Broadcast algorithms for Active Safety Applications over Vehicular Ad-hoc Networks

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***Abstract*— This paper presents a qualitative and quantitative comparison of an enhanced version of the Multi-Hop Vehicular Broadcast protocol (EMHVB) and two others protocols: simple flooding and BCAST. In particular, they are evaluated in the context of vehicular communications, where MHVB was primarily conceived for ensuring active safety. MHVB is a flooding protocol indeed, but optimized for vehicular ad hoc networks (VANETs), so it efficiently disseminates information like positions and velocities of the vehicles for the sake of active safety applications.**

MHVB includes a "Congestion detection algorithm", which suppresses unnecessary packets due to vehicular congested traffic, and a "Backfire algorithm", which efficiently disseminates the packet through the network by selecting the adequate forwarder based on the distance from the original sender of the information.

Dynamic Scheduling algorithm is introduced in EMHVB, which prioritizes the packet transmission based upon "processing" of the received packets from the other vehicles. This saves the use of extra network resources and thus improving the performance of the protocol for longer distances.

The simulations are done with the network simulator NS2 and the results obtained are shown. The paper concludes with some analysis derived from the simulation results.

I. Introduction

The purpose of MHVB protocol [1] is to disseminate information in vehicular ad hoc network by efficiently flooding the packets among vehicles based on their position information. Based on the requirements of ITS active safety applications, a mechanism to detect traffic congestion and a method to suppress unnecessary packets for improving the bandwidth utilizations have been introduced. The introduction of congestion detection technique gave a significant impact on the improvement of the performance of flooding protocols in ITS context. However, the scalability of the protocol is not satisfactory because too many packets transmitted by many nodes lead to packet collisions and the consequent packet losses.

In order to tackle the above problem, a dynamic Scheduling algorithm is introduced, which prioritizes the packet transmission based upon "processing" of the received packets from the other vehicles. The key point in the proposal made to enhance the broadcast protocol is, the balance between the application requirement and the performance of the protocol.

For comparison purposes, a naive flooding protocol and the BCAST algorithm [2] are taken. Flooding protocols for ad hoc networks are extensively summarized in [3]. Many studies in ad hoc networking [4], [5], [6], [7], [8] propose mobility patterns in the two-dimensional plane. The nodes involved change their speed more or less randomly. However [9], vehicles in road traffic typically follow the road which allows us to reduce mobility to one dimension. BCAST implements a scalable broadcast algorithm where it uses 2-hop neighbor knowledge that is exchanged by periodic "Hello" messages.

A. Packet Format

The information transmitted between the vehicles have a pre-defined format. When each node transmits data, the information contains a header part and message part. The header contains a field for packet type and another field for number of messages including its own message. The packet type field in our case is MHVB data and designated as zero. The message part may be single or multiple. Each message (see Figure 1) basically contains the following,

1) Node identity, usually the vehicular id, unique for every node in the network

2) Packet identity generated for each packet created by a node, a whole number increasing serially
3) Time stamp, the time at which the particular packet is created
4) Position information obtained from position tracking device, for simulation purposes this is obtained from the network simulator in terms of co-ordinates x,y and z
5) Velocity information obtained from the position tracking device, for simulation purposes this is obtained from the network simulator in terms of co-ordinates x,y and z

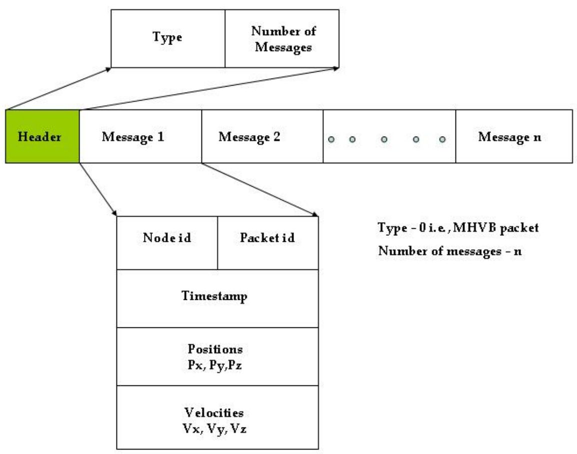

Fig. 1. Packet Format

II. MHVB

Three are the main functionalities of MHVB. This section describes them.

A. Backfire algorithm

The backfire algorithm helps to identify the right forwarding node based upon its relative position from the sender; that forwarder will refrain, i.e."backfire", other potential nodes which have lesser coverage gain by their eventual forwarding. In the earlier version of MHVB protocol [1] the shape of the backfired region is a circle where, among the potential nodes able to retransmit the information, only the farthest node from the original sender retransmits the packet, so that the coverage gain is bigger, assuming message transmission in the forwarding direction. In the enhanced version of MHVB a sectoral backfire region is implemented with its angle as an extra parameter. The main advantage by implementing such a type of backfire is that by changing the angle of the sector we can modify the area covered for backfire, resulting in a "flexible" and "directional" backfiring region.

B. Traffic Congestion Detection algorithm

The second algorithm is based on a specific application requirement of vehicular active safety that the vehicles in the middle of traffic congestion need not transmit information as frequently as the ones which are at the edges of the traffic jam or out of it. In EMHVB, this functionality is integrated and implemented in a decentralized fashion, using V2V communications.

This condition helps MHVB work more efficiently. By counting the number of vehicles surrounding a concerned node, MHVB can detect whether the vehicle is situated in the middle of traffic congestion. If it is the case, it expands the interval of transmitting his own information, therefore saving bandwidth and reducing collisions.

C. Dynamic Scheduling

In the previous version of the protocol [1], the transmitter and the receiver modules of a node work asynchronously i.e., each node transmits information periodically based upon the delay time computed due to congestion detected by analyzing the message cache. In the case where there is no congestion detection, the transmission takes place periodically every 0.1 sec with some jitter in the transmission within $(0.08,\ 0.1]$sec. Thus the timer for the next transmission is "pre-determined" ahead of one transmission interval.

In this work, we modify the pre-determined time upon each reception of information of the node thus making it dynamic. Here the nodes which are at a distance farther than a threshold are made to forward the received information earlier than the other nodes in the backfire region. Thus the time which was set during the transmission by the process of congestion detection is changed during the reception.

By this process the advantage is two fold. The packet is forwarded more quickly (e.g. an emergency warning message has to be transmitted as fast as possible and over a longer distance, which is the ideal condition for high speed scenarios). The second advantage is that when the nodes in the range greater than threshold, transmit information earlier, they indirectly backfire earlier nodes in the range lesser than threshold, thus saving network resources at lesser ranges.

III. Scenarios

Basically there were three scenarios used for validating the protocol and performing the comparisons. They are,

1) Random Waypoint model
2) Single Lane Model
3) Typical Highway scenario with intersections

The random way point model is used to test the worst case working condition of the protocol, in order to show how far the performance improves with the enhanced techniques. The scenario is a grid of 1000 sq.m. The simulation time runs for about 100secs and the number of nodes vary from 10 to 100. Figure 2 shows the scenario

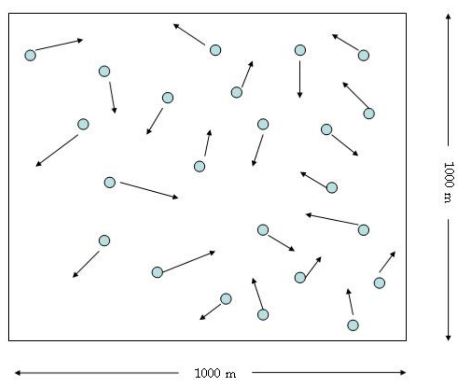

Fig. 2. Random Waypoint scenario

The Single Lane model was initially selected to check the basic performance of the EMHVB protocol itself. Nodes were placed as shown in figure 3 at regular intervals without any movement in a straight line for a certain distance. The number of nodes are also changed in order to check the performance in terms of density variation.

Finally, a typical highway scenario was used. This scenario contains four lanes intersecting each other in a two-by-two lanes fashion. This was sub-divided further into two scenarios where the relative velocities at the adjacent lanes are higher in one scenario and lower in another scenario. The highway model with crossroads is shown in figure 4.

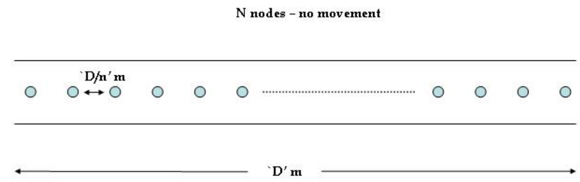

Fig. 3. Single lane scenario

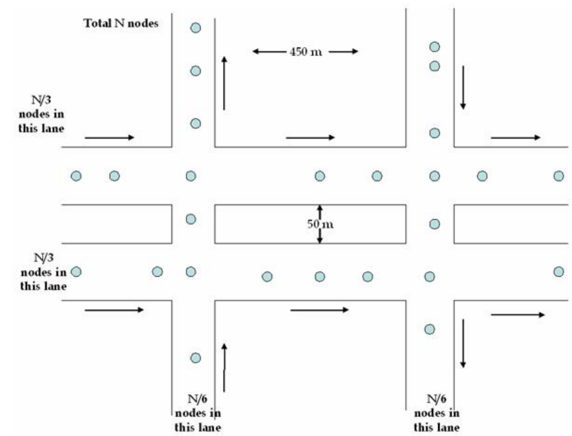

Fig. 4. Highway scenario with intersection

IV. Simulation Results

Basically there are two performance parameters considered for the for the purpose of analysis. They are as follows,

A. Performance based on the Application requirement

Considering the applications for emergency warning systems, the target application requirement stated that the information must be received within 400m and within a time span of 0.3s. Thus we define a performance parameter “Success rate” which is the ratio of the number of packets received within 0.3secs by a node to the total number of packets received by the same node during the entire simulation time T. Ideally speaking, the ratio should be 1 for distances less than 400m and 0 for distances greater than 400m. Figure 5 shows the ideal characteristics of the MHVB protocol

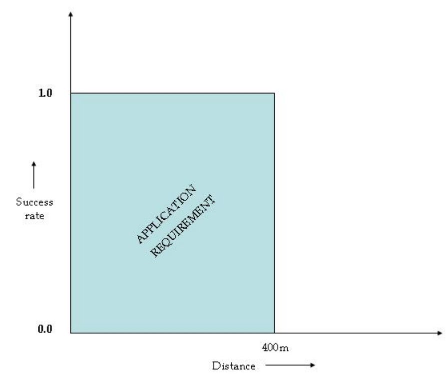

Fig. 5. Ideal Application requirement

1) Comparison with Flooding: The figure 6 shows the performance comparison of the EMHVB with the basic flooding protocol.

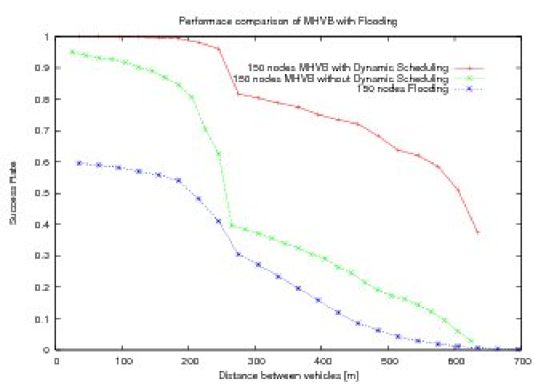

Fig. 6. Flooding vs. EMHVB

When compared to the naive flooding, the EMHVB has 40% increase in packet transmission under the radio range of 250 m i.e., 100% success has been obtained as per the application requirement.

B. Performance comparison based on Collision rate

The results in figure7 show the performance comparison of EMHVB and BCAST for the singlelane

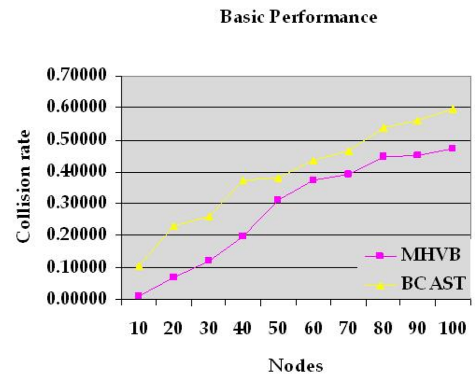

Fig. 7. Basic Performance of EMHVB and BCAST

scenario (basic performance), taking collision rate as performance parameter.

Figure 8 shows the comparative rates of collision for the random way point model.For increasing node density, the collision rate seems to be around 10% for a typical traffic scenario. For the purposes of simulation, we used the random-way point model in order to test the worst case scenario. There, EMHVB performs very well upto 50 nodes/1000 sq.m. Thereafter the gap between closes-in from 60 nodes/ 1000 sq.m and at around 100 nodes/1000 sq.m, the rate is around 35%.

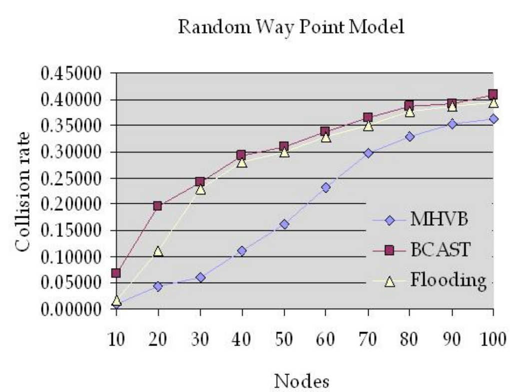

Fig. 8. Random Way-point model

The comparison of the collision rates between EMHVB and BCAST for a typical highway scenario is shown in figure 9.

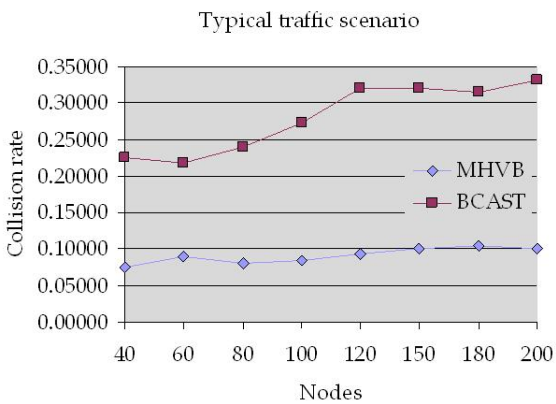

Fig. 9. Traffic Scenario

V. CONCLUSIONS

In this paper a comparative study was made between an enhanced version of the Multi-Hop Vehicular Broadcast protocol (EMHVB), its original version, simple flooding and BCAST. Improvements obtained in efficiently disseminating information through vehicular ad hoc networks (VANETs) using EMHVB are shown. The dynamic scheduling algorithm helped to improve the success rate in terms of message transmission by significantly saving the extra network resources which were unnecessarily used in the prior version of the protocol. EMHVB unlike BCAST does not require to exchange periodic "Hello" messages inorder to know its one-hop and two-hop neighbors. For higher node densities the performance of EMHVB is not as efficient when compared to the lower densities. This might be due to the packet creation process where MHVB does not define a maximum packet size and thus the packet size keeps on increasing with increasing node densities. This maximum packet size can be an optimized value which makes the collision rate become lesser at higher node densities. The optimum value can be only set after further simulation results which is one of the future works that can in proposed for this paper.

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