Design Approach for Anti-collision Mechanism between Vehicle to Vehicle for Improving Safety Operation In Intelligent Transportation System

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Abstract— **InVeTraS (Intelligent Vehicular Transportation System) is proposed as a Vehicle-to-Vehicle (V2V) anti-collision mechanism that determines estimates and absolves collision courses between two or more vehicles based on a correlative and cooperative wireless networking concept. The problem of collision avoidance is abstracted to the generic problem of location awareness and subsequent periodic information exchange (between vehicles). To enable location awareness, the mechanism uses one of two techniques: a Global Positioning System (GPS) receiver aided with dead-reckoning sensors or a RADAR based measurement system. Two nearby vehicles periodically exchange information about their own movement in terms of exact position and local clock time. Using these inputs, vehicles determine whether or not they are on a collision course with each another. A *Communication Cluster* (based on the concept of mobile ad-hoc peer-to-peer networking) is formed, that facilitates the development of a vehicular network characterized by self organization, fault-tolerance, scalability, cooperation and cost efficiency. These characteristics enable avoidance of collision between vehicles in an adaptive and dynamic set up. The paper proposed InVeTraS concept by emulating the streets of Manhattan.**

Index Terms— **Anti-collision, communication cluster, location awareness, periodic information exchange.**

I. Introduction

Road accidents account for a severe threat to human lives from both an injury as well as a financial perspective. Given that vehicles are designed to facilitate a smooth means of transportation, manufacturers have long been in the process of designing vehicles based on principles of reliability and safety. However, due to reasons such as human-error, circumstantial error and negligence, accidents occur. Today, special attention is focused on the technologies that can reduce traffic accidents [1].

Services provided by the Intelligent Transportation System (ITS) include collision warning; collision avoidance; and automatic control are eventually expected to result in a reduction of critical traffic accidents. The data is provided by sensors, information systems and analyzer devices located inside the vehicles. Low-cost vehicular enhancements are an impediment for large scale deployment. What is desired is a simple in-service upgradeable method for avoiding collisions amongst moving vehicles. Vehicular communication (V2V) resulting from ad hoc and peer-to-peer networking has recently gathered significant attention [2],[3][4], as both a communication technology as well as for providing possible collision avoidance. V2V technologies are also expected to augment the Intelligent Transportation System (ITS) services. V2V technologies are simple to implement primarily because of their reliance on wireless communication. A wireless location aware ad hoc network of mobile nodes (vehicles) facilitates a framework for collision avoidance. Creating a wireless ad hoc location aware communicating infrastructure involves several components – location awareness, real-time communication, mapping of mobile entities and taking appropriate action upon detection of collision courses. InVeTraS is a solution that satisfies the aforementioned components leading to effective collision avoidance.

Concept: The central idea of the InVeTraS solution is to enable vehicles within each other's proximity to be aware of their own location and then estimate their position with respect to other vehicles. The location awareness problem constitutes of three *sub-problems:* (1) determining either the exact location using a GPS receiver (at discrete intervals) or determining relative location by periodic exchange of distance observations done by the RADAR, (2) applying corrections to the measured location using continuous-time active sensors and (3) sharing this information (pertaining to observed measurements) with other vehicles using Inter-Vehicle Communication. The above mentioned aspects are used by the InVeTraS framework to enable a vehicle to estimate collision course with another vehicle. The process of collision course detection involves several periodic iterations of information transfer through the wireless network. The choice of iteration period is critical in determining the efficiency, reliability and scalability of the InVeTraS system. The time interval should be small enough to reduce the possibility of an accident occurring while the protocol is in the process of finding a collision course; and large enough so that the location information sent by one vehicle to another is meaningful. The challenge is to develop a location aware mechanism that does not require complex signal processing or synchronization. The protocol for location information exchange is based on a cooperative principle of wireless channel utilization – resulting in low-cost wireless systems. Further, by using cooperative medium access, the protocol enables efficient resource (spectrum) sharing enabling good

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scalability and reliability. The approach shown by us is different from the approaches of trilateration [5] and triangulation [6], where landmark sites are assumed to be known with their exact position available. We assume that all communication objects in our framework are mobile and that the communication is ad hoc in nature. The procedure for location awareness is a time-dependent version of trilateration – whereby difference between two relative positions of two mobile vehicles is used for computation. In our system, we trace a quadrilateral – whose two sides represent the movement undergone by two vehicles between two measurement iterations, and the other two sides represent the distance between the two vehicles at each of the iterations.

II. InVeTra System

The central idea of InVeTraS is to enable vehicles within each other's proximity to be aware of their own location and then estimate their position with respect to other vehicles. The location awareness problem constitutes of three sub problems: determining the exact location using a GPS receiver, applying corrections to the measured location using continuous-time dead-reckoning sensors and then sharing this information with other vehicles using Inter-Vehicle Communication (IVC).The InVeTra system is in fig 1.

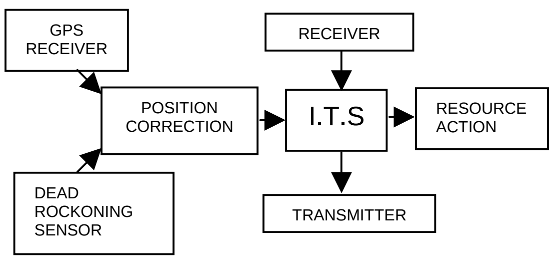

Fig. 1 Intelligent Transportation System for Vehicle

The above mentioned aspects are used by the InVeTraS framework to enable a vehicle to estimate collision course with another vehicle. The estimation of collision course is done through a wireless network that enables periodic information exchange between vehicles (which also have computed their individual locations using GPS). The process of collision course detection involves several periodic iterations of information transfer.

2.1 Inter-Vehicle Communication (IVC)

Prediction of collision course between two vehicles occurs when they are in a power-limited wireless proximity to each other. A group of vehicles within each other's power limited range form a *communication cluster [5]*. A communication cluster is analogous to a single-hop ad hoc network. Two nodes, part of the communication cluster, are able to predict a collision course by exchanging relevant information periodically. Two aspects of information are exchanged: pertaining to a vehicle's own movement and pertaining to a vehicle's observation of another vehicle. Through a set of consecutive asynchronous information transfers, vehicles are able to compute the path being followed by other vehicles. Let us assume that two moving vehicles are within a communication cluster (marked by a power-limited wireless zone) and hence they are able to directly communicate with one-another. This communication enables transmission and reception of *Information Packets*. These packets contain data pertaining to Geographic location of the vehicle, collision zone radius, velocity, displacement and direction.

2.2 Collision Detection

Consider two vehicles *A* and *B* as shown in Fig. 2. Vehicle *A* computes collision course with vehicle *B*, when its *collision zone* overlaps with that of vehicle *B*. To estimate if there is an impending collision, vehicle *A* records two consecutive instances of Information Packets received from vehicle *B*, say at times *t1* and *t2* such that [*t1, t2*] = *T*, At these two instances, vehicle *A* also records its own position (through GPS) as well as the path traced between the two instances. Through the information carried within the two successive Information Packets received from vehicle *B*, vehicle *A* computes the course of vehicle *B* and then matches it with its own scheduled course (or one a straight line extended from its positions at times *t1* and *t2*). Vehicle *A* now estimates if the two courses are collision centric. If vehicle *A* detects an impending collision then it communicates this information to vehicle *B* in its next Information Packet. This Information Packet also contains information pertaining to *A*'s estimates of distance to collision, time to collision and the *recourse action* that will be or is being taken to avoid this collision. The recourse actions might be a combination of lane change, acceleration or deceleration. Fig. 2 illustrates how two vehicles *A* and *B* deploy the protocol of periodic information exchange to avoid collision. The two inner circles are collision zones of vehicles *A* and *B* and the outer circle is communication cluster of *A*.

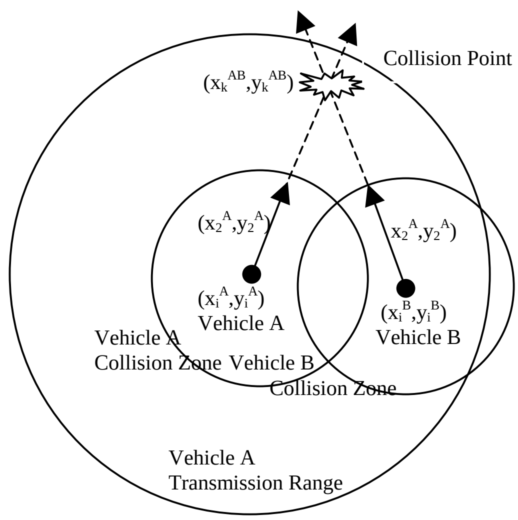

Fig. 2 Graphical illustration of two vehicles A and B and their collision path

III. Related Work

Triangulation and trilateration methods accompanied with measuring time of arrival (TOA), time difference of arrival (TDOA), angle of arrival (AOA), or signal strength have been considered in the past as the possible means of localizing a node relative to some known landmarks The disadvantage of such systems is that they need array of antennas mounted over the vehicles to compute their positions. Moreover the landmarks can not move at very high velocity, as that increases the errors in the position computations. The Cricket location system uses radio and ultrasound signals to estimate Euclidean distances to well-known active beacons spread throughout the building, which are then used to perform triangulation to localize the passive receivers. The system only localizes in-building mobile nodes with a room size granularity and needs the proper positioning of fixed beacons. The key features of our proposed approach, in contrast with the ones mentioned above, are that it is localized, distributed, does not need any fixed road-side infrastructure, and provides absolute (using GPS) or relative (using RADAR) positioning. In RADAR based approach, a vehicle uses the RF signal strength to determine the distance of other neighboring vehicles from itself and then use trilateration to localize itself relatively. Neighboring vehicles then exchange their known graph topology with each others to increase the knowledge of graph topology and improve the accuracy of path computations.

IV. Proposed System Design

This project has provides an insight into the development of vehicles carrying data and passing a new technique to achieve a robust exchange of data in a wireless ad hoc network they are predicted to do over the next 5 years and indeed eventually become pervasive in nature as is envisaged by the 'smart dust concept' established between each other at speed. This is probably the become smaller and cheaper as most challenging of the environments for the ad hoc networks. However, the incorporation of a part infrastructure-based network with some fixed points (possibly wireless devices fitted to street side infrastructure) will broaden the capabilities of such future wireless systems (where investment in the intelligent infrastructure seems appropriate). The business model in the ITS community to invest in such a technology may come when these devices become smaller and cheaper as they are predicted to do over the next 5 years and indeed eventually become pervasive in nature as is envisaged by the 'smart dust concept'.

Now we first present system-wide definitions that are instructive in understanding the concept of InVeTraS.

Communication Cluster: For enabling an environment that facilitates inter-vehicle communication (IVC), we assume that when vehicles are within a certain power-limited wireless (transmission) range (of each-other), they form a communication cluster that resembles a single-hop ad hoc network. Two vehicles which are part of a common communication cluster are able to exchange each other's location and other parameters. For collision detection, vehicles exchange two types of information: pertaining to their own location and their observation of another vehicle's perceived movement. Through a set of consecutive asynchronous information transfers, vehicles are able to compute the path being followed by another vehicle. The information exchange between two vehicles continues while they are part of a common communication cluster.

Collision Zone: Every vehicle maintains a collision zone for itself. The radius of collision zone is determined dynamically based on various parameters. The collision zone is computed by the vehicle through its on-board GPS receiver or RADAR. The communication clusters have two types of communication – an absolute measurement communication (between satellite and the vehicles in case of GPS or between two vehicles in case of RADAR).

Information Frequency: Within a communication cluster, we define a cluster frequency (called as information frequency) that is used for communication by all vehicles part of the cluster. Communication using this information frequency is time-shared by all the vehicles, based on a cooperative time-sharing protocol described later. The data transfer on information frequency helps in vehicle identification, communication cluster formation and IVC.

B. Vehicle Enhancements

GPS Receiver: GPS receiver is used to obtain the longitude, latitude and altitude values of a vehicle. For the sake of simplicity we consider in our simulation model (explained in Section IV) GPS Pathfinder Pro XRS receiver [12] from Trimble Inc that offers sub-meter (1~50 cm) accuracy in real-time. The longer the GPS receiver continuously communicates with GPS satellites, the better the accuracy. Trimble claims that within a few minutes of communication their GPS receives an accuracy level of 1 cm even at very high ground velocities (150km/h). It incorporates various real-time differential correction sources like MSK radio-beacon, Omni Star satellite differential service, and satellite-based augmentation system.

RADAR: The RADAR sensor will be mounted in the vehicle to scan the nearby area, so that the vehicle can find out its relative positions with respect to the neighbor vehicles.

Dead-Reckoning Sensors: Since the GPS receiver takes a measurement (of location) only at discrete intervals, and we require continuous vehicle information, we use onboard sensors for computing the position of the vehicle between two successive GPS readings. Sensors that aid this measurement are referred to as Dead-Reckoning sensors.

They include:

o Accelerometer with tilt sensors: To measure forces resulting from turning, acceleration or breaking .

o Rate Gyroscope: To measure instantaneous change in vehicle direction. These sensors can accurately measure changes in vehicle's position such as displacement, direction with respect to the Geographic North etc. Hence dead-reckoning sensors enable continuity of location awareness between successive GPS/RADAR readings.

Transmitter/*Receiver*: Every vehicle has a wireless transmitter/receiver pair for communication with vehicles in the communication cluster. The transmitter is an omni directional antenna that has sub-kilometer range. The receiver is tuned for reception of data on the Information Frequency.

Central processor: Every vehicle is equipped with a central processor. Its function is to extract information from the data received (on the information frequency) and then execute the protocol described in the next section. Based on the protocol, the central processor computes a collision course and then undertakes a recourse action that results in collision avoidance. Recourse is done by sending signals to either the subsystems of a vehicle (automatic recourse) or to the driver enabling collision avoidance.

V. Protocol

While a vehicle moves along a road, it tries to detect the presence of a communication cluster. If such a cluster is detected (by tapping and reading into the information frequency), then the vehicle attempts to become a member of the communication cluster, based on the protocol described subsequently. If no such cluster is detected (on any one of the information frequencies) then the vehicle starts transmitting Information Packets periodically on its preferred information frequency. In such a case, the vehicle is known as the convener of the cluster. Consider two vehicles A and B that are on a possible collision course; through our protocol we now understand how these two vehicles avoid collision. Let us assume that the two vehicles are within a communication cluster and hence they are able to directly communicate with one-another. This communication enables transmission and reception of Information Packets. These Information Packets contain data pertaining to Geographic location of the vehicle, collision zone radius, velocity, displacement and direction. When vehicle A receives an Information Packet from vehicle B, it computes if its collision zone intersects with that of vehicle B. If such an intersection exists, vehicle A begins dedicated bidirectional communication with vehicle B by allocating some and width (time-slot) in the information frequency. Bandwidth on the information frequency is divided into time-slots. A node cooperatively gets control of a time-slot and dedicates a sub-slot within the time-slot for dedicated bidirectional communication with another vehicle. Time-slot and sub-slot assignment is discussed later. Vehicle A uses the sub-slot to send information to vehicle B, pertaining to its estimate of the distance between A and B. Correspondingly, B also sends information pertaining to its estimate of distance between them. Based on this information the two vehicles are able to estimate if a collision would occur. To estimate if there is an impending collision with vehicle B, vehicle A records two consecutive instances of Information Packets that it receives (from vehicle B), at times t1 and t2 such that [t1, t2] = T, the periodicity of information exchange between two peers. At these two instances, vehicle A also records its own position (through GPS/RADAR) as well as the path traced between the two instances. Through the information carried within the two successive Information Packets received from vehicle B, vehicle A computes the course of vehicle B and then matches it with its own scheduled course. Vehicle A now estimates if the two courses are collision centric. If vehicle A detects an impending collision then it communicates for the same to vehicle B in its next Information Packet. This Information Packet also contains information pertaining to A's estimates of distance to collision, time to collision and the recourse action that will be or is being taken to avoid this collision. The recourse actions that a vehicle takes include:

Change of lane: A vehicle changes a lane if by changing its lane it will avert the impending collision.

Accelerate: If the vehicle is getting tailgated and change of lane is not possible, then the vehicle accelerates.

Decelerate: If the vehicle is accidentally tailgating another vehicle in its own lane and a lane change is not possible, then the vehicle decelerates to avoid the collision.

VI. Conclusion

In this paper, we present a mechanism to estimate collision course of moving vehicles called InVeTraS. It uses an approach of combining location awareness measurements with periodic information exchanges between vehicles. Location awareness is achieved through periodic GPS synchronization or RADAR system coupled with corrections from dead reckoning sensors, to obtain accurate vehicle coordinates in real-time. Vehicles exchange information through a MAC Based cooperative protocol that enables periodic information exchange.

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