A Relative Velocity based Routing Algorithm for Vehicle to Vehicle Communication

Min-Woo Ryu[1], Si-Ho Cha[2], Keun-Wang Lee[2], Seokjoong Kang[1,*], and Kuk-Hyun Cho[1]

[1]Dept. of Computer Science, Kwangwoon University
447-1, Wolgye-dong, Nowon-gu, Seoul, 139-701, South Korea
{minu0921, sjkang, chokh}@kw.ac.kr
[2]Dept. of Multimedia Science, Chungwoon University
San 29, Namjang-ri, Hongseong, Chungnam, 350-701, South Korea
{shcha, kwlee}@chungwoon.ac.kr

Abstract. VANET (Vehicular Ad-hoc Network) is a special kind of MANET (Mobile Ad-hoc network) that operates based on a network of many highly mobile, wirelessly connected vehicles using multi-hop communication without access to some fixed infrastructure. VANET have unique characteristics, including high node mobility and rapidly changing network topology which differentiates it from MANET. Therefore, VANET must be designed to account for changes in topology caused by changes in node speed, moving direction and density. Despite the many studies that are currently under way, local maximum problem in greedy forwarding and link breakage due to change in node speed have yet to be solved. Therefore, this paper proposes RVVR (Relative Vehicle Velocity Routing) algorithm which to solve these problems. The proposed RVVR algorithm solves the local maximum and the link breakage problems by taking into account the density and the speed of neighbor nodes. Simulation results using ns-2 revealed that the proposed RVVR algorithm performs better than the existing routing protocols based on greedy forwarding.

Keywords: V2V, VANET, Relative Velocity, Greedy Forwarding, Mobility

1 Introduction

VANET (Vehicular Ad-hoc Network) is a special kind of MANET (Mobile Ad-hoc network) [1] that operates based on a network of many highly mobile, wirelessly connected vehicles using multi-hop communication without access to some fixed infrastructure [2]. With the advent of ITS (Intelligent Transport System) [3], there is a growing demand for VANET not only to provide various traffic information but also to assist with driver and vehicle safety. VANET communication consists of V2C (Vehicle to Vehicle) transmission enabled by OBUs (On Board Unit) installed in vehicles and V2I (Vehicle to Infrastructure) transmission enabled by OBUs in vehicles and RSUs (Road Side Unit) [3]. VANET is different from MANET in that

* Corresponding author

the nodes travel at high speeds and the topology frequently changes. Therefore it must be designed to take into account the speed of the nodes and to accommodate for changes in density of the nodes. Many studies for VANET are currently under way. In particular, routing algorithms based on Greedy Forwarding that transmits data considering locations and speeds of vehicles are being proposed [4-11].

Greedy Forwarding based algorithms are used to improve the performance of VANET. However, they use GPS (Global Positioning System) to locate the destination node and select the relay node from the neighbor nodes that are travelling toward the destination node. This can increase the possibility of encountering a local maximum problem and link breakage caused by random traveling speed of the nodes. Such problems occur due to changes in speed of nodes caused by road characteristics including traffic signals. Therefore this paper proposes RVVR (Relative Vehicle Velocity Routing) that takes into account the density of the neighbor nodes and relative speed among the nodes. A digital map of Yongsan District in Seoul was used to analyze the moving patterns and the changes in speed of nodes due to road characteristics and traffic signals. By taking into account the actual moving patterns and the changes in speed of the vehicular nodes, RVVR algorithm can solve the local maximum and the link breakage problems.

The rest of this paper is organized as follows. In section 2, related studies on improving the performance of inter-vehicular communication are described. The proposed RVVR algorithm is introduced in section 3. Section 4 presents a performance evaluation of RVVR using NS-2 simulator to demonstrate its benefits. Lastly, section 5 concludes this paper with remarks about possible future works.

2 Related Works

In this section, we examine and analyze the existing routing algorithms for VANET. GPSR [12] is a typical greedy forwarding based routing algorithm. In GPSR, it is assumed that the locations of the destination nodes and the nodes neighboring the transmitting node are known. Greedy forwarding mode is the default mode of GPSR. In greedy forwarding mode, one of the neighbor nodes of the current transmitting node, which is the closest to the destination, is selected as a relay node. Thus, GPSR has the advantage of delivering data rapidly to the destination node. But when a node that is closer to the destination node cannot be found, it changes over to recovery mode and the data is transmitted to a node, which is in the transmitting range, to the right hand side of the current transmitting node. This method is known as the “right hand rule” and it will be repeated until a node closer to the destination node than the current transmitting node can be found. However this can lead to the local maximum problem due to change in direction of the vehicular nodes depending on the road characteristics. In turn, it will lead to increase of time delay in the total network and link breakage by maintaining stale nodes that are outside the transmitting range as neighbor nodes. Eventually, a network failure can occur.

GPCR [13] has solved the problems found in existing GPSR in which a node closer to the destination node is selected as the relay node. GPCR is a routing algorithm designed for an urban environment to solve the problems that arise when GPSR is applied in an urban environment. When the source node reaches a junction, instead of selecting the node closer to the destination node as the relay node, it considers all the nodes at the junction and selects the node most likely to be travelling toward the destination to solve the problems that arise when GPSR is applied in an urban environment. However GPCR may select an incorrect node at a junction thus reducing the performance of the network and because it's basic operation is that of GPSR and it has yet to solve the local maximum problem.

DGPR [14] uses GPS (Global Position System) to identify the locations of the nodes and transmits data according to the moving directions of the nodes. It has solved the link breakage problem caused by maintaining stale nodes as neighboring nodes. Moreover it has minimized delay time of the total network by transmitting data to nodes moving in the direction of destination node when at a junction. Despite these advantages, when transmitting data DGPR constantly requests GPS data from neighboring nodes which creates overhead in the network. Such a problem becomes more obvious at a junction where a higher number of neighboring nodes becomes present than on an open road. An increased number of neighboring nodes can lead to packet collision which in turn can lead to poor performance of the network. Moreover the basic routing algorithm is that of GPSR and it has yet to solve the local maximum problem.

Therefore there is a need for new routing algorithm that has the ability to solve the problems of local maximum and link breakage that are found in existing algorithms.

3 Analysis of Mobility Pattern of Vehicles

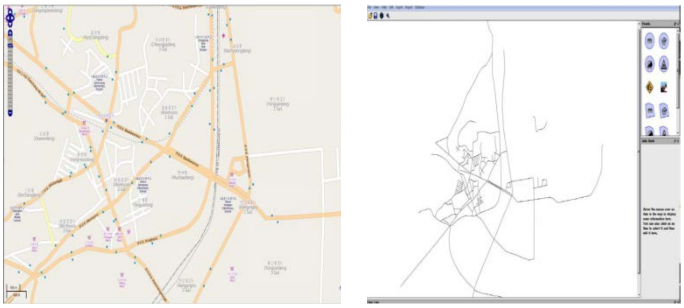
Before describing the RVVR algorithm proposed in this paper, the moving pattern of vehicles in VANET is analyzed in this section. Using a digital map of Yongsan District in Seoul, we have analyzed the moving pattern of a v ehicle in a r eal environment with moving vehicles. The following table lists the parameters of the simulation (Table 1).

Table1. Simulation parameters

Parameter	Value
Topology Size	5000 (m) x 5000 (m)
Location	Yongsan District, Seoul
Number of Node	20 to 100
Density Range	250 (m)
Simulation Time	180 (sec)

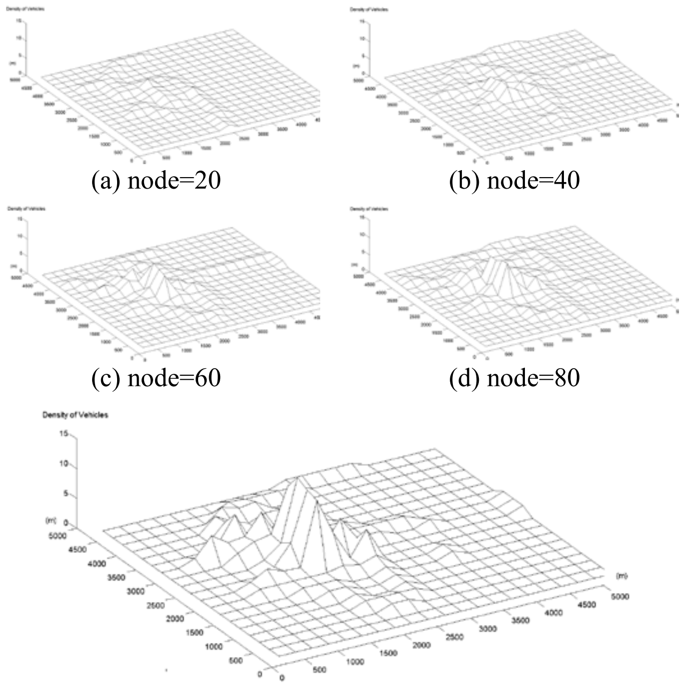
To analyze the moving pattern of the vehicles, we have used VanetMobism as shown in Fig. 1 to convert the digital map of Yongsan District in Seoul into a new format which includes road characteristics such as speed limits, junctions, number of lanes and traffic lights.

For this simulation, we increased the number of nodes by 20 at a time. The speeds of the nodes were varied according to road characteristics with the maximum speed of 60km/h. Fig. 2 shows the moving patterns of the vehicles for each increase of 20 in the number of the nodes. It also shows that at a road junction, the density of the nodes increases as the number of nodes increases. Moreover the speed of the nodes decrease significantly at a junction compared to an open road. In each simulation, it was difficult to predict the change in speeds of nodes on an open road, however at a junction the speeds of the nodes were found to be in a similar. The moving pattern of the nodes are analyzed to solve the problems of local maximum and link breakage, which arise due to road characteristics, and applied to the RVVR algorithm design proposed in this paper.



(a) Source digital map (b) Converted digital map

Fig. 1. The digital map of Yongsan District in Seoul



(a) node=20 (b) node=40

(c) node=60 (d) node=80

(e) node=100

Fig. 2. Movement pattern according to the number of nodes

4 RVVR Algorithm

In this section the RVVR (Relative Vehicle Velocity Routing) proposed in this paper is explained in detail based on the moving pattern of vehicles analyzed in the previous section.

RVVR algorithm operates in greedy mode and recovery mode as GPSR does. In the greedy mode of RVVR, the next relay node is selected after comparing the distance between each neighboring node in the transmitting range and the destination node. It can solve the link breakage and the local maximum problems by taking into account the speeds of the transmitting node and its neighboring nodes and selecting a node, which is within the transmitting range, as the relay node. However, when such a neighboring node does not exist, it enters the recovery mode. In the recovery mode of RVVR, it tries to return to the greedy mode by comparing the relative speeds of the transmitting node and the 1-hop neighbors and selecting the node with faster relative speed to the current transmitting node as the relay node. Table 2 lists the symbols used in the proposed RVVR algorithm.

Table2. Define of symbols

Symbol	Define
S_i	transmitting node/sender
n_i	neighboring node of the transmitting node/sender
N_s^i	set of neighbors within the radio range of a sender
REQ_MSG	request message
RES_MSG	response message
POS	location of sender
V	speed information of n_i
ΔV	relative speed/velocity of n_i
RCn_i	relay candidate node
RN	relay node
tx	transmission distance of a sender

4.1 Operation Process in Greedy Mode

Greedy mode is the default mode of RVVR, in which data is transmitted via neighboring nodes when the initial destination node is identified. Table 3 shows the greedy mode algorithm of RVVR. Fig. 3 shows an example in which the transmitting node (s) requests location and speed data from its neighboring nodes in order to transmit data to its destination. Neighboring nodes (a, b, c) of the transmitting node (s) transmits speed and location data as beacon messages and based on this information, the transmitting node (s) compares the distances of the neighboring nodes to the destination node. Then, it selects the node that is closer than itself to the final destination as the relay candidate node.

However when the transmitting node (s) transmits data to the relay candidate node, it calculates the probability that the relay candidate node will move out of the transmitting range by comparing the speed of itself and the relay candidate node. This is to solve the link breakage problem in which the relay node moves out of the transmitting range after it sends back the data requested by the transmitting node.

Table 3. Greedy mode algorithm of RVVR

if $N_s^i = \varnothing$ then
  s send REQ_MSG to N_s^i
    if N_s^i receive REQ_MSG then
      N_s^i send $RES\_MSG(V, POS)$ to s
      $RCn_i = ArgMin(\overline{N_s^i D})$
      if $RCn_i \neq \varnothing$ then
        compute ΔV
        if $\Delta V_{RCn_i} - \Delta V_s < \frac{tx}{2}$ then
          $RN = RCn_i$
        else
          Go to Recovery mode;
      endif
    endif
endif

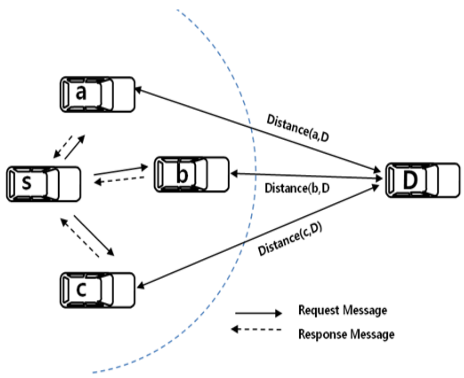


Fig. 3. Greedy mode procedure of RVVR

The transmitting range of the transmitting node can be calculated as $Tx^2\pi$, where Tx is the maximum transmitting distance of the transmitting node. The formula for calculating the relative speed ΔV for selecting the next relay node is as follows [15].

$$\Delta V = \frac{V \times (POS(RCn_i) - POS(s))}{POS(s)} (\cos\theta - \sin\theta) \quad \textbf{(1)}$$

In this formula (1), $POS(RCn_i)$ is the location of the relay candidate node and $POS(s)$ is the location of the transmitting node. $\cos\theta$ is the angle between the line that connects the transmitting node to the relay candidate node and the moving direction of the transmitting node. $\sin\theta$ is the angle between the line that connects the transmitting node to the relay candidate node and the line drawn perpendicular to the moving direction of the transmitting node from the relay candidate node.

4.2 Operation Process in Recovery Mode

Recovery mode comes in to effect when the conditions for operating in greedy mode are not satisfied. In VANET, due to the high moving speeds of the nodes and the frequent change in topology and the density of the nodes, the conditions for operating in greedy mode cannot always be satisfied. Table 4 shows the recovery mode algorithm of RVVR.

Table 4. Recovery mode algorithm of RVVR

if $\overline{sD} < \overline{n_i D}$ then
$ArgMAX(\Delta V_{N_s^i})$
if $\Delta V_{n_i} > \Delta V_s$ then
$RN = n_i$
else
$RN = ArgMAX(\Delta V_{N_s^i})$
if $\overline{RND} > \overline{sD}$ then
break;
else
Go to Greedy mode;
endif
endif
endif

For prompt switch-over to greedy mode from recovery mode, the relay candidate nodes are selected using relative speed between the transmitting node and its neighbor nodes. Fig. 4 shows an example in which there are no neighbor nodes closer to the destination than the transmitting node. In such a case, the transmitting node compares the moving speeds of the neighboring nodes to its own speed. The node with the higher speed than the transmitting node is given priority as the next relay node. If a node with a higher speed than the transmitting node cannot be found, then the node with the highest moving speed is selected instead.

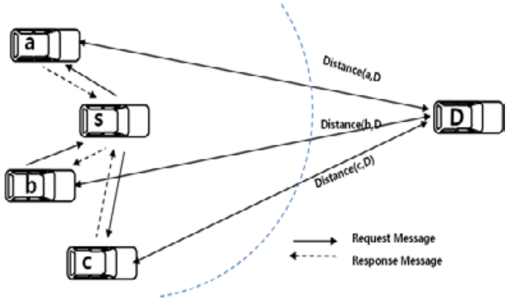


Fig. 4. Recover Mode Procedure of VRVR

5. Performance Evaluation

In this section, we analyze and compare the performance of the proposed RVVR and the existing GPSR and DGRP using the ns-2 simulator. For this evaluation, an actual digital map of an area in Seoul was used for simulating the moving patterns of the nodes. The simulation took into account the packet delivery rate according to increase in the number of nodes and change in the moving speed of the nodes. Each simulation was performed for 180 seconds and the number of nodes increased by 20 each time from 20 to 100. The maximum size of the packet was 1000 byte. The experiments were performed three times and in each experiment, average value was used after excluding the maximum and minimum values. The end-to-end packet delivery rate according to the change in speed of the nodes was obtained by increasing the speed of the node from 10km/h to 100km/h. Table 5 lists the parameter for this simulation.

Table 5. Simulation parameters

Parameter	Define
Topology size	5000 (m) * 5000(m)
Location	Yongsan District, Seoul
Transmission range	250m
MAC protocol	IEEE 802.11
Node number	20 to 100
Node speed	10km/h to 100km/h
Traffic type	CBR
Bandwidth	2Mbps
Packet size	1000 byte

Fig. 5 shows the end-to-end packet delivery rate according to the increase in the number of nodes. In GPSR and RVVR, we can observe that the end-to-end packet delivery rate increases as the number of nodes increases. This is because as the number of nodes increases, more nodes that are closer to the destination node than the transmitting node become available. However, RVVR shows a higher end-to-end packet delivery rate when compared to GPSR. When the number of nodes is low, it becomes more difficult to find a relay node in greedy mode then there is more chance that the conditions for operating in greedy mode cannot be met in which it will enter recovery mode. Due to road characteristics, the transmission node and the neighbor nodes pass by one another repeatedly causing frequent switch-over into recovery mode which increases the delay time that can lead to packet loss. However in RVVR, when recovery mode is in operation, the relative speed of the transmitting node and the neighbor nodes are compared and the fastest node is selected as the relay node regardless of the distance to the destination node. This can reduce the packet loss due to the delay time in the recovery mode of GPSR. In the DGRP, we can observe that the end-to-end packet delivery rate drops drastically when the number of nodes reaches 70. This is because, in DGRP, GPS data is requested for each data transmission which causes packet collision which in turn results in packet loss.

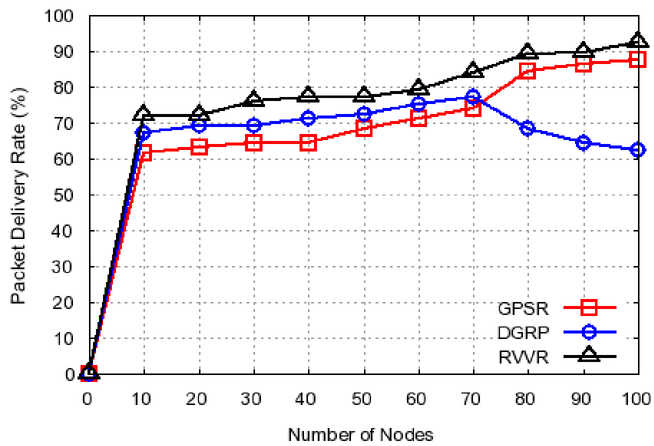


Fig. 5. The end-to-end packet delivery rate according to the increase in the number of nodes

Fig. 6 shows the end-to-end packet delivery rate according to the moving speed of the node. In all of GPSR, DGRP, and RVVR, the packet delivery rate decreases as the moving speed of the node increases. This is because as the speed increases, the density of the neighbor nodes decreases due to frequent changes in the topology. In GPSR, to select a relay node only the distance to the destination node is taken into account. Therefore it has very strong correlation to the increase in the moving speed of the node. In DGRP, the GPS data of the neighbor nodes are requested to transmit data, so as the speed of node increases, the next relay node has a tendency to move out of the transmission range. In comparison, RVVR shows the least decrease in the packet delivery rate as the speed of node increases. In RVVR, when selecting the relay node, relative speeds of the transmitting node and the neighbor nodes are compared to calculate the probability of the nodes moving out of the transmitting range. Therefore even when the speed of the node increases, the packet delivery rate is not strongly affected.

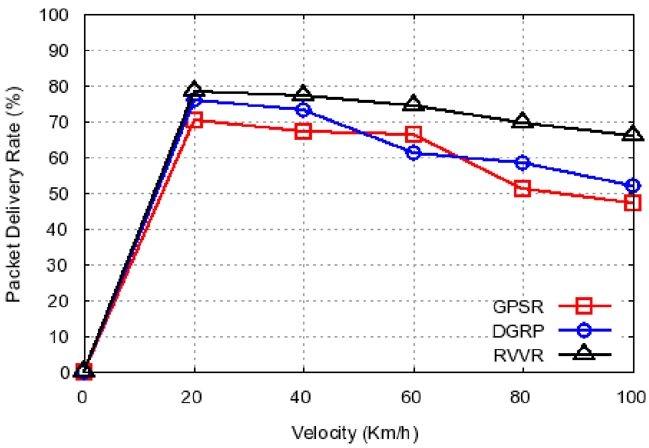


Fig. 6. The end-to-end packet delivery rate according to the moving speed of the node

6. Conclusion

In the paper, we proposed RVVR, a routing algorithm that uses relative speed between nodes to solve local maximum and link breakage problems. The proposed RVVR takes into account the relative speeds between the transmitting node and its neighbor nodes to select a r elay node. This reduces the possibility of packet loss resulting from the time delay due to the local maximum problem in the recovery mode. It also solves the link breakage problem caused by maintaining stale nodes that are outside the transmitting range as neighbor nodes. To demonstrate the benefits of RVVR, a performance evaluation of RVVR using ns-2 simulator has been done.

In the future research, more efficient routing algorithm that can handle the case of the intersection in which the prediction of node moving direction is not possible should be focused.

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