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A Spatio-Temporal Geocasting Protocol Using Regional Caching in Vehicular Ad-Hoc Networks

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ABSTRACT

Vehicular Ad-hoc Networks (VANETS) have enabled to provide a variety of applications such as accident notification, content usage, etc. These applications have spatio-temporal data which have an interesting region and a lifetime according to their properties. However, geocasting protocols to deliver data to an interesting region can provide data to all vehicles in the region through a single transmission only at the current time, but cannot provide data to vehicles passing through the region during the lifetime of the data. Thus, we propose a spatio-temporal geocasting protocol called STGP using a regional caching scheme to send data to vehicles in an interesting region during a data lifetime in VANETs. For efficient and reliable regional caching, the proposed protocol uses the beacon-based data sharing, the extra caching elimination, and the distance-based caching exchange. Simulation results verify that the proposed protocol achieves more reliable and efficient data delivery compared with the existing protocol.

Keywords : VEhicular Ad-Hoc Networks, Spatio-Temporal Data, Regional Caching

VANET 망에서 지역적 캐싱을 이용하는 시공간 지오캐스팅 프로토콜

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요 약

차량 애드혹 네트워크(VANETs)은 사고 통지, 콘텐츠 사용 등과 같은 다양한 응용프로그램을 제공할 수 있다. 이러한 응용 프로그램은 속성에 따라 관심영역과 수명을 갖는 시공간 데이터를 가지고 있다. 그러나, 관심 영역에 데이터를 전달하는 지오캐스팅 프로토콜은 현재 시간에만 단일 전송을 통해 영역의 모든 차량에 데이터를 제공할 수 있지만, 데이터의 수명시간 동안 해당 영역을 이동하는 차량에는 데이터를 제공할 수 없다. 따라서 우리는 VANET에서 데이터의 수명시간동안 관심 영역의 차량에 데이터를 전송하기 위해 지역적 캐싱 기법을 사용하는 시공간 지오캐스팅 프로토콜을 제안한다. 효율적이고 신뢰성 있는 지역적 캐싱을 위해서, 제안된 프로토콜은 비콘 기반 데이터 공유, 잔여 캐싱 제거 및 거리 기반 캐싱 교환을 사용한다. 시뮬레이션 결과는 제안된 프로토콜이 기존 프로토콜과 비교하여 보다 안정적이고 효율적인 데이터 전달을 달성하는지를 검증한다.

키워드 : 차량용 애드혹 네트워크, 시공간 정보, 지역적 캐싱

1. 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 environ-

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ment 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].

When VANET applications are examined closely, they need to reflect new paradigm for data delivery in VANETs. The new paradigm requests vehicles to share data about the world surrounding them with each other, and the data have the spartio-temporal property of local relevance such as an interesting region and a lifetime [8]. The interesting region indicates that data have their own spatial scope. For instance, a car accident warning data is only valid to vehicles within 500m from the car accident spot. The lifetime reflects the fact that data have their own temporal scope. For instance, a road congestion notice data may be valid for 30 minutes. For supporting applications with the spatio-temporal data in VANETs, vehicles should self-organize a communication network between them for data sharing and store data regionally for data caching by an efficient and reliable scheme.

Up to now, a lot of researches have been studied for routing data in terms of unicasting, broadcasting, and geocasting in VANETs [9, 10]. However, all of them have considerable communication overheads to support data with an interesting region and a lifetime or cannot support them. Unicasting [11] should identify all vehicles within the interesting region during the lifetime and send data to each of them individually. Broadcasting [12] and geocasting [13] can send data to all vehicles to the whole network and a specific region only at the current time by using global flooding and regional flooding, respectively. However, they have no caching scheme in the interesting region, they should send data to the interesting region during all of the lifetime periodically.

Therefore, we propose a Spatio-Temporal Geocasting Protocol (STGP) using a regional caching scheme to send data to vehicles in an interesting region during a lifetime in VANETs. The proposed protocol sends data in the interesting region by geocasting just once. For efficient and reliable regional caching, the proposed protocol uses the beacon-based data sharing, the extra caching elimination, and the distance-based caching exchange. The beacon-based data sharing is used to send data from a vehicle in the region to new vehicle moving in the region. The extra caching elimination prevents unnecessary caching of vehicles moving out of the interesting region. The distance-based caching exchange replaces caching vehicles to efficiently send caching data to the interest region. Simulation results conducted in various environments demonstrates that the proposed protocol has better performance than a geocasting protocol in terms of the data delivery ratio and the number of transmitted packets by reliable and efficient regional caching.

The remainder of this paper is organized as follows. Section II describes our spatio-temporal geocating protocol in detail. Performance evaluation is provided through simulation results in Section III. This paper is concluded in Section IV.

2. Spatio-Temporal Geocasting Protocol (STGP)

In previous papers, the geocasting schemes in VANETs are proposed to transmit the data only once. These papers do not consider the data lifetime (e.g., accident handling terms, etc.). In VANETs, the data maintenance approach using geocasting protocol for certain period of time in a certain region is to perform the geocasting periodically in several times due to mobility of the vehicles. However, this method is inefficient in terms of data delivery ratio and efficiency. In this section, we propose efficient scheme to maintain the data in the interesting region depending on the movement of the vehicles with a single geocasting. The vehicles use their GPS devices to get their location information. The VANETs can do geographic routing using location service [14]. We describe the proposed algorithm according to the movement of the vehicle as mentioned above in detail.

2.1 Geocasting to Interesting Region

Fig. 1 shows the scheme of transmitting data to the interesting region in VANETs. The source adds local validity and data lifetime in the packet header to maintain data in the interesting region when the data is generated. Then, the source transmits the packet to the interesting region. The vehicles received the packet which is verified the local validity of the packet header to check whether its position is within the interesting region, and compares its position within the interesting region. The first part of the process of this scheme is same with original geocasting scheme, however the way which uses the center point after the packet

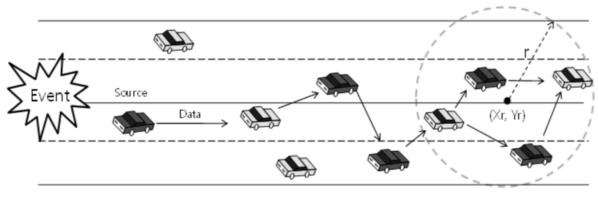

Fig. 1. Geocasting to Interesting Region

goes into the interesting region gets the result of the better performance than original geocasting scheme. The local validity is calculated by equation (1) using the center point (Xr, Yr) of the interesting region, the radius of the interesting region is r and the position of vehicle (Xv, Yv). The equation (1) is as follows:

$$(\mathrm{Xr}-\mathrm{Xv})^2-(\mathrm{Yr}-\mathrm{Yv})^2<\mathrm{r}^2 \qquad (1)$$

If the vehicle compares its position with the interesting region and the vehicle is located at the outside of the interesting region, the vehicle forwards the data to the interesting region. The vehicles received packet that searches its routing table and confirms the information of the interesting region, and then transmits the packet to the vehicles in the direction of the interesting region. If any vehicle exists in the interesting region, the vehicle uses flooding the received data in the interesting region. After the geocasting is completed and data lifetime is over, the vehicles in the interesting region delete the flooded data. If the vehicles get out of the interesting region when the data lifetime is not expired, the vehicles verify its position whether the last vehicle in the interesting region to maintain data in the interesting region. After verifying, if it is the last vehicle, it maintains data in the interesting region using the algorithm in II-C.

2.2 Beacon-based Data Sharing

Conventional geocasting schemes mainly focus on efficient geocasting schemes. Therefore, when a new vehicle is moves in the interesting region, there is a need to maintain data for transmitting data to this new vehicle. To solve this problem, we propose efficient data transmission the scheme to a new vehicle of maintaining data in interesting region and new vehicle moves in the interesting region.

When a new vehicle moves in the interesting region, the new vehicle should be received data from existing vehicles to maintain the data in the interesting region. Fig. 2 shows how a new vehicle is received the data. When a new vehicle sends the beacon signal [15] to the existing vehicle in the interesting region, the existing vehicle in the interesting region receives the beacon signal transmitted by the new vehicle and recognizes the new vehicle. We proposed a different way from the original geocasting protocol which exchanges beacon signal between the new vehicle and the exsisting vehicle to transmit the data even the new vehicle enter the interesting area after the forwarding process is ended. The original geocastng protocol transmits the packet only once to the vehicle until a new packet forwarding set an order.

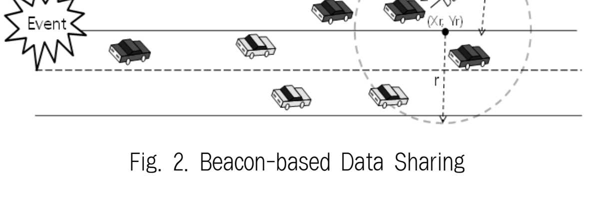

Fig. 2. Beacon-based Data Sharing

Then, the vehicle which is located in the interesting region which recognizes the new vehicle should register the new vehicle in its routing table and confirm whether to transmit data to a new vehicle to maintain data in the interesting region. The existing vehicles identify the data lifetime in the stored in the packet header to determine whether the data should be transmitted to the new vehicle. Also, the existing vehicle determine the delivery of data by calculating the above mentioned equation (1) using the position information of the new vehicle and the information of the interesting region stored in the routing table. If the new vehicle is inside of the interesting region and the data lifetime is sufficient, the existing vehicles in the interesting region transmit the packet to the new vehicle. Therefore, all vehicles can maintain data in the interesting region.

2.3 Extra Caching Elimination

The vehicles in the interesting region can be changed at any time due to the vehicles move freely. That is, the vehicles may go out of the interesting region or the new vehicles may move in the interesting region because the mobility of the vehicle. The existing scheme is to remove the data. Since the required data in the interesting region becomes unnecessary when the vehicles move out of the interesting region.

However, since the new vehicle can move in the interesting region, the data must be maintained during the data lifetime for the new vehicle. Therefore, the vehicles moving out of the interesting region need to store the geocasting data to maintain the data of the interesting region. Thus, when the vehicle moves out of the interesting region, the vehicle identifies itself whether the last vehicle. After that, if the vehicle is the last vehicle, the proposed scheme maintains data during the data lifetime. In the following, we explain how to keep data when the last vehicle is move out of the interesting region.

The data maintenance scheme in the interesting region is shown in Fig. 3. During the time that the data should be maintained, if the vehicle V1 moves out of the interesting region, V1 confirms itself whether the last vehicle in the

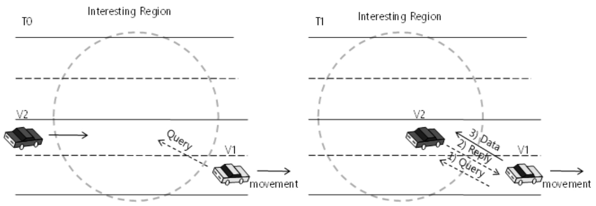

Fig. 3. Extra Caching Elimination

interesting region. The reason for confirming the last vehicle in the interesting region is following. If V1 is the last vehicle, the V1 must transmit the cached data to the interesting region. The V1 recognizes its own moving direction to determine whether it is the last vehicle and periodically transmits the query to the interesting region in the opposite direction. At this time, the V1 transmits the query to the vehicle which is the furthest in the communication range of the V1 among the vehicles on the moving direction of the interesting region. The vehicle received the query recognizes the local validity and data lifetime, and sends a response to vehicle V1 if it exist in the interesting region.

If any vehicle exists in the interesting region, that is, when the vehicle receives a response packet from the vehicle in the interesting region, the vehicle V1 determines that the data is maintained by other vehicles in the interesting region and then it deletes saved data to reduce the overhead for maintaining the data. If any vehicle not exists in the interesting region, that is, when the vehicle V1 does not receive the response packet, the V1 judges that the vehicle is the last vehicle that stores data. Then, the V1 periodically transmits the query to maintain the data in the interesting region. If the vehicle received the query is also located outside the interesting region, the query is transmitted in the direction of the interesting region in the same approach as described above. This process is repeated until the vehicle which is capable of maintaining the data in the interesting region identifies the local validity and sends the response to vehicle V1. When the vehicle V1 receives response, the vehicle V1 transmits the cached data.

2.4 Distance-based Caching Exchange

As described above, the cost of data maintenance and transmission also increases more and more when the vehicle storing data moves away from the interesting region. However, there is a possibility that the vehicle moving closer to the interesting region due to the mobility of the vehicles. We use the vehicles which move closer to the interesting region to solve the problem of vehicles increasingly moving away from the interesting region and increasing data maintenance and transmission costs. The vehicle moving away from the interesting region can forward data to the vehicle moving closer to the interesting region, thus we can make it possible to maintain the data of the interesting region more efficiently. The vehicle moving away from the interesting region can identify the vehicle moving closer to the interesting region by verifying the directionality using the periodic beacon signal informing the location of vehicles. In the following, we explain in detail how to vehicle moving away from the interesting region uses the vehicle closer to the interesting region.

Fig. 4 shows that the vehicle V1 meets the vehicle V3 outside of the interesting region within the data lifetime. If there is no vehicle in the interesting region, the vehicle V1 determines that it is the last vehicle which has moved out of the interesting region, as described in II-C. And then, the V1 forwards the query periodically to maintain data and identify another vehicle in the interesting region. On the move, if the V1 encounters another vehicle V3 while transmitting the query periodically to confirm the other vehicle, the V1 identifies the direction of movement of the V3 to maintain the data in the interesting region more efficiently.

If the moving direction of V3 is the direction approaching the interesting region, the V1 transmits data to the V3 to maintain the data of the interesting region. Since V3 approaches interesting region even if it may enter or not enter the interesting region, data can be maintained by transmitting data to the interesting region. If the moving direction of V3 is away from the interesting region, the V1 ignores the V3 and continuously transmits the query to identify whether the any vehicle exists in the interesting region. If the vehicle exists in the interesting region, the V1 transmits the stored data to the vehicle to maintain the data in interesting region.

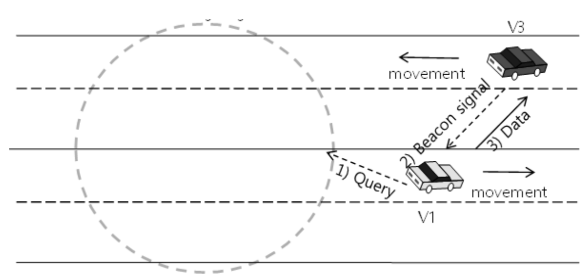

Fig. 4. Distance-based Caching Exvhange

3. Performance Evaluation

In this section, we compare the proposed STGP and the well-known geocasting protocol [16] through simulation. First, we describe the simulation model and performance metric, and second, compare the performance of the two protocols through simulation results.

3.1 Simulation Model and Performance Evaluation Metrics

We compares STGP and the well-known geocasting protocol by operating 1, 2, 3, and 4 times, respectively using the NS-3 ver. 3.23[17]. The simulated network consist of 25 vehicles moving in a highway environment [18]. The vehicles uses a highway mobility model with an average speed of 60km to 80km. The highway is four-lane round-trip road with a length of 2km and a width of 20m. The vehicles are placed at arbitrary location in the lanes with predefined speeds. The default value of the simulation was set to the data lifetime of 10s, the density of vehicles is 80m, and the size of the interesting region with the radius of 100m. the simulation measured the data delivery ratio and the number transmitted of packets as performance evaluation metrics. Additianlly, the original geocasting protocol only process one time to transmit packets. Therefore, in order to compare the proposed scheme which exchanges beacon signal to tranmit the packets even the new vehicle enters the interesting area after the forwarding has finished and the original geocasting only trnasmit once, we set the geocasting protocol actives more than one time compulsory.

3.2 Simulation Results for the Data Delivery Ratio.

Fig. 5 shows the data delivery ratio of STGP and the geocasting protocol according to the lifetime of the data. The geocasting protocol is not much different from STGP because the time to maintain data in interesting region is short if the data lifetime is short. However, if the data lifetime is long, the geocasting protocol must keep the data in the region during data lifetime, so the data must be trasmitted several times and propagated in the region. While data is being transmitted multiple times, the vehicle not be able to receive data due to mobility and exist outside the interesting region pass the region. Therefore, as the data lifetime becomes longer, the data delivery ratio of the geocasting protocol becomes lower due to the mobility of the vehicles. However, STGP has no difference in the data delivery ratio according to data lifetime. As a result, when the data lifetime is 30 seconds in Fig. 5, the data delivery ratio which compares each geocasting protocol is forwards the data at 1,2,3 and 4 times and STGP is 22.5%, 16.9%, 11.2%, and 5.6%, respectively.

Fig. 6 shows the data delivery ratio of the STGP and the geocasting protocol according to the distance between the vehicles. As the distance of the vehicle increases, the data delivery ratio of geocasting protocol decreases, while the data delivery ratio of the STGP does not change. The STGP maintains the data in the interesting region with single data transmission regardless of the interval of the vehicles. However, the geocasting protocol is affected by mobility and interval when transmitting multiple times in order to maintain data in the interesting region, and the data delivery ratio in the interesting region is decreased. When the distance between vehicles is 100m, the data delivery ratio which compares each geocasting protocol is forwards the data at 1, 2, 3 and 4 times and STGP is 26.5%, 21.1%, 15.9% and 10.6%, respectively.

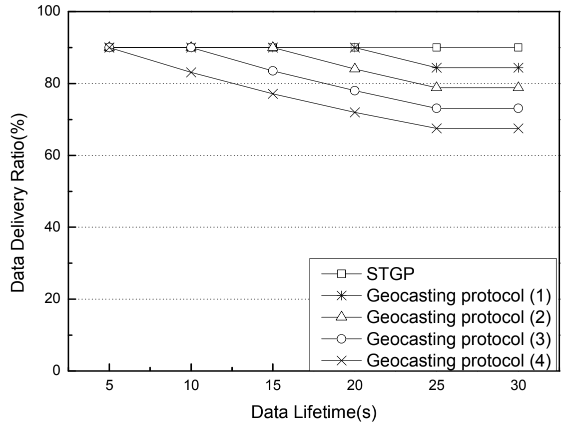

Fig. 5. The Data Deliver Ratio for the Data Lifetime

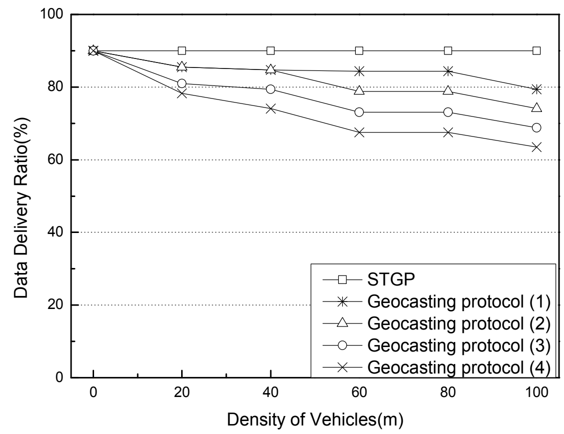

Fig. 6. The Data Deliver Ratio for the Density of Vehivles

Fig. 7 shows the data delivery ratio of the STGP and the geocasting protocol according to the size of the region. The geocasting protocol reduces data delivery ratio as the size of the interesting region becomes smaller, since the number of vehicles receiving and transmitting data is small and the influence of the vehicle mobility increases. However, since STGP solves the maintenance of data in the interesting region without needing to transmit a new data, the data delivery ratio of STGP is constant. When the radius of the interesting region is 100m, the data delivery ratio which

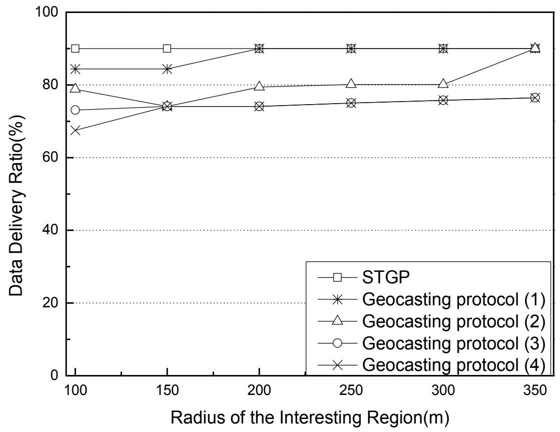

Fig. 7. The Data Deliver Ratio for the Radius of the Interesting Regio

compares each geocasting protocol is forwards the data at 1,2,3 and 4 times and STGP is 22.5%, 16.9%, 11.2% and 5.6%, respectively.

3.3 Simulation Results for the Number of Transmitted Packets

Fig. 8 shows the number of transmitted packets of the geocasting protocol and STGP according to the data lifetime. The number of transmitted packets in geocasting protocol is constant even if the data lifetime becomes longer since there is no data delivery for maintenance after forwarding into the region. Also, the number of transmitted packets increases according to the number of transmissions of the geocasting protocol for maintaining data in the interesting region. On the other hand, since STGP uses the schemes of maintaining data in interesting region after transmission at one time, the number of transmitted packets increases as the data lifetime increases. When the data lifetime is 25s, there is no difference in the data delivery rate between the STGP and the geocasting protocol which implemented 4 times, but there are about 40 packets.

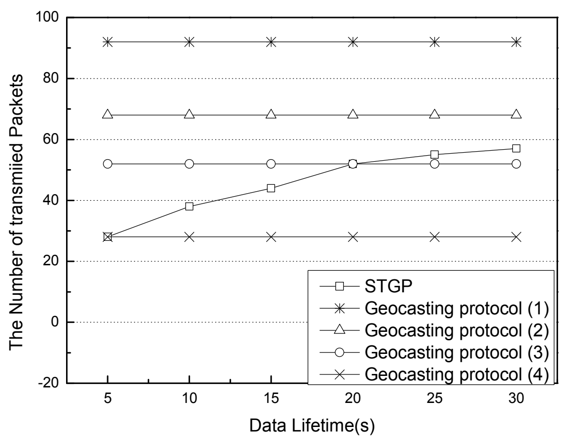

Fig. 8. The Number of Packets for the Data Lifetime

Fig. 9 shows the number of transmitted packets of STGP and geocasting protocol according to distance between vehicles. Since the number of vehicles in the interesting region increases as the distance between the vehicles decreases, the number of transmitted data increases, while the further the distance of the vehicles, the fewer vehicles are in the interesting region, so the smaller the number of data transmitted. Comparing the STGP with the geocasting protocol, the STGP has a similar number of packets than the one transmitted by the geocasting protocol, and comparing the two data delivery ratios, the data delivery ratio increases as the interval of the vehicles, the higher the, but the difference in the number of transmitted packets is very large. This means that the number of packets due to flooding is large. In addition, the STGP is more efficient than geocasting protocol, since it performs flooding once and maintains data in the interesting region.

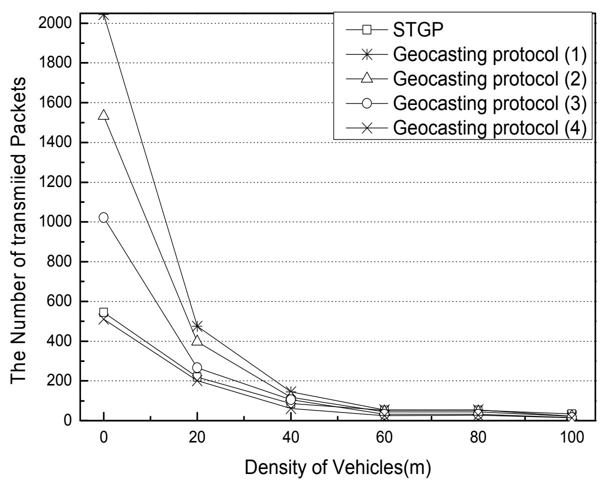

Fig. 9. The Number of Packets for the Density Ofvehivles

Fig. 10 shows the number of transmitted packets of STGP and geocasting protocol according to the size of the interesting region. As the size of the interesting region larger, the number of transmitted packet increases, since the number of vehicles that need to maintain data in the interesting region increases. When comparing the data delivery ratios, there is a slight difference depending on the arrangement of the vehicles, but as the size of the interesting region increases, the data delivery ratio increases. However, in the case of geocasting, the number of packets increases greatly even if the data delivery ratio increases, and STGP has the highest data delivery ratio with the smallest number of packets. Therefore, STGP is more efficient than geocasting protocol.

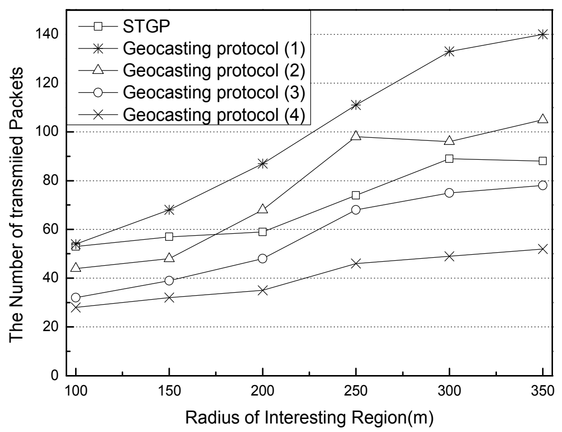

Fig. 10. The Number of Packets for the Radius of the Intersting Region

4. Conclusion

We proposed a protocol called STGP, which is efficient in maintaining data within the interesting region in the VANETs. STGP has been proposed in three approach depending on the situation in the interesting region: the beacon-based data sharing, the extra caching elimination, and the distance-based caching exchange. The beacon-based data sharing approach uses the beacon signal to recognize the new vehicle, and then forwards the data. If there is no vehicle in the interesting region, the extra caching elimination approach is to keep the data of interesting region by detecting the vehicle using the query/response and forwarding the data. When a new vehicle is encountered outside the interesting region, the distance-based caching exchange approach is to forward the data after recognizing the direction of the new vehicle using the beacon signal. The performance of STGP is evaluated in comparison with the basic geocasting protocol. STGP is more efficient in terms of maintaining data in the region than the basic geocasting protocol.

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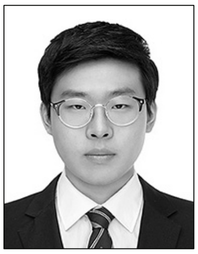

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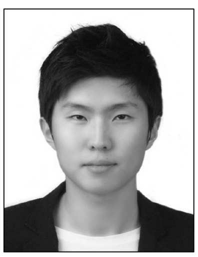

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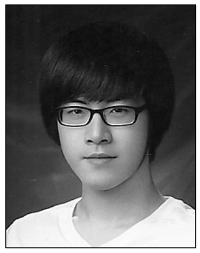

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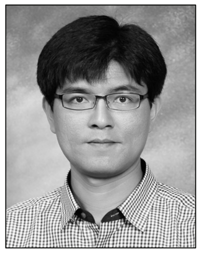

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