An Adaptive Forwarding Mechanism for Data Dissemination in Vehicular Networks

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Abstract— **Efficient dissemination of messages in a Vehicular Ad Hoc Network (VANET) still face many challenges in the current research scenario. This paper addresses the problem of redundant forwarding of messages that occur during broadcast and proposes an adaptive forwarding mechanism which controls the amount of redundant messages thereby improving message dissemination over a VANET. The mechanism will enable a node to efficiently forward a message and at the same time refrain other potential forwarders of the same message in a chosen area to forward the message. The algorithm exploits the density of nodes on the network for its functionality and will make an adaptive sector under which the redundant nodes will be refrained from sending the same message. The area of the sector for a particular node will be proportional to the density of its neighbors that are within the node's communication range. The proposal assumes that the nodes in the VANET are aware of their surroundings up to a certain area by periodic exchange of location information from each of the nodes. The mechanism will enable routing algorithms and/or beaconing systems to consume lesser bandwidth and thereby enhance the efficiency of the algorithm itself.**

I. INTRODUCTION

Vehicular Ad Hoc Network (VANET) is a Dynamic Ad Hoc network containing set of vehicles communicating between each other in ad hoc mode using the wireless medium. The vehicles move on a predefined path due to road topology and at the same time have high speeds. The kind of communication between vehicles is called "Inter-Vehicular Communications". In addition to communicating among themselves, the vehicles also communicate with fixed units on the road also known as Road Side Units (RSUs).

Recently, Inter-Vehicular Communications (IVCs) [1] are highlighted as a way to increase the road safety by utilizing the information exchanged among vehicles utilizing VANET concepts and technologies, in particular, Active Safety which aims at applications like Driver Assistance/Information or Decentralized Floating Car Data for improving traffic flows. IVCs are regarded suitable for active safety applications because of their nature to be available anywhere, to require the strict latencies and to cover localized communications. However, ITS can also deal with solutions for better comfort and/or entertainment for drivers and passengers, like (video-) chatting, Internet connection or driving information. Intelligent Transport Systems (ITS) services based on the infrastructures, such as vehicle information and communication system (VICS) and electronic toll collection (ETC), have been already implemented and deployed for practical services.

In a VANET every vehicle will be able to send and receive data packets into/from a shared medium [2]. The control channel will be utilized for the exchange of safety messages, and will contain few service messages, e.g., announcing services, if feasible. Therefore, all vehicles will have to monitor the control channel often enough to receive all safety related information so that the safety applications achieve their goal. Under high vehicle densities, problems occur with respect to the reservation of channel for exchange of safety-related information. In this context, it is likely that the limited capacity of the so-called control channel is not enough to support the safety related load generated by a large number of vehicles unless the offered load is carefully controlled. In order to achieve a good performance of safety-related protocols, a limited load has to be sent to the channel using a strict fairness criterion among the nodes.

Scarce bandwidth and interferences in mobile ad-hoc networks [3] yield the need for more efficient diffusion techniques than these employed on usual wired networks, especially in dense environments. When the network is dense, a simple flooding leads to too much overhead: not only are most retransmissions actually unnecessary, but even a single broadcast could break the network down in an ad-hoc environment, where the scarce bandwidth and the radio interferences between users will jam the traffic. A simple flooding of a message over the entire network, thus is not an efficient way to spread useful information over the network and will only use up the bandwidth which is already limited. These imply the need to create efficient dissemination algorithms which focus on tackling the above mentioned constraints.

The rest of the manuscript is organized as follows: section 2 deals with related work, section 3 explains the principle idea of the adaptive forwarding mechanism, section 4 covers the simulation results and analysis and finally section 5 will give conclusion and discuss possibilities for future work.

II. RELATED WORK

There are various techniques by which a message could be disseminated over the network but pros and cons do exist for each of them. Many studies [4], [5], [6], [7], [8] have been done to efficiently disseminate a message over the network.

Flooding is an important communication primitive in mobile ad-hoc networks and serves as a building block for more complex protocols such as routing protocols. Flooding is the mechanism by which a node, receiving flooded message for the first time, rebroadcasts it once. . Because flooding is important in MANET applications, there is a clear need for storm-resistant flooding protocols that operate efficiently. However, reducing the number of redundant broadcasts leads to a lower degree of reliability. Hence, the challenge we face is to strike a balance between message overhead (i.e., the level of redundancy) and reliability.

Multi-Point Relaying (MPR)[7] is a technique to decrease the number of broadcast message copies generated in a mobile network, while at the same time ensuring that all nodes in the network will receive at least one copy of the broadcast message. It consists in identifying redundant nodes in the broadcast distribution graph and preventing those nodes from relaying broadcast messages, thereby reducing the number of redundant transmissions. The authors have proved that the computation of the minimum MPR set is an NP-complete problem and propose a simple and efficient heuristic to compute an MPR set that in practice is close enough to the minimum [9].

In [10], the authors propose a waiting time before forward based on a contention window. This waiting time is randomly computed based on a contention window value for faster broadcasting of a message.

In [11] Menouar et al. present a Movement Prediction-based Routing (MOPR) algorithm. MOPR, by predicting the movement of the vehicles during a transmission, helps traditional routing protocols to select the better route to use.

In [8], we have proposed a backfire algorithm based over a constant area. The constant area was obtained as a result of simulation with various scenarios. The angle of the forwarding area was found to be optimal for varying node densities and thus was not the best for any particular instance of density. The objective was to enable only the nodes within that constant area, to participate in message forwarding and also the nodes will enter into contention based upon distance in order to forward the message. The hybrid combination of forwarder selection based on an area and the contention among those potential forwarders based on their relative distances from the source enabled to disseminate messages with minimum redundancy of forwards.

In the next section we will present the principal idea of our work which deals with the optimization of the forwarder area selection based on the density of the nodes on the network. This will be followed by some interesting results and analysis.

III. ADAPTIVE FORWARDING MECHANISM

In [1], [8] we have developed a backfire algorithm which has a constant area within which the nodes are refrained from forwarding. In [1], the area was circular and in [8] the area was modified to a sector, more adapted to vehicular environment but still remained pre-determined from simulation which does not take into account the density of neighbors around.

Fig. 1 briefly explains the concept of backfire algorithm on an urban vehicular environment. Assuming that Node O has broadcast a message to nodes B and F. The nodes B and F set a time to forward that particular message received from O. The waiting value is inversely proportional to the distance from the source, in our example, the node O. From our illustration, node F will be forwarding the message from O earlier than B. The node B after receiving the same message from O through F, will refrain itself from forwarding the message from O by canceling the timer which was already set and thus dropping the message from O. The node B here is said to have been “backfired” by node F.

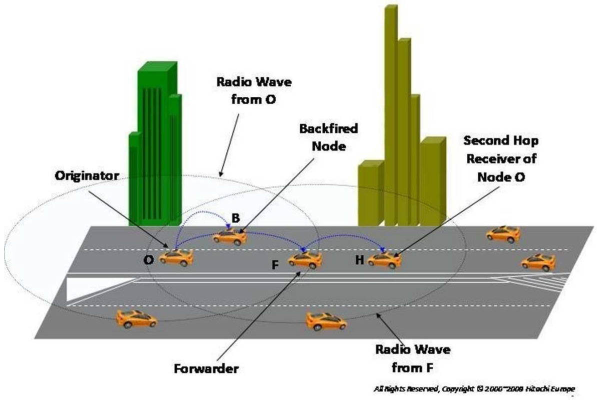

Fig. 1. Backfire Algorithm Urban Scenario

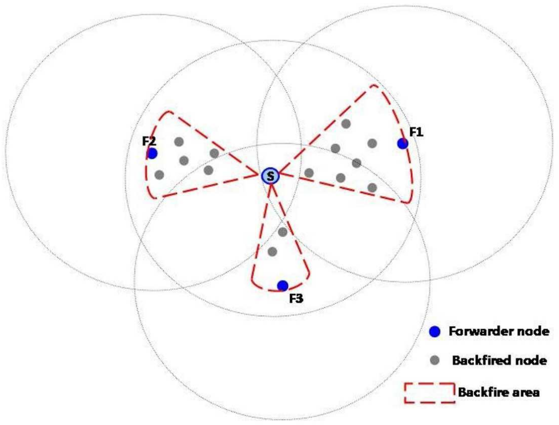

Fig. 2. Dynamic Backfire Algorithm

This paper will mainly focus on providing an adaptive solution [12] to the forwarding area depending on the density of nodes around a receiver for every instance of a received message. Providing such variation in the sector will improve the dissemination process in terms of removal of the forwarding of redundant messages and also the packet delivery ratio. This is because a larger percentage of nodes are refrained from forwarding when the density is higher. Figure 2 illustrates how an adaptive sector could help in refraining larger percentage of nodes from forwarding the message from source node S according the instantaneous density around the node. The forwarders F1, F2 and F3 have relative distance larger than the other nodes from the source S. Since their timers to resend the message from S counts down to zero faster than other nodes who have received the message, they eventually backfire other nodes (who hear the message from their respective forwarders) by forwarding the message at an earlier time.

The flowchart 3 presents the mechanism by which a node makes a forwarding decision.

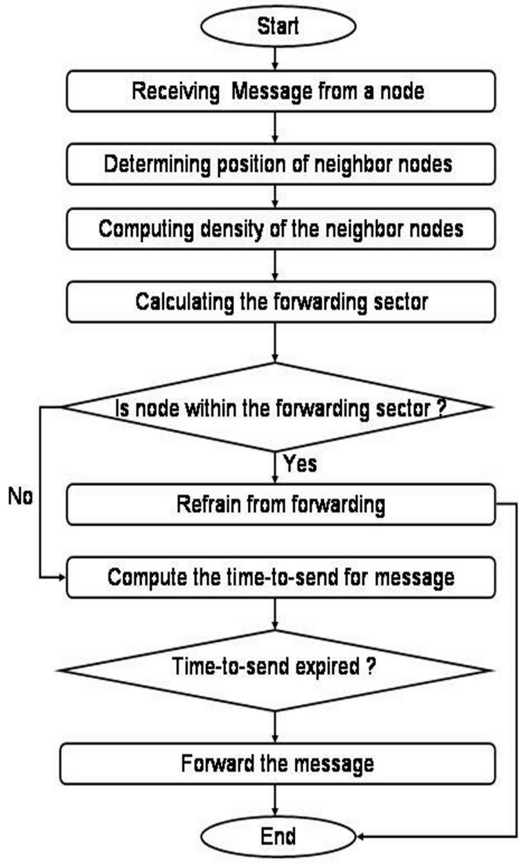

Fig. 3. Adaptive Forwarding Mechanism

After receiving a message from the sender, the node computes an area depending upon the density of neighbors at that particular instant. It will judge itself by checking the condition necessary to get backfired and if it seems matching the condition, it will not forward the message. On the other hand, if the condition is not satisfied, the node waits until the timer which was set for the message expires and then forwards the message to its neighbors.

IV. SIMULATION RESULTS

We have performed our simulation with NS-2 [13] in order to evaluate the proposed adaptive mechanism. The simulation parameters that were used are shown in table I

$Parameter$	$Value$
$Frequency$	5.9 GHz
$802.11pDataRate$	6 Mbps
$CommunicationRange$	250 m
$RadioPropagationModel$	Two-ray ground
$MobilityScenario$	Random Way Point
$Gridsize$	1000m x 1000m
$VehicleDensity$	100 nodes / sq.km (max)
$Max.VehicleVelocity$	90kmph
$CWMin$	15
$CWMax$	1023
$SlotTime$	13 μs
$SIFSTime$	32 μs
$SimulationTime$	100s

TABLE I
SIMULATION PARAMETERS

A. Packet Delivery Ratio

In this sub-section we compare the performance of the the proposed adaptive mechanism with our previous work and also show how they differ when compared with flooding in terms of Packet Delivery Ratio (PDR) for varying vehicle densities. The setup we had for such a simulation is that all nodes in the scenario have to disseminate their location presence up to a range of 400m, which is more than the one hop radio range.

Fig.4 shows the overall comparison and Fig.5 shows a zoomed-in version between the Constant and Adaptive Backfire mechanisms. There is a drop in the performance of flooding when the density is high, whereas the other mechanisms strive hard to maintain the delivery by promptly eliminating the redundancy during forwarding.

For the adaptive mechanism which uses a dynamic backfire algorithm, we have even better PDR (see Fig5), because the mechanism adjusts the area within which the forwarders have to be refrained from sending a particular message based on the density of neighbors.

B. Percentage of Nodes Reported

In the previous sub-section, we made an analysis on PDR. Here, we give more insight into the performance by providing results on the number of reported within the

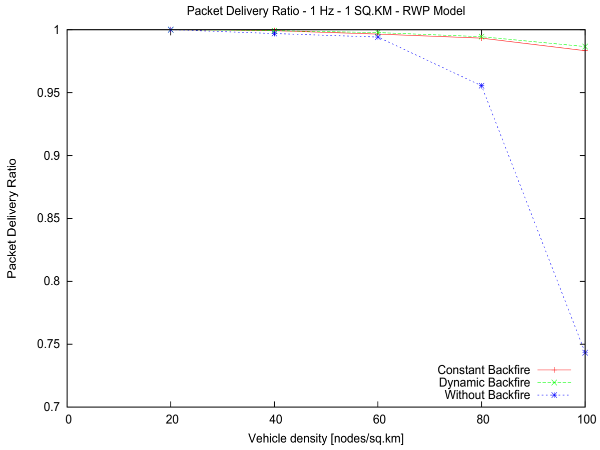

Fig. 4. Packet Delivery Ratio - Overall Comparison

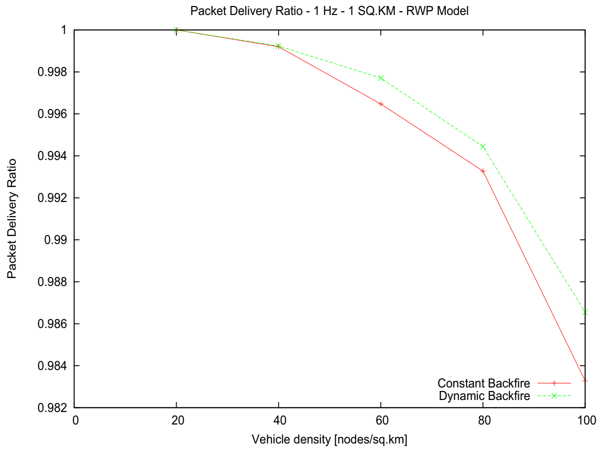

Fig. 5. Packet Delivery Ratio - Constant and Dynamic Backfire

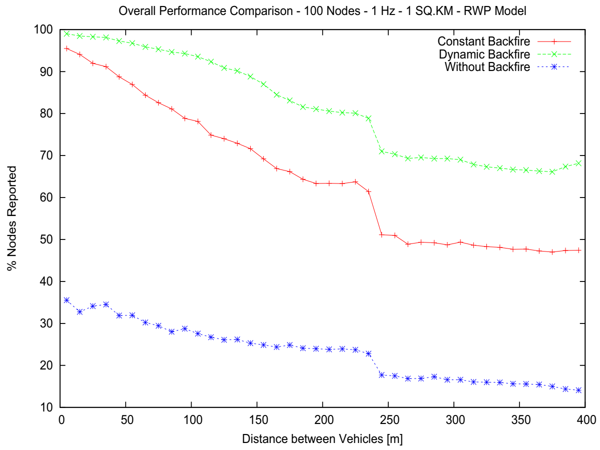

Fig. 6. Node Report Percentage - Overall Comparison

prescribed area for a particularly high-density scenario (100 nodes/ sq.km).

Fig 6 shows the percentage of nodes reported within the required dissemination area for varying distances between the source and destination. The simulation's goal was to make inform all nodes up to a radius of 400m having a density of 100 nodes/ sq.km. As the receiver's distance increase from the source, the probability of the node's message reaching the receiver decreases. Since the goal of the work was to produce performance improvement under high density scenario, we present such a result for a particular value of high density.

C. *Average Packet Size*

Fig 7 shows the performance comparison in terms of average packet size. In the proposed adaptive mechanism since the refraining percentage becomes more for high density scenarios, higher number of nodes are refrained from transmitting the same message and thus the number of messages that are put into the packet decreases.

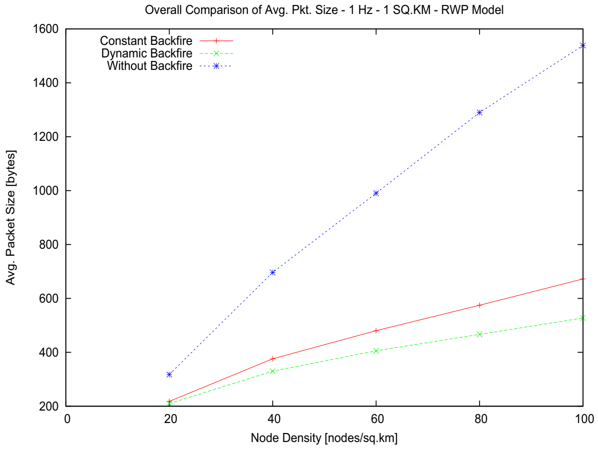

Fig. 7. Average Packet Size - Overall Comparison

Fig 8 shows a close-up graph of the adaptive and non-adaptive mechanisms. As the node density increases, the gain in the reduction of packet size increase. This is primarily due to the larger area of the sector within which the nodes are refrained from forwarding the same message.

D. *Freshness or Delay performance*

For active safety applications, freshness of the messages are considered as an important performance parameter. For eg., in our scenario, any location based routing protocol will need to have a fresher location information of a node in order to perform a more accurate location based routing. On that basis, we have computed the freshness of the location messages for varying distances.

Figs 9 and 10 show the performance. The adaptive mechanism still proves that it is better than the other schemes.

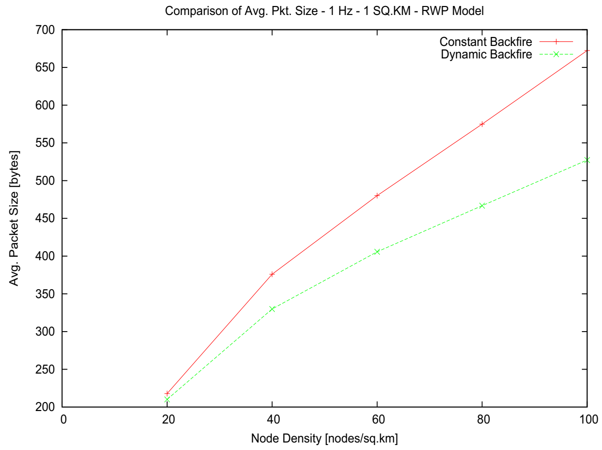

Fig. 8. Average Packet Size - Constant and Dynamic Backfire

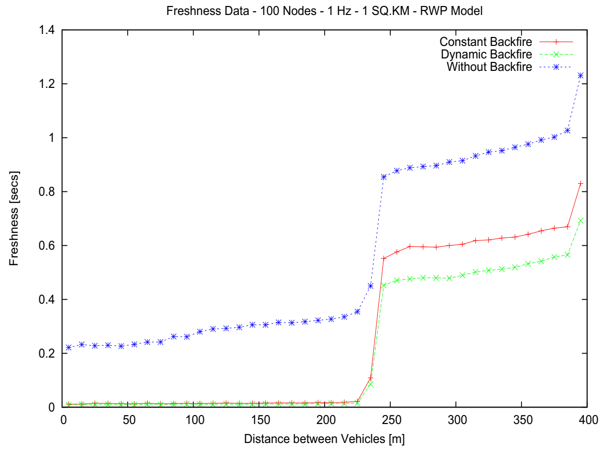

Fig. 9. Message Freshness - Overall Comparison

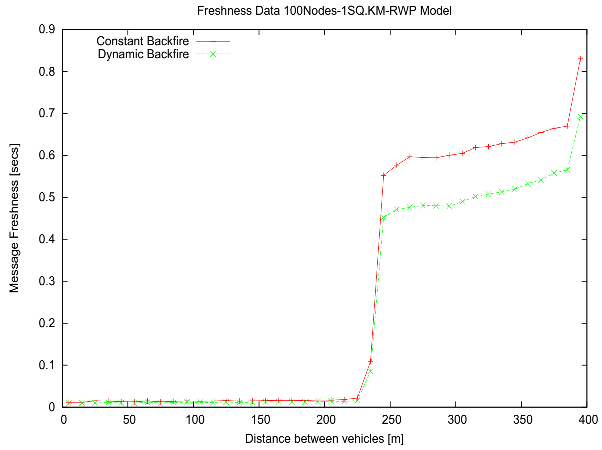

Fig. 10. Message Freshness - Constant and Dynamic Backfire

V. CONCLUSION

In this paper an adaptive forwarding scheme is proposed and a comparative study is made with the previous non-adaptive scheme [8]. Improvements obtained in efficiently disseminating information over VANET were shown. The adaptive mechanism which uses a dynamic backfire algorithm dynamically adjusts the area within which the forwarders have to be refrained from sending a particular message based on the density of neighbors. Overall, we have a 5% to 25% increase in comaprison with the non-adaptive scheme and much more when compared with flooding.

Future work could possibly be made on the range of the angle set for sector depending on density. Also study has to be made whether parameters other than density could be taken into account for computing the sectoral area. Extensive simulation could be carried out to verify the robustness of the mechanism presented.

REFERENCES

[1] T. Osafune, L. Lin, and M. Lenardi, “Multi-hop vehicular broadcast (MHVB),” *ITST*, 2006.

[2] G. Marc Torrent-Moreno (University of Karlsruhe, I. Paolo Santi (Italian National Research Council, and G. Hannes Hartenstein (University of Karlsruhe, “Fair sharing of bandwidth in vanets,” in *The Second ACM International Workshop on Vehicular Ad Hoc Networks (VANET 2005)*, (Cologne, Germany), 2005.

[3] E. Baccelli and P. Jacquet, “Diffusion mechanisms for multimedia broadcasting in mobile ad hoc networks,” in *Proceedings of the IASTED International Conference on Internet and Multimedia Systems and Applications (IMSA)*, (Hawaii, USA), Aug. 2004.

[4] E. Fasolo, R. Furiato, and A. Zanella, “Smart broadcast algorithm for inter-vehicular communications,” in *Wireless Personal Multimedia Communication 2005*, 2005.

[5] S. Biswas, R. Tatchikou, and F. Dion, “Vehicle-to-vehicle wireless communication protocols for enhancing highway traffic safety,” *Communications Magazine, IEEE*, vol. 44, no. 1, pp. 74–82, 2006.

[6] X. Yang, J. Liu, F. Zhao, and N. H. Vaidya, “A vehicle-to-vehicle communication protocol for cooperative collision warning,” *Mobile and Ubiquitous Systems, Annual International Conference on*, vol. 0, pp. 114–123, 2004.

[7] A. Qayyum, L. Viennot, and A. Laouiti, “Multipoint relaying for flooding broadcast messages in mobile wireless networks,” in *Proceedings of 35th Annual Hawaii International Conference on System Sciences (HICSS’2002)*, (Hawaii, USA), 2002.

[8] M. N. Mariyasagayam, T. Osafune, and M. Lenardi, “Enhanced multi-hop vehicular broadcast (MHVB) for active safety applications,” in *7th International Conference on ITS Telecommunications ITST 2007*, (Sophia Antipolis, France), June 2007.

[9] L. Yamamoto, “Epidemic dissemination in ad hoc networks, extended abstract, dagstuhl seminar 04411, service management and self-organization in ip-based networks,,”

[10] C. E. Palazzi, S. Ferretti, M. Roccetti, G. Pau, and M. Gerla, “How do you quickly choreograph inter-vehicular communications? a fast vehicle-to-vehicle multi-hop broadcast algorithm, explained,” in *Consumer Communications and Networking Conference, 2007. CCNC 2007. 4th IEEE*, pp. 960–964, 2007.

[11] H. Menouar, M. Lenardi, and F. Filali, “An intelligent movement-based routing for vanets,” in *ITS World Congress 2006*, (London, United Kingdom), Oct 2006.

[12] H. Menouar, M. N. Mariyasagayam, and M. Lenardi, “METHOD AND APPARATUS FOR DISSEMINATING A DATA PACKET VIA MULTI-HOP COMMUNICATION IN A COMMUNICATION NETWORK,” in *European Patent Application, Application Number: EP 09162641.6, Filed on June 12*, 2009.

[13] K. Fall and K. Vardhan, *The ns Manual, http://www.isi.edu/nsam/ns/doc/, The VINT Project*. 2005.