Efficient Data Delivery Protocol using Vehicle Mobility Information in VANETs

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***Abstract*— Vehicular Ad-hoc Networks (VANETs) have been widely recognized as a promising technology to deliver data between vehicles to support various vehicular applications such as safety driving, traffic information sharing, and infotainment service. In the environments of VANETs with a frequent network dynamic feature due to high mobility of vehicles, geographic routing is considered as an attractive approach to send data to a destination vehicle by using only the location information of vehicles. However, mobility of a destination vehicle causes a highly challenging issue for data delivery to it due to its frequent location changes according to its continuous movements. Fortunately, the future trajectory information of a destination vehicle provided by its on-board navigation system can efficiently support data delivery to it. Thus, we propose an efficient data delivery protocol using the trajectory information of a destination vehicle. The proposed protocol decides an optimal location on the trajectory of a destination vehicle by providing an arithmetical model based on a road map information to achieve the cost-minimized data. Then, to deliver data to the optimal location, the proposed protocol sends data through a route determined by considering the moving direction of the target vehicle and the forwarding direction of data. Additionally, the proposed protocol uses a trajectory-based forwarding and a redirection forwarding to cope with trajectory changes of a destination vehicle due to its moving speed and direction changes, respectively. Simulation results show that the proposed protocol is superior to a well-known geographic routing protocol, GPSR.**

***Index Terms*—Vehicular Ad-hoc Network, Mobility support, Trajectory-based, Optimal location, Cost-minimized**

I. INTRODUCTION

With the fast development in ad-hoc wireless communications and vehicular technologies, vehicular ad hoc networks (VANETs) have enabled to deliver data between vehicles through self-organizing vehicle-to-vehicle ad hoc mobile communication networks [1]. Many projects (e.g., VIC'S [2], CarTALK 2000 [3], NoW (Network-on-wheels)) and industry groups (e.g,. the Car2Car communication Consortium [4]) have conducted various researches to provide the intelligent transport system by using VANETs. In the intelligent transport system, VANETs enable to provide drivers and passengers with safety and convenience, and furthermore introduce new applications for entertainment and environment monitoring [5]. Many literatures on VANETs have been addressed various applications such as car accident warning for active safety, emergency vehicle access for public service, road congestion notice for improved driving, and commercial advertisement for business [6, 7, 8].

When VANET applications are examined closely, they need to reflect new paradigm for data delivery in VANETs. Fundamentally, the way of delivering data in VANETs is one source to one destination forwarding using a vehicle and an infrastructure on the road. In order to forward the data to the destination, there are three categories have been researched broadcasting, geocasting and unicasting [9, 10]. Broadcasting is the way of deliver the data to the node which is located within the source node range. This causes a signaling overhead. Geocasting has a similar way of broadcasting which delivers the data to the nodes within a specific area. This also causes a signaling overhead but not more than a broadcasting way. Unicasting is consisted of topology-based and geographic-based. Topology-based unicasting requires the topology information of the nodes in communication areas using resources of the nodes. Geographic-based unicasting only requires the localization information of the nodes. And the three ways which is mentioned above cannot support mobility in real road map scenarios.

Supporting the mobility in VANETs is getting issued in order to respond immediately. All the complicated mechanical devices called add-on devices are in the vehicle and those serve many information to the client and even more in the cloud system. For supporting the mobility of the client vehicle, all the intermediate nodes have to improve their respond time and give the information that client need to know as soon as possible. There are many protocols which support vehicle's mobility previously [11, 12, 13]. However, the protocols already mentioned from the past are not efficiently support the mobility of the vehicle in terms of the tracking location, supporting a recovery mode and others. We focus on the protocol that can support the mobility of the client vehicle using trajectories for better efficiency. All the vehicles have their own trajectories to the destination due to navigation GPS system in the vehicles. The GPS devices can make the data to support all the vehicles can know each other for the data delivery. The point of this is, how to know the trajectory of the other vehicles in order to predict the mobility of the vehicles.

We focus on the prediction of all the vehicles using trajectory

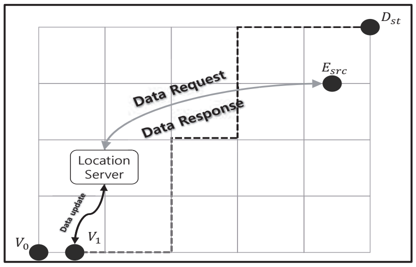

Fig.1. Data exchange scenarios of the proposed protocol

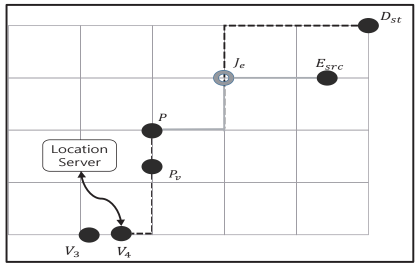

Fig.2. An optimal reception point determination of the proposed protocol

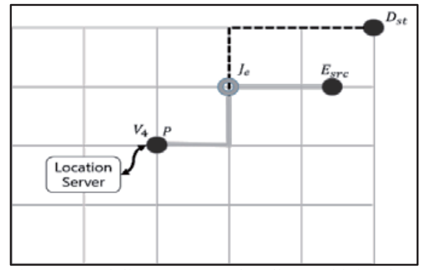

Fig.3. Data delivery way to the client vehicle of the proposed protocol

data in order to support the proposed protocol then set an optimal reception point to deliver the data to the destination vehicle.

Therefore, we proposed an efficient data delivery protocol using vehicle mobility information in VANETs. The proposed protocols support the mobility of the client vehicle. For efficient the proposed protocol reduces the delay time in overall algorithm and proposed mathematical calculations in order to get the optimal reception point for delivering the data to the client. The remainder of this paper is organized as follows. Section II describes our proposed protocol in detail. Performance evaluation is provided through simulation results in Section III. This paper is concluded in Section VI.

II. Proposed Protocol

A. Network Model and Protocol Overview

When the event has happened at the first time, a location server knows a location of a source node that requests the information of the event. This can be possible because of a vehicle's add-on devices. And this location information is always synchronizing for serving the information to the nodes in all the location server's communication area. Immediately after the event has happened, the source node has to generate a path to a client who requests the information of the event. The information from the location server is composed of a location of the event, a destination of the client, a speed of the client, a route of client, arrival time, and others about the client and the source. An existing protocol only generates the shortest path from a source to a client using current roadmap circumstances without additional conditions such as mobility. However, in this case without the mobility of a client, a source cannot deliver data in satisfactorily. Thus, we set improvement focus on supporting mobility in this thesis. In this section, we summarize the overall algorithm in time order. First, t0 is time an event has occurred.

At this time, a location of the event is E and a location of a client's vehicle is V(t0). At the time t0, data has generated and this means the event has also occurred. The vehicle is always synchronizing with a location server and the synchronizing data are composed of a location of the event, a destination of the client, a speed of the client, a route of client, arrival time, and others about the client from vehicle's add-on devices. At time t1 a source which wants to deliver data requests client's data from the location server. At time t2 the source gets responded to the data of the client. At time t3, the source calculates P which is an optimal data reception point with considering road circumstances. At time t4, the data has arrived at the P point. At time t5, the client's vehicle receives the data requested at the first, then the event situation of this algorithm is over. We will describe more detail about a proposed protocol as we mentioned above in time order figures.

Before we explain a process at time t0, we assume a client vehicle synchronize to a location server and the exchanging data with the location server and the client vehicle are vehicle's add-on information. E is a location that an event has happened, the event includes all of the circumstances that the client wants to know such as an accident, a market information and others.

Figure 1 shows data exchange scenarios of the proposed protocol at time **t0** and **t1** for data request and response in order to know all the information of the nodes to forward the data. ***Dst*** is a destination of client vehicle, ***Esrc*** is a location of the event and source, and **V0** is a location of client vehicle at time **t0**. At this time process, all the nodes in the figure they prepare to deliver data. And only the location server is synchronizing to client vehicle for the proposed protocol. At time **t1**, a source request data which is the all of the client vehicle information and road data to the location server in order to generate a path to the client. When the event has happened, at the same time the source requests localization data of client vehicle and respond the data for generating the path to the client and delivering the data.

Figure 2 shows an optimal reception point determination in a proposed protocol scenario at time **t3** and **t4**. The source that gets the data from the location server calculates an optimal data reception point ***P*** using the data. Before we get the point ***P***, we have to get the point ***Pv*** first. ***Pv*** is the point that source can send data to the client as fast as possible without any obstruction. This is an ideal situation. However, in real road circumstances, it is not possible on the actual road to make an ideal movement to the calculated point due to various external factors such as road condition and vehicle condition. Thus, the proposed protocol delivers the data to ***P*** instead of ***Pv***. ***P*** is a point that the next junction of the client vehicle on the destination direction route. The proposed protocol is possible to actively respond to the occurrence of errors according to the factors and efficiently transmit data. We are going to describe more detail of calculating ***P*** point in the next section. At time **t4**, in order to deliver the data to optimal data reception point ***P*** mathematically deducted. The source could use the shortest path to the ***P*** point but we proposed another way. From an efficient data delivery perspective, putting the data on the route that the client follows to the destination as fast as possible then move to ***P*** is more effective in order to handle errors. In this way, that could make a little more delay in overall process, however, the difference is small and if the client vehicle moves faster than the expected time, the data packet which is delivered from the source has a chance to meet the client vehicle while the data are forwarding to the optimal data reception point ***P***. Thus we can reduce the error rates and delay in this process. To progress this, the source has to find Je point which is the closest point in order to forward the data on the client vehicle's destination route.

Figure 3 shows a data delivery way to the client vehicle scenario that the data get reached ***P*** point without any errors and also the client vehicle pass ***P*** point with receiving the data at time **t5**. However, when proceeding in this order of time, there is a possibility that a circumstance that the client vehicle does not arrive at the point ***P*** may occur. The occurrence of such an error circumstances can be categorized into two. First, an occurrence of an error situation due to a variable of a speed of the client vehicle. Second, an occurrence of an error situation due to a variable of client vehicle's moving direction changes. In this article as we mentioned above in time order with figures, we proposed a protocol that has a solution of two error circumstances and can handle the mobility of the client vehicle. Thus, we improve the data delivery ratios in vehicular ad hoc networks (VANETs). In the next section, we describe how we calculate ***P*** point and handle the mobility in detail.

B. Decision of the Optimal Reception Point

The client vehicle moves to the destination. While the client vehicle is moving to the destination, all the add-on devices in the vehicle get localization information and vehicle's information such as a destination, a vehicle's speed, a destination route, arrival time, vehicle's specific spot transit time and others. And, this information is synchronizing with the location server with short intervals. Thus, the location server always keeps updating the client vehicle's data in a communication area and immediately react when an event has happened in order to deliver client vehicle data to a source.

At time **t0**, an event, data delivering circumstance has happened during the time that the client vehicle and the location server are synchronizing. The event point **E** is a source that wants to deliver data to the client. At time **t0**, the source has to calculate an optimal data reception point ***P*** with a vehicle's mobility consideration in order to deliver the data. And, for processing the calculation, the source needs to requests all the materials data to the location server. This requesting time is **t1**, and the time that requesting process is over is **t2**. At time **t3**, the optimal reception point ***P*** has calculated. From an efficient data delivery perspective, putting the data on the route that the client follows to the destination as fast as possible then move to ***P*** is more effective in order to handle errors. The point the data is on the client vehicle's route is **Je**. In this way, that could make a little more delay in overall process, however, the difference is small and if the client vehicle moves faster than the expected time, the data packet which is delivered from the source has a chance to meet the client vehicle while the data are forwarding to the optimal data reception point ***P***.

The reason to have this progress is supporting the mobility of the client vehicle and improve delivery ratios when an error situation has happened due to a variable of a speed of the client vehicle and a variable of client vehicle's moving direction changes. In order to calculate optimal reception point ***P***, ***Pv*** has to be calculated first. ***Pv*** is an ideal rendezvous point between the data from the source and the client vehicle as we mentioned before. We need various data such as a velocity of the data (**Vdata**), the time that the data get reached to ***Pv*** point (**t4-t3**), the distance between the destination and the client vehicle when time **t0** ($\overline{\boldsymbol{V_0DST}}$), the distance between the source and **Je** which is the closest point the data on the client vehicle's route to destination ($\overline{\boldsymbol{J_eDST}}$), the distance ($\overline{\boldsymbol{P_vV_0}}$) and the distance $\overline{\boldsymbol{EJ_e}}$ to calculate ***Pv*** point. The equation is at the below.

$$V_{data} \times (t4 - t3) = \overline{V_0DST} - (\overline{J_eDST} + \overline{P_vV_0}) + \overline{EJ_e}$$

Equation 1. Optimal reception point equation.

we get ***Pv*** point using the equation. However, ***Pv*** is not an optimal reception point. ***Pv*** is calculated in an ideal situation without error circumstances. We have to regulate ***Pv*** point to fit on a real road situation. In figure 2, when ***Pv*** point is placed on the middle of the road, not on junction, the protocol cannot respond the error circumstances flexibly and may occur more overhead to deliver the data when the client vehicle is not at the prediction point. Mostly there are many traffics at junction points then on the roads. That means many data get through at there. Thus, we can actually have many nodes to deliver the packet to the client vehicle and improve the delivery ratios. in order to have those advantages we regulate the optimal reception point ***P*** at the junction points of the road.

C. Data Delivery to The Optimal Reception Point

In order to forward data to the client vehicle has mobility, first, the source has to know the client vehicle's destination. Base on this information, the source can calculate a specific transit spot of the client vehicle. All the information for calculating the optimal reception spot came from the location server that synchronizes with the client vehicle and has localization information of the vehicle by a request and response process.

As an ideal data forwarding process, the source that responds client vehicle's information has to calculate the point ***P*** with consideration of the mobility of the client vehicle at time **t0**. In order to forward the data to the client vehicle, first, the source has to transfer the data to ***P*** point by one-hop sequence on the shortest path. However, if the shortest path is far away from a route that client vehicle uses to the destination when errors have occurred, it takes more delay and may have problems in order to do a reconfiguration process.

In addition, the source has to do a long way reconstruction process to find a client vehicle when the client vehicle off the expected route to the destination. Thus, generating data and forwarding the data to a route that the client vehicle generates to get reached the destination as fast as possible then moving to the

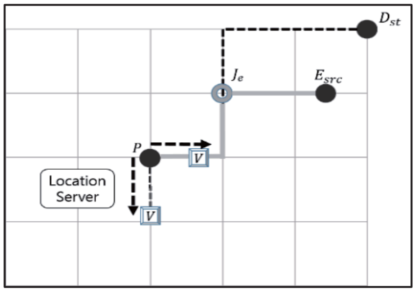

Fig.4. The recovery handling scenario due to the error of the speed of the vehicle

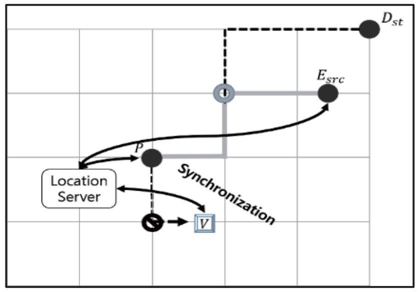

Fig.5. The recovery handling scenario due to the error of the vehicle's direction

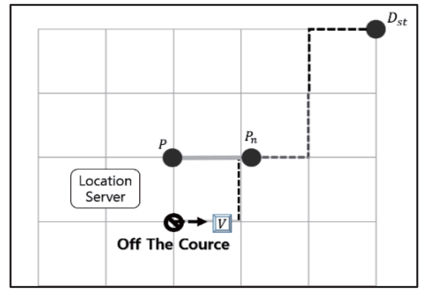

Fig.6. The data delivering way to the new optimal reception point in Fig.5 scenario

optimal reception point improves the delivery ratios as long as the data keeps matching the client vehicle that the source wants to forward while the data is moving on the route to the vehicle's destination. Moreover, this process can reduce the error occurs probability due to a variable of client vehicle's speed.

D. Handling Error Circumstances

1) The error situation due to the speed of the vehicle

There are two factors that error circumstances have occurred due to a client vehicle's speed in the proposed protocol. First, the client vehicle may pass the prediction point because the driver drives the vehicle faster than the average speed limit on a road without off the route. Second, the client vehicle may not get reached the prediction point because the driver drives the vehicle slower than the average speed limit on a road without off the route. The key point of this errors we have to consider to forward the data is, the error circumstances occur due to the vehicle's speed. In other words, there are two error circumstances that the client vehicle passes the optimal reception point *P* which is calculated by the source using the localization add-on devices or does not get reached in time that is from the localization add-on devices.

First, In the error case that situation which client vehicle does not reached the optimal reception point *P*, the data is forwarded from *P* to the client vehicle's location by one-hop forwarding. As figure 4 shows, the direction of the data and the client vehicle is opposite so, in this case, using this way the proposed protocol minimizes delay time when the error has occurred.

Second, in the error case that when the client vehicle already passes *P* point, the data follow the client vehicles route that passed *P* point by one-hop foot print chaining protocol. Moreover, in order to minimize the error occurs probability, the generated data from the source starts matching process after the data is on the destination route of the client vehicle. The matching process is that when the moving data which towards to the *P* point pass every single node which is vehicles, match the vehicles and the data's client vehicle that wants to receive the data. If the data and the client vehicle pass each other, although the data does not reach *P,* the data is received by the client vehicle. Because of this process, the proposed protocol can reduce the error rates in overall.

2) The error situation due to the direction

The causes of the data transmission error caused by the direction are few circumstances. One is that a driver who drives client vehicle offs a route set to a destination. The other is that map data does not match with real map roads so a transmitted data cannot find a way to deliver the data to the client vehicle or cannot find nodes to forward.

While the source in figure 5 delivering the data to an optimal reception point ***P***, if a client vehicle off the route that leads to a destination at the first time, a GPS navigation in the client vehicle re-search a route to the destination. At the same time that the GPS navigation starts re-searching, all the information for calculating optimal reception point is synchronizing with the location server. In addition, location server has to let the source and the data that is already reached ***P*** point or is moving to P know that re-searching to the destination and a route reconfiguration have happened. If the error due to a variable of a direction of the client vehicle has occurred before the data has reached to the optimal reception point, location server lets the source knows this error situation and goes back to the time **t1** and repeats a process from figure 1 to others in time order.

However, if the error due to a variable of a direction of the client vehicle has occurred after the data has passed the optimal reception point, the client vehicle lets the source and the location server know that the vehicle passed. Therefore, instead of recalculating an optimal reception point ***P***, a node has the data and placed at ***P*** does a process of the algorithm at time **t1** so the node implements the data transmission. Figure 6 shows a process after the synchronizing, requesting and responding the data and calculating new ***Pn*** point in order to hand the error situation.

The reason why always the source does not re-transmit data is a delay of overall protocol. The proposed protocol uses the way for delivering the data as we mentioned above in order to minimize the delay due to a distance between the source and ***P***. Moreover, basically, a vehicle's speed is way slower than data speed, the proposed protocol assumes that data arrives at an optimal reception point first. In that case, re-transmit from the source takes more energy and make more delay in overall time

III. PERFORMANCE EVALUATION

In this section, we compare the performance of the proposed protocol and GPSR-footprint chain [14]. We implemented two protocols in NS-3 simulator. First, we describe a simulation model and performance metrics. Second, we compare the performances of the proposed protocol and GPSR-Foot print chain protocol based on the simulation results

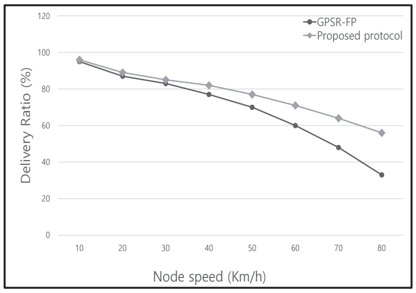

Fig.7. The delivery ratio depends on the node speed

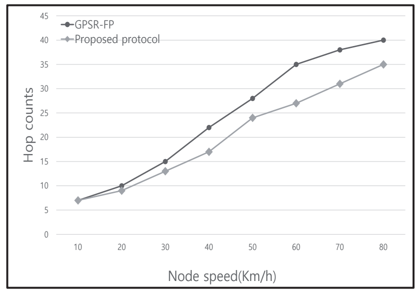

Fig.8. The hop counts depend on the node speed

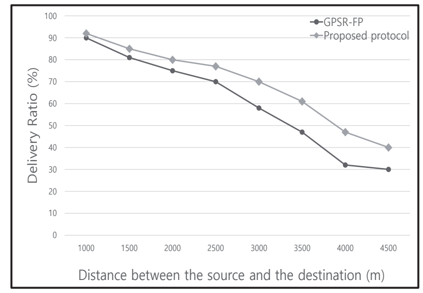

Fig.9. The delivery ratio depends on the distance between the source and the destination

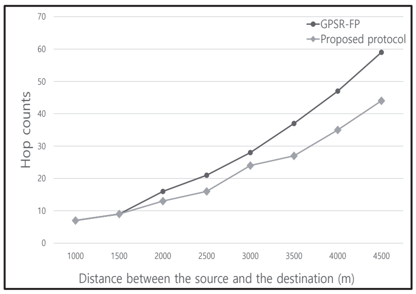

Fig.10. The hop counts depend on the distance between the source and the destination

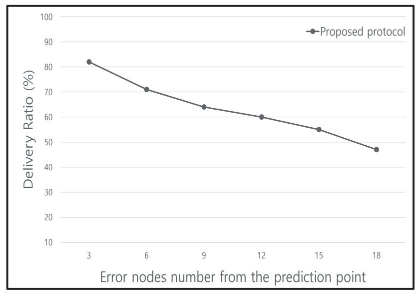

Fig.11. The delivery ratio depends on the error nodes number from the prediction point

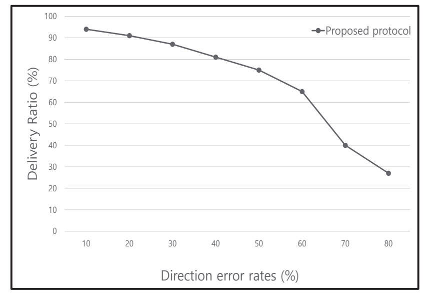

Fig.12. The delivery ratio depends on the direction error rates

A. Simulation Model and Performance Evaluation Metrics

We compare the proposed protocol and GPSR-Foot print chain, respectively using the NS-3 ver.3.23. The simulated network sensor field size is 5000m x 5000m. We set a vehicle node, an event node, a location server, and nodes placed on a road to a client vehicle's destination statically. The sensor nodes are distributed on the sensor field up to 200 nodes depend on the distance between client vehicle and the destination. The sensor device parameters are mostly chosen in reference the MICA specification. However, especially in VANETs does not care about the energy efficiency because almost vehicles have a large battery so we pull out the parameter of the energy efficiency in the evaluation metrics. We use the 802.11 protocol as the MAC protocol and the reference Point Group Model as the mobility model for a mobile vehicle. A node does a role of the client vehicle synchronizes every 1s and updates the client vehicle information. When the event has happened the source node's location is static and communicates with the location server every 1s. The source node calculates a path followed the proposed protocol in order to deliver the data to the client vehicle. If there are no errors, the source node does not reconfigure and generates packets every 0.5s then deliver the packets every 2s to the calculated spot. The overall time of the simulation is 300s. In order to evaluate the proposed protocol, delivery ratio and hop counts in the data transmission are used as evaluation indexes. A delay is defined by overall simulation time from the time the event has happened to the end of the transmission to the client vehicle. A node speed is defined by the client vehicle speed. In the simulation, the node speed does a role of the client vehicle.

B. Simulation Results

Figure 7 shows the delivery ratio depends on the node speed. In VANETs, the vehicle speed influences the delivery ratio. GPSR-Foot print chain protocol is the way of chasing the vestiges of the client vehicle every time without any ways for reducing the delay. Therefore, if the client vehicle's speed is getting faster, the total movement distance also gets increased a lot. The total delivery ratio is affected by this because of those reasons. We can figure out the gap between both protocols when the node speed is over 50km/h. otherwise, the protocol predicts the route of the client vehicle and support the mobility of the vehicle in order to deliver the data with less delay, the proposed protocol has 20% better delivery ratio than GPSR-Foot print chain protocol.

Figure 8 shows the hop counts depends on the node speed. as we mentioned above, the moving distance of the client vehicle gets increased when the client vehicle speed gets increased. GPSR-Foot print protocol has more hop counts than the proposed protocol up to 20% because the GPSR-FP chases all the route that the client vehicle uses on the road. We can get the results that the proposed protocol has better performances in the hop counts depends on the node speed because the proposed protocol calculates the optimal reception point using the synchronization data from the location server. Thus the proposed protocol reduces the delay in overall and the hop counts in order to transmit the data more efficiently.

Figure 9 shows the delivery ratio depends on the distance between the source and the destination. a location of the source is a starting point of the transmission and the destination is the client vehicle's destination which is set on the GPS navigation.

The GPSR-FP protocol is based on the route that client vehicle moves. Therefore, if the destination distance gets increased, the number of nodes participating in transmission also get increased. This makes the delivery ratio get decreased because all of the single nodes does not have 100% delivery ratio. The proposed protocol uses prediction algorithm in a mathematical way. Therefore, even if the distance between the source and the destination get increased, the source calculates the optimal reception point in order to deliver the data to the client vehicle in order to decrease the participating number of the nodes in the transmission. Thus, interference factors to increase the delivery ratio have removed.

Figure 10 shows the hop counts depend on the distance between the source and the destination. As we mentioned in figure 9, the number of the nodes in the transmission get increased when the distance between the source and the destination get increased. Thus the number of the hop counts also get increased. The GPSR-FP protocol is a direct approach that only follows the client vehicle's route in order to deliver the data. So, even if the client vehicle uses a duplicated path, this protocol traces the path. As a result, overheads and the delay occur in the protocol than the proposed protocol. Generally, if we assume the client vehicle does not use the duplicated path to the destination. There is not a big difference in the result. However, after the 3500m distance, the result shows the noticeable difference.

Figure 11 shows the delivery ratio depends on the error nodes number from the prediction point. From figure 7.5 we evaluate only the proposed protocol. The GPSR-FP protocol uses foot print changing way for delivering the data to the client vehicle. There is not a recovery mode in order to handle the error circumstances. However, there are two recovery modes in the proposed protocol. The first is the recovery mode in order to handle an occurrence of an error situation due to a variable of a speed of the client vehicle. The second is the recovery mode in order to handle an occurrence of an error situation due to a variable of client vehicle's moving direction changes. Figure 7.5 is an evaluation of the first recovery mode. Figure 7.5 shows a result of the performance that the delivery ratio depends on how many nodes far from the prediction point. We can figure out when the number of the nodes from the prediction point get increased, the delivery ratio gets decreased. The key point in this figure indicates is that the proposed protocol has an efficient recovery mode because the proposed protocol uses a prediction algorithm in order to reduce the overall overhead

Figure 12 shows the deliver ratio depends on the direction error rates. This figure is about the recovery mode in order to handle an occurrence of an error situation due to a variable of client vehicle's moving direction changes. There are two factors that we called the error due to the direction of the client vehicle. One comes from the negligence of the client and the other comes from the mechanical devices. And those two factors we assume the same errors. There is not a big width of decrease from 10 percent to 50 percent of the error rates. However, we can figure out the big decrease graph after the 60 percent. The reason that this occurs is that when the error conditions overlap, the increase in the number of cases increases in multiples, which leads to a sharp decrease in the transmission rate.

IV. CONCLUSION

We proposed the VANETs protocol that supports the mobility of the client vehicle, which is effective in reducing a delay and improving the transmission delivery ratio in VANET. The proposed protocol has been proposed in two big recovery modes which support the vehicle's mobility that cover the overall situation. We proposed the mathematical way in order to get the optimal reception point for delivering the data efficiently. The mathematical algorithm has verified a various evaluation using the NS-3 simulator. We describe the proposed protocol using the figure that has the node table and all the materials for the client in time order from T0 to T5. The performance of the proposed protocol is evaluated in comparison with the basic GPSR-Footprint protocol. The proposed protocol is more efficient in terms of reducing the delay and improving the transmission delivery ratio in VANETs.

REFERENCES

[1] F. Li and Y. Wang, "Routing in Vehicular Ad Hoc Networks: Survey," IEEE Vehicular Technology Magazine, Vol. 2, No. 2, pp. 12-22, Jun. 2007.
[2] S. Yamada, "The strategy and deployment plan for VICS," IEEE Communication, Vol. 34, No. 10, pp. 94–97, 1996.
[3] D. Reichardt, M. Miglietta, L. Moretti, P. Morsink, and W. Schulz, "Cartalk2000 – safe and comfortable driving based upon inter-vehiclecommunication,"in Proc. of IEEE IV'02. http://www.cartalk2000.net, Jun. 2002, pp. 545–550.
[4] C. Consortium, www.car-2-car.org.
[5] F. Bai and B. Krishnamachari, "Exploiting the Wisdom of the Crowd: Localized, Distributed Information-Centric VANETs," IEEE commun, Mag., vol. 48, no. 5, pp. 138 – 46, May 2010.
[6] E. Schoch, F. Kargl, M. Weber, and T. Leinmuller, "Communication Patterns in VANETs," IEEE Communications Magazine, pp. 119-125, Nov. 2008.
[7] V. Kumar, S. Mishra, and N. Chand, "Applications of VANETs: Present and Future" Communications and Network, 5, pp. 12-15, 2013. No. 2, pp. 148-155, Feb. 2014.
[8] C. Suthaputchakun and Z. Sun, "Routing Protocol in Intervehicle Communications Systems: A Survey," IEEE Communications Magazine, pp. 150-156, Dec. 2011.
[9] S. Panichpapiboon and W. Pattara-atikom, "A Review of Information Dissemination Protocols for Vehicular Ad Hoc Networks," IEEE Communications Surveys & Tutorials, Vol. 14, No. 3, pp. 784-798, 3rdQuarter2012.
[10] J. Bernsen and D. Manivannan, "Unicast Routing Protocols for Vehicular Ad Hoc Network: A Critical Comparison and Classification," Pervasive and Mobile Computing, 5, pp. 1-18, 2009.
[11] R. Chen, W. Jin, and A. Regan, "Broadcasting Safety information in Vehicular Networks: Issues and Approaches," IEEE Network, pp. 20-25, Jan./Feb. 2010.
[12] S. Allal and S. Boudjit, "Geocast Routing Protocols for VANETs: Survey and Guidelines," in Proc. International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing, Jul. 2012.
[13] Jaehoon (Paul) Jeong, Member, IEEE, Shuo Guo, Student Member, IEEE, Yu (Jason) Gu, Member, IEEE, Tian He, Member, IEEE, and David H.C. Du, Fellow, IEEE "Trajectory-Based Data Forwarding for Light-Traffic Vehicular Ad Hoc Networks" IEEE Transactions on parallel and distributed systems, VOL. 22, NO. 5, MAY 2011.
[14] B. Karp and H. T. Kung, "GPSR: greedy perimeter stateless routing for wireless networks," in Proc. ACM MOBICOM, pp. 243–254, Aug. 2000.