

Vehicle Location Service Scheme using the Vehicle Trajectory for VANETs

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Abstract—In vehicular ad-hoc networks (VANET), which has high node mobility, location based routing is more scalable and incurs lower overhead compared to the address based routing protocols. In providing location based routing, vehicle location service, which tracks the location of moving vehicles and provides correct location information of a target vehicle in the VANET, is essential. In recent year, the vehicle location service is researched which reflects characteristic of VANET, i.e., high mobility of the vehicle, a wide moving range and limited moving path along the road layout, however, in existing methods, performance is degraded since location of server is limited to geographical areas. In this paper, we propose the vehicle location service using the vehicle trajectory. Since the location server is moving together with the vehicles receiving the service, geographical proximity between the location server and the vehicles can be maintained while the mapping between the location servers and the vehicles lasts long due to the characteristics of VANET mobility, i.e., majority of the vehicles running on the same road segment move with a similar trajectory maintaining the proximity for a while. Through a simulation, the performance of the proposed mechanism is compared with an existing approach. The simulation results show that the proposed mechanism provides more accurate location discovery service with lower overhead.

Keywords— VANET, location service, vehicle trajectory, mobile group, position-based routing protocol

I. INTRODUCTION

Position-based routing protocols are designed for Vehicular ad-hoc networks (VANET) which has high mobility [1-4]. The location of the target vehicle needs to be found for the position-based routing protocols. In VANETs, the location service tracks the position of moving vehicles and provides proper location information for the target vehicle. The location service management mechanisms proposed for the conventional mobile ad-hoc networks (MANETs) may not be appropriate for VANET due to its inherent characteristics such as high mobility, large-scale movement range, limited moving path following the road layout, etc.

Existing protocols fall into two categories: flooding-based location service and rendezvous-based location service. In flooding-based location service, each node broadcasts its location information to the network, location the source node floods request to find the location of the destination. Since nodes have to flood packets to the whole network, occur

seriously scalability reduction to broad network like VANET. Rendezvous-based location service [5] can be divided into quorum-based and hashing-based approaches, in the former one, each node periodically forwards its location information to a given update quorum, node in the update quorum are location servers. A node forwards location request to the query quorum when it needs location of target node. In the Quorum-based approach, there is trade-off between the number of quorums and the robustness of location service. Also, it is unsuitable for large size VANET due to lack of network expandability. The latter one, hashing-based protocols, the location servers are chosen via a hashing function, in some hashing-based protocols [6], they divide the network into hierarchical grids. Because distance between the vehicle and the location server is not considered during serving mapping, if distance from the sender to the location server is farther than distance from the sender to the destination, the hashing-based protocol will increase the service cost and delay. In addition, in the hierarchical hashing-based protocols, while location update/request is transferred through the chain of each location server, location update/lookup failure probability is increased if mobility of node is high.

The novel region-based protocols such as RLSMP are proposed [7,8]. The network is divided into geographic regions, usually in a hierarchical way. In RLSMP, the entire VANET area is divided into clusters, and the clusters are subdivided further into cells. Fixed location server, called location service cell (LSC), is placed in each cluster, and a location server called a 'cell leader (CL)' is designated at the center of each cell. The CL is in charge of collecting location information of all the vehicles located within its cell, and informs the LSC of the corresponding cluster. The approach has a merit in terms of the geographical proximity of the server and the vehicle locations. The change of mapping between the vehicle and the location server, however, occurs frequently due to the high mobility of vehicles. Since the provision of location server is subjugated to a region of geographical area, the change of location server mapping occurs whenever the vehicle as well as the location server (in case of a mobile server) moves out of the corresponding cell. In order to reduce the location update overhead, RLSMP proposes that the CL to accumulate the location update

information from the vehicles for a certain length of time instead of delivering them immediately to the LSC. Even though it may reduce the location update overhead, it may result in inaccuracy in the location information maintained by LSC.

In this paper, we propose a Location Service using the Vehicle Trajectory (called LSVT) mechanism in which vehicles running nearby are dynamically grouped and one of the vehicles in the group takes the role of location server. Since the location server is moving together with the vehicles receiving the service, depending on similar trajectory, geographical proximity of the location server and the vehicles can be maintained while the mapping between the location servers and the vehicles may last long for the majority of the group.

The rest of this paper is structured as follows. Section II describes the proposed vehicle trajectory based location service mechanism. In Section III, we provide the performance studies of the proposed mechanism, and finally we conclude the paper in Section IV.

II. VEHICLE LOCATION SERVICE USING THE VEHICLE TRAJECTORY

In proposed LSVT, the vehicle becomes 'group leader (GL)' of group which offers location service to vehicles located in the range of broadcast, or has to try to join one of the appropriate groups in the vicinity. For the proposed mechanism, the VANET area is divided into the regions, and each region is provisioned with a fixed location server, called 'region head (RH)'. We assume the location of RH is already known to vehicles. The GL collects and maintains the exact location information of the vehicles in its group. It also periodically reports to the RH about the exact location of itself and group membership. The RH maintains the information reported by the GLs that are located within its region, and replies to the location queries from the member vehicles of those GLs. In order to reply to the location query from a vehicle, the RH contacts the GL of the target vehicle. The proposed LSVT includes the following mechanisms:

1. Location registration and discovery
2. Dynamic group management
 - Group join/leave
 - Group formation/disbandment
 - Group merging process

A. Location Registration and discovery

The GL of each group periodically broadcasts the GL_advertisement message. The range of broadcast for the GL_advertisement message is restricted to a certain number of hops, h , so as to maintain the size of the group as well as the geographical proximity of the GL and the member vehicles to a desired degree. The GL_advertisement message includes the node ID, group ID, moving direction and speed, and location coordinate of the GL and vehicle trajectory, etc. For the member, the GL_advertisement message is used to confirm the existence of the GL so that the group membership status can be maintained in soft state at the member vehicles, i.e., if

a member vehicle does not receive the GL_advertisement message from its current GL for a certain number of times, u , in a row, it determines that the group is no longer available. For the non-member vehicles, the GL_advertisement message is utilized for the group joining purpose: vehicles may find out the available GLs in its vicinity through the GL_advertisement messages.

If a vehicle wants to join the group advertised by a GL, it sends the GL_registration message to the GL. The GL_registration includes the node ID, moving speed and direction, and location coordinate of the member vehicle, etc. While the vehicle remains in the group, the GL_registration is sent to the GL periodically. Since the GL_registration message is sent periodically, the GL may also maintain the membership information of a vehicle in a soft state.

The GL maintains the complete location information, collected from the GL_registration message, for each of the member vehicles in its group. There are three kinds of messages that a GL sends to its RH: RH_registration, RH_deregistration and RH_location_update. When a vehicle is initialized to be the GL of a group or enters a new region, it sends out RH_registration message to the RH of the region, in order to inform its identity and the group that it is in charge of. The RH_registration includes the node ID, group ID, moving direction and speed, and location coordinate of the GL, etc. When a GL disband its group (see section B for the procedure to disband a group) or moves into another region, it sends out RH_deregistration message to the RH where it was previously registered. The RH_location_update message is used in order to periodically update the current location of GL and membership to the RH. In proposed mechanism, information of the vehicle which joins or disbands is contemporarily stored and only changed membership information is transferred to RH, thus updating cost is reduced.

Through the above messages from GL, RH can maintain the mapping of the GL to member vehicles as well as the exact location coordinate for every GL in its region. Based on this information, RH provides replies to the location queries from the vehicles. For a location query, RH first finds out the GL of the target vehicle, and then the RH consults the GL to obtain the exact location information of the target vehicle. If the GL of the target vehicle is not located within its region, inter-region information exchange should occur. Detailed explanation about inter-region communication is referred in our previous work [9]. Figure 1 shows the basic message flows in proposed LSVT.

Vehicle trajectory means moving path between starting to destination position. Moving path consist set of intersections and path between the intersections. Set of the intersections is represented sequence of intersections (for example, 1->2->3->... ->M) or coordination of the intersections. There are a number of choices in representing a trajectory: functional, equational, or parametric representation [10]. LSVT is not depended on vehicle trajectory representation, however, information of intersection coordinates, average vehicle speed v per road segment, and moving direction θ of intersection is mandatory. In the proposed protocol, vehicle is supposed

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sequenceDiagram
    participant GL2
    participant V
    participant GL1
    participant RH_A
    participant RH_B

    RH_A->>GL1: RH_registration
    GL1->>V: GL_advertisement
    V->>GL1: GL_registration
    GL1->>V: GL_advertisement
    V->>GL1: ...
    GL1->>RH_A: RH_membership_update
    RH_A->>V: RH_membership_update
    V->>GL1: GL_registration
    V->>GL1: GL_registration
    V->>GL1: ...
    GL1->>RH_A: RH_membership_update
    RH_A->>V: RH_membership_update
    V->>GL1: ...
    V->>GL1: disband a group
    GL1->>RH_A: GL_deregistration
    RH_A->>RH_B: RH_registration
    RH_B->>RH_A: Ack (assign a group id)
    RH_A->>GL1: RH_deregistration
    GL1->>V: inter-region movement
  
```

express trajectory to the destination from its (or time limit value for trajectory computation or value) to digital map. Trajectory which is set up is translated based on encoding method and TR field of GL_advertisement message. The compare own trajectory and GL's trajectory. is to determine the best group to join among groups by comparing the benefit of each group for the procedure to determine an appropriate

A vehicle entering the VANET has to first try to join one of the appropriate groups in the vicinity. The appropriateness of a group is defined by trajectory similarity. If there is more than one appropriate group, the vehicle has to determine the best group to join among them by comparing the benefit of each group. The benefit of joining a group is defined as the trajectory similarity to GL in case the vehicle joins the group. The trajectory similarity for joining a group is computed according to the algorithm in Table 1 and Formula (1). In the proposed method, moving direction of the vehicle is presented $0^{\circ}\sim 360^{\circ}$ on longitude 0° .

On the other hand, if a vehicle does not hear from the current GL for a while, it assumes that the group is no longer available, and also tries to join another group in its vicinity, if possible. If it cannot find one, it starts a new group on its own. In this case, deregistration notification to the previous GL is impossible, and the group leaving has to be taken care of with the soft state membership status management at the previous GL.

$GL_C(x,y), V_C(x,y)$: Current location coordinate of the GL (vehicle)
 $GL_I(x,y)$: Location coordinate of the next intersection in GL's trajectory
 $V_I(x,y)$: Location coordinate of the next intersection in vehicle's trajectory
 $GL_P(x,y)$: Expected location coordinate of the GL when the vehicle is located at the next intersection in vehicle's trajectory
 $V_P(x,y)$: Expected location coordinate of the vehicle when the GL is located at the next intersection in GL's trajectory
 $GL_S(x,y) = (x_s, y_s)$: location coordinate of the starting point of GL
 $V_S(x,y) = (x_s, y_s)$: location coordinate of the starting point of GL (vehicle)
 D : Distance from $GL_S(x,y)$ to $V_S(x,y)$
 T : Expected sojourn time, T_{MAX} : Maximum expected sojourn time
 $t1$: Moving time from location coordinate of starting point to location coordinate of the next intersection
 $t2$: Moving time when the D is acceptable distance threshold
 $GL_Intersection, V_Intersection$: Flag indicating whether the existence of a next intersection in GL's (vehicle's) trajectory
 (x_{i+t2}, y_{i+t2}) : location coordinate of the vehicle in $t2$ seconds
 (x_{j+t2}, y_{j+t2}) : location coordinate of the GL in $t2$ seconds
 $d_1 = V_v * t2$: Moving distance of the vehicle for $t2$ seconds
 $d_2 = V_{GL} * t2$: Moving distance of the GL for $t2$ seconds
 V_v, V_{GL} : Average speed per road segment in the starting point of the vehicle (GL)
 θ_i, θ_j : Moving direction in the starting point of the vehicle (GL)

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1: Set  $T = 0$ 
2: Set  $GL\_S(x,y) = GL\_C(x,y)$ ,  $V\_S(x,y) = V\_C(x,y)$ 
3: while  $T < T_{MAX}$  do
4:   if  $(GL\_intersection == TRUE \parallel V\_intersection == TRUE)$ 
5:     if ( $t1$  of the GL  $\leq t1$  of the vehicle) then
6:       Set  $GL\_S(x,y) = GL\_I(x,y)$ ,  $V\_S(x,y) = V\_P(x,y)$ 
7:     end if
8:     else
9:       Set  $GL\_S(x,y) = GL\_P(x,y)$ ,  $V\_S(x,y) = V\_I(x,y)$ 
10:    end else
11:    if ( $D \leq acceptable\ distancethreshold$ ) then
12:      Set  $T += t1$ 
13:    end if
14:    else
15:      Compute the  $t2$  then
16:        Set  $T += t2$ 
17:      end of algorithm
18:    end else
19:  end if
20: else
21:   end of algorithm
22: end else

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23: end while

Algorithm 2 for computing the t_2

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24:  $\sqrt{(x_{i+t} - x_{j+t})^2 + (y_{i+t} - y_{j+t})^2} = \text{acceptable distance threshold}$ 
25: if  $0^\circ < \theta_1 || \theta_2 \leq 90^\circ$  then
26:   Set  $(x_{i+t}, y_{i+t}) = (x_i + d_1 * \cos(90^\circ - \theta_1), y_i + d_1 * \sin(90^\circ - \theta_1))$  or
27:   Set  $(x_{j+t}, y_{j+t}) = (x_j + d_2 * \cos(90^\circ - \theta_2), y_j + d_2 * \sin(90^\circ - \theta_2))$ 
28: end if
29: if  $90^\circ < \theta_1 || \theta_2 \leq 180^\circ$  then
30:   Set  $(x_{i+t}, y_{i+t}) = (x_i + d_1 * \cos(\theta_1 - 90^\circ), y_i - d_1 * \sin(\theta_1 - 90^\circ))$  or
31:   Set  $(x_{j+t}, y_{j+t}) = (x_j + d_2 * \cos(\theta_2 - 90^\circ), y_j - d_2 * \sin(\theta_2 - 90^\circ))$ 
32: end if
33: if  $180^\circ < \theta_1 || \theta_2 \leq 270^\circ$  then
34:   Set  $(x_{i+t}, y_{i+t}) = (x_i - d_1 * \cos(270^\circ - \theta_1), y_i - d_1 * \sin(270^\circ - \theta_1))$  or
35:   Set  $(x_{j+t}, y_{j+t}) = (x_j - d_2 * \cos(270^\circ - \theta_2), y_j - d_2 * \sin(270^\circ - \theta_2))$ 
36: end if
37: if  $270^\circ < \theta_1 || \theta_2 \leq 360^\circ$  then
38:   Set  $(x_{i+t}, y_{i+t}) = (x_i - d_1 * \cos(\theta_1 - 270^\circ), y_i + d_1 * \sin(\theta_1 - 270^\circ))$  or
39:   Set  $(x_{j+t}, y_{j+t}) = (x_j - d_2 * \cos(\theta_2 - 270^\circ), y_j + d_2 * \sin(\theta_2 - 270^\circ))$ 
40: end if

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trajectory similarity =

$$\frac{\text{expected sojourn time, } T}{\text{mean speed btw. intersections} * \text{num. of intersections contained in the vehicle trajectory}} * 100 \dots (1)$$

When the vehicle joins VANET network or leaves current group, if the vehicle cannot hear any GL_advertisement message from the appropriate groups for a certain period of time, s seconds, it assumes that no appropriate group is available in the vicinity and initializes itself as the GL of a new group. If sojourn expected time of the vehicle is very short (i.e., trajectory similarity < minimum trajectory similarity) even though the existence of groups in the vicinity, the vehicle should initialize itself as the GL of a new group. The *minimum trajectory similarity* is defined in order to avoid unnecessary group changing. If every vehicle in the group moves to other group, the GL informs the RH of the group disbandment.

If multiple groups exist within a close distance, close enough for the members of the groups to be able to listen to the GL_advertisement of the other groups, combining those groups may help manage the valuable wireless resource in a more efficient way. The LSVT, hence, attempts group merging whenever it is needed, and it is done in a completely distributed way. Purpose of group merging process is minimizing the number of group, which has similar trajectory, including the overlapping regions. A GL's service regions overlapped case (overlapped region $\geq R$) is shown in Fig. 2.

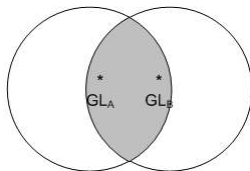


Figure 2 overlapped service regions btw. GLs

The GLs are located close to each other thus a GL can be recognize the existence of other GL by GL_advertisement messages of neighboring GL. Table 2 shows the group merging trigger condition. Location and trajectory of neighboring GL is required to decide group merging.

Table 2 group merging trigger conditions

(distance btw. GLs < threshold_{GLs}) && (trajectory similarity > $x\%$)

Group merging process as follow: Group merging is started verifying group merging triggering condition or notifying group merging trigger from the member vehicle at every group merging interval. If there is group which satisfies group merging trigger condition, GL notifies to member vehicles starting of group merging and group id of merging target GL by GL_gm_notification message. In 'merging' state period, GL broadcasts GL_advertisement message where group merge flag is set then notifies the vehicles within its vicinity that the group is 'merging' state in order to prevent other GL to start merging its group as well as to let the vehicles in the overlapped region attempting to join the merged target GL. After declaring the group merging, GL stays in the 'merging' state for a fixed amount of time, m seconds, which should be larger than the GL_advertisement interval. Each of the member vehicles tries to join merged target GL and notifies the result to the GL. At this point, the member vehicle which didn't receive GL_advertisement message of merged target GL for s seconds (i.e., vehicle doesn't located in merged target GL region) notifies trajectory similarity which is available when GL selects new GL. If all of the group members deregister from the group in m seconds, the GL also attempts to join merged target GL. If the GL also successfully joins merged target group, the GL informs the RH of group disbandment. However, if some member vehicles are left in the group when the "merging" state is over, the GL selects new GL to maintain a certain distance to merged target GL. GL selects a vehicle with distance between it and merged target GL is proximate $2R - \beta$ among member vehicles that satisfy the formula (2). While group merging triggering condition are satisfied, the GL keeps trying the group merging at every periodic interval. The priority of group which tried the last group merging among groups within in vicinity becomes low, hence the oscillation problem, that is, the group merging is repeated by GLs, will resolve itself.

$$2R - \beta \leq \text{distance from the vehicle to the merged target GL} < 2R, \beta \text{ is constant} \dots (2)$$

III. PERFORMANCE EVALUATION

In this chapter, we analyse the performance of the proposed LSVT, and compare it against the RLSMP using OPNET Modeler 14.5 simulator. For the RLSMP, two variants are compared: FRLSMP and MRLSMP. In FRLSMP, it is assumed that a fixed location server is provisioned in each cell, and in MRLSMP, similar to the proposed LSVT, a user vehicle is utilized as the location server for a cell. Note the RLSMP divides the VANET hierarchically, i.e., into the clusters and then cells. In the simulation, the VANET with 36km² area is divided into 4 regions (clusters for the RLSMP) and the fixed location management server is located in each region (cluster). For the RLSMP, each cluster is further subdivided into 25 cells. The road layout contains 100

intersections by placing an intersection in each of the unit space corresponding to the RLSMP cell. By default, 1000 vehicles move in the network, and their movement pattern is determined by a Manhattan Mobility model [11]. The rest of simulation parameters are summarized in Table 3.

Table 3 simulation parameters

Parameter	Value	Parameter	Value
size of VANET	36km ²	simulation time	800secs.
speed of vehicles	6~8m/s	number of vehicles	1000
GL (CL) adv. interval	10secs.	Transmission range of a vehicle	300m
GL (CL) reg. interval	25secs.	RH (LSC) updating interval	30secs.
m	(11+RTT)secs.	s	11secs.
h	1hop	u	3times
trajectory similarity, x	20%	mean speed btw. intersections	85secs.
minimum trajectory similarity, y	10%	group leaving trajectory similarity	5%
distance btw. GLs, $threshold_{GLs}$	230m	acceptable distance threshold	250m
group merging trigger check interval	30secs.	α	75m
β	50m		

* m , s , h , u , α and β are defined in the sections II.A and II.B.

Table 4 describes the messages that are used in the experiment.

Table 4 the type and size of messages

Type	Name	Size (bytes)
GL overhead	GL_advertisement	24
	GL_registration	16
	GL_deregistration	4
	GL_changing	1+14*n
RH overhead	RH_registration	16
	RH_deregistration	4
		8 (added old/new RH addr.)
	RH_membership_update	11+2*n
group merging overhead	RH_registration_ack	4
	GL_gm_notification	4
CL overhead	GL_gm_notification_ack	4
	CL_advertisement	16
	CL_registration	16
	CL_deregistration	4
LSC overhead	LSC_registration	1 + 14*n
		1+2*n (FRLSMP) 11+2*n (MRLSMP)

* n : the number of member vehicles

Table 5 shows the location management overhead, which includes the amount of messages exchanged between the member vehicles and the GL (called GL overhead), and

between the GL and the RH (called RH overhead) and the merging overhead which counts the merging state notification from the GL, the merging trigger notification from member vehicles and the reports on the result of merging from the member vehicles for each merging process, of the three different mechanisms. FRLSMP has the smallest overhead among the three compared mechanisms. FRLSMP is, though, a costly solution which requires the provisioning of location servers as an infrastructure at the cell level. The total location updating overhead of MRLSMP is about 1.8 times of FRLSMP's due to the additional overhead caused by the changes of mobile CLs within a cell (membership transferring overhead between CLs). Also, additional LSC cost occurs due to CL-registration overhead for dynamic management of moving CL. The results show that LSVT could be a very efficient way of exploiting the user vehicles as temporary location servers collecting the local location information.

Table 5 the location service management overhead

mechanisms	FRLSMP	MRLSMP	LSVT (tr=4)	LSVT (tr=3)	LSVT (tr=2)
GL(CL) overhead	577259	1017230	888042	791603	717526
RH(LSC) overhead	29240	117375	144943	25113	23741
merging overhead	-	-	24395	173506	160932
total overhead (bytes)	606499	1134605	1059131	990222	902199

Table 6 shows the service disruption and the accuracy of the location service of the three mechanisms. The accuracy is measure as the ratio of queries which received the reply containing the correct location to the entire queries. The query about any 100 vehicles is issued every 30~50sec during simulation time. In RLSMP, if the location of a vehicle changes from one cell to another in the middle of an LSC updating interval, the service disruption will occur. At this point, the location discovery service will fail to give correct reply to the query looking for that vehicle. In MRLSMP, the empty cell which doesn't have CL can be existed due to mobile CLs thus the service disruption time is longer than other mechanism as well as number of service disruption is increased. In the experiment, 110 empty cells are occurred. On the other hand, if the vehicle doesn't receive CL_advertisement message for a certain period of time, s seconds, after cell changing, the vehicle initializes itself as the CL of a new cell, and therefore service disruption time per node is smaller than FRLSMP. The dynamic management cost of the CL, however, is increased. LSVT, like RLSMP, if the location of a vehicle changes from one group to another in the middle of an RH updating interval, the service disruption will occur. LSVT, however, has smaller service disruption time than RLSMP because the GL is moving together with the member vehicle thus membership changing is reduced. If a member vehicle does not receive the GL_advertisement from its current GL for a certain number of times, u , in a row, the member vehicle determines that service disruption is occurred.

The average service disruption time of LSVT, also, is short compared to MRLSMP. The location discovery accuracy, therefore, is better due to less number of service disruptions. As a result, the LSVT can provide a lot higher accuracy in the location discovery service than the RLSMP mechanisms.

Table 6 the service disruption and the location discovery accuracy

mechanisms	FRLSMP	MRLSMP	LSVT ($\kappa=20$)
average service disruption time per node	178.3	149.7	41.6
maximum service disruption time	51.9	147.2	60.2
total no. of service disruption	6466.3	7546.8	1038.3
accuracy (%)	78.1	80.3	92.0

IV. CONCLUSIONS

We proposed a vehicle location service mechanism using the vehicle trajectory. In the proposed mechanism, vehicles have the similar trajectory dynamically form a group, and one of the vehicles in the group serves as the location server. The regional proximity and the mapping relationship between the vehicles and the location server are maintained without causing trade-off between them. We proposed the vehicle trajectory representation and its utilizing process, and trajectory similarity computation algorithm. A dynamic group merging process, also, is defined to improve the performance of proposed mechanism. Through simulation, we verified that the proposed mechanism provides the more accurate location discovery service with the lower overhead than an existing approach.

ACKNOWLEDGMENT

"This research was supported by the MKE (The Ministry of Knowledge Economy), Korea, under the ITRC(Information Technology Research Center) support program supervised by the NIPA (National IT Industry Promotion Agency) (NIPA-2011-(C1090-1111-0013))."

"This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(2011-0012370)"

"The work was supported by the Ewha Global Top 5 Grant 2011 of Ewha Womans University"

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