

Adaptive Distance Filter-based Traffic Reduction for Mobile Grid*

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Abstract

The mobile grid introduces various research challenges distinguished from existing grid computing systems. They are low bandwidth, low processing power, low battery capacity, frequent disconnectivity, and mobility. Mobility of the grid node increases the system load of the mobile grid in a constrained operating environment by increasing the number of communication messages required to confirm the location between the grid broker and mobile grid node. Therefore, this paper proposes an adaptive distance filter that can effectively reduce communication traffic between the mobile grid node and grid broker. This filter constructs clusters based on the mobility and velocity of the grid node and filters the location updates. However, the reduction of location updates generates location errors, which occur when the grid broker cannot acquire the exact location of mobile nodes. To solve this problem, if the location updates are filtered, the grid broker can estimate the location of the mobile node using a statistical estimation method. For the performance evaluation of the adaptive distance filter, we modeled the mobility of the grid nodes. We then measured the reduction in location updates and location errors. In these experiments, we prove that the adaptive distance filter is an effective scheme for reducing location updates and the grid broker can reduce location errors through location estimation.

1. Introduction

Recently, grid computing has rapidly developed and is becoming the new paradigm of distributed systems. Grid computing, which enables the sharing of geographically distributed and unlimited amounts of heterogeneous resources, is resolving computation-intensive problems in the science and business fields that supercomputing technology was unable to [1-2]. Grid computing is designed and implemented to en-

hance wired network desktops or workstations. Wired network-based computing resources have no mobility (static) but guarantee reliable network connectivity. Integration between the grid and mobile computing known as the "Mobile Grid," is becoming the new research issue due to the rapid development of radio communications and mobile computing technology. However, to integrate mobile devices with the Grid, mobile devices face some constrained conditions. Specifically, mobile devices experience low bandwidth, low processing power, low battery capacity, frequent disconnectivity, and relocation issues [3-9]. These constrained conditions are improving with the development of mobile technology. However, the technology is still insufficient when it comes to integrating mobile devices as part of the shared resources of a Grid. Mobile devices can change their location at any time. The grid broker must know the location of mobile devices in order to use mobile devices as a part of grid resources. Thus, frequent communication between the grid broker and mobile devices is required. As frequent location changes of the MN (Mobile Node) occur, frequent communication between the grid broker and MN is needed. This operation increases the system load of the mobile grid in a limited bandwidth environment. Therefore, a tradeoff between a reduction of communication traffic and the precise location accuracy of the MN is needed in the mobile grid due to the limited operating environment of the MN.

This paper proposes a communication reduction scheme between the grid broker and mobile devices in the mobile grid. This method decreases communication traffic, which occurs while the grid broker is trying to locate the MN, by using an Adaptive Distance Filter (ADF). This ADF is based on the MN's moving distance. The ADF classifies the MN into suitable clusters based on its mobility pattern and velocity and then filters LU (Location Update) of the mobile devices. Thus, the ADF reduces communication traffic between mobile devices and the grid broker. The reduction of

* This research was supported by the MIC(Ministry of Information and Communication), Korea, under the ITRC(Information Technology Research Center) support program supervised by the IITA(Institute of Information Technology Assessment)

LUs can enable mobile devices with constrained network conditions to use their resources more effectively. However, the reduction of LUs generates location error, because the grid broker cannot acquire the MN's precise location. Therefore, this paper introduces an algorithm to estimate location of the MN when LUs are filtered. This method reduces location errors generated from the reduction in LUs. For performance evaluation of the ADF, we developed the HLA-based distributed simulation system to simulate the mobile grid environment. To simulate practically, we modeled the movement of the mobile grid node using a real university campus. We conducted two experiments. The first experiment measured the number of transmitted LUs between the MN and grid broker, and the second experiment measured location errors by using the ADF.

2. Related Work

There have been various studies on the mobile grid. Current Grid is optimized to share stable resources with reliable network connectivity. However, mobile devices have some limitations when used as grid resources because of constrained performance and the operating environment. However wireless Internet connection technologies like WiMAX and HSDPA continue to develop as mobile technology markets like PDAs, laptops, and cell phones expand their size every year. As a result of this market growth and innovation in wireless technology, environments are being created for high-performance devices to be connected to the Internet anytime and anywhere. Therefore, integration between mobile device and grid computing has become inevitable. In addition to mobile computing, there is research being conducted concerning the integration of sensor networks, ad-hoc networks, and various mobile technologies with Grid, which is called the "Wireless Grid" [3]. Ahuja and Myers [3] divided wireless grid research into three categories: the sensor network grid, mobile wireless grid, and fixed wireless grid. Among these, the mobile grid is in the second category, the mobile wireless grid. We can further classify the mobile grid into the following three big categories.

- Proxy-based architecture to combine mobile devices with existing grid infrastructure
- Expansion of existing grid middleware to provide services for mobile devices
- Mobile grid research using mobile agents

First, taking a look at research that is related to proxy-based architectures, Phan and et al [4] insisted on the necessity for integration between mobile de-

vices and grid computing and proposed the proxy-based clustered architecture. Hwang and Aravamudham [5] suggested a scalable proxy-based middleware architecture that can integrate mobile devices into the existing Grid. Also, there are many research studies in progress focused on making existing grid platforms support mobile devices. The Condor grid [6] suggests the hierarchical access layer interoperate with various handheld devices. In addition, the Legion grid architecture [7] has designed middleware that can interoperate with mobile devices. OGSINET has been conducting research to expand itself to the mobile OGSINET [8]. This research has expanded the system domain of the existing OGSINET to mobile devices and guaranteed interoperability between mobile devices and existing grid, while solving the resource limitation and disconnection problem of mobile devices. Mobile grid research using mobile agents [9] focuses on mobility of users. The mobility issue is one of the research challenges in mobile grid research. To solve the mobility problem of the user, this research has used mobile agent and proposed mobile agent-based solutions to access grid services. Complete integration between the Grid infrastructure and mobile device has yet to reach the level of perfection, but with the rapid development of mobile computing technology and the research being actively conducted, it is expected that integration between these computing technologies will reach that level in the near future.

3. Adaptive Distance Filter-based Traffic Reduction

In this section, we will describe the ADF-based communication traffic reduction scheme. First of all, the ADF classifies MNs into similar groups and creates MN clusters. Each MN has its own movement velocity and direction called the mobility pattern. Thus, we will model the mobility of MNs on a real experiment site in section 3.1. Then, in section 3.2, we will describe the ADF which creates MN clusters according to the mobility pattern of MNs and reduces communication traffic using the distance filter. However, the reduction of communication traffic using the ADF generates location errors in the filtering process. Thus, we will discuss the location estimation in section 3.3 and location estimation can revise the filtered location of a MN and reduce location errors when location generated.

3.1. Modeling of Mobile Nodes in Mobile Grid

MNs in a mobile grid are geographically distributed and have their own peculiar mobility pattern. The mobile grid should perform collaborative work to solve

computation-intensive problems using the shared resources of the MNs. For this work, the grid broker must know the location of the MNs, which move frequently. If a MN relocates, the MN transmits a LU to the grid broker in order to inform it of the change in its location. However, this operation decreases system performance by increasing mobile communication traffic. Therefore, communication traffic must be decreased by executing a LU that is appropriate for the respective moving pattern of the MN by observing the moving pattern of the MN in the mobile grid. MNs in the mobile grid have their own mobility pattern in accordance with the type of mobile device and intention and situation of the users. This research modeled the mobility of the MN based on a real university campus. The mobile devices used were limited to a laptop, PDA and cell phone.

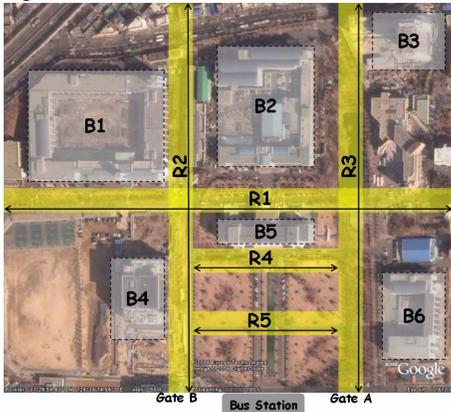


Figure 1. Map of a university campus from the Google Earth™

Figure 1 shows the experiment site at the university campus obtained by Google Earth™. *R* is the road and *B* is the building. Almost every MN in the university uses 5 roads and 6 buildings expressed in Figure 1. Cellular network services are provided for the roads and buildings within the campus, and wireless Internet access is provided for 6 buildings. In total 11 regions provide access to the mobile grid. We will look further into the mobility pattern of the MNs in the real university campus in the following scenario.

Tom is an undergraduate student. He gets off the bus at 9 o'clock every morning, and the bus station is located somewhere between gate A and gate B, which are located on the south-side of the campus. The first thing he does when he comes to school is find a seat in the library (B4). (1) He goes to library (B4) by passing through gate B and R2. (2) He studies in the library for 1 hour. (3) Then, he goes through R5 and arrives at B6 in order to attend class. (4) He attends a class for 2 hours. (5) After class, he comes back to the library (B4) by passing through the R5. (6) He studied for 90 minutes in the library. (7) And he takes a 30-minute recess for eating a coffee and talking with his friend. During this break,

he moved his location slowly and randomly. (8) After a 30-minute break, for a chemistry experiment, he goes to B3 by passing through R2, R1 and R3. (9) In B3, he walks through the hallway and entered the laboratory. (10) In the laboratory, he conducts an experiment for 3 hours and he moved here and there in the lab in order to use the equipment. (11) After the experiment, he goes to the bus station, passing through R4 and gate A in order to work at a part-time job.

This example shows the daily task of an undergraduate student, and includes 12 cases of movement. We will take a look at the moving patterns of Tom in the each case.

- (1) Tom moves toward a destination. Movement velocity and direction are normal.
- (2) Tom does not move (stop) for 1 hour.
- (3) Tom moves toward a destination. Movement velocity and direction are normal.
- (4) Tom does not move (stop) for 2 hours.
- (5) Tom moves toward a destination. Movement velocity and direction are normal.
- (6) Tom does not move (stop) for 90 minutes.
- (7) Tom moves randomly for 30 minutes.
- (8) Tom moves toward a destination. Movement velocity and direction are relatively normal. But, twice changes of direction occur where A is at the crossroads between R2 and R1 and between R1 and R3.
- (9) In the building, Tom moves toward a destination with continuous velocity. But, some changes in direction occur in accordance with the structure of the hallway.
- (10) Tom moves randomly for 3 hours.
- (11) Tom moves toward a destination. Movement velocity and direction are normal.

If we generalize all 11 cases of Tom's movement, the following three mobility patterns are evident.

1. *Stop State (SS)* – Case (2), (4), and (6) are stop states which means “no movement.”
2. *Random Movement State (RMS)* – Case (7) and (10) are RMS, which means “moves randomly.”
3. *Linear Movement State (LMS)* – LMS means “movement with destination.” LMS can be classified into 2 types of subsets. One is the case where the movement velocity and direction are normal from the start to end point such as cases (1), (3), (5), and (11). A second is the destination is determined but a change of direction occurs. Generally, the change of direction occurs at an intersection. In this case, beside the intersection, and Tom's velocity and direction are at a uniform rate, so it is a different type of LMS.

Also, when you look at the distribution of Tom's mobility pattern based on region, you can see that he

has shown a LMS pattern on the roads and SS, RMS, and LMS patterns inside of buildings.

3.2. Adaptive Distance Filter

3.2.1. Classification and Clustering of Mobile User

An ADF creates MN clusters according to the mobility pattern of a MN, which is described in previous section, and filters LUs between the MN and grid broker by using a Distance Filter (DF). The process of making a MN cluster is composed of two steps: classification of the MN's mobility pattern and cluster construction according to the MN's mobility pattern.

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//  $V_{mn}$  : Velocity of MN
//  $V_{walk}$  : Maximum of Walking Velocity
//  $MP_{mn}$  : Mobility Pattern of MN
//  $D_{mn}$  : Direction of MN
If ( $V_{mn} == 0$ ) then
     $MP \leftarrow Stop$ 
Elseif ( $V_{mn} > 0$ ) then
    If ( $V_{mn} > V_{walk}$ ) then
        // MN is running or using vehicle
         $MP_{mn} \leftarrow Linear\ Movement$ 
    Elseif ( $V_{mn} \leq V_{walk}$ ) then
        // MN is walking
        If ( $V_{mn}$  and  $D_{mn}$  are constant) then
             $MP_{mn} \leftarrow Linear\ Movement$ 
        Elseif ( $V_{mn}$  or  $D_{mn}$  change are frequent) then
             $MP_{mn} \leftarrow Random\ Movement$ 
        Endif
    Endif
Endif

```

Figure.2 The mobility pattern classification algorithm

The algorithm of the mobility pattern classification is as follows and shown in Figure 2.

1. ADF measures the moving velocity of MN (V_{mn}) – If V_{mn} is greater than 0, then MN is in the movement state (RMS or LMS). On the other hand, if V_{mn} is equal to 0, then MN is in a stop state (SS).
2. If V_{mn} is faster than V_{walk} (maximum of walking velocity), then MN is either running or moving by vehicle. Thus, the state of MN is LMS. If V_{mn} is slower than V_{walk} , then MN is walking toward his destination or is moving randomly.
3. In $0 < V_{mn} \leq V_{walk}$, if MN changes its velocity or direction frequently, then the state of MN is RMS. On the other hand, if the velocity and direction are regular, then the state of MN is LMS.

After the first classification, the ADF constructs MN clusters through the execution of the second step. In the second step, in order to make MN clusters, the ADF uses sequential clustering [10]. The sequential clustering is executed for every the MN except MN in the SS and the process of sequential clustering is composed of the following two steps.

1. *Velocity/Direction Measurement* – measures the moving velocity/direction of MNs and calculates the similarity difference ($d(MN, C)$) between existing clusters (C).
2. *Cluster Construction* - In this stage, the system sets the minimum difference in velocity (α), which represents the similarity boundary between the MN and C . And the system compares $d(MN, C)$ with minimum difference in velocity. If $d(MN, C)$ is less than α , then MN is contained in C . But, If $d(MN, C)$ is more than α , then a new cluster is created.

Classification and clustering of MNs are repeatedly executed, because a MN's mobility pattern can be changed.

3.2.2. Distance Filter

After construction of MN clusters, the ADF filters LUs by using a Distance Filter (DF), and reduces the communication traffic of the mobile grid. We used the DF to filter LUs in accordance with change in the MN's location. This DF is based on the moving distance of the MN. The general DF is a simple method for LU reduction and uses a predefined DTH (Distance Threshold). The DF applies the same size of DTH to all of the MNs.

The ADF uses the MN clusters based on the MN's mobility pattern and velocity. The general DF decides the size of the DTH based on the average moving distance of the MN and uses the chosen DTH for filtering LUs and reducing communication traffic. In this case, the DTH size can be decided on based on the moving velocity of all the MNs, and the DTH size can be large for some MNs and vice versa.

The use of an unsuitable DTH will fail to reduce communication traffic effectively. Hence, if the ADF uses suitable DTH with clustered MNs with a similar moving pattern and velocity, it can reduce communication traffic more effectively than the general DF.

3.3. Location Estimation

An ADF effectively reduces communication traffic between the MNs and grid broker in a mobile grid. However, the reduction of communication traffic by the ADF leads to the occurrence of location errors be-

cause the grid broker cannot acquire the pinpoint location of MN. However, the grid broker can estimate the location of the MN when LUs are filtered.

Generally, ARIMA [11] and exponential smoothing [12] are used for estimating the locations of moving entities. ARIMA can estimate precisely, but it needs a massive dataset to estimate and it is hard to update parameters. Therefore, we estimate the location of MNs using Brown's double exponential smoothing method [12], because exponential smoothing can make estimation easy and convenient to use. Moreover, it is suitable for estimating moving patterns such as the travel path of moving entities.

To estimate a MN's location, the estimated velocity and direction can be calculated using double exponential smoothing and we can obtain the next coordinates of x and y by using trigonometric function. The difference between MN's the estimated location and real location is an estimation error.

3.4. Design of the Adaptive Distance Filter

We designed and developed a distributed simulation environment for a mobile grid. Figure 3 shows the system architecture of the mobile grid with an ADF. This system is divided into two parts: the Grid infrastructure and mobile computing infrastructure. The Grid infrastructure is an existing grid environment connected into wired networks and has a grid broker which manages various grid resources. The mobile computing infrastructure has MNs, wireless gateways, and an ADF. The MN is the end user of the mobile and wireless computing system and is connected to the cellular network or wireless Internet. The wireless gateway means base stations and APs.

MN (Mobile Node) – The MN is the end user of the mobile grid and uses cell phones, PDAs, or laptops which can all access the wireless Internet. MNs are connected by a wireless gateway, like a base station or AP. If the MN moves to another location, then MN should transmit its location to the wireless gateway. The wireless gateway collects the incoming location information and transmits this information to the ADF.

Adaptive Distance Filter – The ADF receives the LU of the MN from the wireless gateway to compare the moving distance of MN with the DTH (Distance Threshold) for the reduction of LUs. To decide on the suitable DTH for MNs, the ADF has a mobility classifier, which classifies the MNs into several clusters according to the MN's moving pattern and velocity. Moreover, the ADF has a cluster manager which constructs, manages, and adjusts the MN clusters.

Grid Broker – The grid broker has the location DB and location estimator. The location DB stores the location information of the MN and the location estima-

tor predicts the MN's location when the LU is filtered. The grid broker receives the filtered location information from the ADF. If the LUs of the MN are received, then the grid broker stores this information to the location DB. On the other hand, if the LUs are filtered, the grid broker uses the location estimator to predict the location of the MN and the grid broker stores an estimated location of the MN to the location DB.

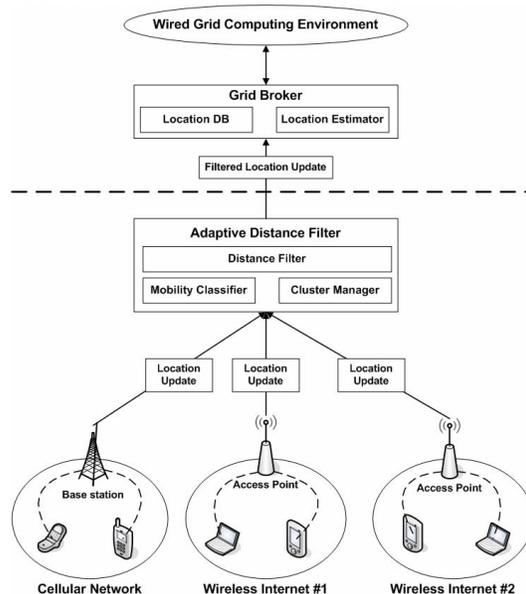


Figure 3. The system architecture of the mobile grid with ADF

The operation of the mobile grid with the ADF is composed of two processes: the ADF process and the grid broker process. The ADF process consists of the following six steps.

- (1) Initial recognition of the MN's mobility pattern and velocity
- (2) Initial construction of MN clusters
- (3) MN's location acquisition
- (4) Filtering by the DF
- (5) Transmission of LUs to the grid broker
- (6) Reconstruction of the MN clusters

As we described in section 3.2, the ADF recognizes the MN's mobility pattern and velocity. Then, the ADF constructs MN clusters based on classified information. The ADF acquires the MN's location information and compares the MN's moving distance with DTH of the DF. If the MN's moving distance is shorter than the DTH, the ADF filters the MN's LU. On the other hand, if the MN's moving distance is longer than the DTH, then the ADF transmits the LU to the grid broker. The ADF must adjust and reconstruct the MN's cluster, because change in the MN's mobility pattern or velocity is possible. Among the above steps, steps (1) and

(2) are only executed once while the rests of the steps are repeatedly executed.

On the grid broker side, the grid broker waits for the LU from the ADF. If the grid broker receives the LU from the ADF, this location information is stored in the location DB in the grid broker. On the other hand, if the grid broker does not receive the LU, then the grid broker estimates the location of the MN by using the location estimator and stores the estimated location of the MN to the location DB.

In this paper, we used the HLA specification ver1.3 [13] to design and develop the distributed simulation system for the mobile grid with an ADF. The HLA was developed for use in the effective development of a distributed simulation by the US DoD. The main reason for using HLA to simulate this mobile grid system is because simulation entities in a distributed simulation have a high mobility and HLA was developed for the effective communication of messages among objects that have a high mobility. Therefore, the features of HLA could be effectively applied to the mobile grid for real world MNs.

4 Experiments and Results

For the performance evaluation of the ADF, we used 140 MNs during a period of 1800 seconds (30 min.) and measured the reduction of in LUs and location errors according to the movement of the MN in a university campus. As shown in Figure 1, we divided the university into 11 regions (6 buildings and 5 roads). As we described in section 3.1, the LMS-type MNs are on the roads and SS-, RMS-, and LMS-type MNs are in the buildings. In this experiment, we assigned 5 MNs to each mobility pattern. The MNs on the road are divided into two types of MNs: human type of MN and vehicle type of MN. Thus, we assigned 5 human-type MNs and 5 vehicle-type MNs to the road. Therefore, the single road has 10 MNs (5 human-type MNs and 5 vehicle-type MNs). There are 50 MNs in total on the 5 roads. We assigned 5 MNs of the SS, 5 MNs of the RMS, and 5 MNs of the LMS mobility patterns to the buildings, because the buildings have only the human-type of MNs. There are 90 MNs in 6 buildings. Thus, a total of 140 MNs are used in this experiment and each MN was given a suitable velocity and mobility pattern, depending on its region, as shown in table 1.

The velocity range was set as 1~4 m/s, since there can be users either running or walking for the human-type MNs on the road. For the MNs moving by vehicle, their velocity was set between running velocity and 40km/h. The MNs with SS inside of the buildings have a moving velocity of 0. 0.5~1.5m/s which was set as the velocity of the MNs with LMS by considering their

walking velocity. The velocity of the RMS in the buildings was set between SS and LMS.

Table 1. Specification of MN used in experiments. (R: Region, MP: Mobility Pattern, VR: Velocity Range)

R	# of R	MP	MN Type	# of MN	VR
Road	5	LMS	Human	25	1~4m/s
			Vehicle	25	4~10m/s
Building	6	SS	Human	30	0m/s
		RMS	Human	30	0~1m/s
		LMS	Human	30	0.5~1.5m/s

4.1. Number of Location Updates

We have measured the change in the number of LUs by using the ADF. In this experiment, we have compared the ADF with the ideal LU, which is the LU without the DF. Sizes of the DTH (Distance Threshold) are decided on based on the average velocity of the MNs and $1.25 \cdot av$ (average velocity), $1.0 \cdot av$, $0.75 \cdot av$ of DTH are used. Figure 4 shows the transmitted number of LUs per second categorized by DTH size.

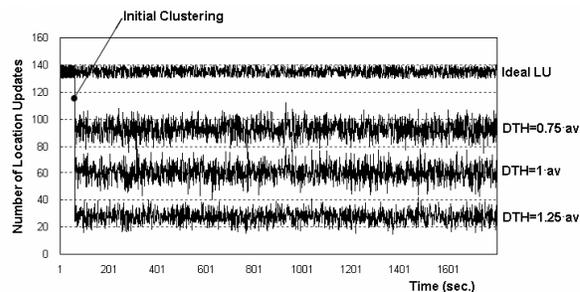


Figure 4. The number of transmitted LUs per each second

In Figure 4, the number of LUs of the ADF is similar to the ideal LU at initial. But, after the initial clustering, it is discovered that the ADF effectively reduces the number of LUs when compared with the ideal LU. Finding the difference in LUs depends on the DTH in the ADF and requires that the ADF transmits a small amount of LUs when the DTH size is large.

The ideal LU transmits an average 135 LUs every second. But the ADF sends an average of 94 LUs per second when the size of the DTH is $0.75 \cdot av$. This is a reduction result of 30.53% less when compared with the ideal LU. And, the ADF sends an average of 63 and 31 LUs when the size of the DTH is $1.0 \cdot av$ and $1.25 \cdot av$, respectively. This results in a 53.35% and 76.73% reduction, respectively, when compared with the ideal LU.

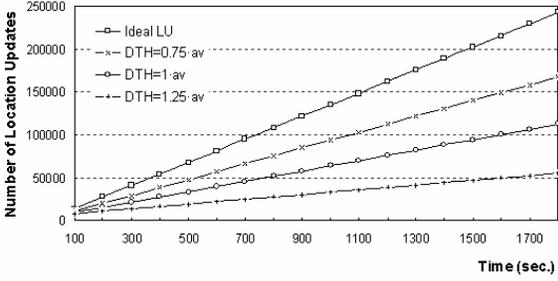


Figure 5. The number of accumulated LUs

In addition, we measured the number of accumulated LUs for 1800 seconds and this result is shown in Figure 5. 243084 of the LUs are transmitted to the grid broker in the ideal LU. But the ADF sends 167862, 112299, and 55211 of the LUs to the grid broker during the 1800-second period when the sizes of the DTH are $0.75\cdot av$, $1.0\cdot av$, and $1.25\cdot av$, respectively. These results are 75222, 130785, and 187873 fewer, respectively, when compared with the ideal LU

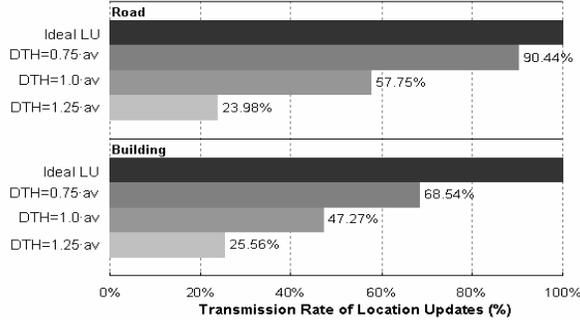


Figure 6. Transmission rate of LUs by region

We also measured the number of LUs by the location of the MNs. These results are expressed in Figure 6. When the size of the DTH was $.75\cdot av$, the ADF transmitted 90.44% of the LUs on the roads and 68.54% of the LUs in the buildings, compared with ideal LU. And when sizes of the DTH were $1.0\cdot av$ and $1.25\cdot av$, the ADF sent 57.75% and 23.98% of the LUs on the roads and 47.27% and 25.56% of LUs in the buildings, respectively. It was discovered that the transmitted LUs on the roads were more than in the buildings when the sizes of the DTH were $0.75\cdot av$ and $1.0\cdot av$. But the result from the road was similar to the result from the building. Therefore, we can conclude that ADF with a small DTH can effectively reduce the number of LUs when the MNs are in a building or limited area.

4.2. Location Errors

We evaluated the location estimation of the grid broker, which can revise the location error by using the ADF. In order to measure the degree of location errors,

we used the RMSE (Root Mean Square Error) method [14], which is $SQRT((\sum (RL_i - EL_i)^2)/n)$ where RL is MN's real location and EL is MN's estimated location and n is the number of MNs. With the RMSE method, the average difference between the real value and estimated value and RMSE provides an effective way to measure the degree of error between real and measured data.

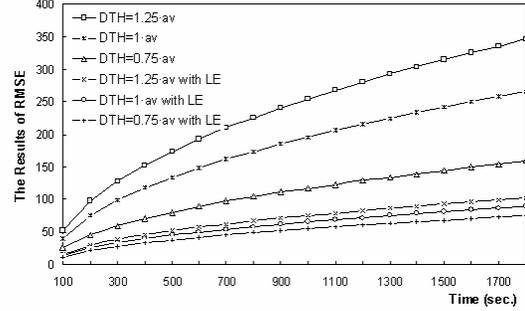


Figure 7. The results of RMSE

Figure 7 shows the result of the RMSE for 1800 seconds. In Figure 7, the three lines above are the RMSE of the location error when the ADF filters LUs using different sizes of DTH ($0.75\cdot av$, $1.0\cdot av$, and $1.24\cdot av$). And, the below three lines are the RMSE results when the grid broker estimates the MN's location using LE (Location Estimator). We obtained a lower RMSE when the grid broker used the LE. When the ADF uses $1.0\cdot av$ and $0.75\cdot av$ of DTH, the RMSE without LE are 265.74 and 158.88, respectively. But, if the grid broker uses LE, the RMSE is reduced to 88.78 and 74.63, and these are 33.41% and 46.97% of the RMSE without LE. Therefore, we can conclude that the grid broker effectively reduces location errors using LE in this experiment.

We compared the RMSE of the MN's by region. The RMSEs of the road and building are expressed in Figure 8 and 9. Figure 8 is the RMSE w/o LE and Figure 9 is the RMSE w/ LE. We can see that there are more location errors of than of buildings depends on whether the grid broker uses LE or not. The RMSE on the road is 4.5 times more than that of building when the grid broker does not use LE. And the when grid broker uses LE, the RMSE on the road is 4.7 times more than in the building. The reason for the fewer occurrences of location errors even with a higher number of MNs located in the building was that the MNs in the buildings moved with slower velocity than the MNs on the roads.

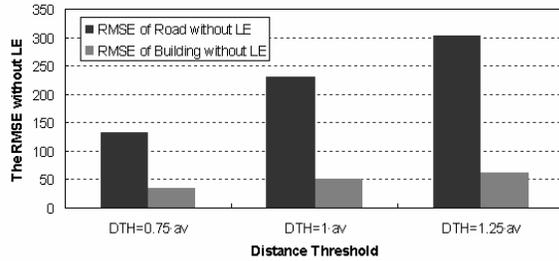


Figure 8. The RMSE without LE

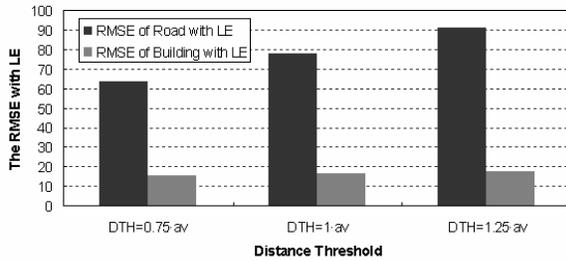


Figure 9. The RMSE with LE

In the summary, the ADF can effectively reduce LUs between MNs and the grid broker. The ADF reduces approximately 30~70% of the LUs. However, as the ADF effectively reduced the number of LUs, location errors were generated. To reduce the location errors, the grid broker uses a LE method to reduce the location errors down to 30%~50%

5. Conclusion

This paper proposed an ADF to reduce communication traffic in mobile grids. The ADF constructs MN clusters based on the mobility pattern and velocity of the MN to decide the DTH size based on the average velocity of each MN cluster. The ADF reduces LUs between MNs and the grid broker with a DF. In the DF, the effective reduction of LUs is expected. However, the DF generates location errors by decreasing LUs and The ADF also creates the same problem. In this paper, to solve this problem, we added a LE to the grid broker. This LE helps the grid broker to estimate MN's location when LUs are filtered.

For performance evaluation of the ADF, we measured the number of transmitted LUs and location errors. The ADF can reduce the LUs by 30%~70%. The reduction of LUs, in turn, can decrease the communication traffic of the mobile grid. Regarding location errors generated by DF, achieved the effective reduction of location errors by using LE in grid broker. These empirical results show that the ADF is an effective method for communication traffic reduction in a mobile grid when considering a MN's mobility.

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