Context-Aware Routing for hovering information in Vehicular Ad-Hoc Networks

Zubair Amjad
Department of Computer Engineering
Jeju National University
Jeju, Rebublic of Korea
Email: xubairamjad@gmail.com

Wang-Cheol Song*
Department of Computer Engineering
Jeju National University
Jeju, Rebublic of Korea
Email: philo@jejunu.ac.kr

Khi-Jung Ahn
Department of Computer Engineering
Jeju National University
Jeju, Rebublic of Korea
Email: kjahn@jejunu.ac.kr

***Abstract*—Road traffic information is considered vital for drivers and passengers in a VANET. Recently many approaches have been proposed for sharing the road information among the vehicles on the roads. Applications that use hovering information for road safety consider TTL and a radial distance from a center point to disseminate the information in a geographically limited area. These approaches generally do not define any technique for the routing of content. In this paper, a context-aware routing mechanism is proposed for the content that hovers in a predefined geographic region. Road probability model is presented to calculate the probability of content to be disseminated on the roads. The vehicles use an efficient low overhead routing mechanism to forward the content/information towards the destination/anchor region. Proposed protocol is evaluated over a road network and the results show that it can be helpful in the design and deployment of VANETs.**

***Index Terms*—VANET; Traffic information system; Intelligent transport system; Context-aware; Routing; Hovering information; Location service.**

I. INTRODUCTION

Recently Vehicular Ad-hoc Networks (VANETs) have gained interest of automobile industry and researchers due to its potential of promising road safety and multimedia applications. VANET enables vehicles moving on the roads to communicate with each other and provides opportunity to develop different kind of applications. Various applications have been envisioned so far such as, traffic management, emergency warning message, lane change assistance and/or collision warning. These applications will help to reduce accidents and enhance passenger safety since VANET has the potential to reduce the traffic jams and accidents significantly [1].

VANETs have a highly dynamic topology due to the fast moving vehicles. Vehicles with active connection can have link failure frequently because of the short lifetime of the connections and unpredictable drivers behavior. Due to these characteristics of VANET, it becomes a challenge to provide an efficient technique for sharing road information between vehicles. Recently, many approaches have been proposed to address the problem of sharing road information among the vehicles. Broadcast-based information sharing techniques [2], [3] aim to broadcast the messages to a certain destination and do not consider the maintenance of the content.

In some scenarios, the information about roads/traffic needs to be logically attached to a geographic region for a certain amount of time. For example, information about a congestion/accident needs to be delivered to the vehicles before entering to that particular road. It is important to notify the vehicles headed towards the road which has some situation so that they can choose another way in order to avoid the traffic congestion. Moreover, the information should remain available there for some time to be delivered to the newly coming vehicles. The information that remains available in mobile nodes rather than in fixed infrastructure is known as the $Hovering\ Information$ [4]. Hovering information is considered to be an effective way to share road safety information within a specific geographic region called the $AnchorZone$ (AZ). The information hovers from one vehicle to another, posing the objective to remain within the anchor area and make itself available to vehicles currently present or entering its anchoring geographical location.

Geocasting is a concept available in network literature that also addresses the issue of forwarding the messages to the vehicles in a geographic area. Geocast protocols [5] forward the messages to the target region (also called as geocast region) and disseminate to all interested vehicles residing inside the area. Geocast is different than hovering information as the vehicles inside geocast area receive the message only once. However, information hovering requires the information to be present in the anchor region for a certain period of time. Therefore, routing of the messages from source to the anchor zone and dissemination of messages within the anchor zone is a challenge in hovering information paradigm.

In this paper, we investigate aforementioned problems of routing for hovering information and present a context-aware routing scheme designed for information dissemination. The anchor zone is defined by calculating the probability of each road connected directly or indirectly to the source road. The information is delivered to the vehicles inside anchor zone based on the road probabilities. The source vehicle generates the message, which is then forwarded towards the anchor zone using context-aware routing scheme. The routing scheme is designed specifically to reduce the extra routing overhead by

* Corresponding Author

carefully choosing the forwarding nodes.

The remaining of this paper is organized as follows. Section II introduces Related work. Section III describes the context-aware routing for hovering information. Section IV presents the evaluation of proposed scheme. Section V concludes the paper.

II. Related Work

Information Hovering involves decoupling of the hovering information from its host and promotes coupling it directly with a specific geographical location which is called the anchor location. The hovering information stays attached to a specific geographical area (called the anchor area). The information hovers from one mobile device to another, in a quest to remain within a specific vicinity and avail itself to users currently present or entering its anchoring geographical location [6].The concept of hovering information that survives on its own over a specific geographic area was proposed by authors in [4] and extended in [7]. Their work is mainly focused on Mobile Ad-hoc networks (MANETs) and cannot be used directly for VANETs.

In [8], authors perform similar work for VANETs and propose a probabilistic flooding scheme to limit the dissemination of information. This approach focuses on the anchor zone ranges and does not consider necessary road attributes, such as number of lanes and direction which is necessary in order to effectively deliver the messages and reduce the transmission overhead. In [9] authors propose another concept similar to hovering information called floating content. They proposed a general approach for hovering information where two radii technique adds information replication scenarios. However, it is mainly designed for MANETs and does not consider VANETs explicitly. Furthermore, it does not use a context-aware approach to reduce the extra overhead.

Routing in VANETs is a well studied field and many protocols have been proposed previously. Connectivity Aware Routing (CAR) [10] is a position-based routing protocol designed for VANETs. CAR introduces the concept of Guards that help in path failure recovery process. However, the discovery packet is received by all vehicles between source and destination at-least for once which introduces an extra overhead on the network resources. There are some proposed Geographic Routing (GR) protocols that return the shortest path between source and destination [12], [13], [14]. However, it is not always possible that the shortest path between source and destination is populated. Furthermore, if the local maximum is reached at any point, a new route is calculated. This process may take some time and may waste network capacity.

Typically, GR protocols require the location information of the destination before starting the data forwarding process. The majority of proposed GR protocols assume destination location is known at any time [20], [15], [16]. The performance of these protocols is evaluated with zero location service overhead. However, it remains unclear how destination location discovery process can influence the network capacity. Moreover, if the destination vehicle moves a substantial distance from its known position, these protocols fail. Our routing scheme is different than the already proposed methods because it uses a context-aware approach to reduce the routing overhead. The proposed routing protocol is effective in terms of data delivery as it reduces the redundant transmissions and avoids the broadcasts of messages.

III. Context-aware Routing for Hovering Information

Based on the observations and issues explained in previous sections, we present context-aware routing for hovering information in VANETs. Previously proposed hovering information studies do not consider the routing of messages and we believe it is one of the most important topics in hovering information paradigm. Existing studies only take a radial distance from the anchor point as the anchor zone, however, in case of VANET the anchor zone should only contain the roads rather than a circular region. We use the concept of road probability in our previous work [17] and extend it to be used as the selection criteria for anchor zone. The information hovers in the anchor zone based on the road probabilities. The proposed framework is shown in Fig. 1.

We consider a road scenario of accident or congestion where a source vehicle sends the warning information to other vehicles. To reduce the routing overhead, we use context-aware routing with adaptive beaconing. The following subsections explain road probability model and context-aware beaconing.

A. Road probability model based information hovering

The information that is maintained by the mobile nodes rather than any fixed infrastructure is known as the hovering information. The hovering information is logically attached to a geographic region instead of being stored in servers.

This study assumes that every vehicle can get the road attributes and its location through the use of navigation system and GPS. Number of lanes on the roads are used to determine the probability of roads across the intersections. Let us explain how the probability of roads is calculated at a given junction by using Fig. 2 as an example. Five roads having different number of lanes are connected to an intersection. If an accident occurs on road (1) and accident information is transmitted, all vehicles heading to the accident location on the same road should get the accident information with probability 1, but for

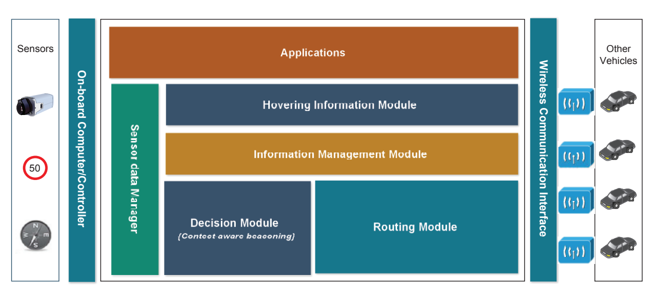


Fig. 1: Context-aware routing for hovering information framework

vehicles on other roads, source vehicle needs to know their probabilities of entering into road (1) across the junction. We propose to calculate the probability using number of lanes for the road. As mentioned before, every vehicle knows the number of lanes on a road using a map. So, we propose to use the number of lanes in the road and probability for all roads across the intersection is calculated using Eq. 1.

$$P_{ri} = \frac{N_a}{\sum_{k=1}^{M} N_k - N_i} \tag{1}$$

where N_a is number of lanes on the accident road; N_i is the number of lanes on the ith road for which the probability P_{ri} is being calculated and M is the total number of roads across the intersection.

Eq. 1 expresses a simple ratio of the number of lanes for a road that a car selects over all possible roads into which a car will enter from the currently riding road. In Fig. 2, 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). Then, we can say that road (1) can be selected with probability P_1 = 1 and road (2) can be selected with probability P_2 = 2/7. In the same way, probabilities for road (3), (4) and (5) can be calculated. So, when an accident occurs on road (1), vehicles on roads (2), (3), (4) and (5) are expected to go to road (1) with probabilities 2/7, 2/8, 2/9 and 2/8 respectively. Therefore, with those probabilities, we can represent the roads using the spanning tree in Fig. 3. Also, the spanning tree can be extended by calculating probabilities in the same way. Probability of a road being selected as an anchor zone is computed by multiplying all the road probabilities between source vehicle road and the target road using Eq. 2.

$$P_{kr} = \prod_{i=1}^{k} P_i \tag{2}$$

Therefore, road k have the probability P_{kr} = P_1 x P_2 x ... x P_k which is product of probabilities P_i of roads along the path from the root to node k in the spanning tree. The depth of tree can be unlimited, but we limit it using a threshold probability. For example, if there is an accident on a road, the source vehicle can select all roads having $P_{kr} > 0.05$ while for other scenarios this threshold can be changed. All incoming roads on an intersection are included in the packet as anchor zone. The roads are specified in the packet header by the road ids. The source vehicle initiates the message and forwards to nodes as per the routing policy explained in next section.

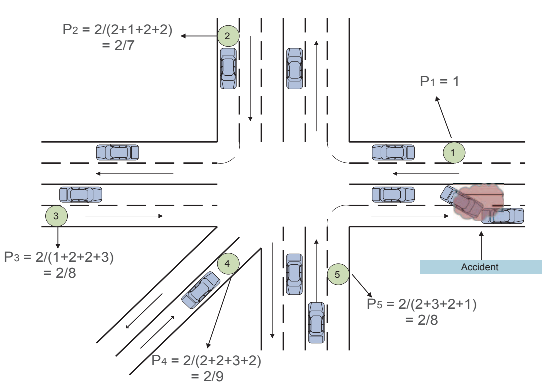


Fig. 2: Road probability calculation

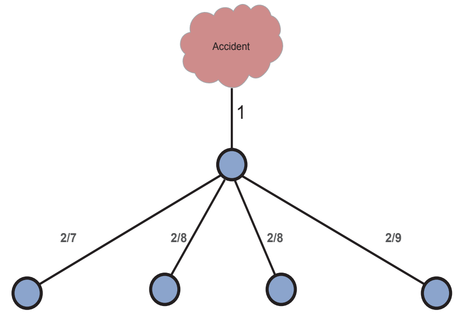


Fig. 3: Spanning tree representing roads and junctions

B. Context-aware routing

We extend our previous hierarchical routing protocol presented in [18] with the context-aware beaconing to reduce the routing overhead. Roads are divided into segments with unique $roadIDs$. Vehicles asynchronously broadcast link requests to discover their neighbors. Neighbors within communication range in turn reply to link request. Vehicles wait for an interval to receive the response of link requests from their neighbors. After receiving the response of link requests from the neighbors, every vehicle generates its neighbor link state packet (LSP) which contains the information about all the neighbors of the vehicle. Vehicles then propagate their neighbor-LSP locally within their road segment via intermediate neighbors. Vehicles may also receive neighbor-LSP from other roads. After receiving the neighbor-LSP from other vehicles, each vehicle knows the road segment level topology. The shortest path algorithm is used to build its road segment routing table. The vehicles on the intersection or near to intersections also receive link requests from the vehicles on different road segments. We call these vehicles the Gateway Vehicles (GVs) as shown in Fig. 4 (with red color). GVs provide connectivity between road segments.

In our previous work [18], the process of link request was performed after a pre-defined time interval by every vehicle to detect the changes in the road topology and update the local routing table accordingly. If there is a change in the road topology, the protocol broadcasts entire LSP within the road segment to keep the routing tables up-to-date. In the dense traffic scenarios where cars move with different velocities, the road topology keeps on changing. However, in some scenarios e.g., road, most vehicles move with similar velocities and road topology does not change frequently. In such scenarios, the process of link request with a constant periodic interval causes routing overhead which can be decreased further with the use of predictive time interval for link request. Therefore, considering all these properties of a vehicular network, we present an optimized context-aware mechanism that enables vehicles to gather the neighbor information and local routing table while keeping a low routing overhead.

1) Context-aware beaconing: Context represents the surrounding environment of the object which is under discussion, sometimes it is also used to represent the circumstances in which a task is carried out [19]. The context in our system is determined by the speed of vehicles and number of neighbor vehicles. The context of a vehicle is calculated based on two aspects i.e., neighbor vehicle changing frequency and vehicular nodes speed on a road segment. To compute the ratio of changing neighbor nodes between two time stamps t_m and t_n where $t_n > t_m$ and $t_n = t_m + \Delta t$, a vehicle monitors the number of neighbors, number of neighbors that moved out of its range in time Δt, and number of vehicles that remained connected during Δt. Equation 3 presents the mathematical formula to compute the neighborhood stability of a vehicle.

$$Stb_N(t_n) = \frac{N_{new}(t_m, t_n) + N_{moved}(t_m, t_n)}{N_{connected}(t_m, t_n)} \quad (3)$$

Where $Stb_N(t_n)$ represents the ratio of change for vehicles in neighborhood of a vehicle from time t_m to t_n, t_n is the current time, t_m is the previous time stamp for LSP broadcast, $N_{new}(t_m, t_n)$ represents the new neighbors of a vehicle, $N_{moved}(t_m, t_n)$ are the vehicles that moved away from communication range within the time t_m to t_n, $N_{connected}(t_m, t_n)$ represents the vehicles that remain connected during time Δt where Δt = t_n - t_m. The value of Δt is adaptive with respect to the speed and number of neighbors and is updated according to new time interval after each timespan.

When the neighbors of a vehicle change frequently, it represents the traffic mobility scenario in two dimensions; either the vehicle itself is moving with very high speed or the neighbors of the vehicle are moving with high speed. Equation 4 represents the formula to calculate speed stability of a vehicle.

$$Stb_s(t_n) = \frac{|v_c(t_n)|}{Avg(|v_i(t_n)|)} \quad (4)$$

and

$$Avg(|v_i(t_n)|) = \frac{\sum_{i=1}^{n}(|v_i(t_n)|)}{n} \quad (5)$$

where v_c presents the velocity of the current vehicle, n is the number of neighbors of the current vehicle. Equation 6 represents the traffic mobility using the stability values presented earlier.

$$Mob(t_n) = Stb_N(t_n) \times Stb_s(t_n) \quad (6)$$

$$Mob_{dif}(t_n) = \frac{Mob(t_n) - Mob_{Avg}}{Mob_{Avg}} \quad (7)$$

Till here, we have presented the mathematical expressions to calculate stability and mobility for a vehicle. Now we describe the expression to compute the time interval for next LSP broadcast using mobility from Eq. 6. Equation 8 presents the formal mathematical formula for the time interval from current time i.e., t_n to the next time time stamp i.e., $t_n + \Delta t$.

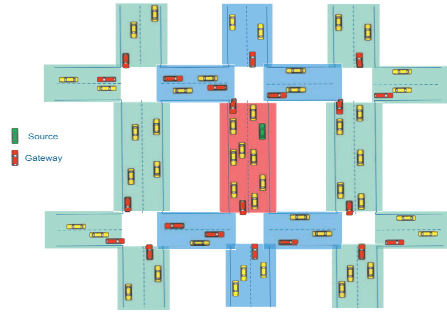


Fig. 4: Anchor zone classification

$$T_{int}(t_n, t_n + \Delta t) = T_{int}(t_n - \Delta t, t_n) - (\alpha \times Mob_{diff}(t_n)) \quad (8)$$

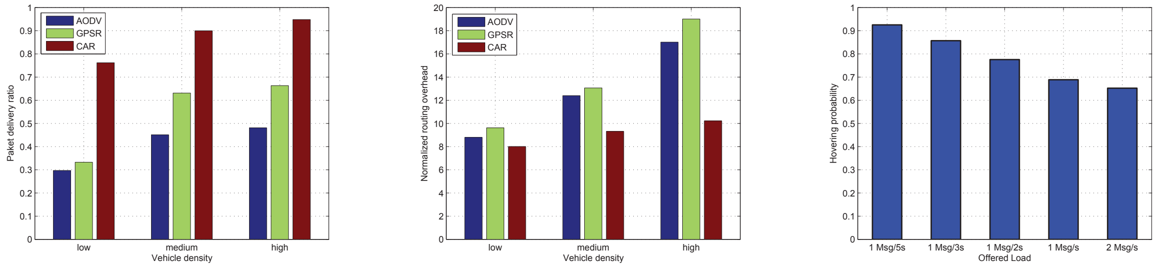
where α is the tuning parameter. The next time interval for LSP broadcast is computed by the above equation and this process is repeated again when the next time span is reached.

C. Information hovering areas

Anchor area is further divided in 3 sub areas based on the road probability presented in previous section. Multiple subareas give the freedom of selecting anchor areas to applications based on the different scenarios. Three different type of areas can be seen in Fig. 4 with three different colors. Red area is called as the primary anchor area. It has the highest probability for information dissemination. Roads marked with blue color is secondary anchor area. The third type includes the roads with green color in the figure and is called relevant anchor area. The main reason for dividing the anchor area in three subareas is that any application can exclude the outermost roads (relevant area) from the anchor region depending on the type of information. For example, an accident warning message should be delivered to all three sub areas; however, a road condition waring message is only useful for the vehicles on that road or the vehicle which are on the roads after one intersection.

Source vehicle originates information packets with a TTL in the header. The packet is sent to the GVs on the current road. Gateway vehicles forward the message to other roads or disseminate it on the current road as per the road probability suggests. Once the lifetime of a message expires, it is deleted by all vehicles. Vehicles with road probability less than a threshold will not accept a copy of the message. The source vehicle generates a warning message with a certain lifetime (TTL). The message is stamped with its time of creation and is identified by a unique ID. Messages are deleted when:

- Messaged lifetime as suggest by TTL expires.
- Vehicle buffer becomes full.
- Probability of the road is less than a predefined threshold.



(a) (b) (c)

Fig. 5: (a) Packet delivery ratio, (b) Routing overhead, (c) Hovering probability versus varying message/sec load

To prevent the message buffer from filling up, every vehicle periodically evaluates buffer to determine the messages to be deleted based on the road probability.

IV. Evaluation

A. Simulation setup

To evaluate the proposed context-aware routing for hovering information, simulations were performed in Network Simulator NS-3 [22]. Performance of proposed mechanism was evaluated over a road network consisting of multi-lane directional roads with turns and intersections. Intelligent Driver Model (IDM) car following model is used to generate realistic mobility pattern of vehicles. We set up 3000m x 3000m simulation area with straight roads. Anchor area is specified by the road segments IDs. Vehicles are configured to move with the velocity of 40 to 120 km/h towards randomly chosen destinations. OFDM 6Mbps data rate is used for wireless links (Wifi ad-hoc mode).

B. Simulation metrics

Performance metrics evaluated for the hovering information are: 1) Fraction of Information availability versus hovering duration as fraction of TTL, 2) Hovering probability versus varying message/sec load, and 3) Fraction of information availability versus hovering duration for varying vehicle speeds (40kph, 70kph, 100kph, and 120 kph), 4) Delivery ratio and, 5) Routing overhead.

Three traffic densities are considered for the experiments as following

- Low: 15 vehicles/km
- Medium: 30 vehicles/km
- High: 50 vehicles/km

C. Results

Fig. 5a shows packet delivery ratio for three different traffic densities. The proposed routing is marked with the legend CAR (Context-Aware Routing) and it is compared with AODV [21] and GPSR [20]. For all traffic densities, AODV performs very poorly while GPSR shows better performance than AODV but shows lower delivery ratio than CAR.

The normalized routing overhead is presented in Fig. 5b. Destination discovery and periodic beaconing contribute mainly in routing overhead for AODV and GPSR respectively. Destination discovery process in AODV consists of broadcasting the packet to all the nodes in the network. However, in CAR, there is no broadcast for the destination discovery process rather a probability model is used in order to determine the anchor zone (destination region). In GPSR, the routing overhead caused by the failed paths contributes significantly to the degraded performance. It can be seen from the evaluation results that CAR generates less routing overhead than other two protocols in both scenarios. It is mainly because CAR does not use broadcasting of destination discovery and it does not start a new discovery process each time a path disconnects.

Fig. 6 shows the information availability inside the anchoring zone at the end of TTL. In all scenarios, the vehicle density improves the availability of messages in the anchor zone i.e., as the number of vehicles in the network increase, information can hovers for longer duration. Also with increased number of vehicles, the probability of hovering information is larger. Even in the low traffic density scenario, more than 50% of the information is available to vehicles at the end of TTL. It is because of the fact that in sparse traffic scenarios, information sinks faster.

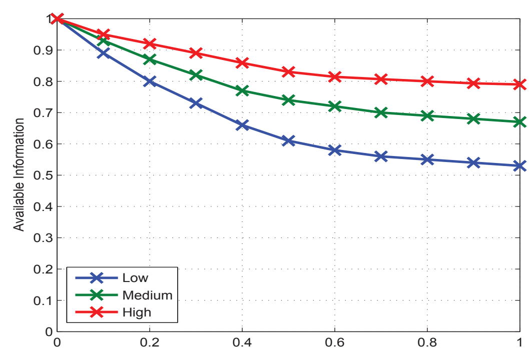


Fig. 6: Fraction of Information availability versus hovering duration as fraction of TTL

Fig. 5c shows the effect of varying message load on the hovering information. We observe that increased traffic load saturates the network capacity that leads to degraded performance. With reduced message load, information hovers

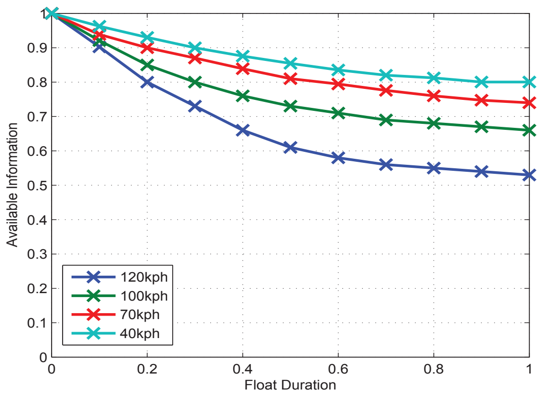


Fig. 7: Fraction of Information availability versus hovering duration as fraction of TTL with different vehicle speeds

for longer duration inside anchor zone. As the capacity of vehicles is limited by the buffer size, it can be seen that for higher message frequency, hovering information probability decreases. Fig. 7 shows the fraction of information availability with time for different vehicle speeds. It can be seen that for higher speeds, the information availability is low. For lower speed, information availability is high with respect to time. It is because at higher speeds, link failures are more frequent that leads to degraded network performance. Also, at higher speeds, the time interval for beacons is comparatively very small in context aware beaconing, which causes an extra routing overhead directly effecting the performance of the network.

V. Conclusion

In this paper we presented a context-aware routing protocol for hovering information. The proposed protocol uses the context of vehicles to make the routing decisions. The anchor zone for the hovering information is determined by the road probability model and information hovers in that anchor zone according to the given probability. The proposed protocol exhibits efficient results in terms of routing overhead and information availability. it reduces the overhead by not using broadcast rather by using an effective routing technique. It is designed for both urban as well as highway scenarios. The evaluation results show that the proposed protocol outperforms GPSR and AODV in multiple performance metrics.

VANETs must deal with the always changing node topologies, and a number of other issues must be addressed before VANETs can be deployed in real world. This study addresses one of the key issues in the design and deployment of VANETs. Evaluation results in this study suggest that using the concept of context-aware routing protocol with the use of gateway vehicles for hovering information can significantly help road information sharing applications.

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