# Position-freshness Based Intermediate Vehicle Filtering Layer with Intersection Detection for VANET

Guhyoung Kwon, Eunbae Moon, Sungwon Lee, Dongkyun Kim

School of Computer Science and Engineering
Kyungpook National University, Daegu, Korea
ghkwon@monet.knu.ac.kr, ebmoon@monet.knu.ac.kr, swlee@monet.knu.ac.kr, dongkyun@knu.ac.kr

## Abstract

Routing in inter-vehicle communication is a challenging task owing to several intrinsic characteristics of vehicular networks, such as intermittent connectivity, dynamic topology, and inaccurate real-time location information. Routing accuracy in vehicular networks is directly proportional to the signaling overhead of the routing protocol employed. This signaling overhead is minimized by position based routing (PBR) protocols that make on-demand forwarding decisions based on the position information of neighboring vehicles. However, inaccurate position information caused by factors such as urban canyons, satellite coverage, intermittent connectivity, and error-prone channels, reduces the performance and reliability of PBR. In this paper, we propose a position-based routing scheme that applies a filtering method over the forwarding or relaying candidate vehicles based on the angle between the vehicle's direction of motion and the line between the sender and neighboring vehicles. By filtering inappropriate forwarding vehicles, the proposed method improves communication reliability in urban environments. Simulation results show that the proposed filtering scheme improves the performance of PBR in terms of packet delivery ratio and end-to-end delay

**Keywords:** VANET, Position-based-routing

## 1 Introduction

In the recent past, a variety of safety and non-safety related applications have emerged for vehicular networks concomitant with rapid developments in intelligent transportation system (ITS). Safety applications aim to save human lives by avoiding hazardous situations on the road. Conversely, non-safety applications, which include infotainment and weather forecast, are designed to make the journey pleasant for commuters.

In order to facilitate these applications in vehicular networks, the vehicles have to connect with other vehicles on the move or the infrastructure. The vehicles may also request data from the infrastructure to satisfy the demands of the applications. However, the installation and maintenance cost of the infrastructure network is directly proportional to the coverage provided. Maintaining connectivity between the vehicles and the infrastructure network(s) incurs additional overhead. Hence, much research has been focused on inter-vehicle multi-hop communication with the objective of increasing coverage and reducing base station overhead without additional cost. Ad hoc communication mode is suitable for inter-vehicle wireless communication without additional infrastructure [1].

Owing to the highly mobile nature of vehicular networks, inter-vehicle communication faces many challenges including intermittent connectivity, dynamic topology, and inaccurate real-time location information. These intrinsic characteristics of vehicular networks complicate and hinder the capacity of routing protocols to provide and maintain accurate routing information for efficient communication within vehicular ad hoc networks (VANETs) at minimum signaling overhead. In addition, mobility makes it virtually impossible to establish and maintain an end-to-end path between source and destination vehicles throughout the communication duration. Instead of establishing an end-to-end path, a set of on-demand and greedy protocols that enable each data relaying vehicle to dynamically select the next forwarder from its neighbors is employed.

On-demand and greedy approach-based routing schemes that promise routing efficiency in vehicular networks abound in the literature. Among these protocols, position based routing (PBR) protocols are gaining increased attention owing to the ease with which they allow position information to be made available at each vehicle. In PBR, when the vehicle has packet to transmit, it selects an intermediate forwarding vehicle based on the neighboring vehicle's position information [2-3]. As PBR reduces end-to-end delay by transmitting packets without route establishment, it is considered one of the most suitable routing options for inter-vehicle communication.

*Corresponding Author: Dongkyun Kim; E-mail: dongkyun@knu.ac.kr
DOI: 10.3966/160792642018011901030

The greedy perimeter stateless routing (GPSR) protocol is a representative PBR protocol. In GPSR, each vehicle periodically broadcasts a beacon message containing position information, and every vehicle maintains a neighbor list that contains the identifiers and recent location information of neighboring vehicles. Subsequently, a forwarding vehicle selects a vehicle from its neighbors that is closest to its destination vehicle, as an intermediate forwarder. With this process, packets are transmitted through minimum hop routes in a multi-hop fashion [4].

However, two issues reduce the reliability of GPSR. First, GPSR does not consider environments in which obstacles (e.g., buildings, trees, and tall vehicles) exist between the two communicating vehicles. These obstacles may disrupt the transmission of data packets and beacon messages [5-6]. When GPSR is employed in an urban environment, the packets may be transmitted to an inefficient route owing to inaccurate communication between neighbors caused by such obstacles. For example, in Figure 1, vehicle 2 may have inaccurate or no information related to vehicle 6 because of the building at the corner of the intersection. These obstacles are common in vehicular network environments and, in the presence of such obstacles, the routing protocols may frequently miscalculate the route. However, in the case of PBR, the miscalculation in forwarder selection can severely affect performance because it uses a greedy approach to transmit packets.

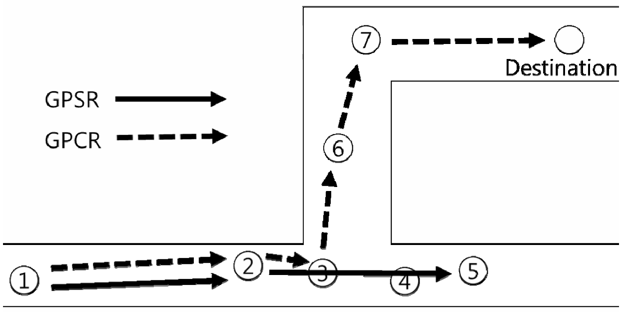



**Figure 1.** Routing scenario in urban environment

We postulate that any vehicle located at an intersection is more suitable to make routing decisions in urban environments. At every intersection, each connecting road segment provides more neighbor vehicles and a chance to change the transmission direction of packets. Therefore, selecting an intermediate vehicle located at an intersection is better in terms of route selection than selecting the closest vehicle to the destination. The greedy perimeter coordinator routing (GPCR) protocol utilizes this strategy by giving higher priority to vehicles that are located at intersections when selecting intermediate vehicles. This results in the packets being transmitted through a more effective path than would otherwise be the case [7].

The second issue that reduces the reliability of GPSR is the fact that position information accuracy is inversely proportional to beacon interval and is very important in PBR. In PBR, each vehicle collects neighbor position information through periodic beacons and this information is used to select a suitable intermediate forwarder. As the length of beacon arrival increases, the freshness of the neighbor information decreases. As a result, routing decisions made based on stale information may severely degrade routing performance [8].

Reducing the beacon interval could conceivably alleviate this problem; however, the beacon overhead within the entire network would then increase, which would result in errors and low link quality. Further, cases in which the position information is inaccurate may still persist even when the beacon interval is reduced. Figure 2 shows the difference between the position information stored in a neighbor's table versus the actual position. In this simulation, 100 vehicles are located in random position, each vehicle's maximum speed is 72km/h and moving on the grid shape road segments without obstacles. These differences in position information will severely decrease the performance of PBR. The performance of PBR based on a vehicle's position information in the neighboring table (termed "interval") and the actual/real-time accurate vehicle's location information (termed "real-time") are compared in Figure 3 and Figure 4. It is evident from the graphs that the position information accuracy has a major effect on the performance. More specifically, real-time position information in PBR reduces end-to-end delay by approximately 0.15 second and increases packet delivery ratio (PDR) by approximately 30% compared to interval-based position information. These performance differences are regardless of the beacon interval. Therefore, methods for increasing position information accuracy are required instead of changes in beacon interval [9-10].

Menouar *et al.* [11] proposed the movement prediction-based routing (MOPR) scheme with focus on the accuracy of neighborhood position prediction. In the proposed scheme, vehicles share velocity information through beacon messages and the vehicle receiving the beacon calculates the predicted position based on beacon information when selecting an intermediate vehicle or node [11]. However, combining of above two methods to solve problems has flaws that preclude it from being used in urban scenarios. In Urban, obstacles that can disrupt the transmission are exist. Using position prediction, if the selected intermediate vehicle and forwarding vehicle are in non-line of sight (NLOS) state by obstacle, transmission between the two vehicles will fail. Therefore, in order to use position prediction in urban situations, neighbor vehicles with a probability of being in an NLOS state need to be removed from consideration as an intermediate vehicle.

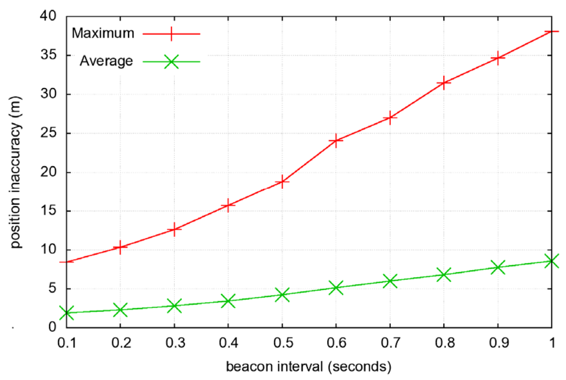



**Figure 2.** Position inaccuracy versus beacon interval

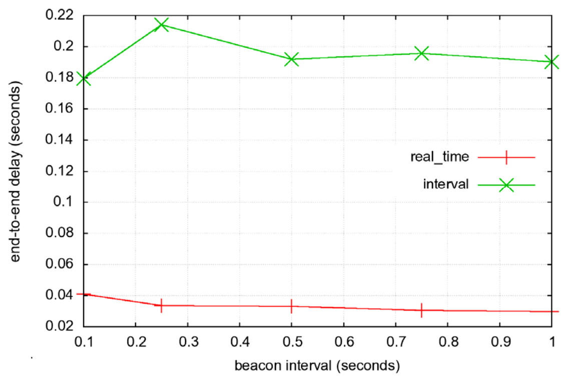



**Figure 3.** Delay versus beacon interval

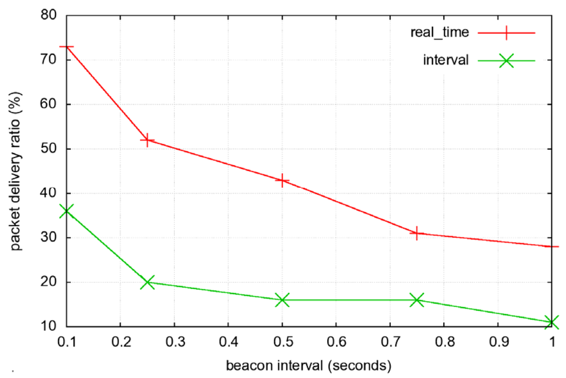



**Figure 4.** Packet delivery ratio (PDR) versus beacon interval

On the basis of these considerations, in this paper we propose a layer that filters vehicles with any probability of being in an NLOS state with the forwarding vehicle. By filtering these vehicles, the proposed filtering layer improves the reliability of transmission in urban situations. Further, by adopting an approach in which a vehicle in an intersection is used as the intermediate vehicle, the performance of the routing protocol increases.

## 2 Protocol Description

### 2.1 Predicting Neighbor Position

Each vehicle periodically broadcasts a beacon message containing location, velocity, and position (e.g., at intersection, at road segment) information. Each vehicle updates its neighbor table when a beacon message is received.

When a packet being transmitted to a destination is received or created by an intermediate forwarding vehicle, the forwarding vehicle calculates the predicted position of each neighbor vehicle using position and velocity information, and the lapsed time after receiving the beacon message from each vehicle.

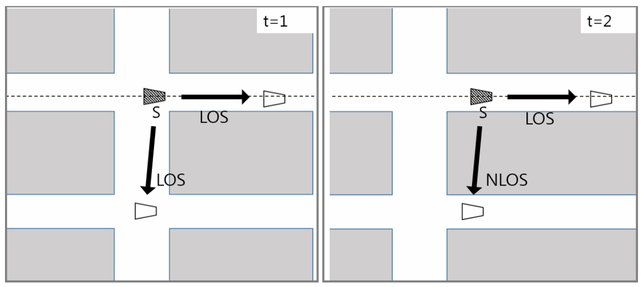



**Figure 5.** LOS/NLOS state of each neighbor vehicle

### 2.2 Threshold Calculation and Filtering

If a forwarding vehicle receives a beacon message from a neighbor vehicle located in a different lane immediately or with a short time lapse, then the two vehicles have a high probability of being in an LOS state. Conversely, if the time lapse is long, then the probability is high that they are in an NLOS state as a result of obstacles, such as buildings. On the other hand, if the forwarding vehicle and its neighbor are located in the same lane, then these two vehicles have a high probability of being in an LOS state regardless of the time lapse. Hence, there is a need to include intermediate selection from neighbor vehicles that are located in the same lane as the forwarding vehicle. The remaining vehicles determine their position according to the time elapsed after receiving a beacon, based on the lifetime of the neighbor vehicle's position information, and the angle between the direction of motion of the forwarding vehicle and the line connecting the two vehicles. The forwarding vehicle can filter neighbor vehicles that have a high probability of NLOS from intermediate vehicle selection. The threshold value used is calculated as,

$$Threshold = ((x + T_{init})^4 + M_{AA} \times 90^{\circ} \quad \textbf{(1)}$$

where "x" is the ratio of the remaining time and the lifetime, $T_{init}$ is a network parameter to set the beginning point at which the threshold value is less than one, and MAA is used to set the minimum value of the threshold. These values can be modified to consider the speed limit or width of the road segment. If the angle between the direction of motion of the forwarding vehicle and the line connecting the two vehicles is less than the threshold, then the forwarding vehicle includes the current neighbor vehicle in the intermediate vehicle selection process. Conversely, if the angle is greater than the threshold, the forwarding vehicle removes the current neighbor vehicle from the intermediate vehicle selection process. After performing the above procedure for all neighbors, packets are transmitted through a reliable path in the urban environment by selecting an intermediate vehicle from among the remaining neighbor vehicles. Although, using proposed layer has probability of hop count increase. However, execution of recovery procedure for failed transmission are decreased, therefore end-to-end transmission delay will be decreased.

### 2.3 Filtering Decision Based on Road Shape

The filtering method can provide an effective path if the forwarding vehicle is located at or near an intersection. However, if the forwarding vehicle is located at any road segment other than an intersection, then using the filtering method causes loss of neighbor vehicles without any improvement. To avoid this problem, each vehicle decides whether to use the filtering method based on its position information and whether it is located at an intersection or not. Pearson correlation coefficient [12], which describes the shape of input data, is used to detect the intersection. When the absolute value of the Pearson correlation coefficient is close to one, it can be assumed that the input data is in the form of a line. Each vehicle calculates Pearson correlation coefficient based on its neighbor vehicle's position. If the absolute value of the Pearson correlation coefficient is less than 0.9, the vehicle marks the beacon message and broadcasts it. Any vehicle that is located at an intersection or receives a marked beacon message uses the above filtering method.

**Algorithm 1.** Filtering process

```
if (CloseToIntersection(CurrentNode)) then
  for (i = 0; i < NeighborList.GetSize(); i++) do
    NeighborList.Get(i).position = ClaculateCurrentPosition(i);
    if (GetAngle(NeighborList.Get(i), CurrentNode,
    CurrentNode.direction) > NeighborList.GetThreshold(i))
      then NeighborList.Remove(i);
    end if
  end for
else if (!CloseToIntersection(CurrentNode)) then
  for (i = 0; i < NeighborList.GetSize(); i++) do
    NeighborList.Get(i).position = ClaculateCurrentPosition(i);
  end for
end if
MakeRoutingDecision(NeighborList);
```

## 3 Simulation

In this section, we evaluate the performance of the three routing protocols MOPR-GPSR, GPCR, and GPCR-fresh. GPCR-fresh is the GPCR protocol combined with the proposed filtering layer

### 3.1 Simulation Environment

NS3 and SUMO were used to evaluate the performance of the protocols [13-14]. Simulation runs were conducted on a 1000 m × 1000 m grid topology road segment. Obstacles were placed in several areas except road segments. The shape of obstacle is a rectangular parallelepiped. Each obstacle is located in center of rectangular that surrounded by road segments, the area occupied by obstacles is changed by ratio for the rectangular. Vehicles were randomly placed in the simulation area and moved randomly. The speed of the road segment was set in the range 36–108 km/h, and the transmission range was 300 m. The beacon interval was from 0.1 seconds to 1.0 seconds, and Tinit and MAA were set as 0.0602 and 0.15, respectively. The Tinit and MAA values indicate that when the remaining lifetime of the location information is greater than 90%, the threshold is 100% in the transmission area, and the minimum area is almost 27 degrees in the forwarding vehicle's direction.

### 3.2 Simulation Result

**Simulations according to obstacle areas.** PDR simulation results where 25%, 50%, and 75% of the simulation area was covered with obstacles and with number of vehicles ranging from 50 to 250 are shown in Figure 6 to Figure 8, respectively. From the figures, it is evident that PDR increased when the number of vehicles reached 200, because the probability of intermediate vehicle presence increased. As GPCR-fresh avoids selecting vehicles that have a probability of being in the NLOS state, it achieves higher PDRs than the other routing protocols. In the end-to-end delay comparison, the simulation results show that there is marginal or virtually no difference in the end-to-end delay performance of GPCR-fresh and the GPCR scheme (see Figure 9 to Figure 11). However, both GPCR and GPCR-fresh have less delay than GPSR-MOPR. This gap is due to the scheme assigning priority to vehicles at intersections.

GPCR-fresh has the possibility of increasing hop count; however, it was not effected on the simulation results. The PDR performance degradation for 250 vehicles in the simulation area is caused by the high beacon overhead that degrades the link quality. The performances show that the 25% obstacles scenario has better PDR performance than the 50% obstacles scenario. This is because it reduces the possibility of data transmission interruption owing to a decrease in the area occupied by obstacles. On the other hand, the

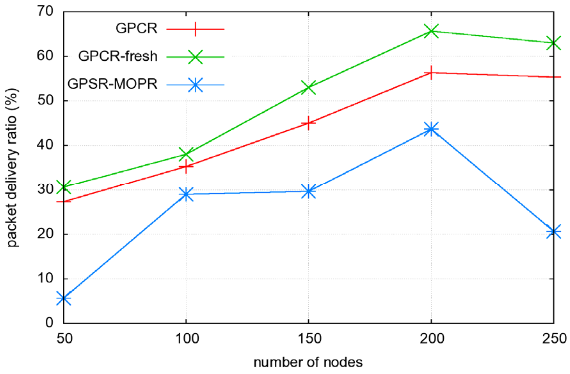



**Figure 6.** PDR with 25% obstacle area

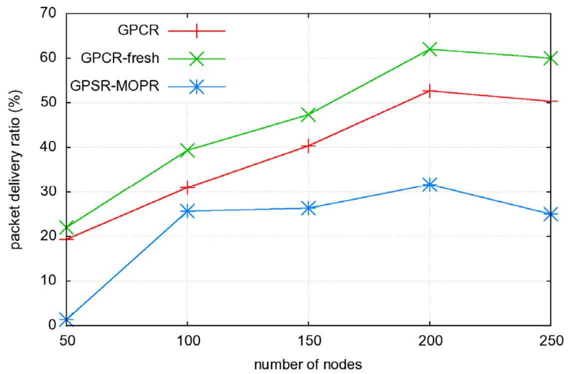



**Figure 7.** PDR with 50% obstacle area

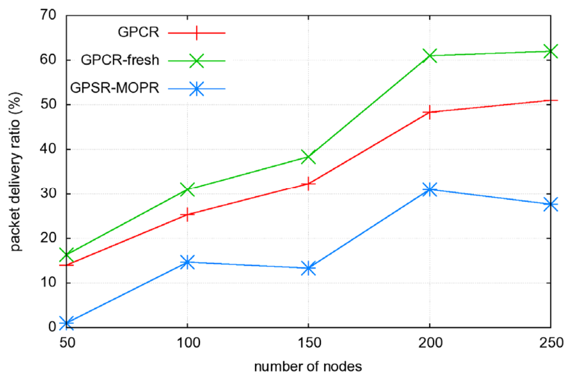



**Figure 8.** PDR with 75% obstacle area

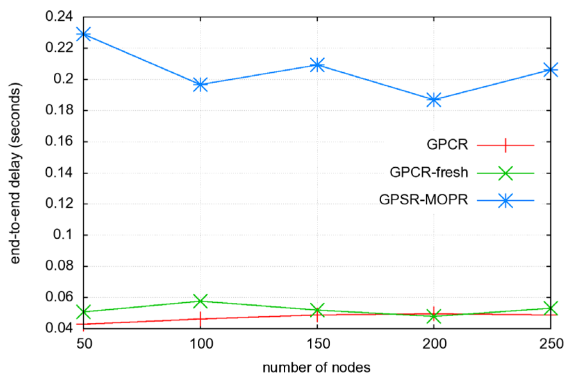



**Figure 9.** Delay with 25% obstacle area

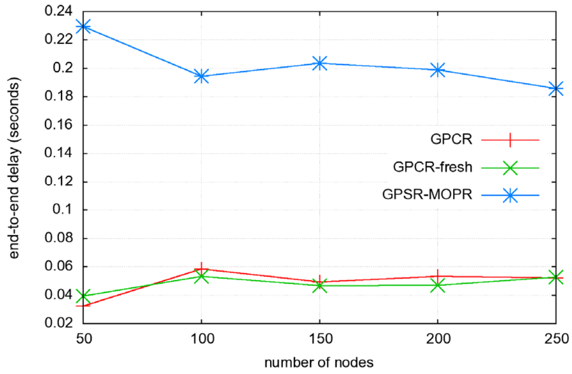



**Figure 10.** Delay with 50% obstacle area

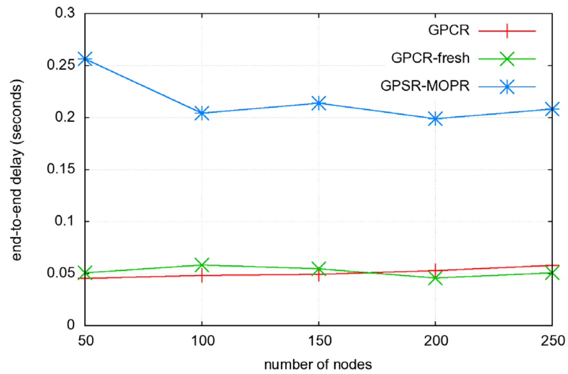



**Figure 11.** Delay with 75% obstacle area

75% obstacles scenario has a lower PDR than all the other scenarios because of the terrible link quality resulting from the high beacon overhead and the presence of obstacles. The difference in the performance of GPCR and GPCR-fresh is smaller than GPSR-MOPR. This is due to the effect of selecting a vehicle at the intersection as an intermediate vehicle.

**Simulations focusing on beacon interval.** Short beacon intervals can provide more accurate position information than long intervals; however, short intervals adversely affect link quality. Transmission success rate is reduced with increases in beacon transmission interval. However, there is only minor degradation in the performance of GPCR-fresh. This is because with GPCR-fresh, packets are transmitted through the effective path based on accurate position information. End-to-end delay graphs show that the increase in the delay caused by large hop-count is minimal; the trends can easily be analyzed in Figure 12 and Figure 13.

**Simulations focusing on vehicle speed.** In the case of GPCR and GPCR-fresh, decreases in PDR are not evident. This is because GPCR and GPCR-fresh select any vehicle that is located at an intersection. In contrast, because GPSR-MOPR selects a vehicle that is located at the edge of the transmission range, its packet delivery ratio decreases with increases in speed.

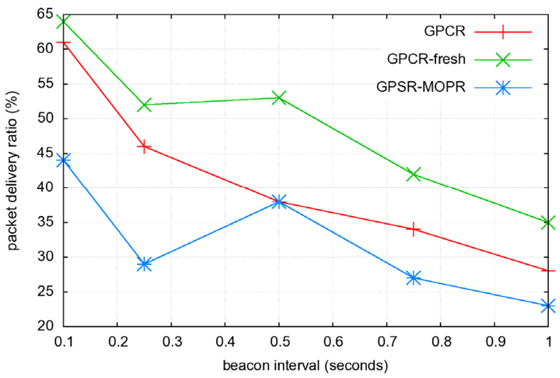



**Figure 12.** PDR versus beacon interval

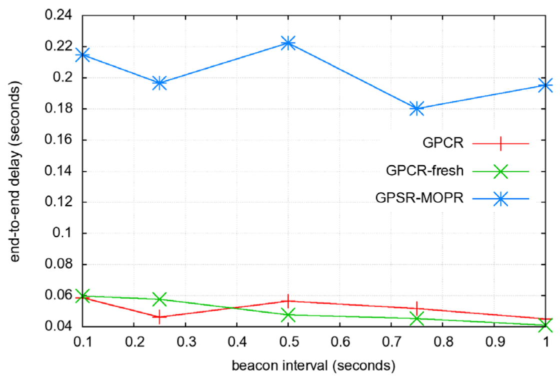



**Figure 13.** Delay versus beacon interval

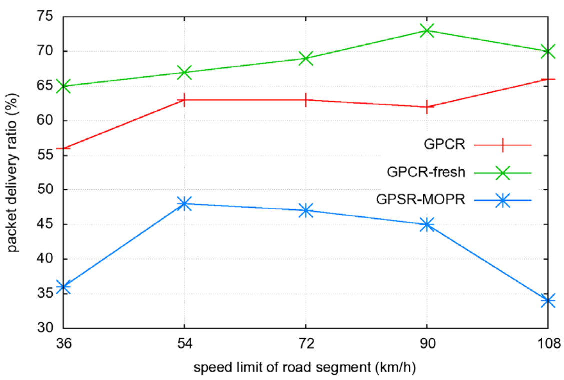



**Figure 14.** PDR versus speed

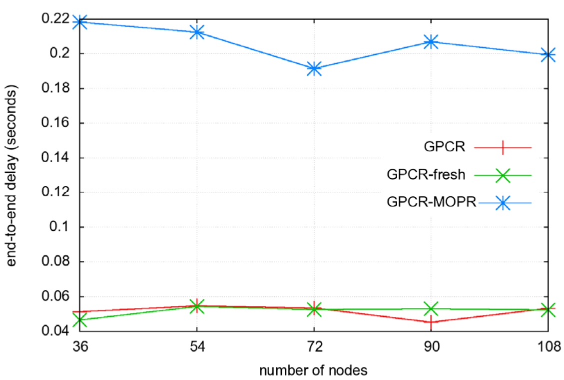



**Figure 15.** Delay versus speed

# 4 Conclusion

In this paper, we proposed a neighbor vehicle filtering layer to remove unreliable vehicles from the intermediate vehicle selection process in PBR. The proposed method compensates neighbor position information to select suitable packet delivery routes and avoid transmission disturbance due to obstacles. Further, based on the remaining lifetime of neighbor vehicle information, along with the angle between the direction of motion of the forwarding vehicle and the line connecting the two vehicles, vehicles with probability of being in an NOLS state are filtered. The end-to-end delay of a routing protocol supplemented with the proposed method decreased by 60% and packet delivery rate increased by 50%.


# Acknowledgement

This study was supported by the BK21 Plus project (SW Human Resource Development Program for Supporting Smart Life) funded by the Ministry of Education, School of Computer Science and Engineering, Kyungpook National University, Korea (21A20131 600005).


# References


[1] ASTM E2213-03, *Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems 5 GHz Band Dedicated Short Range Communications (DSRC) Medium AccessControl (MAC) and Physical Layer (PHY) Specifications*, 2003.

[2] G. Liu, B. S. Lee, B. C. Seet, C. H. Foh, K. J. Wong, K. K. Lee, A Routing Strategy for Metropolis Vehicular Communications, *International Conference on Information Networking (ICOIN)*, Busan, Korea, 2004, pp. 134-143.

[3] H. Füßler, M. Mauve, H. Hartenstein, M. Kasemann, D. Vollmer, Location-based Routing for Vehicular Ad-hoc Networks, ACM SIGMOBILE Mobile Computing and Communications Review (MC2R), Vol. 7, No. 1, pp. 47-49, January, 2003.

[4] B. Karp, H. T. Kung, GPSR: Greedy Perimeter Stateless Routing for Wireless Networks, *ACM/IEEE MOBICOM00*, Boston, MA, 2000, pp. 243-254.

[5] J. Gozalvez, M. Sepulcre, R. Bauza, Impact of the Radio Channel Modelling on the Performance of VANET Communication Protocols, *Telecommunication System*, Vol. 50, No. 3, pp. 1-19, July, 2010.

[6] J. Andersen, T. Rappaport, S. Yoshida, Propagation Measurements and Models for Wireless Communications Channels, *IEEE Communications Magazine*, Vol. 33, No. 1, pp. 42-49, January, 1995.

[7] C. Lochert, M. Mauve, H. Fussler, H. Hartenstein, Geographic Routing in City Scenarios, *ACM SIGMOBILE05*, Vol. 9, No. 1, pp. 69-72, 2005.

[8] C. Lochert, H. Hartenstein, J. Tian, D. Herrmann, H. Füßler, M. Mauve, A Routing Strategy for Vehicular Ad Hoc Networks in City Environments, *IEEE Intelligent Vehicles Symposium (IV2003)*, Columbus, OH, 2003, pp. 156-161.

[9] A. Boukerche, C. Rezende, R. Pazzi, Improving Neighbor Localization in Vehicular Ad hoc Networks to Avoid Overhead from Periodic Messages, *Global Telecommunications Conference, IEEE GLOBECOM 2009*, Honolulu, HI, 2009, pp. 1-6.

[10] V. Naumov, T. Gross, Connectivity-Aware Routing (CAR) in Vehicular Ad-hoc Networks, *26th IEEE International Conference on Computer Communications*, Anchorage, AK, 2007, pp. 1919-1927.

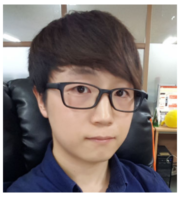
[11] H. Menouar, M. Lenardi, F. Filali, Movement Prediction-based Routing (MOPR) Concept for Position-based Routing in Vehicular Networks, *Proceedings of the IEEE 66th Vehicular Technology Conference*, Baltimore, MD, 2007, pp. 2101-2105.

[12] Rodgers. J. L., Nicewander. W. A., Thirteen Ways to Look at the Correlation Coefficient, *The American Statistician*, Vol. 42, No. 1, pp. 59-66, February, 1988.

[13] NS3, http://www.nsnam.org/, 2016.

[14] SUMO, http://sumo-sim.org/, 2016.

## Biographies



**Guhyoung Kwon** received M.S. degree from Graduate School of Electrical Engineering and Computer Science, Kyungpook National University, Daegu, Korea. He is currently working for Winitech Co.,ltd, Daegu, Korea. His research interests are vehicular ad hoc network and safety & security solution.

**Eunbae Moon** received his B.S. and Masters in School of Computer Science and Engineering Kyungpook National University, Daegu, Republic of Korea, Currently he is in Ph.D. in MoNeT Lab, Kyungpook National University, South Korea. His research interests include Ad hoc and Sensor Networks, Vehicular Communications, and Internet of Things.

**Sungwon Lee** received M.S. degree from Graduate School of Electrical Engineering and Computer Science, Kyungpook National University, Korea. He is currently Ph.D. candidate in School of Computer Science and Engineering, Kyungpook National University in Korea. His research interests are wireless mesh network, wireless sensor network and underwater wireless sensor network.

**Dongkyun Kim** received the B.S. degree at Kyungpook National University, South Korea and the M.S. and Ph.D. degrees at Seoul National University, South Korea. Currently, he is a professor with the School of Computer Science and Engineering, Kyungpook National University. His research interests are connected cars, vehicular ad hoc networks, IoT, Wi-Fi, Future Internet.