challenging. VANET can also use Wireless Sensor Network (WSN) to monitor parameters like temperature, smoke, visibility and noise. The use of sensor network as a roadside infrastructure unit will increase the accuracy of infrastructure VANET localization system.

3.8 Relative Distributed Ad-hoc Network

For estimation of distance with respect to vehicle’s neighbor and exchange of this distance information with neighbor, vehicle constructs local relative position maps. This kind of relative localization has been used mostly in Ad-hoc or sensor networks. One of the distributed localization algorithm is proposed to calculate position of vehicle which does not have GPS equipment. In such situation, position is calculated with the help of number of nearby GPS equipped vehicles. But the main problem with this algorithm is that it is very difficult to identify the situation where communicating vehicles have network cards for communication and does not have GPS receiver. Another technique has been proposed in [3], in which, the distance between vehicles can be measured with the help of RSSI and then some optimization technique is applied to improve the initial position estimation of the vehicle. RSSI hardly improves the initial position estimation, as nearby GPS receiver might have correlated errors. But this solution can be used to improve the position obtained via dead reckoning technique during GPS outage.

There are number of localization techniques that have been proposed but only few of them can be applied to VANET. In one of such techniques, vehicle position can be calculated from the relative positioning of a cluster of vehicles.

3.9 Localization in VANET using Clustering

This technique can be used to calculate the position of vehicle where no GPS information is available. This technique is based on clustering and uses trilateration method to establish the relative positions of the nearby nodes. There are three different phases required.

Phase 1: Selection of the first cluster head which is available in the center of the system and then calculation of relative position of its neighbor in the group.

Phase 2: Selection of other cluster heads and their coordinates based on the cluster head selected in phase 1 in the system.

Phase 3: Only executed when the chain of cluster heads is broken.
Phase 1:
For the selection of first vehicle which is supposed to be available in the center, any vehicle can wait for a fixed delay when there is no GPS available. During this time, if that vehicle receives a message from a cluster head, then it becomes the member of a cluster head’s group. Otherwise, it broadcasts a message saying “is there any cluster head available in the approximate?” If it does not receive response, then again it sends another broadcast message to say “I am the first cluster head”. The newly selected cluster head will become the center of the system having position (0, 0) and the positions of other vehicles in the system is calculated based on the position of the cluster head.

Phase 2:
When all vehicles positions which are neighbor of the cluster head, has been calculated and cluster head has built its own coordinate system, then after it starts to construct the backbone network which comprises all cluster heads available in the system.

Phase 3:
This phase can be executed with the help of two different cases: In the first case, when the first cluster head receives two or more messages via GPS, at that point, it realizes that it has left the environment without GPS. Then, it informs its neighbors that it has left the tunnel by sending a special message. On reception of this message, previous cluster head takes a charge of master cluster head. In the second case, when the master or first cluster head fails, one of its cluster head neighbors will take a charge of master cluster head. For this, each vehicle starts to decrement a random timer and the vehicle whose timer expires first, will become the new center of the network.

4. CONCLUSION

In this paper, I have discussed number of techniques used for localization in VANET with their pros and cons. Some of the techniques require GPS receiver to be installed on the vehicle in order to receive different vehicle position. To avoid the use of GPS, some technique uses relative ad-hoc network for calculating the vehicle position. But the novel approach that can be used to calculate the position is to use cluster of vehicles in which one center vehicle will become the cluster head and all other vehicles in the network will calculate their positions based on the position of cluster head. But still, there is a need to find methods for data dissemination from cluster head to remaining vehicles and also for selection of cluster head based on different parameters.

REFERENCES


