An Efficient Approach towards Vehicle Number Estimation with Ad-hoc Network under Vehicular Environment

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***Abstract*—Ad-hoc network usability extends the application for Dedicated Short-Range Communication. This type of ad-hoc network technology is non infrastructure and due to this fact, it can be used for Direct Short Range Communication System to provide the quick and real time message to the vehicular operator to prevent the damage and fatality of life by meeting accidents and crashes. In this paper, we present a holistic approach to estimate the number of vehicles in specified range of one KM distance. The designed system for vehicle number estimation is based on the Time Division Multiple Access mechanism which further estimates the number of reserved slots by vehicular nodes. This estimation methodology is tested under the digital simulator and approximately 34 number of vehicles for 24 seconds are defined to test the slot reservation. We found that in case of vehicular nodes greater than 20, slot reservation accuracy is 95% and when the vehicular nodes are less than 20 then the slot reservation is 100%.**

Keywords—Vehicular ad hoc networking; hidden vehicle; visible vehicle; time division multiple access; dedicated short range communication

I. Introduction

Dedicated short range communication (DSRC) structure was specially developed for the vehicular communication technology. A bunch of wireless methodologies are available for the primary medium of communication to DSRC. The major needs of wireless system under ad-hoc network for vehicular environment is that the latency should be 20 mili seconds or less than it, throughput should be high, and it cover the communication range up to one kilometer. There should also be support of diverse schemes of communication with the wireless technology. The important one is support of one-way in both uplink and downlink communication allowing the vehicular nodes to dissipate a broadcast message. The second important communication requirement is two-way that allows two vehicles to establish the dialog between them. Third important one communication requirement is point to point and point to multipoint. The point to point communication supports the message delivery to specific location or vehicular node, and point to multipoint communication the message is sent to many locations or vehicular nodes.

It is much important to evaluate the wireless technologies to determine which particular meets the DSRC requirements. A modified version of IEEE 802.11a with Time Division Multiple Access (TDMA) methodology equipped Physical layer is considered to be best suitable for DSRC communication [1]. Also, the other evaluated wireless technologies are not suitable so that these technologies are unacceptable with many different reasons. The cellular and satellite communication systems provide huge bandwidth but these two technologies have high latency. Due to this fact cellular and satellite technologies are suitable only for some of applications of DSRC. The cellular technology does not support the message broadcasting and it is a costly communication system. Similarly, satellite communication system is costly and is not suitable for DSRC applications. The wireless technology under the DSRC applications should be free of cost and must be based on ad-hoc communication. Also, the cost pertaining to the infrastructure must be cheaper than that of the satellite and cellular communication system.

Vehicular ad hoc network (VANET) becomes a challenging task to implement in real world scenario. Ad-hoc network in vehicular environment is a type of mobile ad hoc network where the computing nodes are being implemented on vehicles with modern technique of communication devices. The communication of information from vehicle to vehicle or vehicle to roadside and vice versa is performed with the active help of fast computing environment. The clear scenario for feasible vehicular communication for the different categories of applications is either related to public safety or general, such as internet accessibility based upon the various factors of vehicular ad hoc networking. One of the major problems related to estimate the number of vehicles in a lane with respect to the coverage area of an antenna established at roadside. The roadside installed antenna is also equipped with modern fast computing devices. The major role of roadside installed station is to provide the information related to vehicle safety along with structural aspect of road and highway. The estimation of number of vehicles in the specified range of the road or highway is very challenging task due to dynamic nature of vehicles.

II. Literature Review

Different forwarding methods based on the broadcasting are infrastructure less node to node communication. It is facilitated by ad hoc network under vehicular environment. The broadcast contention control provides the reliable and low latency multi-hop connection. Algorithm behind the broadcast contention control optimizes the back off distribution and provides the priority to forward the information related to the location of the node [2].

Ad-Hoc network under the vehicular environment provides the connection among the vehicular nodes of vehicles on the road. This is considered an important and valuable concept to improve the safety of the transportation system with elegant efficiency. Time division multiple access relies on slotted frame structure having the good quality of service framework. This has low scalability and complex synchronization mechanism. The vehicle number estimation according to the slot reservation is not always be optimal due to the delay and less quality of service having interference and the speeds of the nodes running on the vehicle [3].

Ad-Hoc network under the vehicular environment is more vulnerable to the Denial-of-Service attack [4]. One the most common Denial of Service Attack is Jamming attack which leads to the interference with the used wireless ad-hoc network service and creates the network congestion. Once the Jamming attack progresses, the quality of service of the ad hoc network degrades and the optimal service cannot be achieved. Due to this fact the vehicle number estimation fails and this causes the failure of the overall network service of ad hoc network in vehicular environment.

A cross layered Medium Access Control having clustering mechanism supports the propagation of the broadcast message in ad hoc network under vehicular environment [5]. Distributed dynamic clustering frames, and the dynamic virtual backbone in the ad hoc network are the building blocks of the cross layered Medium Access Control. The members associated and connected with the ad-hoc network in vehicular environment are responsible to implement the efficient message propagation to utilize the slot and count the numbers of allocated slots in the vehicle number estimation. This fails when the vehicle's speed goes beyond the defined threshold value and the performance of this method degrades.

III. Proposed Method for Vehicle Numbers Estimation

In case of vehicular ad hoc networking there are two different categories of vehicles on road or highways. These two categories of vehicles are either visible or hidden vehicles. To estimate the number of vehicles, it should be first determine the estimation method for both hidden and visible vehicles. The hidden vehicle is considered hidden because this type of vehicles has not joined the coverage area of roadside antenna. The estimation of visible or hidden vehicles are taken with the help of reservation of slots under Time division multiple access (TDMA).

A. *Visible Vehicle Numbers Estimation*

The intensity of vehicles with respect to specified time in a given direction is estimated by the number of occupied slots of TDMA channel by sequence numbers from beginning to end [6]. The specific beacon frame containing message indicates by adding an additional field into the frame format. This estimation of number of vehicles is performed with every regular interval of time by roadside station with broadcasting to all vehicles in the coverage range of station. These visible vehicles become under the control of regulation. The determination of visible vehicles is shown with Fig. 1.

In accordance with Fig. 1, it is very clear that the road is only two-lane structure. For left side running vehicles in a lane under same direction reserves the slots of TDMA from left to right [7]. The vehicles running into right side in other lane under opposite direction on road reserve to slot of TDMA in reverse direction. The sequence numbers of reserved slots are not repeated in any case. Hence, the sum of highest sequence numbers of both lanes TDMA slots forward and reverse directions gives the total number of visible vehicles on the coverage area of roadside station.

B. *Hidden Vehicles Number Estimation*

Roadside installed stations checks the number of hidden vehicles with regular interval of time by beaconing itself. The beacons with additional parameters are listening to all the vehicles but vehicles avoid this which is already connected into the network with specified group. An additional sub field that contains the connecting request information for the vehicle node is attached under the beacon frame. There is specified number of two slots under the TDMA slots which depict the beaconing for estimating the hidden vehicles. These two slots cannot be probed and reserved by any vehicles in any direction. These slots are indicated by special identifier Hidden Vehicles (HV) [8]. Under this slot interval any vehicle probing is observed then it is concluded that this is hidden vehicles and roadside unit add one in hidden vehicles number and subsequently broadcast the message to all groups about the hidden vehicle. The TDMA slots are reserved for HV predicted under Fig. 2.

The TDMA channels slots of Fig. 2, shows that the first HV is in a forward direction and second in the reverse direction of vehicles.

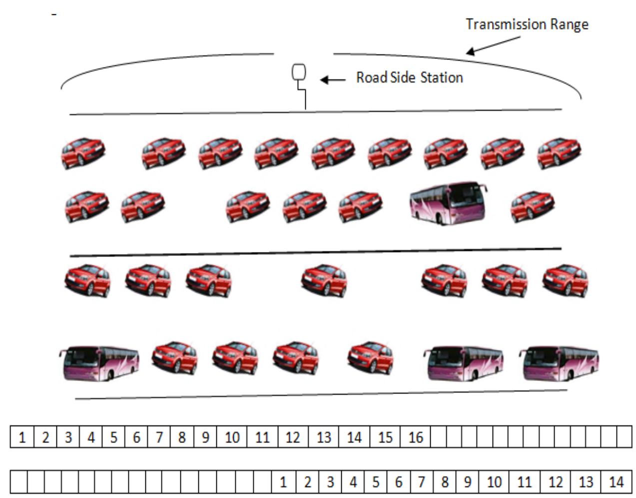

Fig. 1. Visible Vehicles having Ad-Hoc Network Node.

1	2	3	4	5	6	8	9	10	HV	
HV	1	2		3	4	5	6	7	8	9

Fig. 2. TDMA Slots with Hidden Vehicles.

Suppose that the probability is p of hidden vehicle which transmit HV frames under the TDMA slots and n is the total number of hidden vehicles in both directions of vehicles in two lanes of given road. Again, let, n1 be the number of vehicles in one direction and n2 be the number of vehicles in opposite direction. Also, let m be the total number of hidden vehicles under the communication range of a roadside station, we can derive the probabilities of the different status of HV Channel slots.

Probability that HV slot is ideal

$I = (1 - p)^m$

Probability that HV frame is successfully received from a hidden vehicle in a direction is

$DP_1 = n_1 p(1 - p)^{m-1}$

Probability that HV frame is successfully received in opposite direction hidden vehicle is

$DP_2 = n_2 p\,(1 - p)^{m-1}$

Therefore, the total number of estimated hidden vehicles in each same and opposite directions are calculated as,

$$n1 = \frac{s1}{I}\left(\frac{1-p}{p}\right)$$

$$n2 = \frac{s2}{I}\left(\frac{1-p}{p}\right)$$

After getting the probabilities values of vehicles in each direction we can further smooth the values by exponential moving averages by smoothing factor VHAlpha, which is a system parameter [9].

IV. Designed System Simulation

The estimation of hidden and visible vehicles simulation is performed with the above-mentioned criteria with total number of 30 vehicular nodes. The vehicles that are under the vehicular ad-hoc network environment must have the digital map under the designed simulator application. We have used constructed files as a digital map to simulate the VANET. The constructed files contain detailed geographical information about the road. The data which digital map contains comes in the form of geographical coordinates (latitude, longitude) for the road [10]. The constructed files based on the selected road specify the end points, having the intermediate points those are required. In case, when the road is straight, then there is not any intermediate points. This is so because the intermediary points are calculated by the help of interpolation. Further, in case of the road having curves, there are very huge numbers of intermediate points, so that the map is considered accurate.

The traffic simulator that takes actions of each of the vehicle under the given scenario is a digital simulator, as opposed to those digital simulators that use the global measure like density of traffic on road to describe the evolution of traffic. The dynamics of the traffic can be better understood with help of the digital simulator and appropriate design of facilities related to road traffic such as lanes, lights, closure of lanes and corners [10].

A. *Digital Traffic Simulator*

A digital traffic simulator is an application used to simulate the traffic behavior with respect to the wireless ad-hoc network communication message. Each of the vehicles which are taken under the vehicle has the computing node and is able to send and receive the wireless signals to the others. Simulating in digital traffic simulator there is requirement of setup of the vehicles and road with trajectories and intermediary point. The vehicle behavior with respect to the requirements to fulfill the order of traffic is observed in the process of simulation.

With above facts, there is requirement of high level of details to study the suitability of wireless ad-hoc network in vehicular environment. To solve this, we have designed a digital traffic simulator based on a model of behavior of driver. This designed driver behavior model is presented in Fig. 3. There are many traffic simulators such as ‘VISSIM’ and others that use this type of designed driver behavior model for the simulation of vehicular environment. Basically, VISSIM’s purpose is to model and forecast the traffic flow of vehicles, addition of new lane, making of the study of traffic closure to lane and creating the overpass and many more. Also, it is true that this type simulators are very difficult to integrate with the network simulator as these types of simulators are commercial products [12] [13].

Thereafter, we have made the description of the driver behavior model which we have deployed. The assumptions are taken under the driver behavior model are ‘free driving’, ‘following’, ‘braking’, and ‘approaching’.

Driver model with ‘free driving’ states that there is no influence by preceding vehicles under the same lane of the vehicles. Thus, the drivers have to maintain the desired speed. Although, the speed and acceleration depend on the driver and the features of the road on which the vehicles are driven.

Driver model with ‘approaching’ states that the preceding vehicle is slower in speed. In this case the driver has to de-accelerate the speed to make the same speed of preceding vehicle. Basically, de-acceleration is treated as a function of distance between preceding and approaching vehicles, their speed and other parameters in same lane of road.

Driver model with ‘following’ states that the speeds of preceding and following vehicles are equal or same. In this case the drivers of both of the vehicles maintains the same speed and constant acceleration can be maintained.

Driver model with ‘braking’ states that the slower preceding vehicle is close to front of following vehicle. In this case, the following vehicle driver has to deaccelerate by braking the vehicle to avoid the crash.

The rules defined for driver to determine the driver mode is presented by Fig. 2. Two thresholds are taken, where ‘distance1’ is first and ‘distance2’ is second, when the preceding vehicle is closer to ‘distance1’ and slower than the just following vehicle.

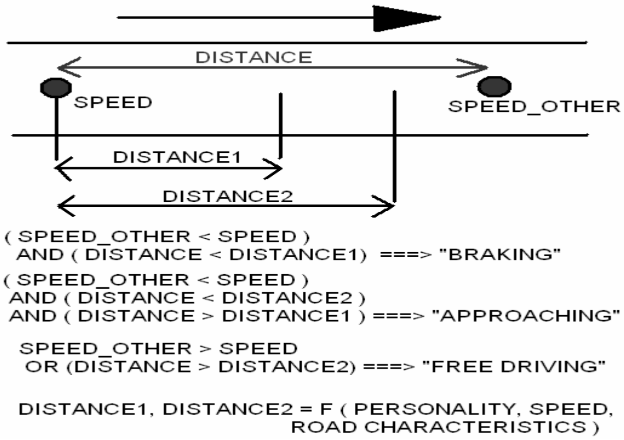

Fig. 3. Designed Digital Traffic Simulator.

In case of 'braking' mode, when the slower preceding vehicle is under the 'distance1' and 'distance2', then the mode is considered 'approaching' then the current vehicle definitely deaccelerates [14]. When the preceding vehicle is away from distance2, then there is no influence to current vehicle by any means, and it is taken under 'free driving' mode. Also, the defined thresholds 'distance1' and 'distance2' are not fixed. These depend on the driver driving style and speed of the vehicle [15] [16].

B. Simulation Data

The simulation data is based on the number of vehicles taken under simulator, lanes defined under the simulator, time specified for simulation and vehicle flow per second. The whole data is presented in Table I.

TABLE I. SIMULATION DATA

No. of Vehicles	No. of Lanes	Time (Sec.)	TDMA Slot Reserved
27	2	24	25
26	2	24	24
28	2	24	25
28	2	24	25
27	2	24	25
29	2	24	27
25	2	24	24
13	2	11	13
12	2	10	12
11	2	11	11
12	2	11	11
32	2	21	31
33	2	22	31
32	2	20	20
34	2	20	32
33	2	21	31
34	2	22	32

C. Simulation Result

The scenario of simulation provides the estimation of vehicles having node connection with station and slot reservation under the range within 24 seconds. The result shows that maximum 5% deviation in case of the heavy traffic (No. of vehicles 30 or more), and in case of the vehicular nodes less than 20 the vehicle estimation is 100% in both visible and non-visible scenarios. The simulation result is presented in Fig. 4.

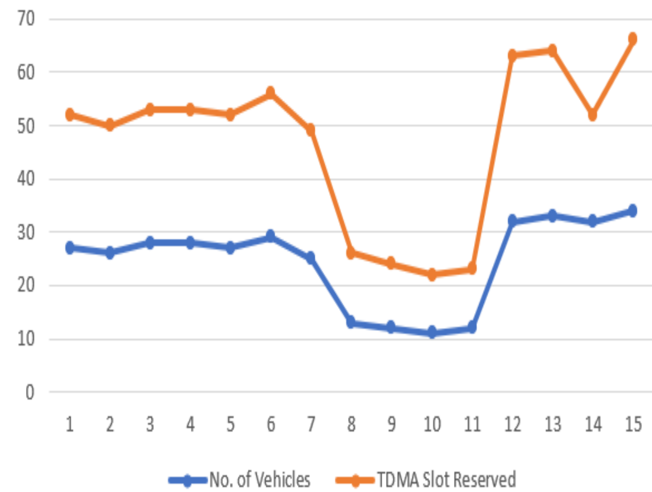

Fig. 4. Simulation Result of Vehicles Number Estimation.

The mentioned data is gathered from real time environment of the roads having two lanes under the simulator to simulate the performance. According to the simulation setup as per the given parameters the time is obtained. The TDMA slot reservation is based on the vehicles on both of the lanes under the simulation environment. Finally, the result of the simulation under the Fig. 4, is well presented.

V. CONCLUSION

The carried research work is performed to enhance safety of the living beings while travelling via vehicles like car, bus and others by employing the ad-hoc network and nodes on the vehicles. In this research work we have done the design of the digital traffic simulator and used various parameters such as approaching, distance to generate the warning message to the operators through the ad hoc network nodes to driver screen. TDMA slot allocation is used to estimate the total number of vehicles in the pre-defined range of road having single and double lane in the city scenario. The number of vehicle estimation and its results show that during the more load of vehicles, means vehicle nodes > 20 the correctness is 95% for estimation and if the number of vehicles having ad -hoc nodes < 20 then correctness is about to 100%

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