

Traffic-Aware Data Delivery Strategy for Vehicular Ad Hoc Networks

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Abstract—Vehicular Ad Hoc Network (VANET) is an emerging class of wireless network that operates in a vehicular environment to provide communication between vehicles. VANET can be used by wide variety of applications to improve road safety, traffic efficiency and driving comfort. With the high dynamic nature of this network, communication linkage among vehicles in the environment suffers from link-breakage problem hence requires a reliable data delivery strategy to cope with this issue. In this paper, we presents a data delivery strategy called Traffic-Aware Data Delivery (TADD). The idea is to use static nodes placed at each road junction to collect real-time traffic information to improve the situational awareness of the real road conditions. With these static nodes, traffic conditions of their surrounding roads can be obtained and a reliability score for each road can be determined. These scores is then used to select what it considers the most reliable path to deliver the data packet to its destination. A path recalculation is also used to re-evaluate the delivery path at each junction during data transmission. A new path is then used if the selected path becomes unreliable. The simulation result shows that the proposed strategy is capable of providing feasible situational awareness in vehicular environment and achieves a higher delivery ratio and lower end-to-end delay.

Keywords—Vehicular Ad-hoc Network, Static Node, Information Collection, Coverage Area, Data Delivery Strategy

I. INTRODUCTION

Vehicular Ad Hoc Network (VANET) is a particular form of wireless network that provides communication capability in both Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I) environments [1]. The wireless communications provided by VANET imposes potential improvements in both road safety and efficiency. In order to share traffic information in VANET, the use of short-range wireless technologies such as IEEE 802.11 or DSRC (Dedicated Short Range Communications) [2-3] among vehicles is required. With such communication mechanisms, vehicles are able to receive traffic information from its neighbours directly or from its intermediate vehicles. In addition, with the large number of vehicular participants in the network, the information that are being exchanged among them may be used to improve the efficiency of data delivery by avoiding the congested network. However, vehicles in this environment are highly dynamic, making the underlying network topology changes rapidly. As a

result, the probability of network partitions is higher and end-to-end connectivity is not guaranteed [4-5]. Thus, the collection and provision of appropriate traffic information in an efficient manner is vital to provide a good estimation on road conditions.

Delivering data between source and destination in vehicular environment requires robust and efficient routing protocol designed especially for this kind of networks. Position-based routing protocol is considered as one of the most promising routing approach for VANET because it adapts well to VANET [6]. With GPS, position-based routing protocols utilizes both the digital road map and the geographical position information of participating vehicles to deliver more accurate and efficient routing decisions. Moreover, vehicle movement in VANET is restricted to the layout of road and traffic regulations. Thus, routing strategies that use geographical position information are practical and efficient for data delivery.

Since VANET topology is changed frequently, traffic density has a large influence on road capacity and vehicle velocity. Observations has been made in both densely and sparsely environments [7]. In a densely environment, higher vehicle density may not always result in higher connectivity. This is because vehicles that shares the same medium may end up in a highly congested network due to redundant rebroadcasts. This condition lead to significant message errors, causing low communication reliability and decreases the network efficiency. On the other hand, in sparsely environments, connectivity among vehicles may significantly decreases the probability of information exchange among vehicles, or sometimes it is just simply not feasible due to lack of participants in such environment. Therefore, the link stability or reliability becomes a major concern when designing a routing protocol [8]. That is why, finding a stable and a reliable path that is adaptable to a highly dynamic environment is an important task.

In this paper, we propose a Traffic-Aware Data Delivery (TADD) strategy to provide an efficient data delivery for urban environment. In TADD, a static node is placed at each junction and assumed to have similar communication capability as a vehicle. Static nodes use a periodic beacon message called Information Collection (IC) packet to collect and update vehicular traffic density and network traffic load conditions of their surrounding roads. Each static node stores real-time traffic information obtained from the received IC packets sent from

different neighbouring static nodes and determines a weighted score for each road. Then, these weighted scores are used to select the most efficient and reliable path from the source to the destination. Data packets are delivered through the selected path in a greedy manner. In order to handle dynamic changes in the environment, the selected path is recalculated dynamically at every junction during data transmission to improve the performance of data delivery. Thus, forwarding packets through roads with low vehicular traffic density or poor-quality communication links can be avoided.

The remainder of this paper is organized as follows: Section II outlines the related work. In section III, TADD is described in detail. In section IV, simulation results and performance evaluation are shown. Finally, we conclude this paper in Section V.

II. RELATED WORK

Data delivery through efficient route has been a major research topic in VANETs. For instance, Greedy Perimeter Stateless Routing (GPSR) [9] applies different forwarding strategies according to the geographical information of neighbouring node. That is, it uses greedy forwarding to forward packets to the neighbour that is geographically closest to the destination, and switches to perimeter forwarding when greedy forwarding become impossible. Geographic Source Routing (GSR) [10] combines position based routing with topological knowledge to compute the shortest path to the destination, and employ greedy forwarding to traverse along it. These protocols neglect the case where the traffic density is low for data forwarding and the selected path that might have insufficient connectivity to ensure the delivery of data packets.

Greedy Traffic Aware Routing (GyTAR) [11] collects the real-time road traffic information from its neighbouring junctions once nodes enters the area of the junction. GyTAR utilizes real-time traffic density and movement prediction in urban environment to perform routing decisions at junctions. In the process, each junction is given a value according to the traffic variations and the distance to the destination. The junction with the highest value will be chosen as the next best junction for packet forwarding. However, GyTAR only acquires the traffic information from its one hop neighbours, such information could result in insufficient data when performing routing decisions in the rapid changing environments. Static-Node Assisted Adaptive Routing Protocol (SADV) [12] utilizes the predictable mobility in VANET and deploys static nodes at each junction to assist with packet delivery. The static nodes in SADV enable packets to wait at a junction until path with the best delivery ratio becomes available. By doing so, this could prevent packets from being delivered through detoured paths, but the packet delivery delay heavily depended on the traffic density on the road. However, the routing performance is affected by the sensitivity of node densities.

Hybrid Traffic-Aware Routing (HTAR) [13] is a junction-based routing protocol that dynamically elect a non-static node at each junction to act as a temporary access point. The non-static node at each junction collects traffic information such as

vehicular traffic density and network traffic load from its neighbouring junctions and these information is then used to determine a road score for each junction. Furthermore, HTAR make their routing decisions based on the availability of nodes and the reliability of links between nodes. However, the non-static node elected at each junction may not always be available when traffic density is low. Thus, the collection of traffic information at the junction without the non-static node is not feasible. As a result, the accuracy and freshness of such evaluation affect the performance of HTAR and inaccurate or outdated information may be used in the junction selection process when non-static node is not available.

III. TRAFFIC-AWARE DATA DELIVERY STRATEGY

A. Assumptions

In this work, we assume that a static node is placed at each junction as illustrated in Figure 1. Each node in the network is equipped with wireless devices that have the same transmission range. Wireless links are only established when the distances between two nodes are within each other's transmission range. Each node knows its own position using GPS service. We also assume that each node can determine the position of its neighbouring junctions through pre-loaded digital maps. Location service [14] is used to acquire the position information of the destination. Furthermore, each node is required to broadcast periodic hello messages to maintain a neighbour table. This table contains information such as the Node ID, Position and Speed to indicate the identity, position and velocity of the node. Road ID represents the road where the node is located. At Junction is a Boolean value indicates whether the node is located at a junction. Channel Load indicates the ratio of channel busy time for the road. Timestamp denotes the receiving time of this record, which is used to ensure the freshness of the record.

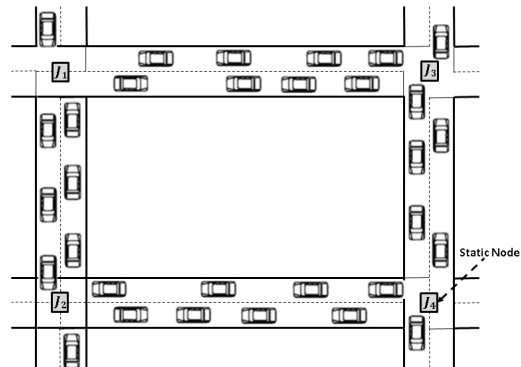


Figure 1. Example of a road segment

B. Basic Concepts of TADD

TADD is a static-node assisted data delivery strategy designed to work in densely populated urban environments. This strategy prefers to deliver data packets using paths that it consider to be efficient and reliable. To achieve this, static nodes placed at each junction uses IC packets to probe its neighbouring junctions using coverage area provided by each node to determine the vehicular density and network traffic status of those junctions. The IC packet incorporates

information such as source and destination Junction ID to represent the source and destination junction of this packet, Number of Nodes and Channel Load represent the estimated value for the number of nodes and the channel load for each road, and a Timestamp for this packet. Then, a weighted score called road weight is determined with these collected traffic information. TADD uses Dijkstra's least weight path algorithm [15] to calculate what it considers the most reliable path with the road weights given by its nearest static node.

At the beginning of a data transmission, the source is required to select the path that has the lowest weight to deliver data to its destination. With the selected path, a relay node called next forwarder is chosen reactively until the packet reaches to the next junction or its destination. In the process, data packet may traverse through many roads and junctions from its source to destination. In order to adapt to the variations in the network, each static node periodically updates and recalculates the road weight of its adjacently connected roads. During data transmission, the node at a junction receives the data packet examines the path with the most recent road weights from the static node. If the weight deviates significantly from the current path, a new path is selected to improve the performance of data delivery.

C. TADD Operations

Operations of the TADD are divided into three processes called information collection, road weight calculation and information distribution. Detail descriptions of these processes are described as follows:

(1) Information Collection

In this process, the static node located at the each junction initiates a search for all the node that are within its transmission coverage area. The node that is the farthest away from the static node with the maximum coverage among its neighbours towards the adjacent junction is selected to forward the IC packet toward the adjacent junction. With the help of periodic beaconing signals sent by neighbouring nodes, the selected node uses its neighbour information table to observe the number of neighbouring nodes in its vicinity and add it into the Number of Nodes field in the IC packet. Thus, the IC packet is delivered to the node with maximum coverage toward the designated junction as the point where the information should be collected. The selected node then acquire traffic density and network traffic load along the given road until it reaches its designated junction. The calculation of network traffic load, refer as Channel Load, begins when a node enters a road, it starts to monitor the channel, trace the channel busy time and calculate the channel load. The value of channel loading is calculated as follows:

$$CL_n = T_{busy}(n)/T_{measure}(n) \quad (1)$$

where CL_n is the channel load monitored by node n on the road, $T_{busy}(n)$ is the channel busy time traced by node n and $T_{measure}(n)$ is the total measured time of node n . As IC packet progresses, the selected the node obtained the highest value from its neighbouring node and inserted the measurement into

the IC packet for further distribution. The channel load of the road i (CL_i) is defined as follows:

$$CL_i = \max_{n \in N} CL_n \quad (2)$$

These information are being updated by each selected node as the IC packet progresses. This enables the calculation of road weight to be more responsive to variations in the network. Once the static node from the designated junction receives this IC packet, it duplicates the packet and sends it back towards the source junction in a greedy manner. By doing so, both the designated and the source static node can obtain the latest information to determine the road weight for the road.

To explain how a node is selected to receive IC packet, let's consider two nodes i and j located at position (x_i, y_i) and (x_j, y_j) and the maximum distance between i and j are denote as $d(i, j)$ as shown in Figure 2, where $d(i, j)$ is defined as follows:

$$\begin{aligned} d(i, j) &= \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \\ &= 2r \cos \theta \end{aligned} \quad (3)$$

The communication radius of each node is r and if $d(i, j) > 2r$, then j is not consider in the node selection process. If road width is R_w and the length from j to the top boundary of the given road is $B_{top}(j)$. To calculate j 's coverage area, we need to remove the intersected area of i and j and the area beyond the road boundary.

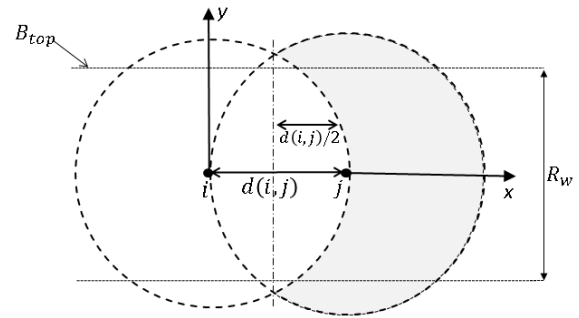


Figure 2. Neighbour Information Table

By knowing that the transmission covering circumference of node i , the spatial intersection of the covered areas denoted as i_{int} , between two nodes located a distance of $d(i, j)$ apart, can be derived as follows:

$$\begin{aligned} i_{int} &= 2 \int_{\frac{d(i,j)}{2}}^r \sqrt{r^2 - x^2} dx + 2 \int_{\frac{d(i,j)}{2}}^r \sqrt{r^2 - x^2} dx \\ &= 4 \int_{\frac{d(i,j)}{2}}^r \sqrt{r^2 - x^2} dx \end{aligned} \quad (4)$$

The coverage area beyond the top road boundary of node j is denoted by j_{top} , and given by:

$$j_{top} = \begin{cases} 2 \int_{B_{top}(j)}^r \sqrt{r^2 - x^2} dx, & B_{top}(j) < r \\ 0, & B_{top}(j) \geq r \end{cases} \quad (5)$$

The coverage area beyond the bottom road boundary of node j is denoted by j_{bot} , and given by:

$$j_{bot} = \begin{cases} 2 \int_{R_w - B_{top}(j)}^r \sqrt{r^2 - x^2} dx, & R_w - B_{top}(j) < r \\ 0, & R_w - B_{top}(j) \geq r \end{cases} \quad (6)$$

The coverage area that node j can cover is denoted by j_{cover_area} , and is derived as follows:

$$j_{cover_area} = \begin{cases} \pi r^2 - i_{int} - j_{top} - j_{bot}, & 0 < d(i, j) < 2r \\ 0, & d(i, j) \geq 2r \end{cases} \quad (7)$$

Nodes that intersects with i forms a set I . From equation (7), we can calculate the coverage area formed by all nodes in set I . Then, the node from set I that is furthest away from i and have the largest j_{cover_area} is selected to collect traffic information. Then, the IC packet is propagated further along the road to locate next node that is located ahead of the selected node. By doing so, the selected node provide additional coverage over what has already been covered by the node i . This process is repeated until the designated junction is reached to ensure that all the nodes located along the given road between the source and the designated junction are included in the information collection process. In addition, once a node is selected to relay IC packet from set I , the other nodes in Set I will not take part in the selection process again to ensure the progress of the information collection process.

(2) Road Weight Calculation

An important factor of TADD is its ability to estimate the reliability of each road and use it to determine a path from the sender to its destination. To achieve this, static nodes located at each junction assigns a road weight (W_{road}) to each road by using the information obtained from the Information Collection process. Therefore, by utilizing such information, W_{road} is calculated as follows:

$$W_{road} = \frac{NB_i}{L_i} + C, \begin{cases} C = 0 & , \text{for } CL_i < CT \\ C \in \mathbb{N} & , \text{otherwise} \end{cases} \quad (8)$$

CL_i is the channel load of road i , L_i is the length of the road i , NB_i is the number of node in road i and CT is the threshold to determine whether the network traffic of the road is congested or not. C is constant used as a correction factor. In (8), if CL_i is greater than or equal to the congestion threshold CT , then network congestion penalty C is added to ensure the weight is not greater than $CL_i < CT$. If the road between the junctions has very poor node density and network connectivity, a big value penalty is assigned to that road so that road is less likely to be chosen. After determining the road weight between junctions, road weight is stored in a table called Weight Information Table that contains information like the Junction ID (From), the Junction ID (To), Road Weight and Timestamp to describe the start/end point of this road weight and freshness of this entry.

(3) Road Weight Distribution

A packet containing weight information is used to distribute the road weight of each road to its neighbouring static nodes. This packet contains information such as Road Weight represents the road weight between Junction ID (From) and Junction ID (To). The number of entries in this packet is

determined by the number of road which the source junction is connected to. When this packet is received by its neighbouring static node, if the static node already has weight information from that junctions, then timestamp is used to compare the freshness of the record.

IV. PERFORMANCE EVALUATION

A. Simulation Settings

In this section, we evaluate the performance of the proposed method with GSR, GyTAR, HTAR. We measure the performance of multi hop data delivery in different intensity of dense traffic environment. In our simulations, the proposed method is implemented with NS2 simulator. The mobility models of vehicles are created by TraNS[16] with the simulation area is set to 2500m x 2500m from the TIGER database[17]. In the simulation, the road comprises of two lanes in all directions and it contains 39 junctions together with a random route generation module. The speed limit of each road is set to 80km/h and the transmission range of each node is 250m. We place a static node in every junction to collect the traffic information from its adjacently connected roads. 10 Constant Bit Rate (CBR) traffic sources are used in the simulation with a packet size of 128 bytes and data rate of 4 packets per second. The number of nodes varying between 200 and 400 and the interval of Hello messages is 2s. Each simulation is run 400 seconds, and each data point is taken from an average of 15 runs. Various metrics are used to evaluate the performance of proposed method, including delivery ratios and end-to-end delay.

B. Simulation Results

First, we examine the packet delivery ratio under various node densities. From figure 3, we observe that for all the vehicle density scenarios, TADD outperforms GSR, GyTAR and HTAR. GSR presents the lowest packet delivery ratio for all the vehicle densities compared to all other methods. This is because GSR neglects the situation where there are not enough nodes for packet forwarding. By sending data packet data on a road without checking if it contains sufficient amount of nodes to route the data packet result in high incidence of disconnections. In GyTAR, it have comparatively higher packet delivery ratio than GSR. This is because the real-time traffic information was considered when performing routing decisions. However, because GyTAR only considers one type of information from its one hop neighbours for packet forwarding. Consequently, insufficient information increases the frequency of modifying routing path and some data packets might not be able to reach to their destination due to the constant changing of network topology.

HTAR and TADD utilizes the road weight provided by the information collection mechanism to avoid the congested region when both the vehicular traffic density and network traffic load increases. Moreover, when the vehicular traffic density is low, the path selected in TADD have the ability to prevent data packets being delivered though unreliable path and forward data packets along the path with higher connectivity. This is because the periodic update of road weight enables

TADD re-evaluated the reliability of the selected path and avoid path that is congested. As for HTAR, the non-static node may not always be available at each junction when vehicular traffic density is low. Thus, the collection of traffic information at the junction without the non-static node is impossible.

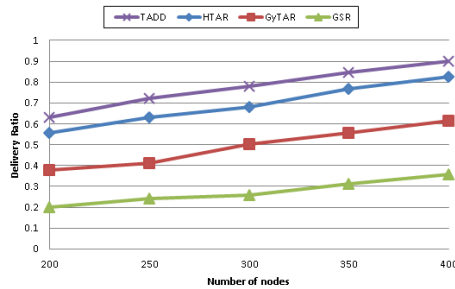


Figure 3. Delivery Ratio

When the node density increases, more opportunities are obtained to forward the packet to the destination. This can be seen in Figure 4 that as the node density increases, the end-to-end delay decreases. GSR has the highest end-to-end delay compared to GyTAR, HTAR and TADD. This is mainly because when node density is low and no next forwarding node is available, the node has to carry the data packet until one becomes available. GyTAR achieves lower end-to-end delay than GSR because an improved greedy strategy is used to the number of hops needed to forward packets between junctions.

TADD and HTAR have comparatively lower end-to-end delay than GSR and GyTAR. This is because the road weights determined at each junctions allows them to select the most efficient route to the destination. Recalculation of route have also helped in the performance improvement by enable them to react faster to the variations in the network and avoid longer path or path that is not traversable to deliver data. However, because the none-static node used by HTAR might not always be available at each junction. Therefore, information at some junction might be missing, which to some degree increases the delivery delay.

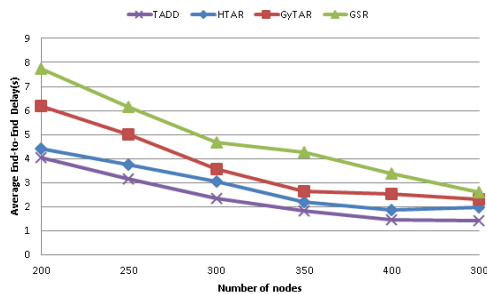


Figure 4. End-to-End Delay

V. CONCLUSIONS

In this paper, we have introduced a data delivery strategy called Traffic-Aware Data Delivery (TADD) strategy. TADD utilizes the static node placed at each junction to collect and update traffic information of their adjacently connected roads. With the information collected by each static node, we are able to assign a reliability score called road weight for each road.

TADD uses these weighted scores as primary factor to determine the most reliable path from the source to the destination. The path is determined by using Dijkstra's least weight path algorithm. That means, a small weight indicates greater reliability and a larger weight indicates the path is unreliable. With a road that is not traversable due to network partition, a large penalty is given to that road to reflect such condition. With the fact that the vehicles are highly dynamic, it is necessary to enable the selected path to re-evaluated the reliability of the selected path and avoid path that is not traversable or congested. The simulation results show that proposed method has outperformed others in terms of higher delivery ratio and lower end-to-end delay under different traffic density.

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