Vehicular Ad-Hoc Network Localization Techniques: A Review

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Abstract

Vehicular Ad-Hoc Network (VANET): Communication between vehicles. Despite of MANET, in VANET nodes are vehicles. They can move with high speed and generally must communicate quickly and reliably. When an accident occurs in a road or highway, alarm messages must be disseminated, instead of ad-hoc routed, to inform all other vehicles. To position a broken vehicle (or vehicle in danger) and locate the vehicles in its vicinity is very important for the safety of the road users. However, vehicles are not necessary equipped with GPS and even they cannot obtain availability of line of sight access to satellites, particularly when they enter tunnels. In this paper, we going to plan out an integrated system to improve localization accuracy in order to support localization of GPS equipped or GPS unequipped vehicles. So, the number of vehicles discovering their localization will be increased. This prevents pile-up of cars when fogs, accident or any other obstacle and then contributes to the driver safety.

Keywords

Vehicular, Localization, DGPS, Map-Matching, Ad-Hoc

I. Introduction

Many Vehicular Ad hoc Network applications require position data, so localization is becoming a critical necessity in VANET. Various localization techniques have been proposed to improve the accuracy.

In this paper, we survey several localization techniques that can be used to estimate the position of a vehicle with their pros & cons when applied to VANETS. By concluding that none of these techniques can achieve the desired localization requirements of critical VANET applications, but we show how localization information can be combined together from multiple sources to produce a single position for accurate positioning using an integrated system.

This paper is organized as follows. In the next section we identify the requirements of critical applications. Section 3 shows survey of all localization techniques for position computation. Section 4 shows how an integrated system can be used to gather all location information from multiple sources. Section 5 provides our conclusion & future works.

II. Critical Applications Requirement

Especially critical safety VANET applications require more accurate and reliable localization system with sub-meter precision.

Driver assistance applications require precise & reliable localization systems. In such applications the driver is informed about the surrounding environment to improve safety & in case of emergency the vehicle can perform some automatic activities such as emergency break.

Vehicle Collision Warning Systems [1] are one of the most interesting applications for driver assistant in VANETs. One part of these systems is Security Distance Warning and other part of these systems is when collision has already occurred and nearby vehicles need to be warned (warn messages) so they can avoid pile-up collisions. These applications require robust, accurate, and reliable localization systems.

Another driver assistance application is Vision Enhancement, in which drivers are given a clear view of vehicles and obstacles in heavy fog conditions and can learn about the existence of vehicles hidden by obstacles, buildings, and by other vehicles.

Automatic parking is another application for driver assistance in which a vehicle needs accurate distance estimators and/or a localization system with sub meter precision.

III. Localization Techniques for VANET

A number of localization techniques have been proposed for computing the position of vehicles in Vehicular Ad hoc Network as GPS/DGPS, Map Matching, Dead Reckoning, Cellular Localization, Image/Video Processing, Location Services, Relative distributed Ad hoc Network, Data Fusion.

A. Global Positioning System (GPS)

GPS is a positioning system [2-3], that has been developed and operated by the U.S. Department of Defense. A GPS system is formed from a network of satellites i.e. it consists of 24 satellites arranged in six orbital planes, operates around the earth. Each satellite circles the earth at a height of 20200 km and every day makes two complete rotations.

A GPS receiver is a piece of equipment that is able to receive the information constantly being sent by the satellites, and uses this information to estimate its distance to at least four known satellites using a technique called Time of Arrival (ToA), and compute its position using trilateration. Then receiver is able to know its latitude, longitude and altitude.

The main solution for VANET Localization is to connect each vehicle node with a GPS receiver. But as VANET advance into critical areas and become more dependent on localization systems, GPS, as well as other satellite-based positioning systems (e.g., Galileo, GLONASS), are starting to show some undesired problems such as not always being available and not being robust enough for critical applications.

In order to function properly and compute its position, a GPS receiver needs access to at least three satellite signals for 2D positioning and at least four satellite signals for a 3D position computation. This is not a major issue since the number of visible satellites usually varies between four and eleven. However, the problem is that these signals are easily disturbed or blocked by obstacles including buildings, rocks, dense foliage, electronic interference, etc. This causes position inaccuracy or unavailability in dense urban environments (urban-canyons), tunnels, indoor parking lots, forests, and any other indoor, underground, or underwater environment.

Also, GPS receivers have a localization error of ±10 to 30 m. These errors are Global errors or local errors. Global errors affect the receiver’s measurements by a value that vary from one area to another because of ionospheric delays, tropospheric delays,
ephemeris, and satellite clocks. Local errors can be caused by multipath effects, by not being in the line of sight, or by the receiver hardware itself. One positive aspect of these errors is that nearby GPS receivers tend to have the same localization error pointing in the same direction. In other words, nearby GPS receivers have correlated errors.

**B. Assisted Global Positioning System (A-GPS)**

A long delay can occur when locating a mobile unit using GPS. A-GPS systems are set up to resolve this long delay [4]. Wireless A-GPS operates on GSM, GPRS and UMTS networks. Like GPS, A-GPS uses satellites in space as reference points to determine location. A-GPS can be accurate up to 10 meters.

**C. Differential Global Positioning System (DGPS)**

Differential GPS (DGPS) consists of two receivers observing the same GPS satellites. One of these receivers is stationary and the other one is roving. The stationary receiver resides at a known location and obtains the pseudo-range from the satellite signals, so it identifies a global error by comparing the measurements with its location. The stationary receiver transmits the global error correction to the roving receiver so that the roving one can correct its measurements. DGPS takes advantage of correlated errors by installing a GPS receiver in an already known fixed location. This GPS receiver can compute its position using the information from the satellites and compare the computed position with its already known physical location. The difference between these two positions can be broadcasted and all nearby GPS receivers can correct their computed positions based on the broadcasted differential information. This is why this technique is known as Differential GPS. A drawback of this technique is that fixed ground-based reference stations must be used to broadcast this differential information. On the other hand, DGPS [5] can lead to a sub-meter precision, which is sufficient for most VANET critical applications. Another advantage of the correlated errors obtained by normal GPS receivers is that relative distances between receivers can be accurately estimated even though the computed positions are not accurate.

Due to the cited limitations, normal GPS receivers are usually used only in VANET applications that do not require accurate and reliable information. In critical applications, position information obtained via GPS needs to be combined with different sources of position information, differential information, and/or geographic knowledge.

**D. Map Matching**

Current advances in Geographic Information Systems (GIS) have allowed the collection and storage of, as well as access to, very accurate geographic data even for less powerful devices. This technology has been successfully applied to store city map information in recently developed map localization systems for vehicle navigation.

Map knowledge is not a localization technique by itself; it can be used to improve the performance of many positioning systems such as GPS. First, by limiting the estimated vehicle positions to roads or other places with vehicle access, it is possible to decrease the error of the estimated positions. But the main application of map knowledge in localization is the Map Matching technique [6-7].

In the Map Matching technique, several positions obtained over regular periods of time can be used to create an estimated trajectory. This estimated trajectory is then compared to known digital map data to find the most suitable path geometry on the map that matches the trajectory. Using this technique, position information (e.g., from GPS) can be accurately detected on the map.

**E. Dead Reckoning**

Dead Reckoning [8-9], technique is used to compute the current position of a vehicle based on its last known location and using such movement information as direction, speed, acceleration, distance, time, etc. The last known position, also known as a fix, can be obtained, for instance, by using GPS receivers (which are most common) or by locating a known reference (road crossing, parking lots, home, etc) on a digital map. Displacement information can be obtained by sensors including odometers, while direction can be estimated easily using such other sensors as digital compasses and gyroscopes.

Practically Dead Reckoning can be used only for short periods of GPS unavailability, or be combined with Map Knowledge. The reason to avoid the use of this technique over long periods of time is that it can accumulate errors easily. For instance, positioning errors from 10 to 20 m can be reached in only 30s after the last position fix when traveling at about 100 km/h [9-10]. Since Dead Reckoning accumulates errors rapidly over time and distance, it is considered only as a backup system for periods of GPS outage, in which a vehicle enters in to a tunnel and loses its GPS connection. In this example, the last GPS computed position is used as a position fix. Another viable application of Dead Reckoning, as noted above, is to combine it with Map Knowledge. In these cases, the positions restrictions can be applied to decrease Dead Reckoning errors, and the traffic patterns can be used to match the estimated path within the known map information (map matching) [7].

**F. Cellular Localization**

Cellular localization [11–14] gets benefit of the mobile cellular infrastructure present in most urban environments to estimate the position of an object. Known applications of this technology include locating mobile phones, tracking domestic animals, and vehicle localization.

In order to function properly, mobile cellular systems require the installation of a communication infrastructure composed of a number of cellular base stations distributed through the covered area. Each base station is responsible for providing communication to mobile phones located in its area. As mobile phones move around a city, they keep changing their base station when the signal strength from a new base station becomes greater than the one in use. This procedure is called handoff.

Although only one base station is used in communication, usually several base stations can listen to and communicate with a mobile phone at any time. This fact allows a number of localization techniques to be used to estimate the position of the mobile phone. A well known technique called Received Signal Strength Indicator (RSSI) [15 Z] uses the strength of the received signals to derive the distance to the base stations. It is also possible to estimate a distance based on the time it takes for a signal to leave the sender and arrive at the base station (Time of Arrival – ToA) or the difference between the times it takes for a single signal to arrive at multiple base stations (Time Difference of Arrival – TDoA). Once we have the distances from the mobile phone to at least three base stations, it is possible to compute the position of the mobile phone using such techniques as trilateration and multilateration.

Another common approach is possible when directive antennas
or antenna arrays are used at base stations, in which the angle at which the signal arrives at a base station can be estimated. Based on the Angle of Arrival (AoA) [16-17] of a signal to three different base stations, we can compute the position of the signal source. Fingerprinting is a localization technique based on a pre-training phase in which signal characteristics from base stations are recorded at each location. After this information is recorded, a mobile node can find the position in the database that best matches its current signal characteristics. This is a very interesting solution for small or medium sized areas, achieving errors of less than 5 m in indoor environments [13]. For large urban areas as in VANET applications it has questionable applicability, but in some recent studies [19], an average accuracy of 94 m is achieved after a 60-h calibration drive in a metropolitan area.

Cellular localization is usually less precise than GPS. The accuracy depends on a number of factors such as the current urban environment, the number of base stations detecting the signal, the positioning algorithm used, etc. In most cases, the average localization error will be between 90 m and 250 m [14], which is not accurate enough even for VANET applications that do not require accurate and reliable information. However, position information gathered from this technique can still be useful when combined with Dead Reckoning and/or Map Matching, and the available information can also be used to feed Data Fusion modules. Also, signals from the Cellular infrastructure have more availability in urban environments than signals from satellite (used by GPS receivers) which can be useful for indoor environments such as parking lots and even tunnels.

G. Image/Video Processing

Image and video information sources and data processing techniques can also be used for localization detection purposes, especially in mobile robot guidance systems [18]. In some cases, however, cameras are already available in security systems implemented in parking lots and tunnels. Commonly, these Image/Video Processing techniques are used to feed Data Fusion algorithms to estimate and predict (track) a vehicle’s location [14]. In fact, both image and video information are actual sources from which we can compute the location parameters of a vehicle. For instance, in [20], vision algorithms [21] are used to detect the sides of lanes in video images. It estimates precisely the vehicle’s geometrical parameters in a local reference system, including lane width, road lateral curvature, and distance of the vehicle from the left side of the lane, vehicle’s direction angle, and the camera inclination angle. These local data are transformed in order to express in a precise digital map of the environment. Such information is used to feed a Data Fusion module that estimates the vehicles’ locations.

H. Location Services

There are places where GPS is not available or not precise enough for local applications. In VANETs, these places include tunnels, urban canyons, and parking lots. In these cases, an infrastructure for communication and positioning service can be implemented to perform the localization of vehicles. A Localization Service can be implemented using any known infrastructure localization system such as the Cricket Location-Support System [22], RADAR [23], Ultra-Wideband Localization [24], or Wi-Fi Localization [25-26]. In [26], Thangavelu et al. propose a system called VETRAC, a vehicle tracking and location identification system designed for VANETs that uses Wi-Fi access points as a communication infrastructure and also as landmarks when positioning vehicles. The proposed system can be used in tunnels, university campuses, airports, etc. The most challenging and important task in VANET localization is most likely the development of infrastructure localization systems to be used in tunnels, which are one of the most critical VANET environments. Tunnels are normally used to connect important regions separated by natural environments with difficult access and are generally the only path between these regions. Thus, a damaged tunnel can have an enormous impact on a city or a region. Also, due to the limited access inside a tunnel, emergency rescue operations can become very difficult and even dangerous. In these scenarios, collision avoidance is crucial and all available information about the state of these tunnels infrastructure as well as the number and location of all vehicles inside these tunnels are key information for rescue teams in case of emergency operations.

VANETs can also use Wireless Sensor Networks (WSNs). The reason for doing this is that WSNs can also be used to monitor other road variables like movement, temperature, smoke, visibility, and noise. Thus, these networks are ideal for monitoring critical environments as well as for emergency operations, as shown by a number of works [27-28]. Also, the use of sensor networks as a roadside communication infrastructure is a frequently used setup in many intelligent performance and accuracy of an infrastructure VANET localization system. For instance, movement sensors can be used to send localization packets only when vehicles are present. Finally, a WSN used as a VANET localization infrastructure will provide a complete safety monitoring system for these critical situations, being able not only to monitor important environment and structural variables like movement, temperature, smoke, visibility, noise, pressure, and structural health, but also the location of all vehicle nodes at a given moment.

I. Relative Distributed Ad-Hoc Network

Vehicles construct Local relative position maps for estimating the distances between its neighbors and exchanging this distance information with nearby nodes in multihop communication. With this dynamic position map, a vehicle can locate itself in relation to nearby vehicles as well as locate the vehicles in its surrounding area. This type of relative localization has been used mostly in Ad Hoc and Sensor Networks, but recently a number of solutions [9-10, 29] has been proposed for VANETs.

In [29], a distributed localization algorithm is proposed to assist GPS-unequipped vehicles in estimating their positions based on nearby GPS-equipped vehicles. To estimate a position, a vehicle not equipped with GPS needs to communicate with at least three GPS-equipped vehicles in its vicinity in order to estimate distances and gather their position information. When the number of nearby GPS equipped vehicles is less than three, the author shows how to estimate at least the direction of the vehicle and the distance from an event (an accident or a danger) based on the small amount of available information. The proposed algorithm can successfully estimate the position of vehicles not equipped with GPS, but it is hard to identify situations where vehicles have network cards to communicate with other vehicles but have no GPS equipment. Also, the direction of the cars can be easily estimated by exchanging digital compass or gyroscopes information.

In [10], another distributed VANET localization system is proposed in which distances between vehicles are estimated using RSSI and the information is used by an optimization algorithm to improve the initial position estimation of the vehicles. This technique is primarily intended to improve GPS’s initial position estimations, but since nearby GPS receivers tend to have correlated errors,
estimating distances using RSSI will hardly improve the position information. However, this solution can also be used to improve positions computed via the Dead Reckoning technique during GPS outages.

A number of distributed relative ad hoc localization systems have been proposed recently for Ad Hoc and Sensor networks [30-31], but only a few of these can be applied to highly mobile and dynamic networks such as VANETs. In [9], Kukshya et al. propose an architecture for the relative positioning of a cluster of vehicles that does not require any GPS information and that is suitable for VANETs. This architecture also relies on distance estimation measurements.

### J. Data Fusion

Data Fusion techniques such as Kalman Filters, Particle filters, and Belief Theory have also been used to improve location estimations in many sensor-based systems [19]. The key idea is to combine information from a cooperative vehicle ad hoc network using a Data Fusion module to allow vehicular safety applications to determine not only a vehicle’s location, but also the lane in which it is traveling. The general idea behind a location system based on Data Fusion is to combine several information sources to provide accurate location estimation. In order to find an appropriate data fusion [32] algorithm, several basic approaches are taken into account as a)Usage of 2nd order statistics, b) Dempster-Shafer method, c) Rule based systems/ Fuzzy logic.

### IV. Possible Integrated System for VANET Accurate Localization

Theoretically, integrated systems may be used for accurate location estimation in VANET. The detailed description of an integrated system is not the focus of this paper.

### V. Conclusion

In this paper, a number of VANET related localization techniques were studied. All of these techniques have their pros and cons. In this paper we kept one point in front of you that future localization systems for VANETs need some kind of integrated systems in order to provide accurate and robust position inform.

### References


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