Road Aware Information Sharing in VANETs

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Abstract

Recently, several approaches to share road conditions and/or digital contents through VANETs have been proposed, and such approaches have generally considered the radial distance from the information source as well as the TTL to provision an ephemeral, geographically-limited information sharing service. However, they implement general MANETs and have not been tailored to the constrained movement of vehicles on roads that are mostly linear. In this paper, we propose a novel application-level mechanism that can be used to share road conditions, including accidents, detours and congestion, through a VANET. We assign probabilities to roads around each of the intersections in the neighborhood road network. We then use the graph representation of the road network to build a spanning tree of roads with the information source as the root node. Nodes below the root represent junctions, and the edges represent inter-connecting road segments. Messages propagate along the branches of the tree, and as the information propagates down the branches, the probability of replication decreases. The information is replicated until a threshold probability has been reached, and our method also ensures that messages are not delivered to irrelevant vehicles, independently of their proximity to the source. We evaluated the success rate and performance of this approach using NS-3 simulations, and we used IDM car following and MOBIL lane change models to provide realistic modeling of the vehicle mobility.

Keywords: Information Sharing, Road data, Tree, Hovering Information, VANET

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1. Introduction

Recently, Vehicular Ad-Hoc Networks (VANETs) have received interest from the automotive industry and the research community since these can be actively used as a medium to share information among vehicles. In addition, VANETs have also emerged as a practical application model for research and development of Mobile Ad-hoc Networks (MANETs). The majority of work done for MANETs can be easily carried over to VANETs due to the similarity in the implementation scenarios of both. Some VANET applications address issues related to road safety and improve the driving experience by providing information on accidents, hazardous conditions and issues related to congestion [1–4] while others have been built for entertainment purposes, e.g., interactive games, content sharing and dissemination of advertisements to interested clients [5–8].

In 2006 Konstants proposed Hovering Information [9], which describes how information can sustainably hover within a specified area. It is considered to be an effective way to share safety-related information or to provide a notification of emergent situation within a specific area. Later, this work was applied in VANETs [10], and many similar works, such as AutoCast, Floating Content, etc. [11, 12], were also presented. These types of information sharing mechanisms assume that vehicles have location-aware capabilities though the use of GPS and its associated means, and they make information wander around the source point for neighboring vehicles to continuously share it. Since a VANET inherits most of its characteristics from a MANET, these approaches can be valid solutions. However, they ignore the fact that vehicles are limited in their movement along roads, unlike mobile nodes in a MANET. This could be problematic because some vehicles that travel closely on different roads may actually have no need to share certain information.

Therefore, this study has investigated an approach that combines hovering information with the limited movement of vehicles along roads. Since modern vehicles usually have navigation systems, the vehicles are assumed to be able to obtain road information and driving information according to their current location that is determined using GPS. When a new road is built, many aspects are considered, including statistics and expectations of the traffic on the area connected to the new road. Therefore, a newly-built road inevitably contains a considerable amount of information, and traffic patterns of vehicles riding on that road are necessarily restricted to its topology. As a result, we consider that efficient communication is possible if a road-aware approach can be considered for vehicular communication.

This road-aware approach is used to propose an efficient probability-based directional information hovering technique for VANET. The direction of the vehicles is considered as a parameter for this approach because when some information is generated at a particular point along the road, outgoing vehicles are usually not interested in receiving it but incoming vehicles have much interested to obtain that information. The road information model is implemented by presenting roads as a spanning tree and defined how and to whom to deliver information in that tree. In our work we have treated the information source point as a fixed geographical location because we expect that our proposed system can be possibly used to share information only for safety-related uses and/or disaster situations, so we do not consider the situation where the source of information may continue to move, as in the case where multimedia or game content is shared.

Since experimentation with VANETs is prohibitively expensive in the real world, we use an NS-3 simulation to evaluate our solution. NS-3 is a realistic implementation of a network protocol stack based on the Linux kernel. Wireless models in NS-3 are more realistic, and the realism can be easily improved by incorporating an application, protocol stack or network interface level emulation that leverage the Direct Code Execution (DCE) capability. Since NS-3 is not tailored for VANET mobility scenarios, we have integrated an IDM car-following model with a MOBIL lane change model to realistically mimic the vehicle mobility. We have thus tested the efficacy and performance of our information sharing mechanism over a road network typical of a modern urban center.

The paper is organized as follows. Section 2 introduces related work, and Section 3 describes the new mechanism that we propose in this paper. In Section 4, the efficacy of our approach is explained, and in Section 5, our experimental work is explained to show the performance of our system. We conclude this paper in Section 6.

2. Related Work

A. Villalba and D. Konstantas proposed [9] and extended [13] a hovering information that survives on its own over a specific area. However, their work mainly focused on MANET with no consideration of VANET-related circumstances.

Xeros, A. [10] performed similar work for VANET and proposed a probabilistic flooding approach that limits the dissemination of information. However, this approach only focuses on hovering area ranges and does not consider necessary road attributes, such as the direction, which are necessary in order to reduce a significant amount of transmission overhead due to the relevancy of the information. Other works, such as Ref. [11], also do not take a road-aware approach for information sharing over a VANET.

Floating Content is a recent technique that is similar to Hovering Information [12]. This method also uses a general approach for information hovering where the “two radii” technique adds some information replication scenarios. However, it is not road-aware like our proposed solution and lacks the probabilistic efficiency that we have provided.

Most of the recent work presented by Koosha Paridel for Teamwork on Road [14] appears to cover our road-aware approach. However, the major difference is that their approach does not implement an information hovering technique, and a closer look reveals that its main emphasis is on grouping vehicles based on spatial characteristics and handling convoys, which is very different from our work because it is not easily applicable in urban scenarios. Furthermore the results of their study cannot be used to carry out proper differentiation of both works since they utilized duplicat content and sufficient results were not provided. Also, since their approach does not use hovering information, it does not have the advantage of using the same light weight application level protocol that is provided by us. The overhead to form groups and to identify a group leader node is significantly higher at a middleware layer or at a network layer and is resource intensive. Their direction calculation algorithm certainly produces overhead while vehicles can obtain this information from the road when using our road-aware approach. The results provided in their study suggest that network utilization of ungrouped highways in urban areas are at a peak and that the information dissemination relevancy is at its lowest, so we definitely have an efficient and realistic approach that produces better results.

3. Probabilistic Road-aware Information Sharing in VANETs

Existing studies on information sharing in VANETs have only taken into account the distance from the anchor node, which is the information source. Three kinds of areas have been defined around the anchor node, including a safe area, risk area and relevant area, and the nodes outside the safe area replicate information to neighboring nodes simply by broadcasting. This approach can be effective in MANETs, but since vehicles in VANETs move along roads, road attributes such as lanes, intersections, turns and directions need to be considered to effectively share relevant information. Not all vehicles in an anchor zone need the information from the anchor node. In other words, vehicles riding on other roads or in an opposite direction on the same road may have no interest in such. Sharing information in an anchor zone in a mountainous areas may also be inefficient since those roads are usually very long and rarely have any junctions, and information related to disasters/accidents on such roads can be of interest to all vehicles riding along the road. With these considerations in mind, we propose a road-aware mechanism to share information in VANETs.

We first assume that every vehicle is equipped with a navigation system because modern vehicles are often equipped with some kind of navigation system. For the sake of simplicity, we consider a scenario consisting of an accident on a road, as shown in **Fig. 1**. The accident is obviously relevant to to vehicles riding in the direction of the accident, and its information should be delivered in the outgoing direction shown in **Fig. 1**. As with other approaches [10][12], our mechanism consists of a vehicle with the relevant information broadcasting it to neighboring vehicles. Vehicles that receive this information may discard some of it if their buffer is full. In this case, the information of interest can be selected in our road-aware approach, not by using the radial distance, but by assigning a probability which can be used to decide whether information can remain or be discarded.

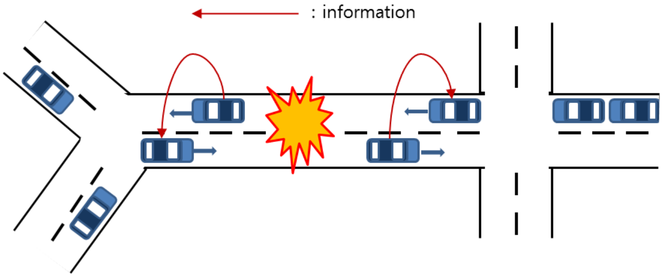

Fig. 1. An accident occurred on a road

Information that is generated in response to events, such as traffic accidents, is relevant to all vehicles that are travelling on that road. Therefore, all of the vehicles on the road where the accident took place need to receive such information without exception. If the road is very long without any divergence, such as a road in a mountainous area, then the information should be delivered to all vehicles regardless of the distance. In urban areas, roads frequently meet at a junctions with short distances in between, and then the information may therefore need to be shared only over a small, local area. A special case is that of a traffic accident that occurs in a multiple-level complex interchange, and the information of the accident should then be delivered to all vehicles only on roads where traffic can be affected by the accident.

Our information sharing mechanism works as follows. First, when an accident occurs on a road, the relevant information needs to be delivered with a probability of 1 to all vehicles on the road. Then, we define how information can be further shared among vehicles on other roads that are connected via intersections. Since the number of lanes of a road is determined during construction according to the expected traffic load, it is resonable to estimate the probability that a given vehicle will select a specific road at an intersection according to the number of lanes of that road because during construction, the number of lanes of a road is determined to be large if the road is expected to be more heavily used and only one or two lanse if the road is not expected to have much use.

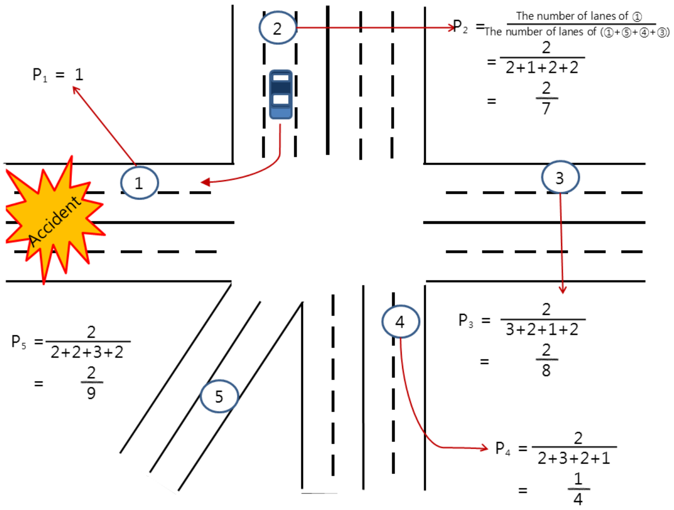

Fig. 2. Calculating the P_i for roads

First, let us explain how to calculate the probability that a road can be selected at a given junction by using **Fig. 2** as an example. Five roads are connected to a junction, and each has a different number of lanes. If an accident occurs on road (1), information is transmitted to all vehicles heading toward the lcoation of the accident on the same road with a probability of 1. However, we need to know the probability that other vehicles will enter road (1) at the junction. We propose that this probability can be calculated by using the number of lanes of the roads. As mentioned earlier, when a road is built, the number of lanes is determined according to the expected traffic load. Therefore, we propose using the number of lanes in the road with Equation 1 to calculate the corresponding probability. Equation 1 expresses a simple ratio for the number of lanes of a road that a car selects over all possible roads that a car can enter from the road it is currently on.

$$p_i = \frac{number\ of\ lanes\ on\ the\ accident\ road}{total\ number\ of\ lanes\ of\ roads\ except\ road\ i\ where\ the\ car\ rides} \tag{1}$$

In **Fig. 2**, the probability for a car to enter from road (2) into road (1) can be estimated by dividing the number of lanes of road (1) by the number of total lanes of roads (1), (3), (4) and (5), not road (2).

$$p_2 = \frac{number\ of\ lanes\ on\ the\ accident\ road\ \textcircled{1}}{total\ \ number\ of\ lanes\ on\ roads\ \{\textcircled{1},\ \textcircled{3},\ \textcircled{4},\ \textcircled{5}\}} = \frac{2}{2+2+2+1} = \frac{2}{7}$$

Then, we can say that the vehicles on road (1) can share information with a probability of $p_1 = 1$, and vehicles on road (2) can share it with a probability of $p_2 = \frac{2}{7}$.

In the same way, $p_3 = \frac{1}{4}$, $p_4 = \frac{1}{4}$ and $p_5 = \frac{2}{9}$ can also be calculated. Then, we can know that when an accident occurs on road (1), the vehicles on roads (2), (3), (4) and (5) are expected to go onto road (1) with probabilities of 2/7, 1/4, 1/4 and 2/9, respectively. Therefore, those probabilities can be used to represent roads using the spanning tree in **Fig. 3**. Also, we can extend the tree by calculating the probabilities in the same manner.

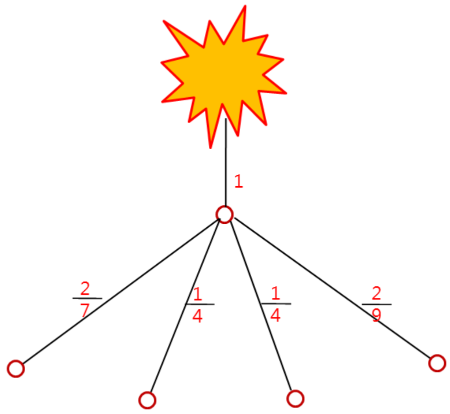

Fig. 3. A spanning tree representing the roads and junctions

Now we need to consider the range over which to share information by extending the spanning tree to more intersections. As was previously mentioned, we can specify this in terms of the related road probabilities p_i. These are calculated by considering how much information is valid in the road. When a given road is far from a the source road where information is generated by crossing many junctions, the validity of the information essentially decreases. The result can be expressed as a probability from a source road to a current road, and it is computed by multiplying all p_is from the source road to the current road k by using Equation 2.

$$p_{road\_k} = \prod_{i=1}^{k} p_i \tag{2}$$

We can say that the vehicles on road k have a probability of $p_{road\_k} = p_1 \times \ldots \times p_k$, which is the product of probabilities p_i of roads along the path from the root to node k in the spanning tree. The depth of the tree can be unlimited, but we limit it by using a threshold probability. In this paper, we consider the case $p_{road\_k} > 0.05$ for the sake of simplicity, but it may be determined to be different according to the importance and the nature of the emergency. As we can see, p_{road_k} itself is relevant to the source information that has been generated. Our method uses this to control the amount of information that can be replicated to neighboring vehicles. A vehicle can share a piece of information by periodically broadcasting, and when a vehicle A meets another vehicle B, A will replicate item I to B with a probability of $p_r(k)$:

$$p_r(k) = p_{road\_k} \tag{3}$$

where k is the number of the road. A priority level can be assigned to the information that has been replicated by using this probability and handling it accordingly.

The vehicles that have received this information can decide whether it will be stored or dropped according to its status, such as the amount of memory available in the receive buffer.

We define the deletion probability $p_d(k)$ in a similar manner:

$$p_d(k) = 1 - p_{road\_k} \tag{4}$$

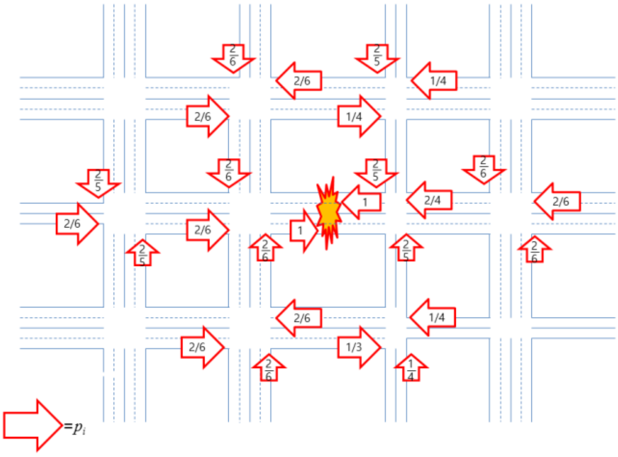

Fig. 4. An example where an accident occurs on a road

In this way, we have created a new mechanism to share information among vehicles in a VANET by taking into account the information on the road rather than the distance from the source. As an example, we can consider the case in **Fig. 4**. When an accident occurs in the center of the road, an alert is delivered to all vehicles coming towards the accident location from both sides. We can calculate probability p_i of the road according to the location of the accident. **Fig. 5** shows probability p_i for each road i in **Fig. 4**, and **Fig. 5** also shows the probabilities that are assumed to have been assigned for extended roads in order to demonstrate the computation of p_{road_k}. The final probability tree is shown in **Fig. 6**, and the depth of the tree is limited by the 0.05 threshold, i.e., $p_{road\_k} > 0.05$. The depth can increase or decrease by choosing a different value for the threshold according to the application scenario.

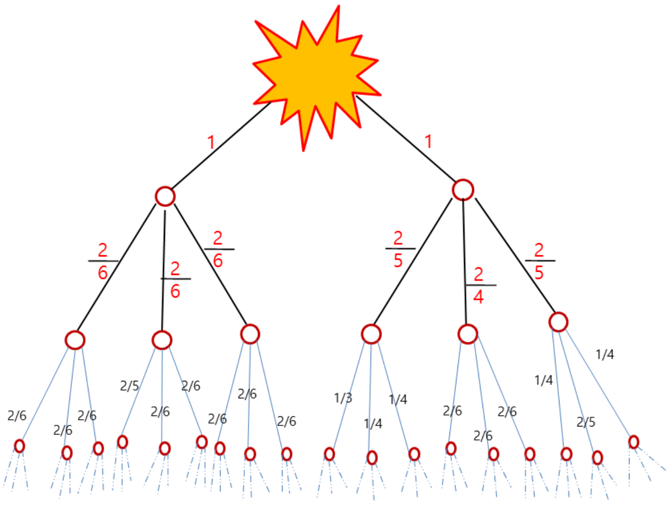

Fig. 5. p_i calculated for the roads in **Fig. 4**

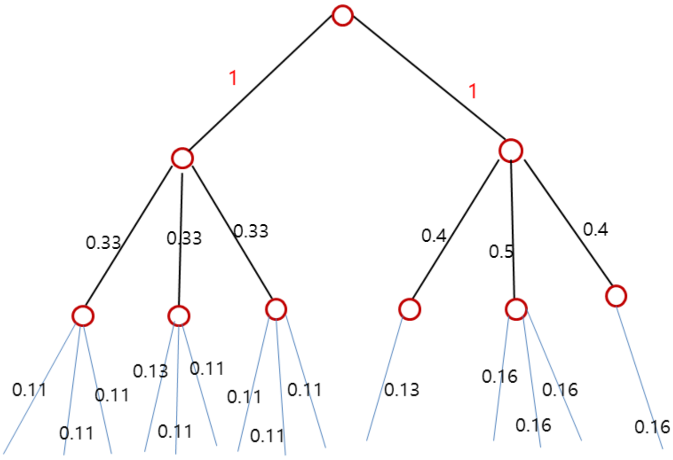

Fig. 6. p_{road_k} in a spanning tree for $p_{road\_k} > 0.05$

4. Effect of the road-aware approach

The road-aware approach that we proposed in this paper is clearly different from existing approaches that are usually based on the radial distance, and this difference is further clarified in **Fig. 7** and **8**.

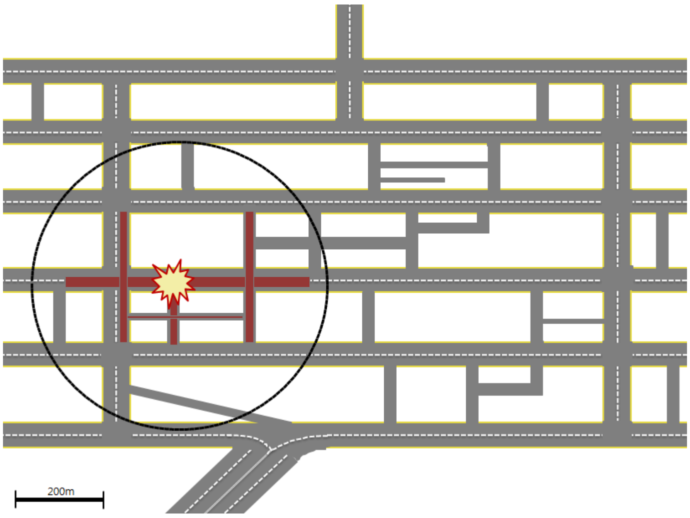

Fig. 7. Information sharing in an urban area

Fig. 7 shows a typical road in the urban area. In an urban area, roads are usually complex and the distance between their intersections may be short. Vehicles on the road select their path from several possible paths that can be considered, so even when a vehicle rides on a road close to another road where an accident occurred, many nearby vehicles may not be interested in the accident at all. If information is shared by considering the radial distance of vehicles within given distance, as in **Fig. 7**, then the information can be disseminated inefficiently to unrelated vehicles. Therefore, if the road-aware approach that is proposed in this paper can be chosen, information is shared only on related roads. The more complex that the topology of the roads is, the smaller the area over which the road-aware approach will provide information, relative to the radial distance approach, without affecting vehicles on unrelated roads. **Fig. 7** shows a conceptual example of the information that is shared only on roads in red, using Equations 3 and 4 when $p_{road\_k} > 0.3$ in the spanning tree of **Fig. 6**.

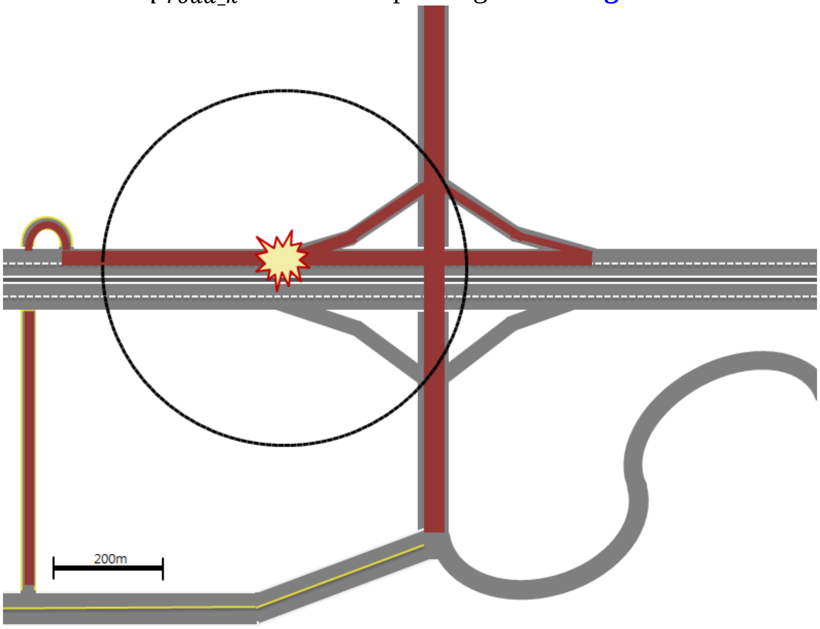

Fig. 8. Information sharing in a rural area

On the other hand, roads in a rural area or in highways are usually simple, and the distance between intersections can be expected to be long. **Fig. 8** shows a typical road topology. The information for such a road may be valid along the road over a distance of many kilometers, which is the same case when information of highways is mentioned in the mass media such as TV, where only the road number is referred to, regardless of the length of the road. The existing radial distance approach does not have a way to share information among vehicles in a road regardless of the distance. **Fig. 8** shows the radial distance approach shares information within an area of a circle, but the road-aware approach can share information over long distances. We can see that our road-aware approach may be more effective in providing information in a rural area than the existing radial distance approach.

5. Experimentation

For our experiments, we consider an event that consists of a traffic accident under the following scenario. The accident vehicle(s) originates ("post") warning messages with a TTL. Other vehicles within range and on roads (present) in the spanning tree accept copies of these messages according to the replication probability and forward these meassages to other vehicles. We explicitly allow the information to disappear from the network and provide no guarantee of its availability. If no (or too few) nodes are around to replicate a message, it will disappear after its lifetime expires. Once the lifetime of a message expires, it will also be deleted by all nodes. In addition, vehicles with probability less than 0.05 will not accept a copy of the message.

The damaged vehicle then generates a warning message with a certain lifetime (TTL). The message is stamped with the time of creation and is identified with a unique ID. We then use the following protocol to exchange messages.

1. Vehicles continuously send neighbors discovery beacons or hello messages to discover their peers.
2. After discovering a peer, i.e., receiving a beacon message, a summary message is sent that includes a vector of the message items that are available for replication. The summary size is limited to one MTU size packet. Currently, the vector contains the IDs of messages that are available.
3. As soon as a vehicle is aware of what a neighbor has to offer, it requests a subset of the items by requesting all items that correspond to the road probability. For example, if the road probability is 0.6, the vehicle will select 60 percent of the messages. The decision of which messages to request is based on random numbers that generated using a uniform distribution in the range from 0 to 1. The messages requested by the vehicle are those for which the random number is less than 0.6. The vehicle may prioritize the order in which the messages are replicated according to a replication policy. The replication policy determines the order in which messages are replicated when two vehicles come within radio range of each other. We define two such policies with FIFO preserving the order in which messages were created/received at a node and RND randomizing the order.
4. The requested messages are exchanged, and the buffer of each vehicle is periodically evaluated in order to determine the messages that are to be deleted. This prevents the buffers from filling up. The deletion function depends on the road probability. A high road (replication) probability means a lower probability of deletion, and it is computed as $1 - p_{road\_k}$. The buffer is also evaluated upon each encounter with another node, and if there is still a need to free the buffer, the oldest messages are discarded.

Messages are deleted following one of the following policies: 1) The message lifetime suggested by TTL expires, 2) the node buffer becomes full, and 3) the probability for the vehicle is less than 0.05.

5.1 Simulation Environment

We evaluate the performance of the hovering messages over a street map that is typical of roads in a metropolis. The roads consist of multi-lane directional highways with turns and intersections. We generate a realistic mobility pattern of vehicles by using an Intelligent Driver Model (IDM) traffic flow model and Minimizing Overall Braking Induced by Lane change (MOBIL) model. IDM involves making a decision whther a given vehicle driver will accelerate or brake depending only on his or her own speed and on the position and speed of the vehicle that is immediately ahead. However lane changing decisions depend on all neighboring vehicles, and various IDM parameters, such as the desired velocity, maximum acceleration and braking, minimum gap, and the minimum time headway, etc., can be customized using an XML configuration file. During each step, the Highway object passes information to the IDM model of the vehicle in front, and the model then determines what the current acceleration should be.

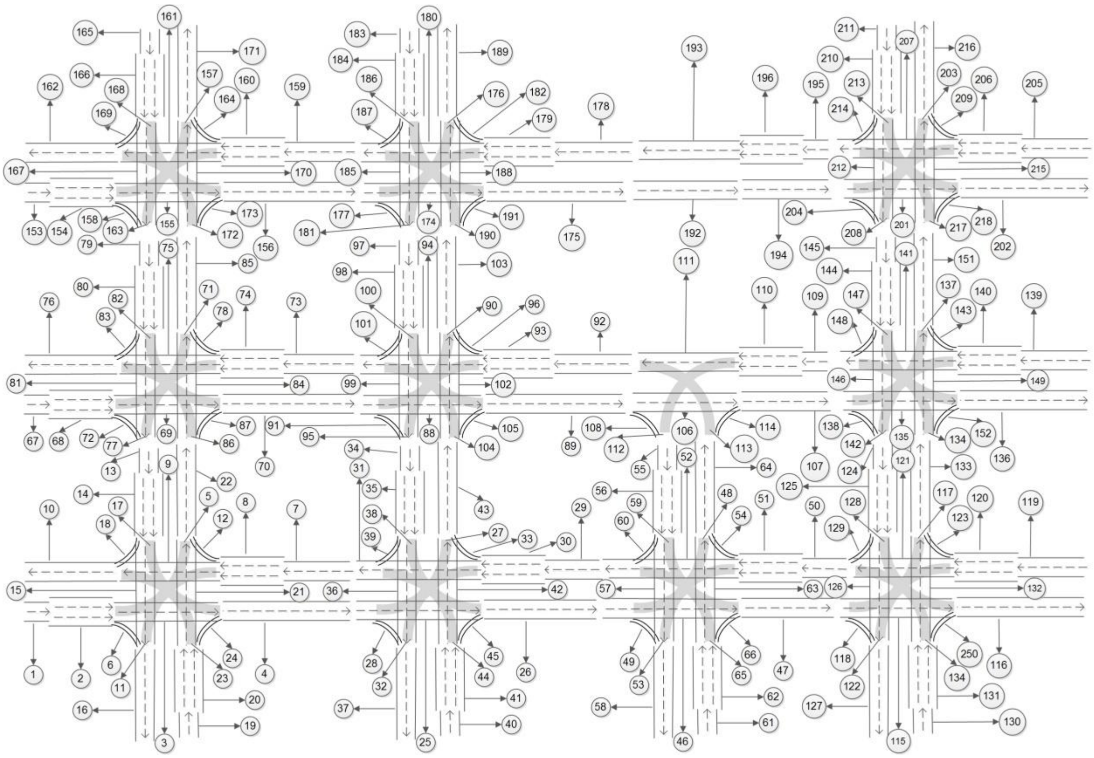

Fig. 9. Road Network used in the simulations. Roads are made of highway segments that are identified with numbers. In our simulations, Highway 10 is blocked using stationary vehicles as obstacles.

The details related to the highway, such as the highway id, the number of lanes, direction, length, turn velocities, etc., are specified in an XML file. The highway connections are created by defining the associated front, back, left and right highways, and vehicles are generated according to the desired density by defining the starting highway and multiple destination highways. The weight can be assigned to distribute the percentages of vehicles that have been generated on each destination road.

We used NS-3 to implement our information dissemination mechanism for VANETs. A snapshot of the animations showing the mobility of vehicles is shown in **Fig. 9**. Vehicles are configured to move at a speed of 18-23 km/h towards randomly chosen destinations using shortest the path that has been calculated using Dijkstra's algorithm. We developed a HoveringApplication that creates and periodically broadcasts messages where each message consists of a message ID, TTL, timestamp, source vehicle number, coordinates of the source vehicle and message. We also implemented a HoveringRouter application that implements replication and deletion policies.

We created six vehicle mobility scenarios, as shown in Table 1. We use the OFDM 6Mbps data rate for wireless links (Wi-Fi ad hoc mode) for two radio transmit power levels of 6 dBm and 12 dBm with Nakagami channel fading. Both of the transmit and receive antenna gains are fixed at 2 dBi. The energy detection threshold is set to -101 dBm. These configurations use a transmit power of 6 dBm to achieve a propagation range of roughly 50 m and a transmit power of 12 dBm to provide coverage up to 100 m. We use three vehicle density scenarios: small (160 vehicles), medium (280 vehicles), and large (500 vehicles).

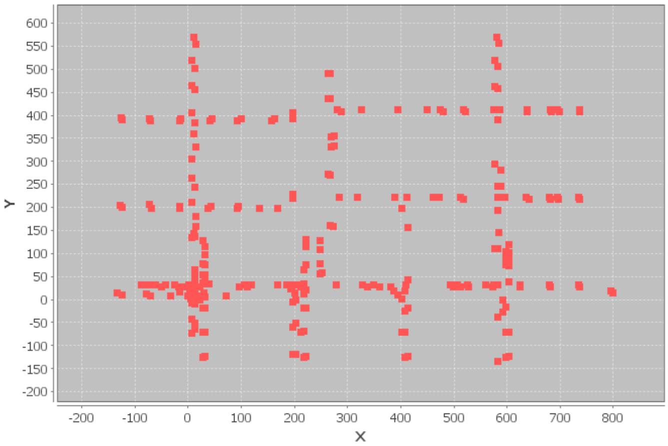

Fig. 10. Snapshot of the vehicle traffic over the road network. An obstacle on highway 10 at -50, 25 has blocked the traffic flow on it.

TABLE I. SIMULATION SCENARIOS

Reference	Transmit Power	# vehicles
S50	6 dBm	160
S100	12 dBm	160
M50	6 dBm	280
M100	12 dBm	280
L50	6 dBm	500
L100	12 dBm	500

We simulate a single anchor point. The accident vehicle generates and broadcasts warning message every second. All other vehicles that want to receive traffic information broadcast a 1 hop hello message every second. Hello messages signal a vehicle's desire to obtain a copy of warning messages that are hovering around.

5.2 Evaluation

In the first series of simulations, we evaluate the feasibility and success of the hovering messages in an accident anchor zone. We compare the results of our approach using the *Floating Content* mechanism described in Ref. [12]. For our road-aware information sharing mechanism, we use radio transmit powers of 6 dBm and 12 dBm. For comparision, we set the transmit power of the *Floating Content* mechanism to 9 dBm in all scenarios, and we compare the mean hovering time as a fraction of the TTL across all scenarios.

Fig. 11, **12** and **13** show that our road-aware hovering mechanism is successful in all scenarios, i.e., the probability of the message availability in the anchor zone is greater than 0. In all scenarios, the availability of the messages increases as the radio transmit power increases. Similarly, the vehicle density also improves the availability of messages in the anchor zone. In scenario M100, around 80% of the total messages are hovering in the VANET at the end of their lifetime. In the case of L100, the availability of the messages is 85% at the end of their life time. When the vehicle traffic is sparse, the messages sink faster, and this fact is shown in Fig. 11 where 20–40% of the messages sink after 60% of their lifetime has passed.

We can also interpret the results of **Fig. 11**, **12** and **13** in terms of the hovering probability. The hovering probability is the fraction of the messages that are available at the end of the TTL (i.e., 120 seconds). In **Fig. 11**, the hovering probabilities for S50 and S100 are of 0.5 and 0.7, respectively. In **Fig. 12**, the hovering probabilities for M50 and M100 are 0.65 and 0.76, respectively. In **Fig. 13**, the hovering probabilities for L50 and L100 are 0.78 and 0.83, respectively.

In a comparison with the Floating Content, it is evident from **Fig. 11**, **12** and **13** that our road-aware mechanism performs better when the density of the vehicles in the anchor zones is greater. In less dense scenarios, our mechanism may be comparable to the floating content mechanism [12].

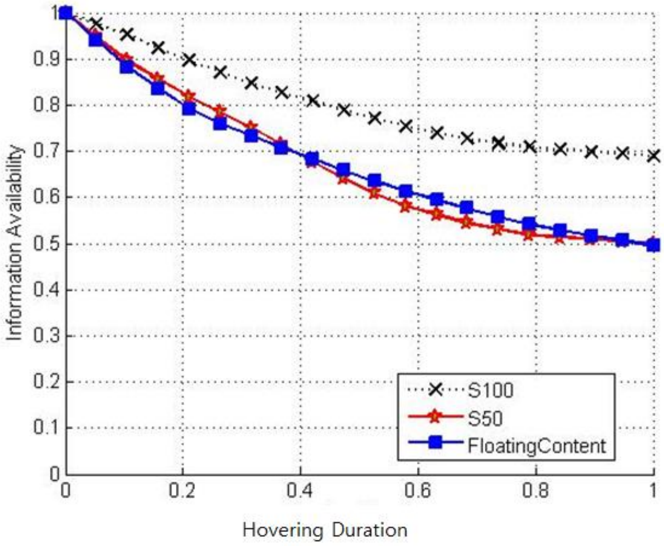

Fig. 11. Fraction of messages available versus Hovering duration as a fraction of TTL for scenarios S50 and S100

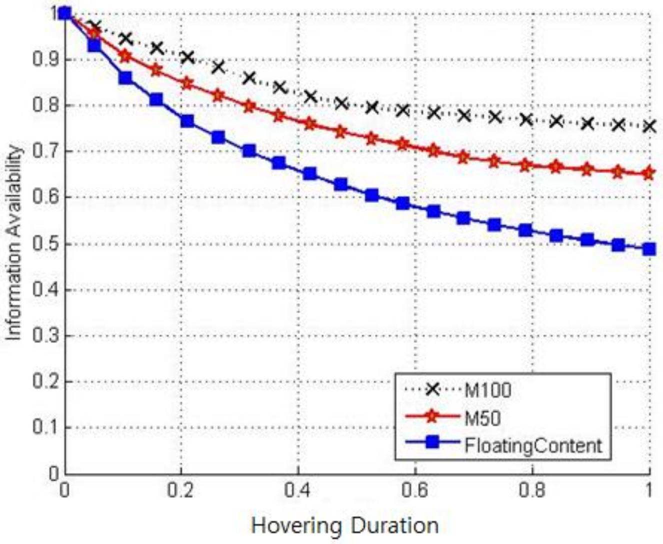

Fig. 12. Fraction of messages available versus Hovering duration as a fraction of TTL for scenarios M50 and M100

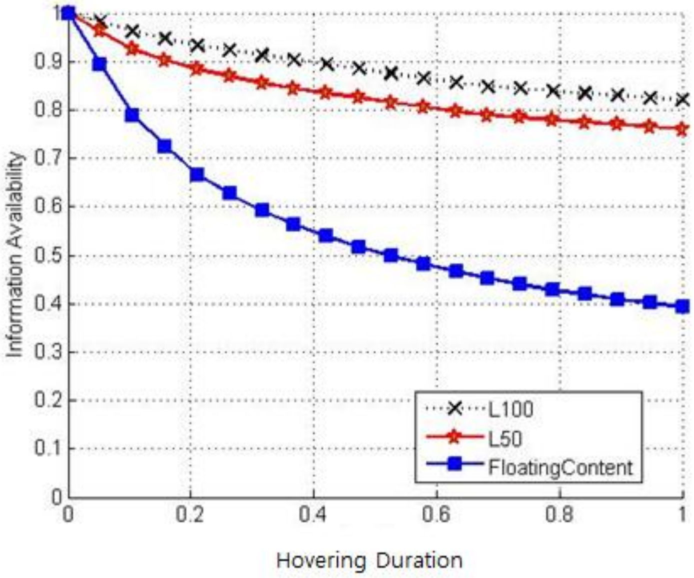

Fig. 13. Fraction of messages available versus Hovering duration as a fraction of TTL for scenarios L50 and L100

In the second series of simulations, we characterize the performance of the floating messages under various message/buffer sizes and offered loads. We choose the M100 scenario because it provides a reasonable success rate for floating messages. Opportunistic communication between the vehicles may be limited by the buffer size when they encounter each other. We vary the buffer sizes that are available to the vehicles and plot the floating probability over the message size in **Fig. 14**. We find that for large message sizes, a larger buffer improves the floating probability of the messages.

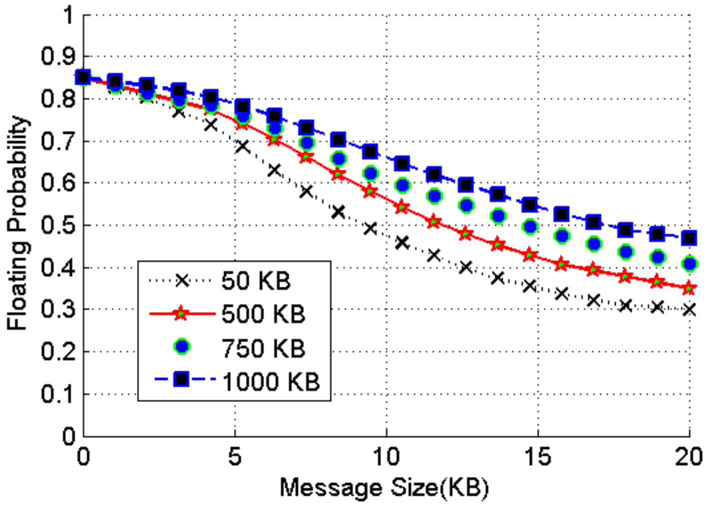

Fig. 14. Floating performance in scenario M100 as a function of node buffer size for different message sizes

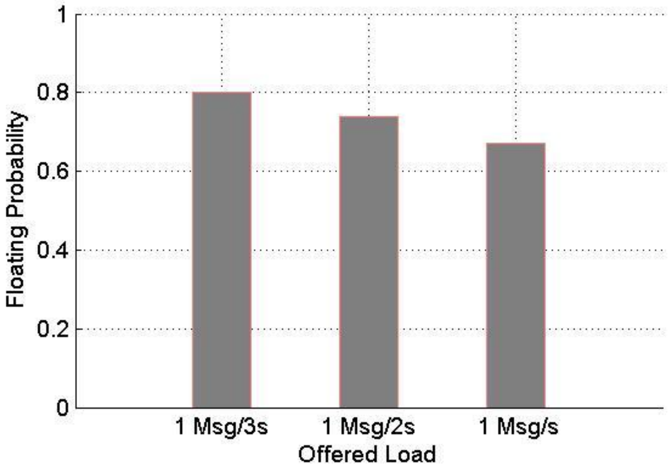

Fig. 15. Floating performance in scenario M100 for different offered loads

Fig. 15 shows the overall performance of our information sharing mechanism based on hovering content. We observe that an increase in traffic load saturates the network capacity and leads to a degradation in performance because the probability of messages being deleted increases as buffer overflows occur. When the load is reduced, the messages float longer in the anchor zone. For short messages, it is feasible to broadcast one message per second, and for larger message sizes, the offered load should decrease so that the hovering capacity of the network is saturated less and the desired level of performance can be achieved.

As described in Section 4, we have evaluated the coverage advantage of our approach against the radial distance based on the Floating Content mechanism that is described in Ref. [12]. We have used the urban and rural road networks that are shown in **Fig. 10** and **16**, respectively. The urban road network covers an area of roughly one square kilometer and the junction shown in the figure is located within that area. The rural road network is around 6 kilometers in length and 4 kilometers in width with junctions that are more than 1 kilometer apart.

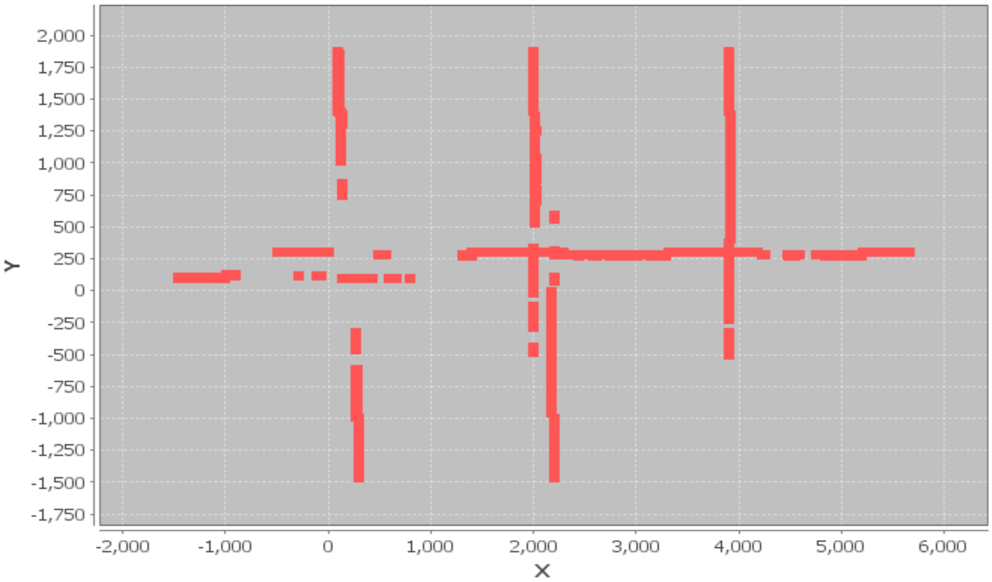

Fig. 16. A snapshot of traffic over the rural road network.

Since our approach does not depend on the distance from the anchor point and considers only the depth of the probability tree, it optimizes the information distribution in the urban area by making it available to a smaller geographical area compared to the floating content mechanism that is demonstrated in **Fig. 17**. This is logical because vehicles that are many junctions away from the accident point have a lower probability of going towards the location of the accident. Our approach considers this characteristics, so information is delivered only to those vehicles that have a higher probability of reaching the accident. The approach based on the radial distance makes information available over a larger area in this case, even though the information may not be relevant to vehicles that are many junctions away from the point of the accident.

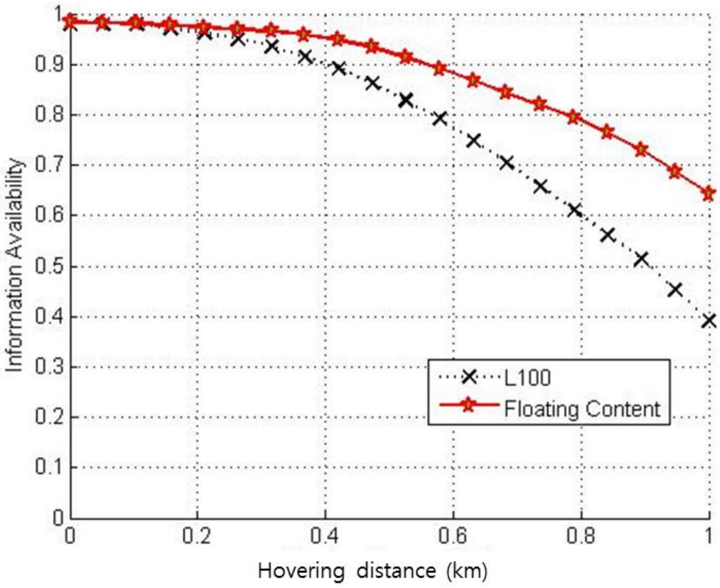

Fig. 17. Comparison of our approach with the Floating Content approach in terms of the information availability in the urban area

In a rural area, the opposite situation is manifested. The roads between junctions are much longer and the probability is high that a vehicle far from the accident would arrive at the location of the accident. So in this case, our approach makes information available over a larger geographical area than the radial distance based floating content approach. Our experimental results agree with this logic. A comparison of the information availability in the case of our approach and in the case of the Floating Content approach is shown in **Fig. 18**. This is a unique advantage of our approach that is not offered by radial distance based approaches.

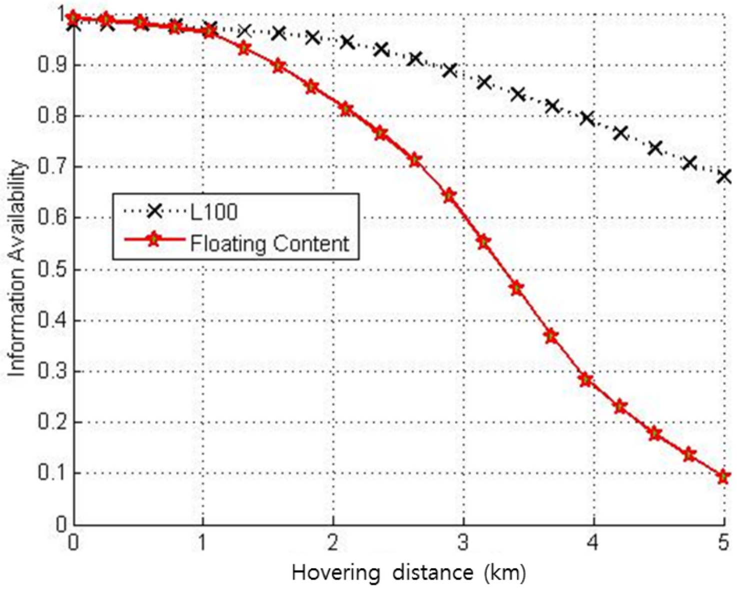

Fig. 18. Comparison of our approach to the Floating Content approach in terms of the availability of information in a rural area

6. Conclusions

Vehicles that suffer an accident periodically broadcast warning messages that are propagated in real-time to other vehicles in the neighbored. The dissemination of the information is geographically limited to vehicles in the neighborhood that have a high probability of arriving at the location of the accident. The location of the accident serves as the anchor point, and the locality beyond which messages do not propagate is the anchor zone of the alert messages. In our scheme, the anchor zone is not based on a circular region defined by a radius, which is the case for information hovering/floating content techniques that are used so far in MANETs.

In order to define the anchor zone, we construct a spanning tree of roads that lead to the location of the accident, and the tree is rooted at the vehicle(s) on the accident. The intersections that are directly connected to the accident road are considered to be level 1 of the tree. Level 1 intersections are then further connected to level 2 intersections. The edges in the tree represent multi-lane roads, and the messages that spread along the branches of the tree form the root towards higher levels (or upstream roads with respect to the accident).

We experimented with various transmission power levels, vehicle densities and network load conditions. The results of the simulation indicate that our information sharing mechanism is effective and propagates information only to the relevant vehicles within a VANET. Also, we proved that our approach offers unique advantages over existing radial distance approaches. Without controlling the anchor area, the area where information is available can be adjusted to the road environment. In a rural area, our approach can make information hover over a wider area, and in an urban area, the information can be available over a smaller area than with the existing radial distance approach.

Vehicles that carry communication devices with a moderate amount of compute/storage resources and network bandwidth can benefit from this solution. Since our solution was developed at the application level, it would be easy to port to real devices. For the next step, we plan to test the mechanism by using a federated experimentation platform where a few real vehicles are integrated with a large number of NS-3 nodes. This would allow us to analyze the solution with greater realism and at a larger scale. Our solution can help travelers reduce their travel time and can cut fuel costs by helping them avoid traffic jams, accidents and obstacles.

References

[1] Little, T.D.C.; Agarwal, A., "An information propagation scheme for VANETs," in *Proc. of Intelligent Transportation Systems, 2005. Proceedings. 2005 IEEE* , pp.155-160, 13-15, Sept. 2005. Article (CrossRef Link)

[2] Q. Sun and G. Hector. ”Using Ad-Hoc Inter-vechicle Networks for Regional Alerts,” TR, Stanford University, October 2004. Article (CrossRef Link)

[3] A. Xeros, M. Andreou, A. Pitsillides and M. Lestas. ”Information Propagation Probability on Intersections in VANETs,” in *Proc. of the third Inter. Workshop on Vehicle-to-Vehicle Communications*, June, 2007. Article (CrossRef Link)

[4] A.Xeros, M. Andreou, M. Lestas, G. Papageorgiou, V. Vassiliou and A.Pitsillides. ”Time Constrained Message Delivery Probability in VANETS,” in *Proc. of the 4th Vehicle to Vehicle Communication workshop*, V2Vcom 2008. Article (CrossRef Link)

[5] Niculescu, Dragos, and Badri Nath. "Trajectory based forwarding and its applications," in *Proc. of the 9th annual international conference on Mobile computing and networking* (MobiCom '03). ACM, New York, NY, USA, 260-272. Article (CrossRef Link)

[6] Lochert, Christian, et al. "Geographic routing in city scenarios," *ACM SIGMOBILE mobile computing and communications review 9.1* (2005): 69-72. Article (CrossRef Link)

[7] C. Lochert, M. Mauve, H. Fubler and H. Hartenstein. ”On Utility-Fair Broadcast in VANETS,” in *Proc. of the 2nd Intern. Workshop on Intelligent Transportation (WIT 2005)* Germany, 2005. Article (CrossRef Link)

[8] Wischhof, L.; Ebner, A.; Rohling, H., "Information dissemination in self-organizing intervehicle networks," *Intelligent Transportation Systems, IEEE Transactions on*, vol.6, no.1, pp.90,101, March 2005. Article (CrossRef Link)

[9] A. Villalba, D. Konstantas. “Towards hovering information,” in *Proc. of the First European Conference on Smart Sensing and Context (EuroSSC)*, pp. 161-166, 2006. Article (CrossRef Link)

[10] Xeros, A.; Lestas, M.; Andreou, M.; Pitsillides, A.; Ioannou, P., "Information Hovering in Vehicular Ad-Hoc Networks," in *Proc. of GLOBECOM Workshops, 2009 IEEE* , pp.1-6, Nov. 30 2009-Dec. 4 2009. Article (CrossRef Link)

[11] Wegener, A.; Hellbruck, H.; Fischer, S.; Schmidt, C.; Fekete, S., "AutoCast: An Adaptive Data Dissemination Protocol for Traffic Information Systems," in *Proc. of Vehicular Technology Conference, 2007. VTC-2007 Fall. 2007 IEEE 66th* , pp.1947-1951, Sept. 30 2007-Oct. 3 2007. Article (CrossRef Link)

[12] Ott, J.; Hyytia, E.; Lassila, P.; Vaegs, T.; Kangasharju, J., "Floating content: Information sharing in urban areas," in *Proc. of Pervasive Computing and Communications (PerCom), 2011 IEEE International Conference on* , pp.136-146, 21-25 March 2011. Article (CrossRef Link)

[13] A. Villalba, G. D. Serugendo, D. Konstantas. ”Hovering Information - Self-Organising Information that Finds its own Storage,” in *Proc. of Intern. IEEE Conference on Sensor Networks, Ubiquitous and Trustworthy Computing*, Taiwan, pp. 193-200, June 2008. Article (CrossRef Link)

[14] Koosha Paridel, Ansar-Ul-Haque Yasar, Yves Vanrompay, Davy Preuveneers, Yolande Berbers, “Teamwork on the Road: Efficient Collaboration in VANETs with Context-based Grouping,” *Procedia Computer Science*, Volume 5, pp. 48-57, 2011. Article (CrossRef Link)

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