Location-Based Flooding Techniques for Vehicular Emergency Messaging

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Abstract— **This paper analyzes the scalability of message flooding protocols in networks with various node densities, which can be expected in vehicular scenarios. Vehicle safety applications require reliable delivery of warning messages to nearby and approaching vehicles. Due to potentially large distances and shadowing the delivery protocol must forward messages over multiple hops, thereby increasing network congestion and packet collisions. In addition to application-layer backoff delay and duplicate message suppression mechanisms, location-based backoff techniques have been proposed for vehicular networks. We propose a new hybrid method of location-based and counter-based method, and study several variants through simulations. Our preliminary results in the various density scenarios indicate that the proposed hybrid methods outperform conventional backoff delay techniques and adaptively operate in extremely congested network condition.**

I. INTRODUCTION

A major application of Vehicle-to-Vehicle (V-to-V) and Vehicle-to-Roadside (V-to-R) communication protocols such as DSRC/WAVE [1] is the avoidance of traffic accidents. These applications require delivery of an emergency warning message (EWM) with high reliability and low latency constraints to nearby and approaching vehicles. The delivery of EWM packets is expected to benefit from flooding techniques, since high mobility, channel fading and shadowing render one-hop broadcast delivery to all approaching vehicles difficult. While network efficiency might not be a prime concern for emergency communications, the protocols must operate reliably in a vast range of different scenarios—from two vehicles on a rural street to a major traffic jam on a metropolitan highway. In the latter scenario, hundreds of vehicles can be packed into one-hop communication range. In this case, naive flooding protocols lead to the well-known broadcast storm problem [6] and are likely to lose many messages due to packet collisions on the wireless channel. The presence of background traffic from other applications can further exacerbate this problem. The worst case node densities can be higher and the application constraints are stricter than those typically considered in the general scenarios in mobile ad-hoc networks. Therefore, more sophisticated flooding primitives warrant detailed study in vehicular networks.

One key difference of V-to-V communication system to conventional radio systems is that radios in automobiles are expected to have access to precise position information. The considered safety applications already rely on positioning through the Global Positioning System(GPS), possibly refined through internal sensors in the vehicle. This availability of position information enables a set of novel wireless networking protocols that use location-based heuristics. In this paper, we compare a set of flooding mechanisms that can be deployed on an existing 802.11 MAC, which serves as a basis for WAVE standardization. Using multiple channels and transmission power adaptation, network congestion could be alleviated. However, the number of available channels is limited and the coordinating channels between sender and receiver incurs overheads. Similarly, operating with reduced transmission power leads to frequent retransmissions per a message, which incurs additional delay. Multi-channel communication and transmission power adaptation are unlikely to fully address these issues. The protocols considered here are orthogonal to these and can be used in combination with them.

Specifically, this paper considers a counter-based method to assign additional delays on top of the MAC backoff, and uses it as a rebroadcast suppression mechanism that reduces packet collisions. We also combine a location-based method with the counter-based method to make a better choice of the next hop forwarder. We present preliminary simulation results support that such a hybrid mechanism is more efficient over various network densities. Most promising is a mechanism that prioritizes rebroadcasts at the edge of the range of the previous transmission and suppresses additional rebroadcasts once a certain number of transmissions have been overheard. We find, however, that this rebroadcast suppression fails in very high density networks and must be complemented with other suppression mechanisms.

The remainder of this paper is organized as follows. Section II describes related work. Section III defines the flooding problem in vehicular networks and introduces conventional flooding methods. Section IV introduces the algorithms under consideration and our evaluation methodology. Section V describes the preliminary simulation results, before we conclude.

II. PREVIOUS WORK

Due to the vehicular networks' characteristics of decentralization, high mobility, and unreliable wireless channel [11], it is challenging to deliver EWM packets to all the vehicles in a certain area with a required level of latency. The communication in vehicular networks is similar to that of MANET. However, the topology and directional mobility of vehicles make V-to-V communications distinct from that of MANET. Some message dissemination protocols based on the unicast protocol have been studied in [13], [14], but they are not appropriate for latency-constrained EWM dissemination. As pointed out by [12], message dissemination protocols in vehicular networks can be optimized by the directional nature of message propagation. Increasing the coverage by using the directivity of nodes has been studied in [15]–[17].

Reliability is another important issue in delivering EWMs. In a dense network, an EWM packet can collide with service message packets which have more flexible delay and coverage requirements. We can consider this background data traffic as interference against EWMs. In [9], the authors try to suppress this interference by assigning priority to EWMs in the MAC layer. On the other hand, [8] enhanced the reliability of EWM delivery by periodically retransmitting EWMs and sharing resources by power adjustment. However, packet retransmission and prioritized MAC do not always enhance the reliability of the protocol. In highly congested networks, the repetition of packet transmission results in packet collisions and degrades network throughput [25]. Therefore, a new collision avoidance mechanism should be considered in the vehicular communication protocols to improve operations in very high density networks.

To minimize the congestion level caused by unicast packet forwarding in a dense network, EWM delivery based on the MAC-layer broadcasting is also studied in [10], [11]. However, multi-hop retransmissions to cover a larger area cause a well-known problem called *broadcasting storm*. In [22], the authors alleviate the broadcasting storm problem by adaptively adjusting the probability of transmission or delay timer. However, their scheme requires local connectivity knowledge, which is hard to be maintained in a highly mobile environment. [23] removes unnecessary packet forwarding by checking for message duplications in the application layer, but this protocol also needs the local neighbor knowledge and additional application processing, which is difficult to acquire and maintain for collision avoidance protocols requiring low latency. In [24], the authors suppress redundant packet forwardings by combining neighbor nodes' GPS information in finding an appropriate forwarder. [3] uses the estimated distance from its previous forwarder by exchanging their neighbor list, and uses this information in calculating the probability of a specific forwarding. In this paper, we build on these ideas for broadcast messaging in vehicular networks.

In modeling channel characteristics of vehicular communication, a probability-based Nakagami channel model is used in [9] for the realistic vehicular communication channel environment. More realistic PHY/MAC models for DSRC specification is made in [7] to measure the bit error rate, throughput and latency. Empirical channel models were also used in [20] by measuring the signal power in road environments. We consulted those empirically measured data in adjusting the Nakagami parameters for our channel modeling.

III. PROBLEM STATEMENT

A. Broadcasting Methods

We can largely categorize the broadcasting methods in wireless ad hoc communications as follows [4]:

1) Simple flooding method
2) Probability-based method
3) Location-based method
4) Neighbor knowledge-based method

The simple flooding method is the most reliable in terms of coverage. But simple flooding cannot be used in normal situations as it generates too many redundant messages. Thus, both probability-based and location-based method have been designed to reduce the number of unnecessarily forwarded messages by trading off reliability with efficiency. In the probability-based method, upon receiving a message, each node tosses a coin and makes a decision whether it will forward the packet or not. This scheme, however, requires each node to configure the parameters for the probabilistic decisions, which is difficult to achieve when the network configuration dynamically changes.

The counter-based method is a variant of the probability-based method. While the probability-based method makes a probabilistic choice on a packet forwarding regardless of network status [22], the counter-based method takes into account the network dynamics in making a decision on the forwarding. For this, nodes have a timer for each non-duplicate message it has received. The delay time for each timer is randomly set when a node receives a non-duplicate message and is decremented afterwards. The counter increases when the node overhears duplicate messages that are forwarded by its neighbor nodes. If the counter exceeds a threshold called *Max_count* when the timer expires, then the node suppresses the forwarding by silently discarding the packet as sufficient number of forwarding is done by its neighborhood. Therefore, the counter-based method is believed to be more robust in various network-wide broadcasting scenarios thanks to its adaptive ability of controlling the probability of packet forwardings in conjunction with the node density [24]. The counter based method is, however, not optimal in the network efficiency side as it cannot completely eliminate the redundancy of forwarding.

Location-based method uses its location information in deciding its probability of forwarding. This method eliminated unnecessary forwarding by choosing the right forwarder that is closest to the destination node. However, this method has several shortcomings. One of them is that the neighbor nodes, who receives a broadcast message at the same time, do not

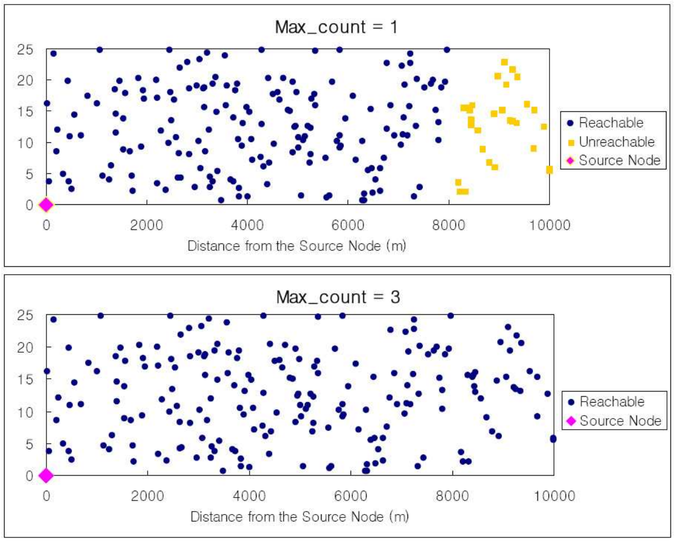

Fig. 1. Connectivity of counter-based method with *Max_counter* values

have a global knowledge on which node should act as a forwarder. Individual node cannot make a correct decision without the knowledge on its neighbor nodes. Exchanging their location information to determine the right forwarder incurs too many overhead message exchanges and is also vulnerable to topology changes, which is very common in vehicular networks. Generally, EWM packets travel multiple hops before it reaches the destination node. The scarcity of network nodes may hinder packets from arriving at the distant node, and this results in low connectivity of the network. Therefore, the location of a forwarder is very important to maintain a certain level of connectivity. If the next hop forwarder is too close to the previous forwarder, an additional number of packet forwarders are required to cover a certain area. Thus, both number and location of the forwarders are the key elements in designing an efficient and reliable message broadcasting protocol.

The key in designing an efficient broadcasting method in terms of connectivity and suppression of redundancy is to choose as small number of forwarders as possible maintaining a certain degree of network connectivity. As the number of forwarded messages decreases, network coverage also decreases. Fig. 1 compares the connectivity of the network for various *Max_counter* values in the counter-based method. The NS-2 network simulator was used. Two hundred nodes are randomly located in 10,000m by 25m road. One source of EWM packet is located at (0,0) and it generates EWM packets with 10 packet/sec rate. Those nodes received EWM packet is marked as 'Reachable' nodes and the nodes who did not receive the packet is marked as 'Unreachable' nodes. This figure shows that larger *Max_counter* value helps the connectivity of the network while it also increases the redundant packet transmission of the network.

There have several researches to overcome the limitations of the probability-based method and the location-based methods by creating a hybrid method of location and counter-based [3]. [24] makes an adjustment to the delay time in the counter-based method using the distance knowledge between the source message transmitter and itself. However, the trade-offs between the efficiency and reliability is apparent, and its optimal point will vary depending on the wireless channel conditions. In the error-prone channel condition, we should increase the number of forwarders to guarantee a certain level of delivery assurance and vice versa. However, in high density networks, the increased number of transmission does not always guarantee high delivery assurance. Because the bandwidth of a channel is limited, the excessive number of packet transmission only results in packet collisions and message drops in the network. Thus, a different forwarder selection algorithm by combining both location-based and counter-based methods is required.

B. Weakness of Counter-based Method in Dense Network

The 802.11 MAC protocol has a collision avoidance mechanism using the random backoff called "Contention Window(CW)" The size of contention window is initially configured as 15 slots and its size doubles whenever a collision occurs in the channel. However, in the broadcast mode, where ACK is not used, the CW value does not increase even the channel suffers from severe collisions. Therefore, as soon as nodes receive a broadcast message, it is highly likely that these nodes will access the channel at the same time, resulting in packet collisions. The packet collision in the broadcast mode is more detrimental because the collided packets will not be retransmitted. This requires an application layer's additional backoff delay mechanism to prevent collisions [4].

The counter-based broadcasting method, which already incorporated the application-level delay mechanism, works well in the relatively dense network with tens of neighbor nodes in the one-hop coverage. But in a very high density network where hundreds of nodes are packed in the one-hop communication rage or tens of nodes are transmitting messages simultaneously, the counter-based method suffers from severe collisions. Let's assume that 20 nodes are transmitting packets with a 100msec interval in a very dense network where 100 nodes are located in one hop distance. Each node will initiate 20 timers one for each non-duplicate packet received, so there will be total 2,000 active random delay timers for each 100msec duration in the entire network. The gab between the timer expirations decreases to tens of μsec level, so the suppression process cannot work properly.

Fig. 2 illustrates the above issue. When node N1's timer is the shortest one and expires, the packet will be forwarded by N1 when the channel is cleared. However, due to the N1's internal processing delay related to the packet forwarding protocol there would be some internal delay before the actual transmission. During this time, other nodes'(N5 and N9) timers may also expire before node N1's actual transmission begins and they wrongly initiate their transmissions. This will result in packet collisions or random backoffs for the next trial. In either case, the network will suffer from severe congestion. In a very high density network, there are always unnecessarily large numbers of nodes competing for the same channel as illustrated in the figure. This clearly shows that the counter-based scheme alone cannot effectively prevent packet collisions which frequently occurs in a vary high density network. In this paper, we propose an aggressive counter-based method combined with an adaptive probability-based method to substantially reduce the redundant messages in conjunction with network congestion degree.

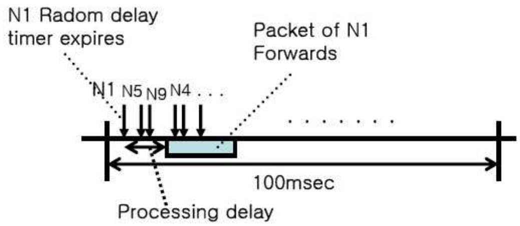

Fig. 2. Collision in very high dense network

IV. FLOODING TECHNIQUES

A. An Hybrid Method in Controlled Flooding

In this paper, a new hybrid method combining the counter-based method and the location-based method with a enhanced random delay timer is introduced. In broadcasting, upon receiving a packet from the Previous Forwarder (PF), each node will make an independent decision of whether it will forward the packet or not. The decision criteria should be changed based on the location of the node and the density of the network. The basic rule of our forwarding decision is very similar to that of the counter-based methods. However, the delay time of each individual node will be adjusted based on the distance from the PF. The farther the node is located, the shorter the delay time is to be set. Therefore, the node that is located farther from the PF will have a higher probability of forwarding the packet.

However, if we give a deterministic delay time according to the distance to the PF like [2], nodes in the similar distance from a PF is likely to access the channel simultaneously, and this will result in a collision in the channel. Another drawback of the deterministically decided delay timer is that only border nodes will have a chance be a forwarder, so inner nodes cannot have a chance for a forwarding. This causes the coverage holes inside of the network. Thus, we assign the delay timers in each node with probabilistic delay values with different statistical means depending on their distance from the PF as in Fig. 3. The farther node N1 from the PF node N will have a higher probability of forwarding. But this is not always the case because the delay time is statistically given to the node for each forwarding. Sometimes, the inner node N2 may have a chance be the next forwarder filling the coverage holes generated inside of the coverage area. We define the variable *Progress* as the ratio of the distance from the PF to the maximum radius of the coverage. The delay time *T_delay* is a random variable that has a Gaussian distribution with a mean value of *Progress* and a variance of *0.3*. As soon as *T_delay* expires, each node counts the number of duplicate packets that are broadcast from its neighbor nodes during the delay time. If the number of overheard packets is equal to or exceeds the limit *Max_count*, the node suppresses the packet forwarding by silently dropping the packet, knowing that a sufficient number of neighbor nodes have already forwarded the packet.

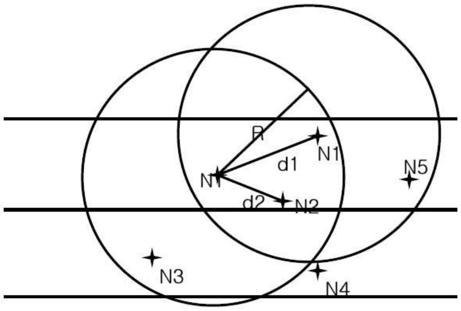

Fig. 3. Distance form the previous forwarder

B. Adaptive Suppression Method for a Very High Density Network

As described in III-B, the counter-based method does not work properly in very high density networks. Especially when there are a large number of message sources, each node needs to reduce the redundant forwardings to ease the network congestion. In our new adaptive suppression method that is based on a probability-based method, each node measures the inter arrival time of the received packets to quantify the congestion level and adapts its forwarding probability accordingly. Therefore, the nodes in the congested area lower their forwarding probability and, by discarding received packets, they alleviate the network congestion.

The reduced packet transmission enhances the network reliability in very high density networks by avoiding excessive packet collisions and congestions in the network. In such a network, EWM packets are initially created redundantly from the multiple vehicles that observe the same situation. Therefore, 100% packet delivery is not so critical in this case and certain level of delivery assurance could be achieved by the proposed method. The benefit of the proposed adaptive suppression method is that this protocol operates in a distributed manner. Nodes do not need the global knowledge on the network status by exchanging beacon messages with each other.

C. Simulated Forwarding Algorithms

We first show the terminology used to describe our methods.

- $Progress$: $\frac{Distance\ from\ PF}{Maximum\ radius} = \frac{d}{R}$
- T_delay: Random backoff delay that a node backs off before forwarding a packet to avoid both a collision and a redundant transmission

```
Receive a packet $PID = k$
    measure $Pkt\_interval$
    if (first reception for $PID = k$)
        Set the timer as $T\_delay$
    else
        increase $Counter$ for $PID = k$
Timer expires
    if (($Counter\ for\ PID = k < Max\_count$) AND
      ($RV(0,1) < Pkt\_interval * \alpha$))
        Forward $PID = k$
    else
        Drop $PID = k$
```

Fig. 4. Basic forwarding algorithm

- $Pkt\_interval$: The inter arrival time of overheard packets.
- PID: Packet ID determined by the source address and the packet sequence number
- Max_delay: The maximum value of T_delay
- $Counter$: The number of overheard packet from its neighbor nodes for each received packet
- Max_count: The maximum value for a $Counter$ before forwarding a packet
- $Backward\ direction$: Direction toward the source
- $Forward\ direction$: Direction that the message is supposed to propagate

The basic forwarding algorithm is shown in Figure 4. Upon receptions of each packet, T_delay is randomly set. T_delay determines the priority of the node for that specific packet forwarding. By adjusting T_delay, we can manipulate the priory of the node. A node that has a smaller timer will access channel before other candidate forwarders do it, so it will have priority and others. The final decision for the packet forwarding is made based on the $Pkt\_interval$ measured to check if the network is currently suffering from excessive congestion. If the network is suffering congestion, the decreased inter arrival time of the overheard packets render the node suppress its transmission by reducing the probability of transmission adaptively. The coefficient α is chosen as 100 in this simulation by empirically.

The following five different methods including our methods are simulated for performance comparison.

- Random Backoff with Counter-Based Suppression (RBCB):
  T_delay has a uniform distribution from zero to Max_delay regardless the distance from the previous forwarder.

$$T\_delay = Max\_delay * Uniform\ RV(0, 1) \tag{1}$$

- Distance-based Backoff with Counter-Based Suppression (DBCB):
  The distance from PF gives priority to the farther nodes by shortening the T_delay value according to its distance from the previous forwarder.

$$T\_delay = Max\_delay * (1 - Progress) * Uniform\ RV(0, 1) \tag{2}$$

- Random Backoff with Directional Suppression (RBDI):
  This method does not consider the location of the forwarder. T_delay has uniform distribution regardless the distance from the previous forwarder like RBCB. However, it does not count the packets received from backward. This method forces the border nodes make a transmission if they have not overheard the packet from forward direction to enhance the connectivity of the network.

- Random Backoff with Directional Retransmission (RBDR):
  This method is based on RBDI, and if a message from forward has not been heard during a particular time interval, the forwarder re-broadcasts the packet (2x transmissions). This is to enhance the connectivity further when the next hop node is apart from its PF nodes. Border nodes will make retransmissions to further increase the possibility of receptions in next hop nodes.

- Distance-based Backoff with Counter-Based Suppression with Gaussian Timer (DBCG):
  The delay timer has a Gaussian distribution with mean value of *(1-Progress)* with variance of 0.3.

$$T\_delay = Max\_delay * Gaussian\ RV((1 - Progress), 0.3) \tag{3}$$

V. SIMULATION RESULT

A. NS-2 Channel Modeling

The deterministic wireless channel models provided by NS-2 network simulator is not appropriate in the accurate simulation of EWM dissemination. In deterministic channel models, the coverage is determined only by its distance from the transmitter. All the nodes in the coverage area will receive messages and none of the nodes outside of the coverage will receive any packets from the source. This eliminates the dynamic characteristic of wireless communications, where nodes experience extremely variable channel conditions. The probabilistic channel models NS-2 provides are hard to exactly model the V-to-V communication channels, and NS-2 does not provide independent signal fading to each node in a coverage area. Thus, we designed a probability-based channel model based on the Nakagami model, whose parameters are configured to meet the empirically measured data in [20], and implemented independent fading channels to all nodes.

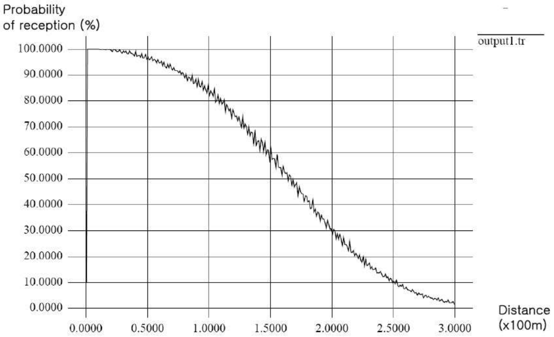

Fig. 5. Probability of reception and the transmission distance

The probability of packet reception with respect to transmission distance under our model is shown in Fig. 5 The NS-2 parameters for our simulations are shown in Table I. These values are based on 802.11a specification to compare with our future field test using off the shelf devices. However, the slot time, interframe spaces and frequency band are adjusted according to the DSRC specification. Max_delay is configured considering the latency of network and maximum number of repetitions in the network [19].

SlotTime	13 μsec
CWmin	15 slots
SIFS	32 μsec
DIFS	58 μsec
packet size	256 Bytes
EWM repetition rate	10 messages per sec
Max_delay	20msec
Data rate	6 Mbps
Tx Power	60 milliwatts
Frequency band	5.9GHz
Maximum radius	350m

TABLE I
NS-2 PARAMETERS

B. Normal Network Condition

In this simulation, we tried to measure how efficiently EWM packets propagate the network in normal traffic conditions with controlled flooding methods. Two hundred nodes are randomly located in road networks. The dimension of the network is $(25m)$ by $(1km, 2km, 3km, 4km, and\ 5km)$ and one EWM source is located at $(0, 0)$ position generating EWM packets with 10 packet/sec(100msec interval) rate. Since the number of nodes is fixed as 200 regardless of the network size, the longer the size of the network is, the lower node density will be. We simulated the five different forwarding methods described in the previous section. We measured the total number of EWM packets received and the number of forwardings in each node and averaged them out for all of the nodes to compare the efficiency of the methods. The ratio of the number of receptions to the number of transmission in each node tells about how efficiently the EWM packets are propagated.

Max_count is the most important variable in the counter based method. An unnecessarily large *Max_count* value produces too many redundant forwardings, and too small *Max_count* value will easily disconnect the network causing loss of EWM messages. Fig. 6 to 8 show the simulation results when *Max_count = 1*. *Max_count = 1* means whenever a node overhears a packet forwarded from its neighbor nodes, it does not forward that packet. *Max_count = 1* produces the minimum number of forwardings in the counter based method, thus, the connectivity is lower than that of *Max_count = 3*. The results for *Max_count = 3* are shown in Fig. 9 to 11.

The proposed method outperforms other methods regardless of the network density. As shown in Fig. 6 and 9, the proposed method has larger number of average receptions and smaller number of transmissions in each node. This means the larger number of nodes receives EWM packets and the proposed scheme provides a better connectivity than other forwarding methods. The proposed method also has smaller average transmission rate by efficiently suppressing redundant forwardings while increasing the connectivity of the network.

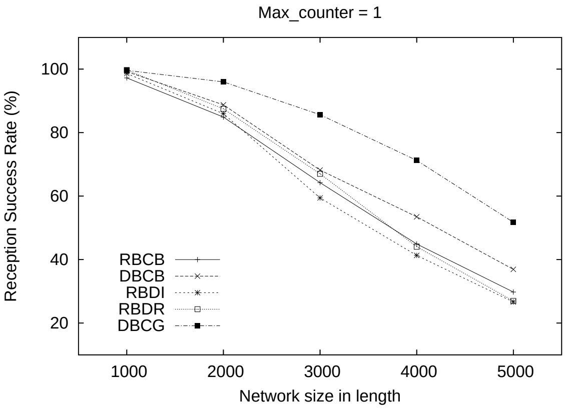

Fig. 6. Reception Rate for Max_count=1

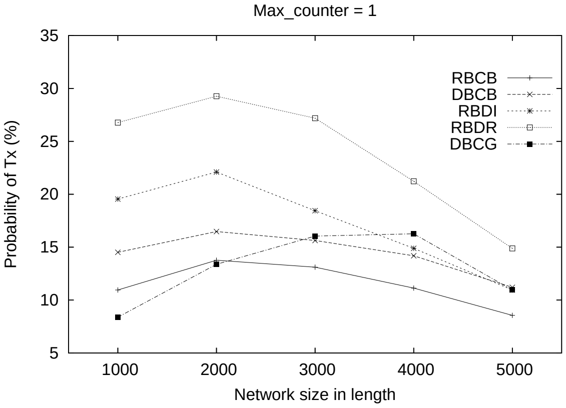

Fig. 7. Transmission Rate for Max_count=1

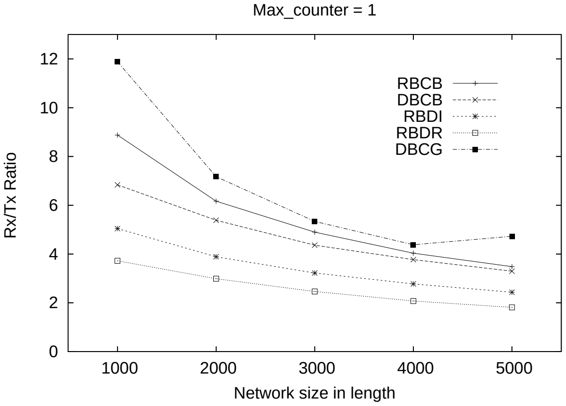

Fig. 8. Rx/Tx ratio for Max_count=1

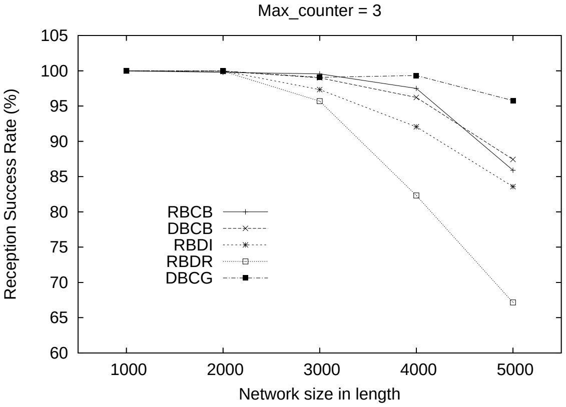

Fig. 9. Reception Rate for Max_count=3

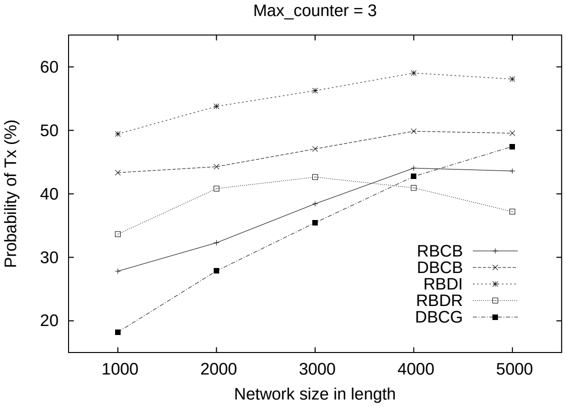

Fig. 10. Transmission Rate for Max_count=3

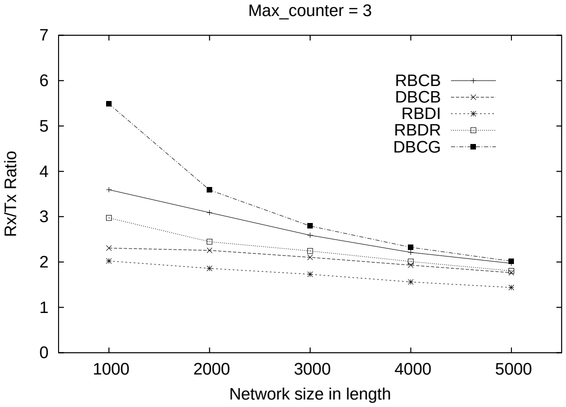

Fig. 11. Rx/Tx ratio for Max_count=3

C. Extremely Congested Network Condition

Extremely congested scenarios with very high node density are simulated with multiple numbers of source nodes. One hundred nodes are randomly located in a 600m by 60m road and we have increased the number of EWM sources from 1 to $100(1, 10, 20, 50, 80, and\ 100)$ and each source generates EWMs with 10packets/sec rate. The simulation is performed with *Max_count = 3*. However, even with *Max_count = 1*, which generates less forwarding, the network congestion status is not improved. This means the counter based method is not working properly in very high density network conditions as indicated in III-B. In the ideal case that the counter based method works perfectly, the number of forwarders within the coverage area should be limited to only 1 or 2. Therefore only small number of nodes should participate in the forwarding processes, and the network should not be congested even a large number of EWM sources transmit messages. However, as shown in Fig. 12 and Fig. 13, according to the simulation result, even with 10 message sources, the network is congested and the number of packet reception and forwarding decrease as the EWM sources transmit more packets. This means the redundant forwarding is not effectively limited by the basic counter-based method, and large numbers of redundant forwarding and packet collisions are happening in the network.

We compared the performance of normal Random back-off counter-based method(RBCB) and the proposed adaptive redundancy suppression scheme(Adaptive_Suppression). The proposed adaptive scheme was not applied to RBCB method. In the proposed adaptive suppression mode, each node adjusts its probability of forwarding according to the time intervals of the received packets. The suppression of excessive forwardings is shown in Fig. 12, while the increase of receptions is shown in Fig. 13.

We also measure the extremely high congested network cases by increasing both number of the nodes and the message sources simultaneously. The number of nodes has been increased up to 200 and all the nodes are assumed to generate EWMs with a frequency of 10pakets/sec. As shown in Fig. 14, 15, when number of the EWM source exceeds 50, the number of forwarding of the EWM packet per node is over 50 packets/sec. However, the reception of the EWM packet per node is below 100 packet/sec even the messages are broadcast in a small area. This means there is huge number of collisions of packets in the channel. The simulation result shows the proposed adaptive suppression method limits the number of forwardings effectively, and it also increases the number of receptions by dramatically reducing collisions in the channel.

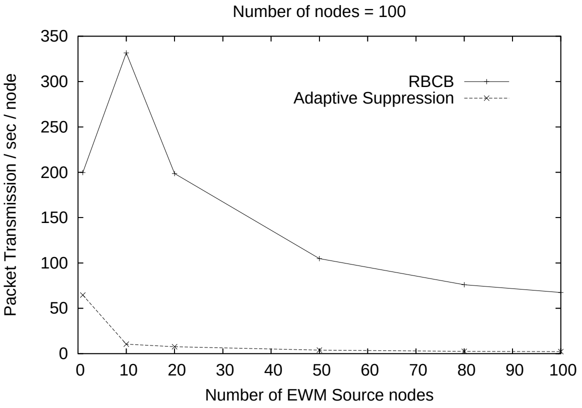

Fig. 12. Packet Transmission with large number of forwarding nodes

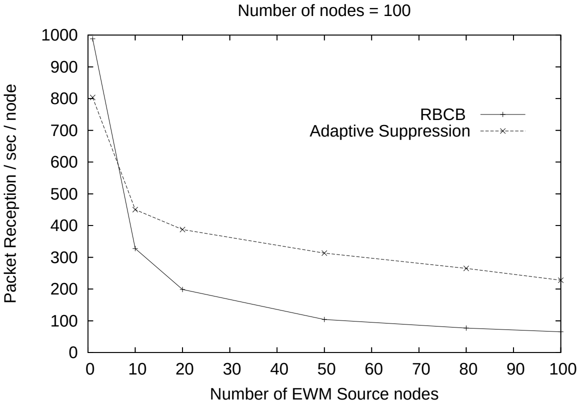

Fig. 13. Packet Reception with large number of forwarding nodes

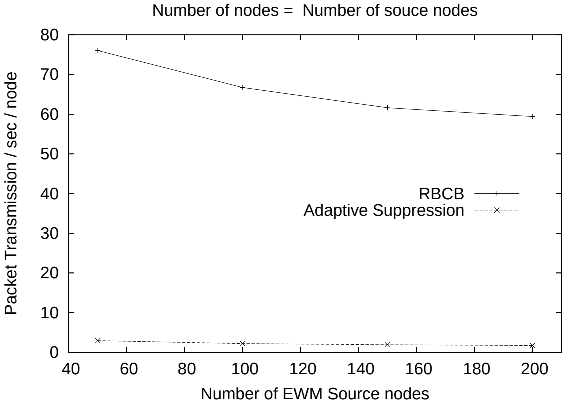

Fig. 14. Packet Transmission with large number of source nodes

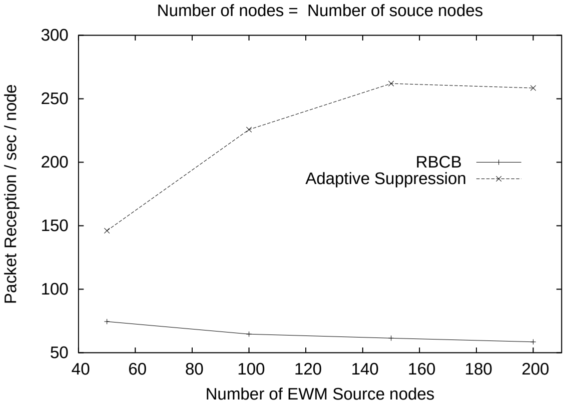

Fig. 15. Packet Reception with large number of source nodes

D. Discussion

The proposed EWM packet dissemination method is mainly based on broadcasting protocols to utilize the randomness and broadcasting characteristic of wireless channels. We combined counter-based method and location-based method and made it adaptive to various road conditions for a better connectivity and reliability. In normal network conditions, the proposed method uses location information to give priority to border nodes to enhance the connectivity of the network. The reliability and the efficiency of the network are enhanced by adopting a random delay timer that has a Gaussian distribution. The mean value of the probability distribution function(PDF) of delay timer is adjusted to according to the distance from the PF. The lower mean values of the Gaussian distribution to border nodes provides a shorter delay time to them and this gives them higher chances of the forwarding of the received packet. The probability based random timer also allows the mid nodes to have a chance to fill the coverage holes in the area. Thus, by combining counter based method and location based method, and with a enhanced delay timer, we have achieved both connectivity and reliability with high network efficiency.

On the other side, with the proposed adaptive suppression scheme, the probability based transmission suppression function is intimated in situations of very high node density or extreme network congestion. The proposed suppression scheme uses network congestion information to adaptively reduce the probability of forwarding in highly congested conditions. Usually, congestion aware protocols require exchange of beacon messages to find out the number of its neighbor nodes. But the proposed method does not use additional neighbor information and it adaptively suppresses its forwarding accordion to the network congestion scenarios. The simulation results prove the proposed method is robust regardless of the network congestion scenarios.

VI. CONCLUSION

In this paper, we have considered location-aware protocols for delivering emergency warning messages with improved reliability to nearby and approaching vehicles. In these protocols, receivers forward messages to extend their range and address packet loss due to shadowing, for example. The protocols can be implemented on a standard 802.11 MAC implementation through an additional delay imposed at a higher layer. The location-based method calculates this delay as a function of the distance traveled from the previous forwarder, thus nodes at the edge of the transmission range receive priority. The method also suppresses excess retransmission when it is combined with counter-based method. In counter-based method, once a node overhears a certain number of retransmissions from other nodes it will cancel its scheduled retransmissions.

The NS-2 simulation results indicate that the proposed hybrid method operates more efficiently and achieves higher message reception rates than conventional random delay techniques. Thus it provides increased messaging reliability in this challenging vehicular scenario. The counter-based message suppression mechanism must be complemented with other mechanisms, such as probabilistic suppression, to scale to scenarios to the highest considered node densities.

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