Comparative Analysis of p-persistent and 1-persistent Techniques for Avoiding Broadcast Storming in VANETs

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Abstract: *The purpose of this paper is to perform a comparative analysis of two famous techniques for avoiding broadcast storming in Vehicular Ad-hoc Networks (VANET). Increase in the number of vehicles on the road throughout the world, has increased the demand for safety of people. VANETs are gaining popularity because of their efficiency, reliability and improved performance than other Wireless Ad-hoc networks used for Intelligent Transportation Systems (ITS). Transmitting messages from one vehicle to another in VANET can be challenging due to frequently changing topologies caused by higher speed and extreme mobility of vehicles. Flooding is hence a technique used for sending messages from one vehicle to another. This flooding of messages can be expensive when there is a shared wireless medium as in case of VANETs. Various techniques are used to avoid flooding, however, in this paper, two basic techniques; p-persistent and 1-persistent are studied. The paper will go into detail for explaining the concept of both the techniques and would elaborate how and when these techniques are beneficial in VANETs. Various experiments have been performed to measure the efficiency and reliability of both the techniques in various scenarios and results have been encouraging.*

Keywords: Intelligent Transportation Systems, Vehicular Ad-hoc Networks, Mobile Ad-hoc Networks, Wireless communication, Broadcast Storming, P-persistent and 1-persistent.

1. Introduction

Rapid increase in the use of technology has significantly increased the performance and efficiency of the systems. Wireless Sensor Networks (WSNs) have been in use for decades and have been performing well in various fields like Agriculture, HealthCare, Education and Enterprise. Recently WSN have been very famous in Transportation. A lot of research is being carried out using WSN in Transportation Systems. This use of WSN in transportation has made it smart and reliable. Such smart and reliable transportation is also called Intelligent Transportation Systems (ITS).

People want continuous communication even when they are moving around in the urban, sub urban or even rural areas. Similarly, the vehicles are expected to be smart enough to provide information like navigation, cruise control, sonar sensors, parking sensors and in-vehicle communication etc. This advancement in vehicles has resulted in developing various types of ITS applications including road safety, traffic control and numerous entertainment applications etc.

With the advent of Global Positioning System (GPS) each vehicle moving on the road can now act as a wireless node and hence a network of nodes is created. This network of cars on the road is called Vehicular Ad-hoc Network (VANETs). Major objectives of VANETs are to provide safety, security and ease of driving on roads. Vehicles can communicate with each other and provide information like accidents, roadblock, bad line of sight and many other events occurring on the road. There are two basic modes of ITS. The communication between the vehicles is referred to as V2V (Vehicle to Vehicle) communication. Vehicles can also communicate with Road Side Units (RSUs) to send and receive the information. This communication between RSUs and Vehicles is referred to as V2I (Vehicle to Infrastructure) communication.

The number of vehicles on roads is increasing immensely, and if each vehicle has to transmit

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the information to every other vehicle in range, the medium of communication might be crowded. Most of the applications of VANETs are developed in such a way that each vehicle broadcasts the information to other vehicle through a shared wireless medium. Since all the vehicles are sharing the wireless medium so there is a higher probability of packet collision, which will result in unreliability and inefficiency of communication. This problem is referred to as Broadcast Storming in VANETs [1]. Broadcast storming can cause packet collision, packet corruption or hidden node problems. In a dense traffic environment, broadcast storming can also cause serious problems of communication, which can result in severely affecting the communication between vehicles and infrastructure. This work will present a clear analysis on the comparison of p-persistent and 1-persistent, two famous techniques adopted by various researchers [2] to resolve this problem.

2. Related Work

This section will review some popular techniques used for controlling the flood over the network proposed by wide range of researchers for vehicular communication. Broadcast has appeared to be a most effective mean to disseminate messages for different types of applications in VANET. There may be a variety of algorithms used for simple ad-hoc networks but as far as the VANET are concerned, using those algorithms lead to degradation of performance due to peculiar nature of VANET.

Different solutions for the Broadcast Storming Problem have been proposed such as probabilistic, counter-based, distance-based and location-based [3]. Probabilistic scheme is designed to tackle the overhead problem by suggesting that each node re-forwards the packet with some fix probability. The counter-based scheme broadcasts a packet when the number of received copies is less than a pre-determined threshold. In the distance-based scheme a node rebroadcasts the message when the distance between sender and receiver is greater than a threshold. The location-based scheme rebroadcasts the message if the additional coverage is larger than a fixed bound. Approximately, all of the techniques discussed below do broadly fall under these areas.

One of the simplest broadcast protocols used in VANETS is simple broadcast protocol [4] for certain type of applications. For example, safety alert application will send alerts to all of the vehicles coming towards accident site when an accident has occurred. On receiving a broadcast message for the first time, vehicle retransmits the message to its neighboring nodes and it can ignore all the subsequent broadcast messages it would receive from all other vehicles rebroadcasting the same message time and again. There is a major issue with the simple broadcast method. Flooding causes many redundant rebroadcast messages over the network in a small amount of time.

Efficient Directional Broadcast (EDB) protocol has been proposed [3,5] for urban VANET using directional antennas. When a node broadcasts a message moving along the road, the faraway receiver is the only responsible node for forwarding the message right in the opposite direction of where the packet was exactly arrived. As there is a frequently changing topology is VANET, EDB makes decisions on the behalf of receiver to forward the packet making use of the GPS information. In this case, the receiver only needs to forward the packet in a single direction that is 180 degree from receiving node. A vehicle waits for an amount of time before taking a decision whether to forward the packet or not after receiving a packet successfully.

A hybrid intelligent broadcast algorithm [6] is proposed for alert message dissemination in VANETs and is also named as Hi-CAST. The proposed Hi-CAST algorithm uses delay and probabilistic broadcast protocols together with token protocol to deliver alert messages efficiently and effectively. Hi-CAST is based on a lot of prior assumptions and is specifically designed for small messages related to safety applications only.

Dynamic broadcasting technique [7] presents a broadcasting approach for safety messages that dynamically adjust waiting time of a vehicle according to the number of neighbor vehicles and distance to source. Dynamic broadcasting approach calculates waiting time of each node based on local density and distance that can reduce the number of unnecessary broadcasting messages in VANETs.

3. Broadcasting in VANETs

In wireless communication, broadcast storming is a common problem which occurs when a nodes receives duplicate messages. If the nodes in a network are larger in number, the problem of duplicate messages can be intense which can cause inefficiency in data communication due to packet losses. In VANETs, broadcast storming is considered as one of the most critical problems due to mobile nature of nodes (vehicles are moving).

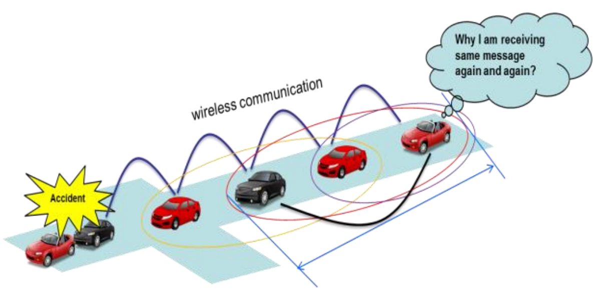

Fig. 1. System model for broadcasting storming problem in VANETs

Fig. 1 illustrates the broadcast storming problem in VANETs. As illustrated in the figure above, an accident occurs on the road and the vehicles want to transfer this information to other vehicles on the road. In a traditional wireless communication, all the vehicles will transfer the information to all the other vehicles in range. The problem emerges when the information is blindly broadcasted to all the vehicles. The last vehicle in the range will receive duplicate messages from all the vehicles, which makes the overall performance of the system inefficient [8]. Subsequently, all the approaching vehicles will start receiving duplicate messages which will not only burden the wireless medium but also causes packet collisions and contention which will result in higher error rates in data communication. Moreover, since the vehicles are moving at variable speeds, packet collision can cause delay in information transmission.

There are different methods of broadcasting the information in VANETs. Fig. 2 illustrates the famous broadcasting methods used in VANETS. This paper will discuss the Probabilistic Flooding, which reduces the redundancy in retransmission of information.

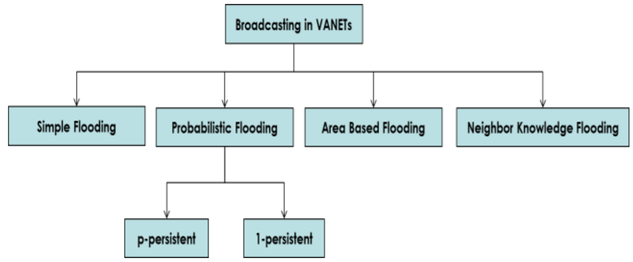

Fig. 2. Broadcasting in VANETs

4. Probabilistic Flooding

Probabilistic flooding reduces the number of rebroadcasts in VANETs. Reduce in the number of broadcasts will reduce packet collision and contention and hence provides reliable data communication. This paper studies and analyzes two suppression techniques of probabilistic flooding, e.g. p-persistent and 1-persistent. Below are the details of each technique:

4.1. P-persistent technique

P-persistent technique uses a random selection of node from available nodes to rebroadcast the message. If a car is receiving this message for the first time (no duplication of message) it rebroadcasts this message with a P probability.

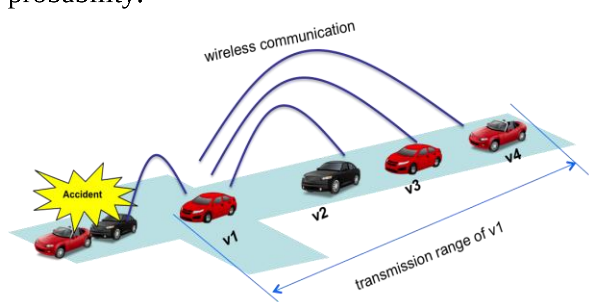

Fig. 3. P-persistent when only one vehicle broadcasts message

Since, not all the vehicles are expected to broadcast the message, this technique reduces the chances of broadcast storming. Fig. 3 below shows the ideal environment in which vehicle v1 has probability P=1 and all other vehicles v2, v3, v4 have probability P<1, hence, only v1 will

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rebroadcast the message to other vehicles in range [5].
However critically analyzing this technique, we figured out that, if all the vehicles have probability P<1, then no vehicle will rebroadcast the message and hence vehicles behind would not receive any information at all. Similarly, if all the vehicles have probability P=1, then all the vehicles will start rebroadcasting the message and hence will result in broadcast storming. This will transform P-persistent technique into simple flooding where all the vehicles broadcast messages to all the other vehicles. Table I below shows various scenarios of P-persistent technique, which we have considered for performing various experiments for p-persistent technique. As shown in the table, if only one vehicle rebroadcasts the message, the scenario is ideal, however, if no vehicle will rebroadcast the message, the system will be inefficient. Similarly, if all the vehicles start rebroadcasting the message to all other vehicles in range, the problem of broadcast storming will occur.

Table 1. P-persistent technique scenarios

Vehicle	Probability	Rebroadcast	Receiving vehicle
P-persistent ideal scenario			
V1	P = 1	Yes	V2, V3, V4
V2	P < 1	No	None
V3	P < 1	No	None
V4	P < 1	No	None
P-persistent no broadcasting			
V1	P < 1	No	None
V2	P < 1	No	None
V3	P < 1	No	None
V4	P < 1	No	None
P-persistent broadcast storming			
V1	P = 1	Yes	V2, V3, V4
V2	P = 1	Yes	V1, V3, V4
V3	P = 1	Yes	V1, V2, V4
V4	P = 1	Yes	V1, V2, V3

In order to overcome the problems of P-persistent technique, a special variation of P-persistent is used, called weighted P-persistent. In this technique, if vehicle V_i wants to send a packet to V_j, the vehicle V_j will check whether it has received this packet already or not? If the packet has already been received, this information is discarded, however, if the packet has not been received, V_j will set a probability to rebroadcast the message to subsequent vehicles in its range. The equation below describes the probability of rebroadcasting the packets:

$$P_{ij} = \frac{D_{ij}}{R} \quad (1)$$

In above equation, D_{ij} is the distance between vehicle V_i and V_j. R is the transmission range of wireless technology used for communication between the two vehicles.

Table 2. Experimental data for weighted P-persistent technique

V_i	V_j	D_{ij} (meters)	P_{ij}
V1	V2	100	1
V1	V3	150	1.5
V2	V3	50	0.5
V2	V4	100	1
V3	V4	50	0.5
V3	V5	120	1.2
V4	V5	70	0.7

Table 2 illustrates the data in the experiments. Random distances are used for

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these experiments to calculate Probability of rebroadcasting the packet, which is mentioned in the table as P_{ij}. From the conducted experiments, two major conclusions were made:

1. Increase in the distance between the vehicles increases the probability of rebroadcasting the packets.
2. Vehicles with probability values between 0 and 1 have higher chances of rebroadcasting the packets.

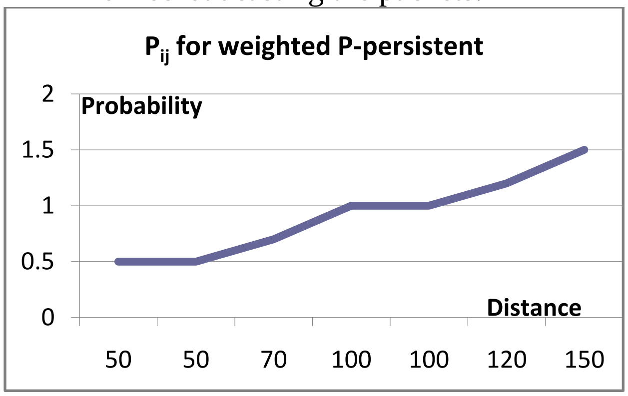

Fig. 4. Graph for weighted P-persistent technique

Fig. 4 further illustrates that increase in the distance between the vehicles will increase the chances of rebroadcasting the packets keeping transmission range constant at 100m.

4.2. 1-persistent technique

This is another suppression technique used to suppress the broadcast storming problem in VANETS. This technique is based on waiting and overhearing of packets from other vehicles. The road is divided into multiple slots and each vehicle must fall in these slots to be a part of the suppression technique. Each vehicle after receiving the packet waits for a specific amount of time before rebroadcasting it to subsequent vehicles. The wait time of vehicles will be different depending upon their slots. The wait time is specified in a way that the vehicle distant from the transmitter will have less wait time and the vehicle closer to the transmitter will have more wait time [9]. Fig. 5 shows the model of 1-persistent technique in which road is divided into different slots and each slot is assigned a time window labeled by T.

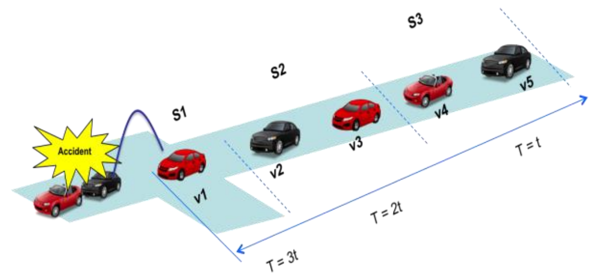

Fig. 5. Model for 1-persistent technique for suppressing broadcast storming

According to this technique, whenever a vehicle receives a packet it will compute its waiting time using the equation below:

$$T_{S_{ij}} = S_{ij} * \tau \qquad (2)$$

In above equation, τ is the time for multi-hop communication between vehicles and wait time for accessing the transmission medium. S_{ij} is the number of slots for division of road or distance between the transmitter and receiver. S_{ij} can be calculated by the equation below:

$$S_{ij} = N_s \left(1 - \left\lceil \frac{\min(D_{ij}, R)}{R} \right\rceil\right) \qquad (3)$$

In above equation, N_s is the total number of slots defined, D_{ij} is the distance between the transmitter and the receiver, and R is the transmission range.

Different simulations were performed to measure the amount of packet time for receiving messages for each car. Fig. 6 shows the graph of received messages per packet time for each car using equation (2) mentioned above.

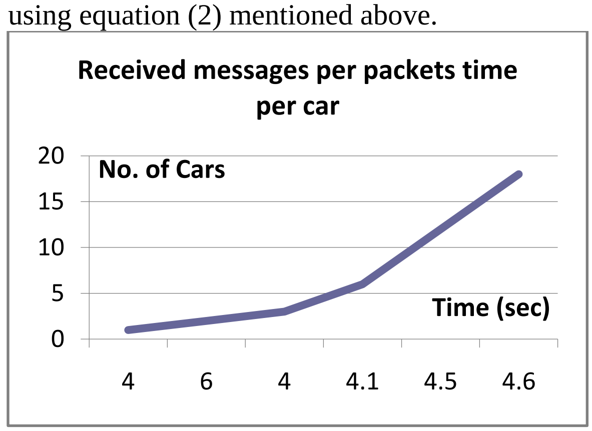

Fig. 6. Messages received per packet time for each car in 1-persistent technique

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From conducted experiments, we concluded:

1. Number of sections must be carefully chosen, since, with this increase in the number of vehicles, the slots become dense that leads to increasing the chances of collisions.
2. The farthest the vehicles, the lesser the wait time for rebroadcasting the packet.

5. Conclusion

Use of Information Technology in vehicles on roads has significantly increased the information transmission between vehicles and infrastructure. It is now possible for vehicles to communicate with each other by sending and receiving messages; however, messages can produce errors if packets collide with each other. In order to avoid duplication and collision of messages, various techniques are used. This paper discussed two techniques, p-persistent and 1-persistent for avoiding packet collision between moving vehicles. P-persistent and 1-persistent techniques reduce packet collisions by measuring the probability and wait time between the vehicles respectively. P-persistent technique is useful, if the distance between the vehicles is within the range of the wireless communication and hence the farthest vehicle will have the highest probability of rebroadcasting the packet, which will reduce the chances of packet collision since not all the vehicles will be rebroadcasting the packets. On the other hand, 1-persistent technique will make vehicles wait for a specific amount of time before rebroadcasting the packets, which will reduce the chances of packet collisions. Our experiments showed that in p-persistent, if the probability is between 0 and 1, vehicle would rebroadcast the messages. Similarly our experiments on 1-persistent technique show that with the increase in the distance between the transmitter and the receiver, the wait time for rebroadcasting the messages decreases.

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