Hindawi
Mobile Information Systems
Volume 2018, Article ID 6252907, 9 pages
https://doi.org/10.1155/2018/6252907

Research Article

Efficient Maintenance of AODV Routes in the Vehicular Communication Environment with Sparsely Placed Road Side Units

Chanhyuk Cho and Sanghyun Ahn

Department of Computer Science and Engineering, University of Seoul, Seoul, Republic of Korea

Correspondence should be addressed to Sanghyun Ahn; ahn@uos.ac.kr

Received 15 December 2017; Accepted 14 February 2018; Published 10 May 2018

Academic Editor: Jeongyeup Paek

Thanks to the vehicular communication network, vehicles on the road can communicate with other vehicles or nodes in the global Internet. In this study, we propose an enhanced routing mechanism based on AODV so that road side units (RSUs) can provide continuous services such as video streaming services to vehicles which may be intermittently located outside of the coverage areas of RSUs. In the highway environment with sparsely placed RSUs, the communications between RSUs and vehicles are frequently disconnected due to high vehicular speeds. To resolve this problem, both V2I and V2V communications are utilized. In order to reduce the route recovery time and the number of route failures in the sparsely placed RSU environment, backup routes are established through the vehicles with longer direct communication duration with the RSU. The backup route substitutes the main route upon route disconnection. Also, for the efficient handover to the next RSU, the route shortening mechanism is proposed. For the performance evaluation of the proposed mechanism, we carried out the NS-3-based simulations.

1. Introduction

The vehicular communication environment is composed of vehicles and road side units (RSUs) [1, 2]. A vehicle may act as a source, a destination, and/or a relay node and can communicate with other vehicles via vehicle-to-vehicle (V2V) communications and with nodes outside of the vehicular communication network through RSUs (i.e., vehicle-to-infrastructure (V2I) communications). RSUs form the vehicular communication infrastructure but require high installation and maintenance cost. Therefore, RSUs cannot be placed densely enough to cover all the areas. This implies that a vehicle may not have direct communication links with any RSUs at the interim area of two adjacent RSUs. In this case, for seamless data delivery services from RSUs, it is required to have a routing mechanism that can provide routes from RSUs to a vehicle via other vehicles. That is, both V2I and V2V communications are required. In this study, we specifically consider the *target* vehicular communication environment with dispersedly placed RSUs from which steadily moving vehicles receive seamless data delivery services. The reason for assuming steadily moving vehicles is that the major focus of our study is not the communications between vehicles, but the communications between RSUs and vehicles.

So far, various types of routing protocols have been proposed for vehicular communications. We can categorize routing protocols for vehicular communications into topology-based and location-based (or geographic) routing protocols. In the topology-based routing protocol, the routes of the source and destination node pairs are maintained at nodes and are to be recovered in the case of route failures. Topology-based routing protocols are further categorized into reactive (or on-demand) and proactive routing protocols [3, 4]. Reactive routing protocols find a route for a source and destination node pair upon a route setup request, and proactive routing protocols configure routes prior to route requests. Due to frequent topology changes of vehicular networks, the reactive routing mechanism is preferred to the proactive one. On the other hand, geographic routing protocols do not maintain route information at nodes. Instead, each node determines the next-hop node for each data packet to be forwarded. In other words, each packet has to struggle to find its own way to the destination, which may result in significant delay and computing overhead. Also, nodes are required to periodically exchange geographic location information with other nodes, incurring significant communication overhead.

In this study, we focus on topology-based routing protocols, especially reactive routing protocols, in the target vehicular communication environment. Among the reactive routing protocols, we aim at applying the ad hoc on-demand distance vector (AODV) routing protocol [5] to the target vehicular communication environment. Even though AODV is originally proposed for mobile ad hoc networks (MANETs), AODV has been considered as a candidate routing protocol for the vehicular communication environment by many researchers [6–14]. Because AODV requires nodes to maintain routes, data packets can be delivered smoothly over the routes if they stay steadily.

Most of the previous work on applying AODV to the vehicular communication environment focuses on providing reliable routes in the harsh vehicular communication environment. To our knowledge, [14] is the only work related to applying AODV to the V2I environment by adopting the AODV+ [15]. However, M-AODV+ in [14] does not consider the quality of continuous data delivery services, such as video streaming services, from RSUs. Therefore, in this study, we propose a backup route mechanism in the coverage area of an RSU, an inter-RSU handover mechanism and a route shortening mechanism for the RSU to which a vehicle is heading. We assume a single-lane highway with steadily moving vehicles since our mechanism focuses on maintaining routes from/to RSUs. Because the vehicles on the route from an RSU to the destination vehicle can be on any lane in a multiple-lane road, the lane which the vehicle is on does not make a difference to our proposed mechanism. Thus, our mechanism is easily applicable to a multiple-lane road.

The rest of the study is organized as follows. In Section 2, we will describe the related work on the adaptation of AODV in the vehicular communication environment. Section 3 describes the detailed operation of our proposed mechanism. In Section 4, we evaluate the performance of our mechanism and analyze the simulation results. Finally, Section 5 concludes this study.

2. Related Work

There has been research done on applying AODV to the vehicular communication environment [6–14]. The previous studies [6–13] analyze the performance of AODV in vehicular ad hoc networks (VANETs) and/or try to figure out more reliable routes in dynamic vehicular communication environment. In [14], the authors propose M-AODV+ which is a modified version of AODV+ [15]. AODV+ allows AODV to be used for the communication between a MANET node and a node in the global Internet via a gateway. M-AODV+ extends AODV+ considering the frequently changing vehicular network environment so that the destination vehicle can communicate based on V2I and I2I routes. In M-AODV+, the proactive gateway (i.e., RSU) discovery mechanism of AODV+ is adopted and the mechanism of sharing the information of mobile nodes in the coverage area of an RSU with the other RSUs is proposed. However, M-AODV+ does not provide the way of continuous delivery of data from RSUs to the destination vehicle.

In [16], the implicit backup routing AODV (IBR-AODV) mechanism is proposed. In IBR-AODV, the neighboring nodes of a route become the backup nodes of the route. Each backup node overhears the ongoing transmissions on the route, and if it detects no ACK message for a transmitted data packet, it initiates the route recovery to the nodes on the route. Then, the nodes on the route include the backup node in their routing tables. Even though IBR-AODV quickly recovers route failures, it does not try to reduce route failures. Furthermore, IBR-AODV is not designed for the vehicular communication environment.

In [17], the authors propose a relay recovery route maintenance protocol that combines both proactive and reactive route recovery mechanisms based on AODV in MANET. A node which is the common neighbor of both the upstream and the downstream nodes of a link is chosen as a relay node. The relay node overhears transmissions from the upstream and the downstream nodes and detects possible link breaks by overhearing retransmissions from the upstream node. If the relay node detects the possibility of a link break, it sends a NOTICE message to the upstream node, and upon asserting a link break, the upstream node sends a CONFIRM message to the relay node. Then, the relay node becomes the new downstream node. Liang et al. [17] also propose a route shortening mechanism in which any node can initiate the route shortening procedure when it overhears a shorter route from its neighbors. However, the mechanisms in [17] are not suitable for the RSU-based vehicular communication environment.

3. RSU-Based AODV Route Maintenance

3.1. RSU-Based Vehicular Communication Environment. For the sake of convenience, we define the terminology related to RSUs. We call the RSU currently delivering data to the destination vehicle as the serving RSU of the vehicle. The serving RSU whose coverage area has been already passed by the destination vehicle is called the passed-by serving RSU of the vehicle, and the serving RSU to which the destination vehicle is heading is called the next serving RSU of the vehicle. The RSU which is not currently serving the destination vehicle heading to it is called the next RSU of the vehicle. The handover from the passed-by serving RSU to the next RSU occurs in the interim area of those two RSUs, and the next RSU becomes the next serving RSU. The next serving RSU of the destination vehicle becomes the current serving RSU once the vehicle moves into the coverage area of the RSU. Figure 1 shows the vehicular communication environment with two RSUs, RSU1 and RSU2.

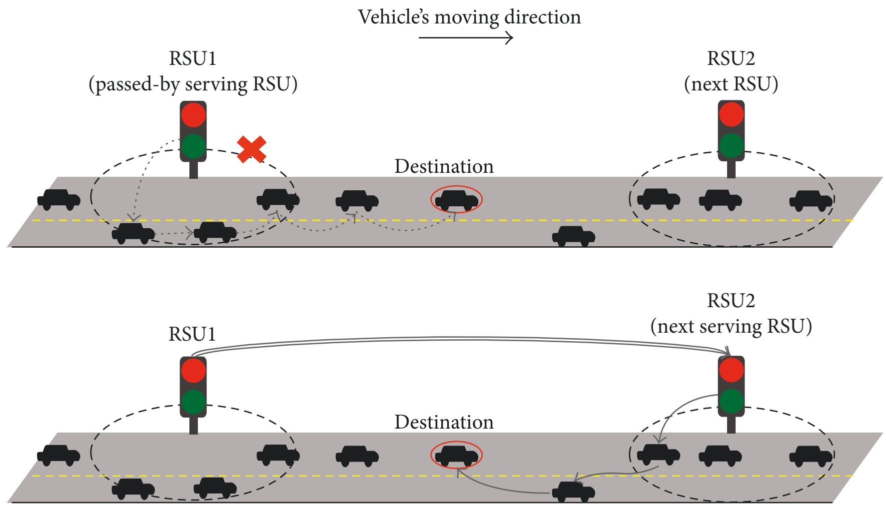

Figure 1: Vehicular communications based on V2I and V2V.

Because of the matter of cost, RSUs cannot be placed densely enough such that vehicles get communication services directly from RSUs. Therefore, we assume that the coverage areas of neighboring RSUs do not overlap.

3.2. Backup Route Mechanism. In the V2I communication environment, the passed-by serving RSU may detect frequent link disconnections to the 1-hop vehicle of the route to the destination vehicle because of vehicle movement. In this case, AODV recovers the broken link by making the RSU send a route error (RERR) message to the precursors. However, from the perspective of the vehicular network, the RSU does not have precursors, so the RSU has to discover a new route to the destination vehicle. This procedure is burdensome in the vehicular network with limited wireless link capacity. Figure 2 illustrates how AODV works in this situation.

We propose a backup route mechanism in the coverage area of the passed-by serving RSU to reduce the number of route recoveries. The procedure of establishing a backup route from the passed-by serving RSU is as follows:

(1) The RSU collects the location information of the vehicles in its own coverage area.

(2) Based on the location information, the RSU selects the vehicle Bn1, which is expected to stay in its coverage area the longest, as the 1-hop vehicle of the backup route.

(3) The RSU unicasts a backup RREQ (BRREQ) message with Gratuitous RREP flag = 1 to Bn1. The BRREQ message is a modified RREQ message with TTL = 1 and with the Destination IP Address = the address of Bn1.

(4) Once Bn1 receives the BRREQ message, it broadcasts an RREQ message to its one-hop neighbors.

(5) The vehicle receiving the RREQ message and having the route information to the destination vehicle sends back the Gratuitous RREP message to the RSU.

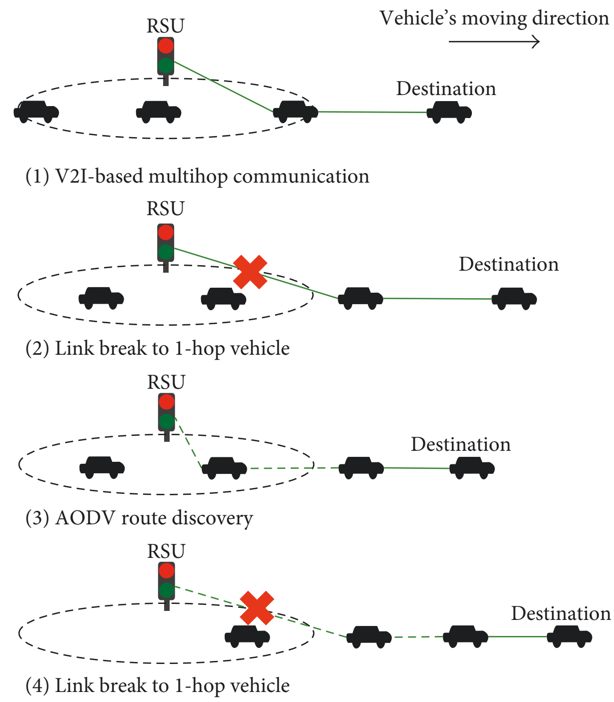

Figure 2: The AODV route recovery procedure in the RSU-based V2I communication.

(6) Once the RSU receives the Gratuitous RREP message, it includes this backup route information in its routing table and sets the status of the backup route to inactive.

(7) Upon detecting the link disconnection to the 1-hop vehicle of the primary route, the RSU activates the backup route and deletes the main route.

Figure 3 shows how the passed-by serving RSU makes the backup route via the vehicle Bn1. We include the step numbers of the above-described procedure in the figure.

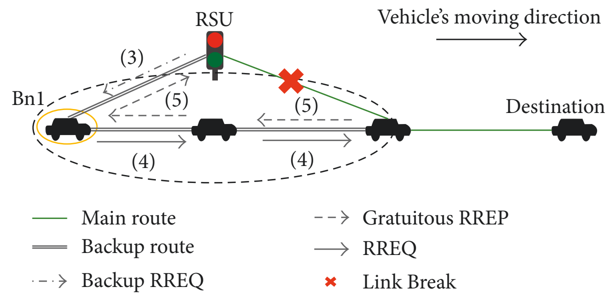

Figure 3: The backup route from RSU to the destination vehicle via Bn1.

0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1

Type	J	R	G	D	U	B	S	Reserved	Hop count
RREQ ID									
Destination IP address									
Destination sequence number									
Originator IP address									
Originator sequence number									

Figure 4: The format of the RREQ message with the newly defined B and S flags.

For the BRREQ message, we include the backup route (B) flag in the RREQ message as shown in Figure 4.

3.3. Handover Mechanism. The quality of delivery service from the passed-by serving RSU deteriorates as the destination vehicle moves away from the RSU because the route lengthens. Therefore, the passed-by serving RSU needs to decide when to handover to the next RSU. For that, the passed-by serving RSU acquires the speed information of the destination vehicle when the vehicle is in its coverage area and computes the average moving speed of the vehicle, V_{dest}. Once the destination vehicle leaves the RSU's coverage area, the RSU estimates the time, T_{mid}, when the destination vehicle is expected to arrive at the middle point of the passed-by serving RSU, R_{prev}, and the next RSU, R_{next}. For that, we assume that each RSU knows the locations of its neighboring RSUs:

$$T_{\text{mid}} = \frac{\overline{\text{Dist}\left(R_{\text{prev}}, R_{\text{next}}\right)}/2}{V_{\text{dest}}}, \tag{1}$$

where $\overline{\text{Dist}\,(R_{\text{prev}}, R_{\text{next}})}$ means the distance between R_{prev} and R_{next}.

At T_{mid}, the passed-by serving RSU sends the handover request (HREQ) message with the address of the destination vehicle to the next RSU. When the next RSU receives this HREQ message, it establishes the route to the destination vehicle. Once the route is established, the next RSU becomes the next serving RSU and the next serving RSU sends back the handover done (HDONE) message back to the passed-by serving RSU and, at the same time, starts to deliver data to the destination vehicle. Then, the passed-by serving RSU stops delivering data to the destination vehicle. Thus, data are delivered to the destination vehicle through either the passed-by serving RSU or the next serving RSU. Figure 5 shows the procedure of the handover from RSU1 to RSU2.

3.4. Route Shortening Mechanism. In Figure 6, we show the procedure of route shortening. As the destination vehicle approaches to the next serving RSU, the 1-hop vehicle, Sn1, of the next serving RSU notifies the next serving RSU of the address of the 2-hop vehicle, Sn2, and its own location and speed information. Sn1 knows the address of Sn2 because it is stored in the routing table of Sn1. The next serving RSU broadcasts a route shortening RREQ (SRREQ) message with Gratuitous RREP flag = 1, S flag = 1, and TTL = 1 and with the address of Sn2 as the Destination IP Address. Figure 4 shows the format of the SRREQ message which is the modified RREQ message with S flag = 1.

If the vehicle which is not Sn2 receives the SRREQ message, it discards the message. When Sn2 receives the SRREQ message, it replies back a Gratuitous RREP message to the next serving RSU. Once the RSU receives the Gratuitous RREQ message, it modifies the route information of the destination vehicle such that the next-hop node (i.e., the 1-hop node) to the destination vehicle is Sn2.

The SRREQ message is sent periodically by the next serving RSU at the period of T_{SRREQ} for the timely adjustment of the route:

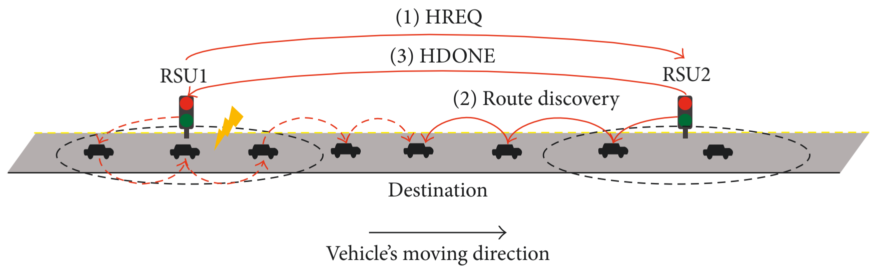

Figure 5: The handover procedure between the passed-by serving RSU, RSU1, and the next RSU, RSU2.

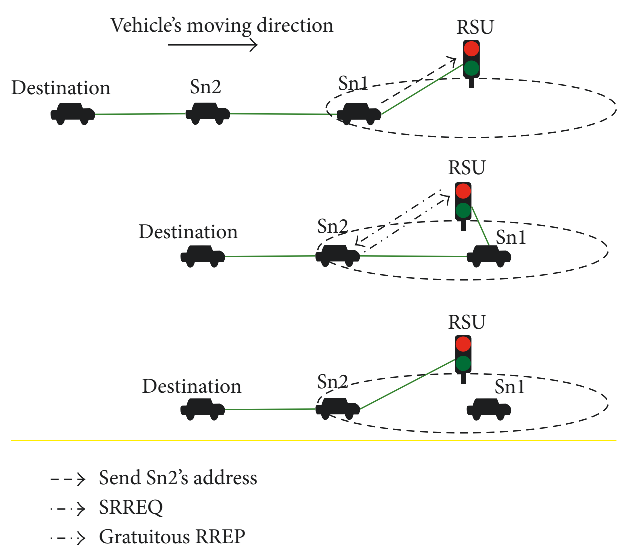

Figure 6: The route shortening procedure.

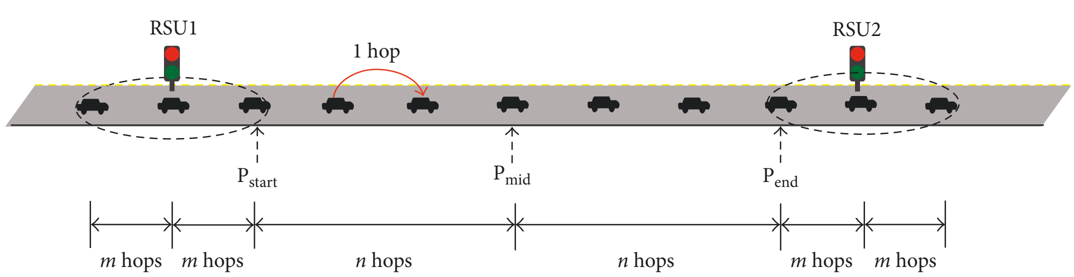

Figure 7: Simplified vehicular network for the control message overhead analysis.

$$T_{\text{SRREQ}} = \frac{R_{\text{vehicle}}}{N \times V_{\text{Sn1}}}, \quad (2)$$

where N is the number of the SRREQ messages transmitted by the next serving RSU for the destination vehicle, V_{Sn1} is the speed of Sn1, and R_{vehicle} is the transmission range of a vehicle.

4. Performance Evaluation

4.1. Numerical Analysis for Performance Condition. To figure out the condition that our mechanism works better than AODV from the perspective of control message overhead, we count the number of control messages such as RREQ, RREP, BRREQ, and SRREQ. For the simplicity of analysis, we use the simplified target vehicular network in Figure 7. In the simplified network, the intervehicular distance is the vehicular transmission range, in short, 1 hop. In this subsection, we use "hop" as the unit of the physical distance. The transmission range of each RSU is m hops and the distance between the boundaries of RSU1 and RSU2 is $2 \times n$ hops, where m and n are assumed to be integers greater than 0 for the sake of simplicity. We count the control messages generated while the destination vehicle moves from the start position P_{start} to the end position P_{end} as shown in Figure 7.

As for AODV, the number of control messages generated is C_{AODV}:

$$C_{\text{AODV}} = 2n \times (1 + (2m + 1) + 2), \quad (3)$$

where "$2n$" is the number of route recoveries while the destination vehicle moves from P_{start} to P_{end}. For each hop the destination vehicle moves, "$(1 + (2m + 1) + 2)$" control messages are generated. In "$(1 + (2m + 1) + 2)$" of (3), the first term "1" is for the RREQ message generated by RSU1 to recover the route, the second term "$(2m + 1)$" is for the RREQ messages generated by the $(2m + 1)$ vehicles in the coverage area of RSU1, and the third term "2" is for the RREP messages generated by the 1-hop and 2-hop vehicles from RSU1.

The control message overhead of our mechanism, C_{Proposed}, is:

$$C_{\text{Proposed}} = \frac{n}{2m} \times 2 \times (1 + 2m) + 2 \times (1 + n) + 2 \times n, \quad (4)$$

where "$n/2m$" is the number of proactive route recoveries while the destination vehicle moves from P_{start} to P_{end}. For each proactive route recovery, "$2 \times (1 + 2m)$" messages are generated to establish a backup route. Here, "1" is for the BRREQ message generated by RSU1 and "$2m$" is for the RREQ messages generated by the vehicles in the coverage area of RSU1 excluding the vehicle located at P_{start} and "2" is multiplied for the corresponding RREP messages. The second term "$2 \times (1 + n)$" is for the RREQ and the RREP messages generated during the new route discovery procedure initiated by RSU2 to the destination vehicle located at P_{mid}. And the third term "$2 \times n$" is for the SRREQ and the corresponding RREP messages generated during the route shortening of RSU2.

The condition that our mechanism outperforms AODV in terms of the control message overhead is $C_{\text{Proposed}} < C_{\text{AODV}}$, which results in the following condition:

$$n > \frac{m}{2 \times m^2 + m - 1}. \quad (5)$$

With any m and n values, $m \geq 1$ and $n \geq 1$, the condition in (5) is satisfied. That is, our mechanism always outperforms AODV in terms of the control message overhead.

4.2. Simulation-Based Performance Evaluation. We carried out the NS-3 simulator-based performance evaluation [18]. The IEEE 802.11p is used as the MAC protocol for vehicular wireless communications. The simulation network is a 2.5 km single-lane highway with two RSUs and eleven vehicles.

The simulation parameters are given in Table 1. The transmission range of each vehicle is set to 130 m and that of an RSU is set to 250 m. The first RSU, RSU1, is placed at 500 m and the second RSU, RSU2, at 1800 m from the leftmost point, as shown in Figure 8(a). At first, the vehicles are placed such that the sixth vehicle is placed right under RSU1 as shown in Figure 8(a). Figure 8(b) shows the final status of the simulation network.

We evaluate and compare our mechanism with the AODV with or without our proposed handover mechanism.

Table 1: Simulation parameters.

Parameter	Value
Network size	100×2500 m
Simulation time	100 sec
Number of vehicles	11
Intervehicular distance	100 m
Vehicle transmission range	130 m
Vehicle velocity	60 km/h, 80 km/h, 100 km/h
Number of RSUs	2
Inter-RSU distance	1300 m
RSU transmission range	250 m
Traffic model	CBR (150 packets/sec)
Packet size	1024 bytes
MAC protocol	IEEE 802.11p

Through the simulations, we measured the packet delivery ratio and the packet delivery delay for the verification of the received quality of service at the destination vehicle.

Figures 9–11 are the simulation results of the case that the vehicular speed is 60 km/h. Figure 9 shows the number of the packets received at the destination vehicle for the previous 10-second time interval (i.e., the result of 45 seconds means the number of packets received during the 35- to 45-second interval). Because the handover occurs around 40 seconds after the simulation start, we can observe the performance of the backup mechanism for the first 40 seconds and, after that, the performance of the proposed route shortening mechanism. As Figure 9 shows, the proposed mechanism performs better than the other two mechanisms throughout the simulation. This indicates that our backup route and route shortening mechanisms perform well enough. Besides, after 60 seconds, AODV does not deliver any more data packets to the destination vehicle. Figure 10 shows the average packet delivery ratio during the simulation start to the point (i.e., the result of 45 seconds means the average packet delivery ratio during the 0- to 45-second interval). We can observe a significant performance improvement for the first 40-second interval thanks to the proposed backup route mechanism. In Figure 11, we can observe that our proposed mechanism shows the smallest delay all the time. After around 50 seconds, the delay of the AODV without the handover mechanism stays the same because no more packets are delivered.

Figures 12 and 13 show the performance results for various vehicular speeds. Figure 12 shows the average packet delivery ratio for the simulation time for the vehicular speeds of 60 km/h, 80 km/h, and 100 km/h. The performance of the AODV without the handover mechanism is the worst, and the proposed mechanism outperforms the AODV with the handover mechanism for all cases. The higher the vehicular speed is, the less the packets are delivered to the destination vehicle. Figure 13 is the graph showing the average packet delivery delay for the various vehicular speeds throughout the simulation. The AODV without the handover mechanism gives very large delay, and our mechanism gives slightly lower delay than the AODV with the handover mechanism. From these results, we can deduce that the backup route mechanism improves the packet delivery

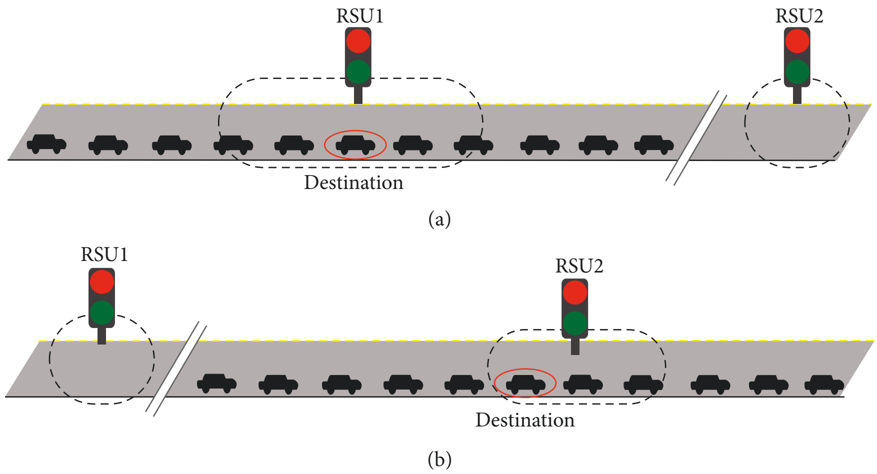

Figure 8: Simulation network: (a) initial status and (b) final status.

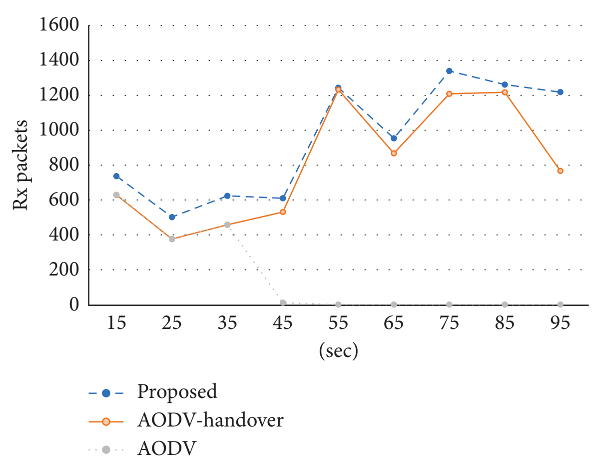

Figure 9: The number of received packets for the previous 10-second interval (for the vehicular speed of 60 km/h).

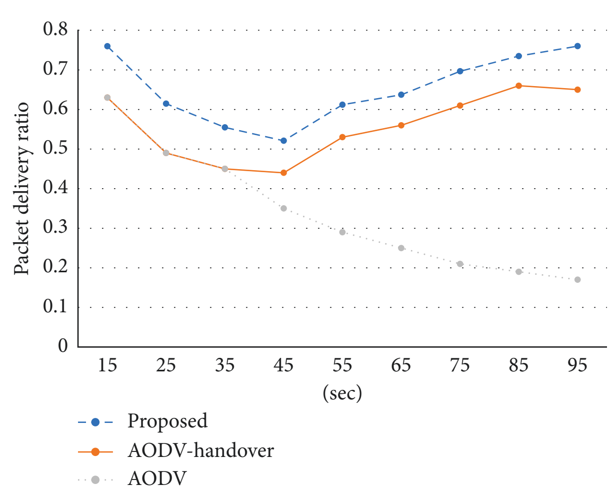

Figure 10: The average packet delivery ratio from the simulation start to that point (for the vehicular speed of 60 km/h).

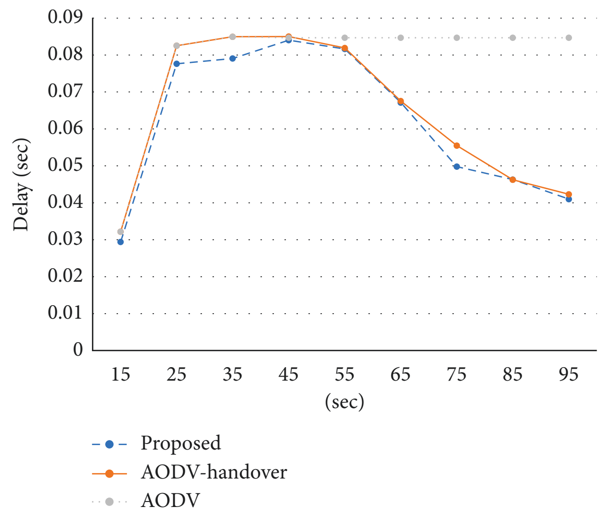

Figure 11: The average packet delivery delay for the previous 10-second interval (for the vehicular speed of 60 km/h).

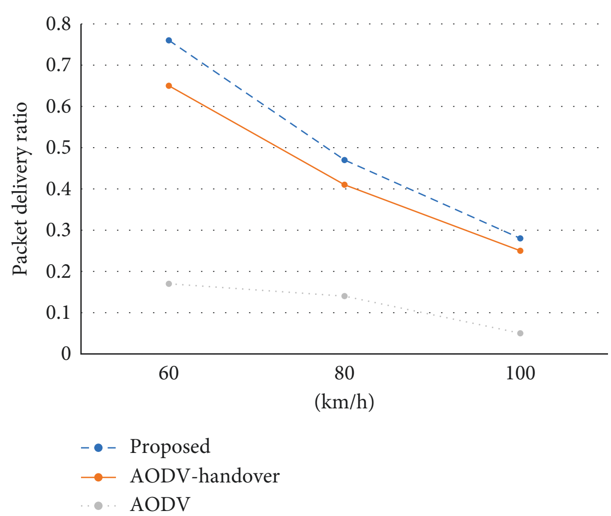

Figure 12: The average packet delivery ratio for the various vehicular speeds (for the total simulation time).

ratio but does not give significant impact on the delay performance.

5. Conclusion

AODV is a reactive routing protocol designed for MANET with mobile nodes. The vehicular communication network is similar to MANET, so AODV can be applied to the vehicular communication network. In this study, we tried to figure out how to apply AODV to the vehicular communication network with sparsely placed RSUs. By considering the constrained vehicular movement, we proposed the backup route mechanism in the coverage area of the passed-by serving RSU and the simple handover mechanism from the passed-by serving RSU to the next RSU and the route shortening mechanism in the coverage area of the next serving RSU. For that, we modified the RREQ message by

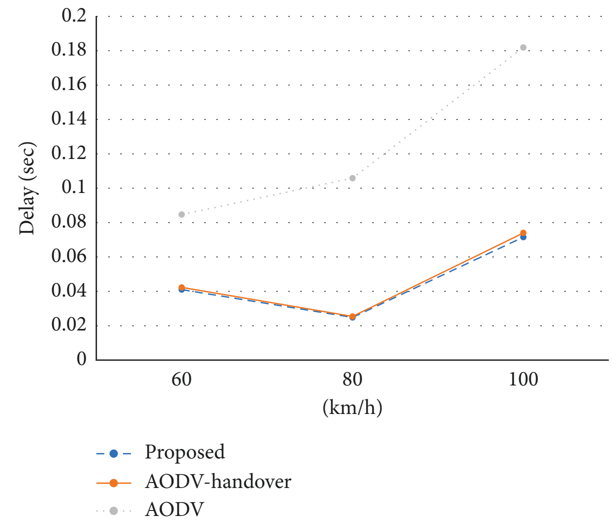

Figure 13: The average packet delivery delay for the various vehicular speeds (for the total simulation time).

adding the B flag and the S flag. The performance of the proposed mechanism was verified by the NS-3-based simulations. Through the simulations, we showed that our mechanism improves the performance in terms of packet delivery ratio and delay compared with AODV with or without the handover mechanism.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

Acknowledgments

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIT) (no. NRF-2015R1A2A2A04005646) and the MSIT (Ministry of Science and ICT), Korea, under the ITRC (Information Technology Research Center) support program (IITP-2017-2015-0-00363) supervised by the IITP (Institute for Information and communications Technology Promotion).

References

[1] K. Abboud, H. A. Omar, and W. Zhuang, “Interworking of DSRC and cellular network technologies for V2X communications: a survey,” *IEEE Transactions on Vehicular Technology*, vol. 65, no. 12, pp. 9457–9470, 2016.

[2] C. M. Silva, B. M. Masini, G. Ferrari, and I. Thibault, “A survey on infrastructure-based vehicular networks,” *Mobile Information Systems*, vol. 2017, Article ID 6123868, 28 pages, 2017.

[3] R. Kumar and M. Dave, “A comparative study of various routing protocols in VANET,” *International Journal of Computer Science Issues (IJCSI)*, vol. 8, no. 4, 2011.

[4] M. Barcia-Campos, D. G. Reina, S. L. Toral et al., “Performance evaluation of reactive routing protocols for VANETs in urban scenarios following good simulation practices,” in *Proceedings of International Conference on Innovative Mobile*

and Internet Services in Ubiquitous Computing (IMIS), Fukuoka, Japan, July 2015.

[5] C. E. Perkins, E. M. Belding-Royer, and S. Das, *Ad Hoc on-Demand Distance Vector (AODV) Routing, IETF RFC 3561*, 2003.

[6] B. Ding, Z. Chen, Y. Wang, and H. Yu, "An improved AODV routing protocol for VANET," in *Proceedings of International Conference on Wireless Communications and Signal Processing (WCSP)*, Nanjing, China, October 2011.

[7] S. Harrabi, I. B. Jaafar, and K. Ghedira, "An enhanced AODV routing protocol for vehicular adhoc networks," in *Proceedings of BDAW*, Paris, France, November 2016.

[8] T. Kaur and A. K. Verma, "Simulation and analysis of AODV routing protocol in VANETs," *International Journal of Soft Computing and Engineering*, vol. 2, no. 3, 2012.

[9] A. Moravejosharieh, H. Modares, R. Salleh, and E. Mostajeran, *Performance Analysis of AODV, AOMDV, DSR, DSDV Routing Protocols in Vehicular Ad Hoc NetworkResearch Journal of Recent Sciences ISSN*, vol. 2277, p. 2502, 2013.

[10] P. Mittal and B. Yadav, "Improving AODV routing in vehicular ad hoc networks," *International Journal of Innovative Research in Computer and Communication Engineering*, vol. 4, no. 9, 2016.

[11] D. Rathi and R. R. Welekar, "Performance evaluation of AODV routing protocol in VANET with NS2," *International Journal of Interactive Multimedia and Artificial Intelligence*, vol. 4, no. 3, pp. 23–27, 2017.

[12] A. Datta, C. Chowdhury, and S. Neogy, "Ant-AODV-VANET: a bio-inspired routing protocol for VANET," in *Proceedings of International Conference on Emerging Research in Computing, Information, Communication and Applications (ERCICA)*, Bangalore, India, July2016.

[13] D. Zhu, G. Cui, and Z. Fu, "DT-AODV: an on-demand routing protocol based DTN in VANET," *Applied Mathematics and Information Science*, vol. 8, no. 6, pp. 2955–2963, 2014.

[14] J. Wantoro and I. W. Mustika, "M-AODV+: an extension of AODV+ routing protocol for supporting vehicle-to-vehicle communication in vehicular ad hoc networks," in *Proceedings of IEEE International Conference on Communication, Networks and Satellite (COMNETSAT)*, Jakarta, Indonesia, November 2014.

[15] A. A. Hamidian, *A Study of Internet Connectivity for Mobile Ad Hoc Networks in NS 2*, M.S. thesis, Lund University, Lund, Sweden, 2003.

[16] J. Jeon, K. Lee, and C. Kim, "Fast route recovery scheme for mobile ad hoc networks," in *Proceedings of International Conference on Information Networking (ICOIN)*, Kuala Lumpur, Malaysia, January 2011.

[17] Z. Liang, Y. Taenaka, T. Ogawa, and Y. Wakahara, "Proreactive route recovery with automatic route shortening in wireless ad hoc networks," in *Proceedings of International Symposium on Autonomous Decentralized Systems (ISADS)*, Tokyo, Japan, March 2011.

[18] *The Network Simulation, NS-3*, http://www.nsnam/org.