Evaluating Information Dissemination Approaches in VANETs

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ABSTRACT
Vehicular Ad-hoc Networks (VANETs) appeared as a subclass of MANETs for inter-vehicle communication. VANETs have relatively more dynamic nature as compared to MANETs with respect to network topology. However, among numerous solvable issues in VANETs, the design and implementation of an efficient and scalable architecture for information dissemination constitutes one major issue. In the past few years, several broadcasting protocols for information dissemination are proposed specifically in the context of MANETs. In this paper, we will first elaborate some differentiable characteristics of VANETs and then will present a performance analysis of these broadcasting protocols in VANETs environment.

Categories and Subject Descriptors
C.2.2 [**Network Protocols**]: Broadcasting Protocols – *information dissemination, MANETs, VANETs, performance analysis.*

General Terms
Measurement, Performance, Experimentation.

Keywords
VANETs, MANETs, Broadcasting protocols, Information dissemination, Pervasive and context-aware applications, Performance analysis.

1. INTRODUCTION
A VANET is a subclass of the MANET in which mobility patterns are more complex, since the network topology changes more frequently because of the higher node velocity and the nodes having to fulfill the traffic rules. Information dissemination in VANETs is a fundamental operation to increase the safety awareness among vehicles expected to be troubled by the safety critical events on the road [3]. Recent research emphasized broadcasting techniques in which nodes exchange messages to a number of other nodes in the network [11]. Its goal is to transmit a message from a source to all other nodes in the network. The core problem in multi-hop broadcasting is how to minimize the number of redundantly received messages while maintaining good latency and reachability since rebroadcasting causes tradeoff between reachability and efficiency under different host densities [5].

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We believe, within VANETs, non-safety information in general, and safety information in specific, is crucial to be disseminated among concerned vehicles [2, 13, 15]. The safety information should be sent to other surrounding vehicles in order to be informed and eventually take preventive actions to avoid getting to inconvenience. For example, a vehicle having an embedded traffic detection sensor can send current traffic state to its following vehicles that can take preventive actions to avoid the congested areas [3].

Several broadcasting protocols for information dissemination have been proposed for MANETs [1, 14]. However, these protocols may behave in a different way when applied in the VANETs environment due to the following reasons:

- Since vehicles are treated as VANETs nodes, these entities can move too fast as compared to ordinary MANETs nodes.
- In VANETs, the network topology changes regularly since vehicles can frequently leave and join the network.
- We can anticipate the direction of vehicles' movement since their routes are predefined.
- The number of vehicles participating in a VANET may vary depending on the traffic situation at a particular point in time. This can be classified as *light* (for small number of vehicles e.g., rural area traffic), *medium* (for average number of vehicles e.g., highway traffic), and *congested* (for large number of vehicles, e.g. urban area traffic or traffic jam situation).

Due to these differentiable characteristics of VANETs, we are interested to evaluate the performance of broadcasting protocols in the context of VANETs with respect to the following two parameters:

- Speed of vehicles: to evaluate the performance of each protocol under different vehicles speeds.
- Number of vehicles: check the performance of each protocol for different number of vehicles.

The rest of this paper is organized as follows. Section 2 presents the related work and short description of each of the major categories of broadcasting protocols recommended for MANETs. Section 3 presents performance evaluation obtained using simulations which were performed using NS2. Conclusions and future work are presented in section 4.

2. BACKGROUND AND RELATED WORK
The design and implementation of efficient and scalable architecture for information dissemination protocol is a challenge

and an open research question. In the past few years, several broadcasting protocols have been proposed for MANETs. These protocols can be categorized as follows.

Flooding is the most simple broadcasting technique in which the source node disseminates a message to all its neighbors, each of these neighbor will check if they have seen this message before, if yes the message will be dropped, if not the message will be re-disseminated at once to all their neighbors [7]. Broadcasting through flooding causes increased redundancy of messages, contention, collision, and wastage of channel bandwidth within the network.

Probabilistic scheme is similar to flooding except that mobile hosts rebroadcast messages according to certain probability. The probabilistic approach works better in dense traffic scenarios; however, its performance suffers in sparse networks. Furthermore, setting the broadcast probability value dynamically in different traffic situations is also a challenge. A dynamic probabilistic based broadcasting protocol has been proposed by [4].

In *Counter based* broadcasting, a message will be rebroadcasted only if the number of received copies at a host is less than a threshold after RDT (Random Delay Time, which is randomly chosen between 0 and T_{max} seconds) [6]. It introduces message delay at each hop which is not suitable for delay sensitive applications. In [13], Authors have modified the counter based protocol and named the new protocol as *Hop Count Ad hoc Broadcasting (HCAB)* protocol. In HCAB, upon receiving a broadcast message for the first time, the node initiates a flag R = true and records initial hop count value HC_0 of this message. Meanwhile, this node sets a RDT value between 0 and T_{max}. During the RDT, the node compares the hop count of redundantly received message HC_x with HC_0 and flag R is set to false if $HC_x > HC_0$. When the random delay expires, the node will relay this message if R is true. Otherwise, it just drops this message.

Distance based **e**xploits the geographical information of the node i.e., a distance threshold value is pre-defined. Upon reception of a previously unseen message, a RDT is initiated and redundant messages are cached. When the RDT is expired, all source node locations are examined to see if the node is closer than a threshold distance value. If true, the node doesn't rebroadcast. *Location based* scheme is an enhanced form of the distance based broadcasting technique and uses a more precise estimation of expected additional coverage area in the decision to rebroadcast [11]. In this method, the source node also appends its geographical position information with the message. The receiving node then calculates the additional broadcast coverage area with the help of positioning data sent by the source node. If the additional area is less than a threshold value, the node will not rebroadcast, and all future receptions of the same message will be ignored. Otherwise, a node assigns a RDT before delivery. If the node receives a redundant message during a RDT, it recalculates the additional coverage area and compares it with the threshold. This process is continued until the message is rebroadcasted or finally dropped.

Neighbor knowledge based exchange neighborhood information among the hosts. There are two major approaches in this scheme [11]. In *Self pruning*, each node maintains the knowledge of its neighbors by periodically exchanging the "Hello" messages. The receiving node first compares its neighbor list to that of sender's list, and rebroadcast the message only if the receiving node can cover additional nodes. The *Scalable Broadcast Algorithm (SBA)* is similar to self-pruning except that all nodes have knowledge of their neighbors within a two hop radius.

Lastly, *Cluster* based approach is also used for broadcasting in which mobile hosts form clusters. Within one cluster, each host is treated as a member, and there is one cluster head and one gateway node responsible to relay messages.

To the best of our knowledge, no performance comparison of MANETs broadcasting protocols in the context of VANETs is made yet. In the rest of this paper, we will consider Flooding (FL), Probabilistic (PB), Counter Based (CB), Hop Count Based (HCAB), and Distance Based (DB) broadcasting protocols and will check their performance in VANETs environment with respect to the chosen metrics described in the next section.

3. PERFORMANCE ANALYSIS

In this section, we will evaluate the performance of broadcasting protocols by investigating the effects of vehicles speed and density using network simulator NS2 [1, 19].

3.1 Mobility scenario

In this study, a realistic vehicular mobility scenario (i.e., street map and a vehicular mobility pattern) for a small part of a city was generated using MOVE (MObility model generator for Vehicular networks) [10] and TRaNS (Traffic and Network Simulation Environment) [9]. We have chosen TraNS beacsue it is an open-source project providing a full-blown application-centric evaluation framework for VANETs.

A vehicular mobility pattern defines vehicles motions within the street map during a simulation time, which reflects, as close as possible, the real behavior of vehicular traffic such as traffic jams and stops at intersections. The scenario generated by using these tools is a grid topology of 800x800 square meters with a block size of 200mx200m as depicted in Figure 1. This scenario is randomly generated and contains 6 roads, nine intersections, and 12 crossover points at the border. Vehicles move along the grid of horizontal and vertical streets on the map. Each line represents a single-lane road and vehicular movement occurs on the directions shown by arrows. At a crossover, vehicles choose to turn left or right with equal probability, 0.5. At an intersection of a horizontal and a vertical street, each vehicle chooses to keep moving in the same direction with probability 0.5 and to turn left or right with probability 0.25.

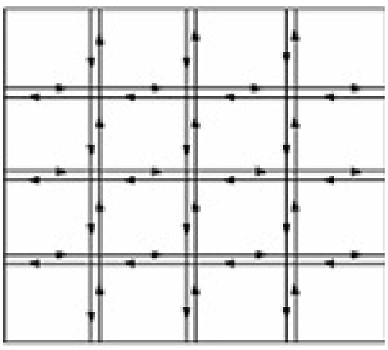


Figure 1. Street map of the simulated scenario

Several simulation scenarios by varying the vehicles speed are generated. An incident was introduced at time 10s and at a randomly selected location. An active node (e.g. RSU) at this location starts broadcasting a warning message to nearby vehicles according to the protocol used. A simulation time of 100s is used, which is long enough to evaluate the broadcasting protocols by varying vehicles speed from higher speed (25m/s) to lower speed (1m/s). Each vehicle use IEEE 802.11 MAC protocol. We used two-ray ground model for radio propagation. Other simulation parameters [12] are described in table 1.

Table 1: Simulation parameters

Simulation Parameter	*Value*
Network range	800 square meters
Transmission range	200 meters
Number of vehicles	25-100
Vehicles Speed	1-25 meters/second
Bandwidth	2Mbps
Message size	1000 bytes
Simulation time	100 seconds
Number of trials	10

3.2 Simulation results

We measured the performance of broadcasting protocols under different vehicles' speed, network topologies, and host densities. Different threshold values for the protocols under investigation are defined as follows: for PB, the relay probability is set to 0.5, for CB, the counter threshold is set to 3, and for DB, distance threshold is set to 150 m (0.75× transmission range). The following performance metrics have been used to evaluate each protocol [3, 4, 7]:

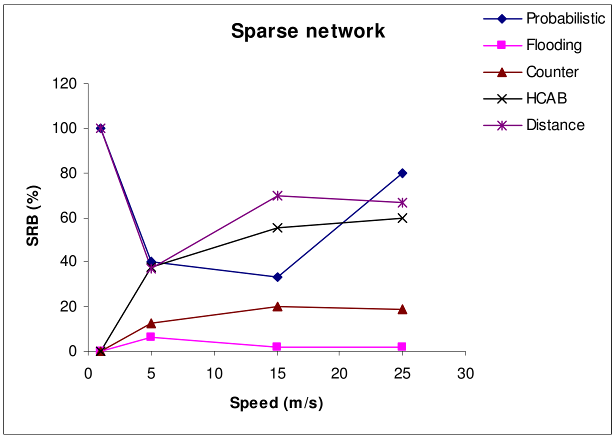
- ***Awareness:*** is the state or ability to perceive or to be conscious of event. Within the scope of VANETs, awareness is defined as a driver's perception and cognitive reaction to a condition or events. Awareness is directly proportional to the reachability of the data to be disseminated.
- ***Saved ReBroadcast** (SRB):* is the ratio between the number of host receiving the message and the number of hosts actually rebroadcasting the message.
- ***Latency:*** the interval from the time the broadcast was initiated to the time the last host finishing its rebroadcasting. It includes buffering, queuing, retransmission and propagation delays. Latency is an important metric to figure out the suitability of a protocol for delay sensitive applications like safety applications.

We performed ten simulation trials for each scenario and recorded each performance metrics. Following subsections analyze the results obtained through simulation experiments.

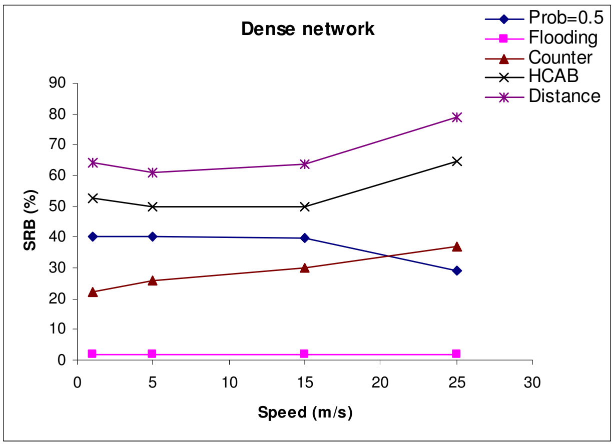
3.3 Speed effect

Figures 2 plot SRB of five schemes as function of vehicles speed. We analyzed the effect of vehicles speed under both sparse and dense networks. In Figure 2 (a), when vehicles speed are very low (< 5 m/s), the PB and DB schemes reveal gradual down in SRB value (although still high from other protocols), however, SRB value of DB improves when vehicles start moving above 5m/s but the SRB for PB still goes downwards and starts improving when vehicles speed exceed the threshold of 15 m/s. HCAB gradually improves SRB as the vehicles speed is increased.

In Figure 2(b), due to greater vehicles density, DB outperforms the other protocols. HCAB (although not efficient as PB and DB) also shows consistent increase in SRB. Unlike sparse network, the amount of saving SRB in PB decreases when vehicles speed is increased while the performance of CB protocol increases in term of SRB. FL shows the worst behaviour in both sparse and dense network. In conclusion, we can say that the DB scheme works more efficiently in term of SRB as compared to other broadcasting schemes.



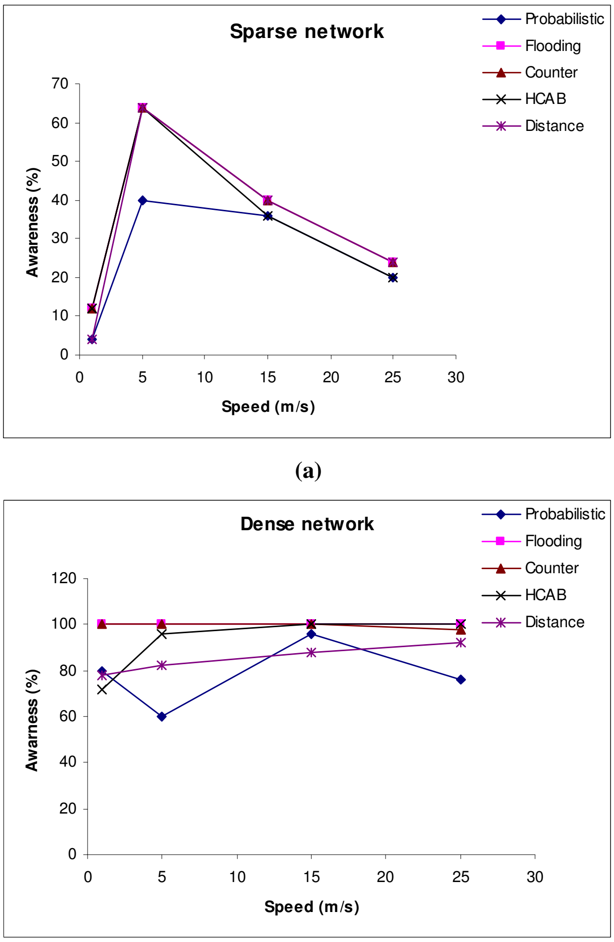
(a)



(b)

Figure 2. SBR vs. vehicles speed: (a) sparse network, (b) dense network

In Figure 3(a), initially the awareness value for each protocol increases with the increase in speed of the vehicles. As we can see, the PB has relatively low awareness value as compared to other protocols when the vehicles speed is below 5 m/s. The rest of the protocols have the same awareness level and it starts decreasing after vehicles speed exceeds 5 m/s. This could be due to less number of nodes in the network that results in the less number of retransmissions or the vehicles may disconnect from the network as they are moving too fast.



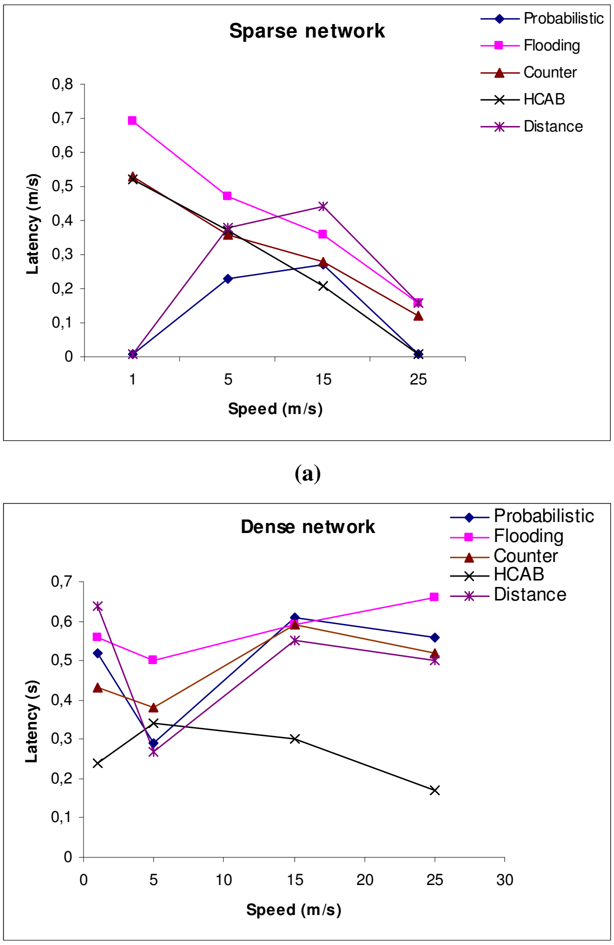
(a)

(b)

Figure 3. Awareness vs. vehicles speed: (a) sparse network, (b) dense network

In a dense network condition, FL and CB protocols show equal strength in term of awareness against different vehicles speed and outperform other protocols. As we can see in Figure 3(b), initially the HCAB is below FL and CB, however, at a certain threshold value (5 m/s in this case), its performance is same as the FL and CB techniques. The performance of DB is worth noting here, In sparse network, DB performs well as other protocols, however, in a dense network, the awareness value is directly proportional to the vehicles speed and the performance of DB becomes equal to FL and CB when vehicles are moving above 25 m/s. This is due to the fact that, as vehicles moves too fast, the network density decreases resulting increase in the efficiency of DB in term of awareness.

Figures 4 shows broadcast latency at various vehicles speed in both sparse and dense network situation. PB has lowest latency in sparse network; however, its broadcast delay suffers in dense network. This is due to the fact that, in PB scheme, the numbers of retransmissions are directly proportional to the number of nodes in the network. This will result in less number of SRB and increases the collision and contention in the network. HCAB especially in the dense network is shown as most efficient protocol because it intelligently increase the number of SRB due to which network become less congested with respect to data traffic that results in lower end to end delay of messages. FL, DB, and CB schemes have comparatively high latency than PB and HCAB.



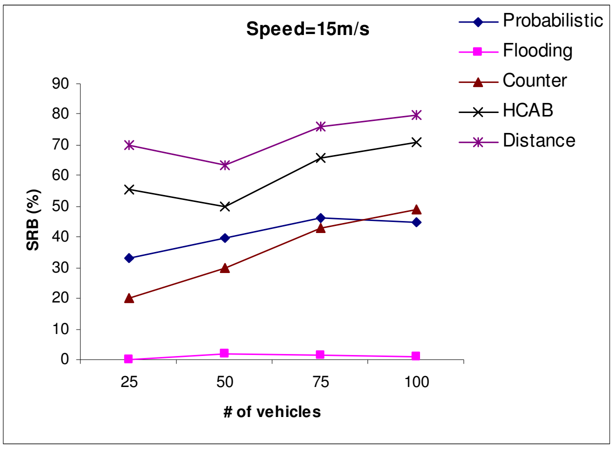
(a)

(b)

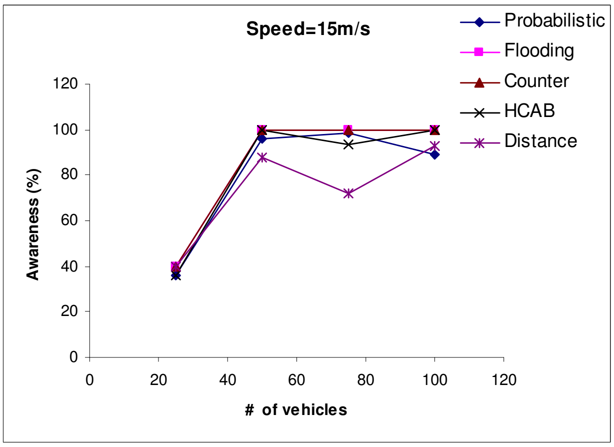
Figure 4. Latency vs. vehicles speed: (a) sparse network, (b) dense network

3.4 Density effect

In this section, we will investigate the effect of vehicles density within the range from 25 to 100 vehicles where speed is fixed to 15 m/s. Figure 5 depicts SRB, awareness, and broadcast latency associated with number of vehicles in the network. While discussing the SRB, DB exhibited better performance when compared with other schemes and number of SRB increases proportionally with the increase in number of vehicles proving once again that DB scheme is the best candidate for dense network. From the Figure 5(b), we can also conclude that FL and CB are best for awareness at the expense of small number of saved retransmissions. CB scheme also performed efficiently in term of latency.



(a)



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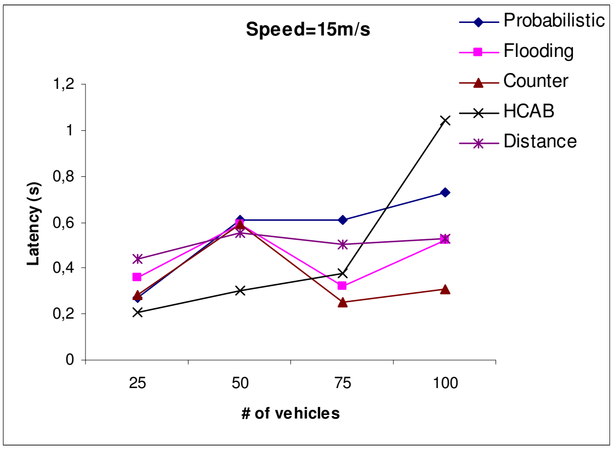

(c)

Figure 5. (a) SRB, (b) awareness, and (c) latency v/s number of vehicles

In Figure 5(c), we examined that the performance of HCAB goes smooth as observed in Figure 4(b) until the number of vehicles are 75. Soon after the number of vehicles exceeds 75, the broadcast latency in HCAB starts increasing contradicting our previous conclusion that HCAB is efficient in dense network. In our knowledge, this annoying behaviour of the HCAB is due to the overhead of hop count comparison in highly dense network. However, in such kind of situation, CB scheme is more efficient instead of HCAB.

4. CONCLUSIONS AND FUTURE WORK

With the emergence of Intelligent Transport Systems, VANETs has recently extended MANETs. Among several issues in VANETs, information dissemination is one of the core problems in VANETs. Several broadcasting protocols have been recommended for MANETs and their performance evaluation is also done in MANETs environment. Keeping in mind, the additional characteristics of VANETs like frequent changes in the network topology, increased nodes speed, fixed traffic routes, and number of vehicles within the network; we evaluated the performance of MANETs broadcasting protocols in the context of VANETs against the chosen metrics. We observed that, DB scheme is efficient with respect to SRB metric in all the situations. CB scheme is the best solution when awareness is more important, it also gives reasonable broadcast latency especially in the dense network. HCAB outperforms CB with respect to SRB and latency but its performance degrades in highly dense network especially when the number of nodes exceeds 75.

In future, based upon current approaches, and using innovative techniques to detect the current traffic condition, we will propose a decentralized protocol to disseminate information within VANETs and will compare that with existing solutions.

5. ACKNOWLEDGMENTS

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