

Vehacol: Vehicular Anti-Collision Mechanism using a Combination of Periodic Information Exchange and Power Measurements

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Abstract: Vehacol or Vehicular Anti-Collision is a mechanism for determining collision course between two or more vehicles. The mechanism uses a combination of physical and logical layer techniques to generate self and remote node information that can be exchanged to enable location awareness. Two vehicles (nodes) periodically exchange information about their individual movement in terms of displacement, speed and direction (with reference to a geographic North). In addition to the information exchange through an ad hoc network, vehicles also measure the separating distance through physical measurement. To do so, the vehicles use a unique but simple modulation format and reception technique that avoids the problems caused by multipath fading. Combining the inputs obtained through the measurement of distance and periodic information exchanges, vehicles are able to determine whether or not they are on a collision course with another vehicle. The paper discusses system parameters, protocol and other design issues related to the implementation of the Vehacol system. Simulation results and assumptions are also presented that validate the mechanism from the perspectives of error computation and discovery times.

Keywords: Vehicular, ad hoc, location aware

I. INTRODUCTION

Vehicle-to-vehicle interaction resulting from an ad hoc network on highways and roads has recently gathered significant attention [2-4]. One of the principal advantages of such a wireless, location aware, signaling mechanism is to avoid collision amongst vehicles on highways and other roads. The central idea of such a mechanism is to make vehicles automatically be aware of each other's presence through location sensing that is dependent on physical distance measuring, combined with a location determining protocol. Vehicles then are able to communicate with each other and guide their movements to minimize collisions (blocking). At a conceptual level, the resultant ad hoc network presents a problem of location aware routing in a wireless environment with constraints of minimizing blocking. Pure physical layer mechanisms have been shown to be either inaccurate or very expensive to deploy, while protocol based location aware schemes require dependence on physical reference inputs. The location aware problem as we observe for a vehicular framework can be partitioned into two parts: of measuring the straight line distance between two mobile nodes (vehicles) and then computing the location of one node with respect to the other as it moves along its own path. While straight line distance measurement between mobile objects has been made possible through a variety of power based measurement techniques, translating this straight line measured distance into pin-pointing the location of the mobile users is a complex task. The only inference a vehicle can draw from the straight line measurement is the existence of the other vehicle (a point) having a locus equidistant from the measuring vehicle meaning its existence on a circle of radius given by the straight line distance measurement. Apart from computing the straight line distance, we propose a protocol enhancement that enables vehicles to be aware of other vehicle's location. The principle

of the protocol is based on exchanging *normalized* information pertaining to a vehicle's movement at known time intervals. Normalized information is computed through simple sensors (transducers) fitted within a vehicle that record vehicle movement such as displacement and average angle traced within the duration of the measuring interval. The information is normalized: the traced out angle a vehicle makes since its previous position (recorded during the last information exchange) is normalized with respect to the geographic north, while the distance a vehicle covers is converted to the net displacement from its previous position. When two vehicles exchange their distance recordings of each other as well as their own normalized movement related information our protocol enables them to discover the location of each other. The process of location sensing or discovery involves several iterations each of time bound durations. Iterations are small enough so as to reduce the possibility of an accident occurring while the protocol is in the process of completing location discovery, conversely iterations are large enough that the normalized information sent by one vehicle to another is rendered useful in aiding location discovery. Logical (protocol) based mechanisms for location sensing require stringent assumptions – global clocks (synchronization), equipment for measurement on a road/highway, GPS systems, all of which are expensive and impractical or require upgrade of the entire vehicle fleet [3, 5]. The challenge is in developing location aware mechanism that requires neither complex signal processing or synchronization, and yet be performed in a wireless ad hoc system. In Section II we explain the abstract model of the proposed protocol. Section III discusses system requirements and enhancements that a vehicle would require in order to implement our protocol. Section III also discusses assumptions that we take into account as well as throws light on certain physical layer characteristics that are necessary for the successful implementation of our protocol. Section IV explains theory of our implementation and also proposes some adaptations as compared to our results in [8]. Section V presents results from simulation while Section VI summarizes the contributions of this paper.

II. ABSTRACT MODEL

When vehicles are within a certain power-limited range of each other they form an ad hoc network. The ad hoc network is formed by sending out discovery packets by vehicles (nodes) to each other, when they are in the proximity (defined with some power threshold) of one-another. Nodes can be members of more than one ad hoc network. Two nodes which are part of a common ad hoc network are able to discover each other's location and other movement parameters through our proposed location and movement tracking mechanism explained next. For discovery, nodes exchange two types of information: obtained from observation of the

other vehicle (node), and obtained from recordings made by the node itself about its own movement. Through a set of consecutive iterations nodes are able to discover each others location and are able to compute the paths that each node is following. Through path computation, nodes are able to predict if an accident can occur and if any adaptation is required to be carried out. The information exchange is done repeatedly even after discovery as long as the two nodes are part of a common ad hoc network.

We assume that all vehicles (nodes) in the entire system are asynchronous i.e. the clock used by each node has no relevance in phase to that of any other node. The periodicity with which a node transmits information to another node is fixed. The information pertains about a node's movements (like net displacement, average velocity etc.) during the interval between current transmission and the previous transmission. Two variants of this periodicity of information exchange are proposed: one is globally fixed while the other is locally fixed. Nodes using globally fixed periodicity transmit information pertaining to their past movement at intervals valid throughout the system. These nodes can be discovered or can discover other nodes that also follow global periodicity. Nodes using locally fixed periodicity change the periodicity with which they send information through a handshaking protocol. The handshaking protocol enables two nodes moving at a certain velocity to best determine what will be the periodicity with which they should exchange information so as to detect collision courses despite their mobility in the least amount of time.

The information sent by a node to another node includes the power-level at which the transmitter is transmitting the packet and the time elapsed between any two consecutive transmissions along with displacement and angle tracings. The receiver node uses the information contained within the received packet, as well as the observed power value of the received signal to compute the location of the transmitting node. Once a node is able to compute the location and movement course of another node, it would be able to predict if a collision would happen (by comparing its own movement during the same interval) and hence can take appropriate recourse action.

III. VEHACOL SYSTEM DESIGN

There are three levels of system requirements to be considered – the ad hoc network, the vehicle enhancements and the protocol.

A. Ad hoc network: Assume an N node ad hoc network such that each node will have 2 mother frequencies and $(N-1)$ peer frequency (explained below) for transmission. Thus each node will need $N+1$ narrow-band channels. Thus, for N nodes, our system needs $(N+1)^2$ narrow-band channels or frequencies. The ad hoc network uses packets for transmission. Packets are Ethernet frames (64-1500 bytes long). Frequency allocation is done in a dedicated way so as to prevent any collision of transmitted packets. As N increases the number of channels/frequencies required increases significantly (square), and hence we suggest the use of narrow band channels that support few Kb/s of bandwidth (packet sizes of few ms).

Mother Frequencies: At every vehicle of the two mother frequencies, one is used for power computation (the mother-p frequency) while the other is used for identification (the

mother-i frequency). The mother frequency is selected based on auto-negotiation of an available frequency. Each vehicle (node) transmits a *proclamation* packet using its mother-i frequency. At the MAC layer the transmission is multicast to a *well-known* multicast address. The mother-p frequency is used for computing distance of nodes from each other. Since measurement of distance based on observed power is known to be inaccurate we insist that the mother-p frequency follow certain transmission guidelines. We assume that interacting vehicles in an ad hoc network are restricted to a zone of interaction that is limited by line-of-sight (LOS) hence implying multipath fading to be the principal degrading factor lowering reliability in the computation of distance from observed power. The LOS assumption does limit our system but we argue that non-line of sight based measurement can result in accidents only at cross-sections of roads, for which we propose some different mechanisms for collision avoidance (discussed in a later article). The mother-p frequency has an objective of enabling a receiver to compute its distance from a transmitter by observing the (received) power of the mother-p frequency sent by the transmitter. We propose simple modifications at the transmitter and receiver ends to circumvent the effects of multipath fading.

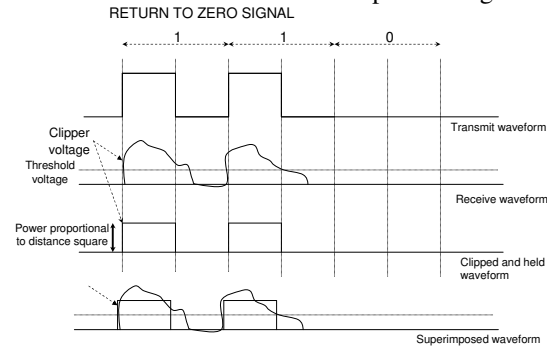


Fig. 1. Mother-p channel characteristics

While general ad hoc networks use complex modulation and coding techniques like OFDM/CDMA with QPSK etc., we argue that since the function of the mother-p frequency is only to convey to the receiver an accurate power level, we can relax the coding technique to simple amplitude modulation (AM). The AM implies that the corresponding receiver has a simple design. Now, despite the mother-p frequency sending a train of pre-determined sequences at a preset power level, there is strong possibility of non-linear delay spread and inter-symbol interference (ISI) affecting the observed received power. To avoid this, we require that the different and in particular non-LOS (reflected, diffracted and scattered) components of the transmitted signal all reach the receiver within the period of the pulse. This requirement is technically impossible to achieve using AM and commonly used NRZ coding scheme. So we propose a CS-RZ (Carrier Suppressed Return-to-Zero) coding technique for transmission on the mother-p frequency. The advantage of the CS-RZ modulation format is seen through Fig. 1. As observed in the figure, multipath components of the signal being delayed and varying in amplitude are spread through out the RZ pulse. The RZ part of the pulse in this case circumvents the multipath fading components. However, there is still one aspect to be considered. From Fig. 1, we see that multipath components can add up within the pulse to increase the received power

level and hence creating an error in measurement of distance. To avoid this, we propose a *clipper and hold* circuit at the receiver. The clipper and hold circuit analogous to a burst-mode optical receiver [7] clips and holds the signal level to the power-level of the received signal components that arrives first. This observed power level is the actual LOS component in the signal – since it was the first to arrive (amongst all components). The clipper also starts a counter once the power level is observed and the counter stops when the pulse width is reached, thus disconnecting (and ignoring) the rest of the pulse.

Shown in Fig. 1 is the diagram of the transmitted and received signal. Note that the effect of multipath fading – both delay spread and ISI are compensated by the dual choice of clipper circuit at receiver and AM RZ signal used by the transmitter.

Peer Frequency: It is used for unicast transmission between the node and another node (with a known destination address).

Formation (and deletion) of the ad hoc network: A node contiguously monitors its $3(N-1)$ receivers ($2(N-1)$ mother frequencies and $(N-1)$ peer frequencies). When it receives a proclamation packet corresponding to an ad hoc network, which it is not part of, it attempts to have communication with this new neighbor. Likewise, a node continues to send proclamation packets on its mother frequencies to enable other nodes to discover it and form an ad hoc network. Upon receiving a proclamation packet from an unidentified node, a node checks if the power level of the arriving packet is greater than the ad hoc networking threshold. Based on the destination address of the received packet, the node then sends a packet (called peer packet) directly to this node on the peer frequency. The two nodes then exchange information periodically and identify whether or not they are on collision course based on the protocol described in Section IV. Conversely nodes that drift away cease to be part of the ad hoc network.

B. Vehicle Enhancements: We assume that a vehicle is equipped with an ad hoc network interface and a wireless power-meter.

Precision Clock: Each vehicle is assumed to have a precision clock (though there is no correlation between clocks).

Transmitter/Receivers: Each vehicle has $3(N-1)$ fixed receivers, each of which is either tuned to the one of the mother frequencies or to the peer frequency of every node in the ad hoc network.

Each vehicle sends a *proclamation* frame on both its mother frequencies every T seconds. The proclamation frame sent on the mother-p frequency consists of 20 bytes of a specific pattern. The first four bytes are training bytes [7] that help the receiver determine the threshold voltage level (separating logical 0s from 1s). The next 12 bytes are power sequences that are used by a receiver to determine the power level. The proclamation frame sent on the mother-i frequency is an actual Ethernet frame consisting of information pertaining to the movement (displacement and angle) that the vehicle traces out since the last time it sent a similar proclamation frame. Note that a vehicle sends a proclamation frame every T seconds, where T may be static (globally fixed) or dynamic (locally fixed).

Reference On-board Compass: A vehicle is assumed to be equipped with a compass. Any angular movement the vehicle makes is measured with respect to the geographic North.

Central processor: Each vehicle is equipped with a central processor. Its function is to collect information about the

vehicle as well as about other vehicles through the ad hoc network. It executes the protocol we describe in the next section. Based on the protocol, the central processor makes a decision pertaining to collision. It is assumed to be able to force a particular movement into the vehicle if it foresees a collision or can alert a driver of an impending collision.

Inputs to the Processor from the Vehicle: Transducers and sensors connected to the axle, steering column, brake pedal and accelerator pedal report actions taken by the vehicle to the central processor. Reported actions include:

- **Angular Movement changes:** Changes in steering movements such as turns are reported by a transducer that converts mechanical movement of the steering column or wheel axle into degrees. A counter makes a net sum of all the directional changes that take place in the duration $[t, t+T]$. After every T seconds, a node computes the angle θ that implies the net angle through which the node has moved from its previous position with respect to the geographic North (with the use of the on-board compass).
- **Displacement changes:** The net displacement of the node in the interval T is also reported to the central processor.

C. Protocol Requirements: There are two types of packets that a node transmits – *proclamation* packets and *peer* packets. Proclamation packets are sent by a node on its mother-i frequency with an objective to inform all nodes about its existence and recent movement (speed, displacement and angle). Peer packets are sent by a node to a particular destination node after contact has been made. Peer packets contain information that tells the destination node about possible course of collision as well as coordinates estimated through the protocol etc.

C.1. Packet formats for Proclamation packets: The fields for the proclamation packet (and peer packet) are shown in Fig. 2.

Source Address field: This field determines the MAC address of the source node that sends the proclamation packet.

Transmit power: This field indicates the transmitted power level by the node (we assume to be 1mw or 0dBm).

Direction: This field indicates the direction in terms of angle made with respect to the geographic North that the vehicle has traveled in the last T seconds. The angle is computed as the resultant sum of the angles traced in the duration $[t, t+T]$.

Mother frequencies: This field indicates the frequencies at which the node continues to broadcast mother-i and mother-p messages.

Displacement: This field indicates the net displacement the vehicle has undergone in the past T seconds. Note that net displacement will be computed as the straight line distance between the point at which the node was at time t and the point at which the node is at time $t+T$, neglecting road topology.

In addition, the packet contains a T value field, which is used to tell neighbor nodes of the interval between which the node transmits proclamation and peer packets.

C.2. Peer packet:

The peer packet contains all the fields in the proclamation packet and the following additional fields:

SA/DA field: indicates the source address of the sender, and destination address of the intended receiver.

Received Power level: This field indicates the power level received by the sending node from the node to which the packet is sent (DA).

Estimated distance: This field tells estimated distance between the transmitter and receiver (if known).

Estimated coordinates: This field tells the destination node what it estimates its coordinates are with respect to the transmitter if they are already computed.

Collision estimate: This field indicates to the destination node the distance and time to collision, if both the vehicles continue to travel on the same *displacement* course. It is possible that the estimated collision spot may not exist (topology agnostic) on the road at all or there may not be a collision spot as in the case of diverging vehicles.

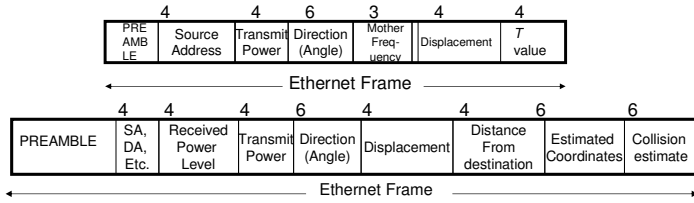


Fig. 2. Format of the proclamation packet (above) and the peer packet (below)

IV. VEHACOL PROTOCOL

Assume two vehicles represented by node *A* and node *B* part of our system and assume them to be part of the same ad hoc network (within each other's vicinity). For node *A*, to estimate if node *B* is on a collision course, node *A* has to compute the relative position of node *B* with respect to itself; trace out the path being followed by node *B*; as well as the path followed by itself and then compute whether these two paths result in collision. To do so, node *A* records two successive instances of peer packets that it receives from node *B* to itself say at times t_1 and t_2 such that $[t_1, t_2]=T$. At these two instances, node *A* also records its own position as well as its path traced between the two instances. Through the information carried within the two peer packets and the approximate distance computed using the proclamation packet (on the mother-p frequency), node *A* will be able to record the course of node *B* and then match this course with its own course (computed between the times t_1 and t_2) hence estimating whether the two courses are collision centric or not.

We now break the above problem of finding the location of node *B* with respect to the location of node *A* into two sub-problems – that of finding the distance between nodes *A* and *B* at time t_1 and time t_2 and the position (angle) of node *B* with respect to node *A* and the geographic North.

A. Distance Computation: Whenever node *B* sends a peer packet to node *A*, it also sends a proclamation frame on the mother-p frequency. This proclamation frame is the sequence of 0s and 1s sent using AM and coded according to CS-RZ format. From this sequence, node *A* is able to record the power level of the packet (from *B*) at its receiver. Simultaneously *A* receives a peer frame from *B*, through which, *A* is informed of the transmitted power level. It then compares the received power level with the transmitted power level. Node *A* can now compute the distance (not position) of node *B* from itself through LOS transmission characteristics of received and transmitted power. We assume that the antenna gains of *A* and *B* are known to each other as well as the wavelengths and other physical transmission characteristics are identical. Likewise, node *B* computes its distance from node *A* (at possibly another

instance) through a similar technique. For this computation we also assume:

1. The area of operation is based on LOS [1].
2. Through our selection of modulation technique and coding format, we are able to isolate the power received purely through LOS measurement (shown in simulation also).
3. Negligible Doppler effect.

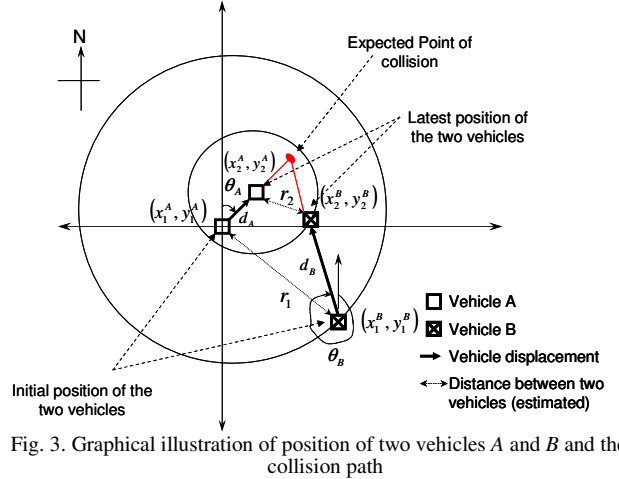


Fig. 3. Graphical illustration of position of two vehicles *A* and *B* and their collision path

Based on the above assumptions we now delve into how the protocol measures distance between two nodes and subsequently compute the exact location of a node perceived by the other. If P_A is the power at which vehicle *A* transmits its packets, and if P_B is the power at which vehicle *B* transmits its packets, and if vehicles *A* and *B* are aware of these transmit power levels (through the power field in the peer packet) and if P_B^A and P_A^B are the received power levels at *B* and *A* respectively, then,

$$P_B^A = K \frac{1}{(r_{AB})^2} P_A \quad \text{and} \quad P_A^B = K \frac{1}{(r_{AB})^2} P_B \quad (1)$$

where, r_{AB} represents the distance between nodes *A* and *B* and K represents the physical constant of the system (function of antenna gain, wavelength of transmission etc.). From above, r_{AB} and K can be found out. For this computation, a maximum time of $2T$ seconds is required (assuming T to be the same for both *A* and *B*).

B Location Computation: Once node *A* knows its distance from node *B*, node *A* desires to find the location coordinates of *B* with itself as a reference. To do so, it must find the angle with reference to the geographic north at which node *B* is located at times t_1 and t_2 . To find the coordinates of node *B* from node *A*, our method involves correlation of the information gathered from the two consecutive readings of observed distance r_{AB} recorded at times t_1 and t_2 and the displacement and direction of *B*'s movement in this time-interval sent to *A* through the peer packet from *B*. To illustrate how this works, consider Fig. 3. In the figure, we have the two moving vehicles *A* and *B*. Our objective is to evaluate at node *A*, if the paths taken by node *A* and node *B* would result in collision or not. Using the distance approximation given in (1), node *A* computes its distance from node *B* as r_1 and r_2 at times t_1 and t_2 . At time t_1 node *A* is at a position $A(t_1)$ (which for discovery purposes is assumed by *A* to be the origin); hence coordinates $(x_1^A, y_1^A) = (0,0)$ and at time t_2 the position is

denoted by $A(t_2)$ with coordinates (x_2^A, y_2^A) (which are known by A through local transducers). Node A assumes node B to have coordinates, $B(t_1) \equiv (x_1^B, y_1^B)$ and $B(t_2) \equiv (x_2^B, y_2^B)$ respectively at time t_1 and t_2 . The coordinates of B need to be computed by A. Using (1), node A is aware of the distance between itself and node B at times t_1 and t_2 as r_1 and r_2 respectively. Hence, A knows that B resides on a circle of radius r_1 and r_2 at times t_1 and t_2 respectively. From the *displacement field* in the peer packet that A receives from B at time t_2 , node A is also aware of the net displacement that node B has undergone from the unknown point $B(t_1)$ to the unknown point $B(t_2)$ on the two circles. From the *direction (angle)* field of the peer packet that node A receives from node B, it is aware of the angle that B traces out with reference to the geographic North as it moves from $B(t_1)$ to $B(t_2)$ and assumes that this angle is θ_B . At time t_2 , node A has reached a point $A(t_2)$ whose coordinates it computes with reference to (a) the geographic north, and (b) with the origin that it assumed for computing B's coordinates (position $A(t_1)$). The coordinates of node A at time t_2 are: $A(t_2) \equiv (x_2^A, y_2^A)$. Since, node A has recorded its own displacement and its own direction (denoted as θ_A w.r.t. geographic north) while moving from $A(t_1)$ to $A(t_2)$, it can compute $A(t_2)$ as $(x_2^A, y_2^A) = (d_A \cos(90 - \theta_A), d_A \sin(90 - \theta_A))$, where d_A is the net displacement that node A undergoes while moving from position $A(t_1)$ to $A(t_2)$. Similarly, we also define, d_B as the net displacement that vehicle B undergoes while moving from position $B(t_1)$ to $B(t_2)$.

Using the known position of itself at times t_1 and t_2 extracting information pertaining to the displacement as well as the direction of the line segment that joins the points, $B(t_1)$ and $B(t_2)$, and considering the position of $B(t_1)$ and $B(t_2)$ as two points on circles of radius r_1 and r_2 respectively, node A would be able to compute the coordinates of $B(t_1)$ and $B(t_2)$ with reference to itself (origin = $A(t_1)$). Node A uses the following four equations for this computation:

$$\sqrt{(x_1^B - x_1^A)^2 + (y_1^B - y_1^A)^2} = r_1 \quad (2)$$

$$\sqrt{(x_2^B - x_2^A)^2 + (y_2^B - y_2^A)^2} = r_2 \quad (3)$$

We know, that $(x_1^A, y_1^A) = (0, 0)$,

$$(x_2^A, y_2^A) = (d_A \cos(90 - \theta_A), d_A \sin(90 - \theta_A))$$

$$\sqrt{(x_2^B - x_1^B)^2 + (y_2^B - y_1^B)^2} = d_B \quad (4)$$

$$\text{Also, } \frac{y_2^B - y_1^B}{x_2^B - x_1^B} = \tan(90 + \theta_B) \quad (5)$$

For clarity, the notation in Fig. 2 is mentioned in TABLE I.

Solving equations (2) through (5) results in (x_1^B, y_1^B) and (x_2^B, y_2^B) . To show that these values are accurate, (since equations are in quadratic form, and more than one solution exists), we have the following proposition.

Proposition: If there are two non-concentric circles with unequal radii lying in the same plane and if there is a line segment of length l with a slope m , then this segment touches the two circles at unique points on both the circles.

The net displacement traced by nodes A and B between times t_1 and t_2 form two lines whose equation is given in (6) and (7). Note actual paths traced by A and B are not

necessarily straight lines, we simply compute if the resultant displacement, direction and speed would result in collision and hence to be aware of the net distance between the two vehicles.

$$\text{Line A, } y = \tan(90 - \theta_A)x \quad (6)$$

$$\text{Line B, } y = \tan(90 + \theta_B)x + c \quad (7)$$

We then need to compute the intersection point (x_k^{AB}, y_k^{AB}) which is the solution for line A, and line B. If (x_k^{AB}, y_k^{AB}) exists, then u represents the integer multiplicand of T such that, the two vehicles A and B collide.

Computation of T:

For computation of T , we have to adhere to the following bounds.

1. It should be large enough such that d and θ have some physical relevance.
2. It should be small enough such that the in the interval t_1 and t_2 a collision does not take place.
3. It should be large enough to ensure circles are separate (unless a vehicle is static, which is a special case and easily solvable for (x_k^{AB}, y_k^{AB})).

In the globally fixed variant, T is fixed for all vehicles throughout the system and does not alter with the velocity. In the locally fixed variant, each ad hoc network in the system has its own T . The value of T in this case is chosen by the vehicle with the fastest velocity since this vehicle is the one which has highest probability of collisions if its course is undetected. The procedure for selection of T is based on cooperative agreements and is not discussed here due to space constraints.

TABLE I: NOTATION

Notation for two vehicles A and B to discover each other:

$A(t_1)$: The initial position of vehicle A at time t_1 and denoted by (x_1^A, y_1^A)

$B(t_1)$: The initial position of vehicle B at time t_1 and denoted by (x_1^B, y_1^B)

$A(t_2)$: The final position of vehicle A at time t_2 and denoted by (x_2^A, y_2^A)

$B(t_2)$: The final position of vehicle B at time t_2 and denoted by (x_2^B, y_2^B)

θ_A : The net angle traced by vehicle A w.r.t. the geographic North moving from the point $A(t_1)$ or (x_1^A, y_1^A) to the point $A(t_2)$ or (x_2^A, y_2^A)

θ_B : The net angle traced by vehicle B wrt the geographic North moving from point $B(t_1)$ or (x_1^B, y_1^B) to the point $B(t_2)$ or (x_2^B, y_2^B)

d_A : The net displacement of A moving from position $A(t_1)$ to $A(t_2)$.

d_B : The net displacement of B moving from position $B(t_1)$ to $B(t_2)$

V. SIMULATION MODEL

We built two simulators: a physical layer Simulink model and a highway based collision emulator. The Simulink model is to verify power computation mechanism proposed by us in Section III and IV. In the model, AM CS RZ waveforms at 10 MHz are sent by an omnidirectional antenna with unit gain. A receiver with a clipper and hold circuit is used for detecting the waveform. The transmitter and receiver are separated by a fading channel. The distance between the transmitter and receiver is controllable through our simulator. The observed distance obtained at the output of the hold circuit by (1) is compared to the actual distance. Shown in Fig. 4 is a plot of error obtained in measurement as a function of actual distance for different mother-p frequencies (10 KHz

and 1 MHz). The vehicles in both cases are assumed to be stationary as we neglect Doppler shift in our computation due to low vehicle speeds (<140 Km/h). We observe that the error is higher (>10 %) for small separations between the transmitter and receiver, reduces for separations above 15 meters and again increases for separations above 80 meters.

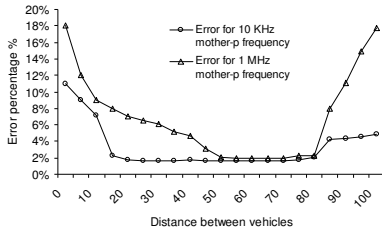


Fig. 4. Error in our power computation based on CS RZ and AM format

Our second model is the vehicle movement emulation. We assume a planar coordinate space with 100×10^6 pixels (x axis is 10×10^3 pixel, and y axis is 10×10^3 pixel), such that each pixel represents a position of a vehicle and the area of a pixel is 1 m^2 (2 seat cars). Vehicles move from 10 Km/hr to 150 Km/hr. The radius of turning of a vehicle is proportional to its speed. Initially, we assume two vehicles in the system. The initial position of the two vehicles is denoted by choice of two random numbers. A vehicle makes a movement in random fashion. However, once it makes a movement, it stays on that path (till it makes the next turn) for time governed by an exponential distribution. If a vehicle is on collision course with another vehicle, upon detection it will change its path by making another movement. The movements that a vehicle takes are acceleration, deceleration (with degrees of rate of change of velocity varying), turns (of different angles) and stopping. We assume that vehicles within 100m can only be part of an ad hoc network. We vary the number of vehicles in the system network as well as the mean speed a vehicle has. The attribute under investigation is to compute collision avoidance and to evaluate performance of our scheme when extended to a multi-node ad hoc network. The number of vehicle nodes in the system is varied between 100 and 10000. The initial distribution of vehicles is assumed to be bursty, i.e. shown through a Pareto distribution (with H parameter =0.82). The burstiness on the expectation of the location of a vehicle, means vehicles begin by being close to each other (like on congested roads). Vehicles part of a burst are assumed to move in the same or the opposite direction (two lane highway without a divider), and while moving they change lanes – lateral movement with angles 3° (careful lane-changer) to 15° (rash driver/lane cutting). The difference of speeds between vehicles is in the range of 0-40 km/hr (60km/hr representing the mean speed). The model aims at observing the number of times collision is avoided, as well as the time required for estimating collision, the accuracy of the model, and the effect of difference in speeds between vehicles. The time required for estimating a collision course is shown as a function of the differential speed between the two vehicles in Fig. 5. The number of times collision was detected was 168 (within a 48 hour simulation time-frame). The average speed of the two vehicles was 94 km/hr.

Shown in Fig. 6 is the accuracy of our proposed scheme as a function of combined vehicle speed (adding speed of two vehicles). Accuracy is defined as the ratio of the net

distance between vehicles to the distance with the actual position of the vehicle. We observe that for constant value of T the performance improves at higher speeds. Intuitively, we can conclude that an adaptable value of T would be best for collision estimation and avoidance. The algorithm for the computation is omitted for lack of space.

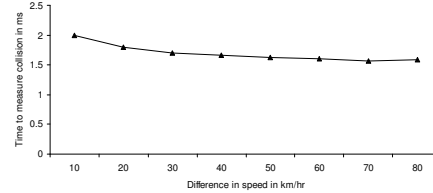


Fig. 5. Measurement time for collision course

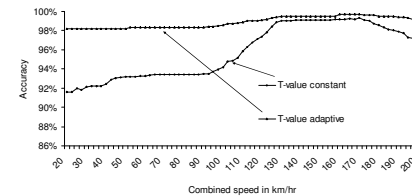


Fig. 6. Accuracy of prediction of position

VI. CONCLUSION

In this paper, we present a mechanism (solution) to estimate collision courses amongst moving vehicles. The mechanism is called Vehacol and it uses an approach of combining power measurements with periodic information exchange between vehicles. The mechanism requires system assumptions that are pragmatic neither requiring synchronization of vehicles, nor any extra upgrading of vehicular infrastructure. For power measurements and translating these to distance measurements we propose a novel AM CS RZ scheme and a clipper and hold circuit that enables a receiver to accurately estimate line-of-sight power components of a multipath signal. We further propose a periodic information exchange protocol that enables detection of collision courses. Simulation study of the proposed mechanism and observance of error is also presented. In future, we aim at extending and testing the mechanism to more complex scenarios.

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