Resolving RACH Congestion for High Speed Moving Group in Wireless Networks

Hongxia Zhao[†], Rongsheng Huang[‡] and Yuguang Fang[‡]
[†]Central Research Dept, Huawei Technologies Co., Ltd, Shenzhen, China
zhaohongxia@huawei.com
[‡] Department of Electrical and Computer Engineering, University of Florida, Gainesville, USA
rshuang@ece.ufl.edu

***Abstract*-When many cellular users take high capacity transit (HCT), a group of cellular phones may have to initiate handoffs and location updates more or less at the same time, which will cause congestion on the random access control (RACH), leading to many handoff and location update failures. To overcome this problem, we propose a new scheme, called GHA/RALU (Group Handoff Avoidance/Rate Adjusted Location Update Scheme), to deal with this group mobility issue. The idea is first to delay the normal location update (NLU) requests until the group handoff requests are completed and then spread the NLU requests within a calculated time interval based on the available bandwidth of the RACH. Our analysis shows that the proposed scheme significantly improves the success probability of the group handoffs and NLUs, saves the RACH resource, and accelerates the handoff initiated by the moving-in-together MTs.**

Keywords- High speed moving group; Group mobility; Handoff, Location update; Access channel

I. INTRODUCTION

Compared to the second generation PLMN (Public Land Mobile Network) systems, the impact of mobility on the network performance in next generation PLMN will be amplified due to the increasing number of mobile terminals (MTs) and the decreasing sizes of cells and location areas [1]. Moreover, when cellular users move in groups, which is the case when they take the high capacity transit (HCT) systems, e.g., high speed railways (HSR), many cellular handsets may have to initiate handoffs and make location updates more or less at the same time, which will cause congestion on the random access control channels (RACHs), leading to handoff failures and location update failures. Therefore, great challenges to the mobility management of cellular networks have emerged.

The research on group-related mobility management can be roughly classified into two categories: group mobility for wireless ad hoc networks and group mobility for infrastructured systems such as wireless cellular networks or mobile IP networks. Due to the lack of infrastructure, a wireless ad hoc network does not have fixed infrastructure facility to manage the mobility information, and the group mobility management proposed in the literature ([2]-[4]) has to either rely on landmarks or bundle a group of nodes to improve routing efficiency, and does not really address the seamless mobility for real-time support. Therefore, group mobility for ad hoc networks will not be suitable to address the mobility issues due to the large-sized moving MT groups. NEMO (network mobility) for mobile IP networks mainly focuses on the interworking issue on the network layer and targets at connectivity for non-real-time data services [5], and has not touched upon the congestion problem of control signaling traffic induced by the moving MT groups. To deal with the group mobility for cellular users using a transportation system (TS), Han et al [8] [9] proposed the virtual visiting location register (VVLR) to act as the localized home location register (HLR) to localize the signaling traffic while the location updates for all cellular users in the group can be carried out by the base station on the TS (TBS), which also serves as the mobility agent. However, the congestion on the RACH is not addressed. Moreover, it is also difficult to determine whether an MT is in TS (joining the group) or not, which is critical for their scheme. IEEE 802.16j [7] relies on the deployment of mobile agents or mobility anchor point (MAP) to localize the signaling traffic for location update while maintaining the connectivity for data connection. All these mobility agent based solutions require the mobile relaying stations or the mobile routers (e.g., MAP) to maintain the group information. However, due to the unpredictable movements of MTs, the cost of maintaining group information may be prohibitive and ping-pong handoff and ping-pong location updates may occur. Moreover, the additions of mobile relay stations imply more complexity and cost to the network operators.

Group mobility for infrastructured systems such as cellular-based solutions usually adopts the method to modify the current resource reservation [10] [11]. Zhang and Fujise [12] suggest that when the DCCH (dedicated control channel) resources are not enough for handling control signaling traffic, the base station subsystem (BSS) can cache location update requests to reduce the failure probability. However, this solution cannot reduce the failure probability of location updates when RACH is congested. A MT in a PLMN cellular network will be allocated with a dedicated channel only after it successfully sends out the request in RACH through contention. Consequently, when RACH is congested, the request for reservation could not be sent out, and hence resource reservation solution will not work properly.

This work was partially supported by a donation from Huawei Technologies, Inc., China, to sponsor the Wireless Networks Laboratory (WINET) at University of Florida.

Kastell et al. [13] focus on the mobility issues of the moving MT groups in high speed trains and claim that the processing of handoff and cell re-selection procedure can be accelerated when the location information of MTs can be acquired by GSM-Rs along the railways. However, GSM-R approach is based on the linear topology which is specifically designed for railway systems. It is not applicable to PLMN networks because the BSs along the railways are required to serve nearby MTs not in the trains in PLMN.

In this paper, we propose a scheme, called GHA/RALU (Group Handoff Avoidance/Rate Adjusted Location Update Scheme), to address the high failure rate problem of location updates caused by the large-sized moving MT groups in the legacy PLMN network. The idea is to let BSs inform the arriving MTs with the delayed location update time as well as the controlled location update frequency based on the current traffic load on the RACHs. This way, the failure probability of handoff and location updates can be greatly reduced.

The rest of the paper is organized as follows. In section II, the proposed scheme is presented. In section III the mathematical model for analysis is described. In section IV, the key parameters of the proposed scheme are derived. Numerical results are provided in section V. Finally, the conclusion is drawn in section VI.

II. PROPOSED SCHEME

In this section, the system model is described before our proposed scheme is introduced.

A. System Model

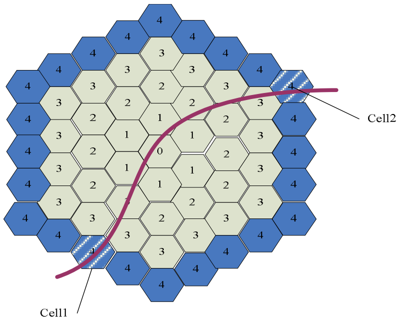

Figure 1. System model

Fig. 1 illustrates the typical scenario that high speed moving MT groups cross a PLMN location area (LA), an area consisting of a certain number of cells. The curve in Fig. 1 stands for the path taken by the high-speed moving groups/vehicles. A large number of handoff requests and even more location update requests will be triggered when the group/vehicle enters Cell 1 or Cell 2 as shown in Fig. 1. These requests from the group will compete for the RACH with the call requests, handoff requests and location update requests initiated by other MTs not moving with the vehicle (e.g., not on the vehicle). Therefore, the RACH will be congested very easily, leading to high failure probability of handoff and location updates. The network operator can configure more resources to deal with the mass arrivals of these requests. However, this may not be an economic approach.

In general, slotted-ALOHA [14] or slotted-ALOHA with priority [15] is adopted to coordinate the transmissions over the RACH. However, the throughput for slotted-Aloha is well-known to drop rapidly as the traffic load increases. Another problem seems to be more critical. Handoff requests from moving MT groups need to compete with a larger number of location update requests, which results in higher handoff failure probability than location failure probability because location update could tolerate longer delay than handoff. Although user-based priority mechanisms can be devised for RACH access, the problem is still not effectively resolved due to the following reasons [15][18]. First, most of current MTs have the same priority for gaining services except some special MTs used by emergency services, network staff, etc. Second, the MTs with high priority can have higher probability to access the network but this may not be helpful to increase the RACH access throughput because the priority can impact the backoff procedure only after the initial collision on the RACH, but does impact the initial access to the RACH. Third, since traditional cellular systems do not use priorities scheme in the initial access to the RACH, a handoff request initiated by one MT may not have higher probability than a location update request initiated by another MT if both MTs have the same priority in the user-level, and hence the contention between handoff requests and location update requests at the initial transmission attempts is still there and the congestion on RACH is still not resolved. Therefore, general priority schemes may not reduce the handoff failure rate effectively. Based on the above observation, we propose a new scheme, the group handoff avoidance and rate adjusted group location update (GHA/RALU).

B. Group Handoff Avoidance/Rate Adjusted Location Update Scheme (GHA/RALU)

The first part of this scheme is group handoff avoidance: to delay the location update requests from the moving-in-together (MIT) MTs while offering the handoff requests higher priority over location update requests to use the RACH. The delay depends on the time for the system to complete the transmissions of the group handoff requests. The second part of the scheme in GHA/RALU is to adjust the frequency of location update requests made by the MIT MTs so that the RACH channel is always operated at the maximum throughput, by considering both the current capacity of the RACH and the mobility management scheme used. In this way, not only the success probabilities of handoff and location update requests for moving MT groups can be increased, but also the access resources can be saved and the times taking for handoff and location update can be decreased. The basic idea is illustrated in Fig. 2 and Fig. 3. As a remark, the work [6] also adjusts the time to initiate location update, but it adopts multiple location areas framework. Moreover, it has not considered the access channel bandwidth and mobility for setting an appropriate delay value and only suggests delaying the MT's location update time according to its residence time in the previous location area.

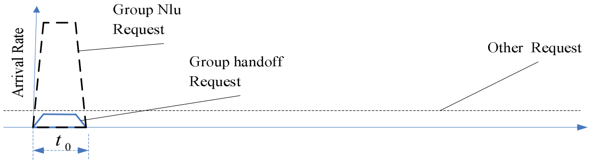

Figure 2. Access request arrival rate on RACH in the cellular network

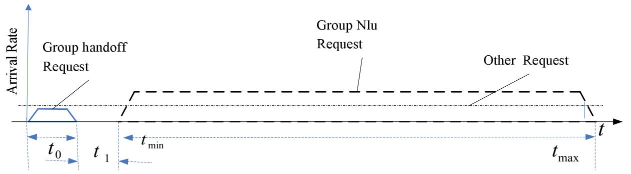

Figure 3. Access request arrival rate on RACH after GHA/RALU is applied

GHA/RALU scheme is described as follows:

Step 1. The BS calculates the minimum delay $t_{\min}$ and maximum delay $t_{\max}$ for location update requests based on the service model, mobility model, RACH bandwidth, and the size and velocity of moving MT groups.

Step 2. The BS broadcasts $t_{\min}$ and $t_{\max}$ parameters to all MTs in the cell.

Step 3. When an MT enters the cell, it acquires the system parameters including $t_{\min}$ and $t_{\max}$ by listening to the broadcast message.

Step 4: If the MT detects its entrance of a new LA, it decides its delay t_{du} in order to update its new location. Here t_{du} is a random variable uniformly distributed in $[t_{\min}, t_{\max}]$.

Step 5. Then the MT starts a timer of t_{du}. The MT initiates the NLU (normal location update) request immediately after the timer is over or when there is an outgoing call.

III. MATHEMATICAL MODEL

In this section, we provide the mathematical model used to determine $t_{\min}$ and $t_{\max}$ which are the key parameters of our GHA/RALU scheme.

A. Mobility model

In this paper, the location area (LA) consists of a number of hexagonal cells with the same size. Each cell has six surrounding cells adjacent to itself as shown in Fig.1 [16], forming the shape of a ring. Each ring is labeled with a value according to its distance to the center. The LA denoted by $A(K)$ is a cluster of cells and the outermost cells are in the Kth ring. S_c denotes the area of the cell and R_c denotes the radius of the cell.

Besides the group of MTs which are moving along the track at high speed, we assume there are many other MTs moving at normal speed in different directions. Therefore, a mixed mobility model is introduced in this paper. Wherein the one dimension (1-D) mobility model is used to model the MIT MTs and the two dimension (2-D) mobility model is used to model the mobility of other MTs.

The Fluid-flow model [17] is a suitable mobility model for 2-D moving MTs. These MTs are assumed to move at random speeds with the average value $\bar{v}_2$ and move in random directions uniformly distributed in $(0,2\pi)$. The density of the 2-D moving MTs in the area is ρ_2. For 1-D mobility model, the moving MT groups are assumed to move at the average speed $\bar{v}_1$ and the length of the path which the MT groups pass through the LA is denoted as d.

B. Traffic model

We assume that the new call arrivals form a Poisson process for both 2-D and 1-D models of MTs with rate of λ_{nu} (call/s/user). The same service model is used by these MTs with two different mobility models because the moving speeds of the MTs usually do not affect the service model. So the new call arrival rate of the cell λ_n is derived with the following equation:

$$\lambda_n = \left(\frac{d}{\bar{v}_1}\right) * \lambda_g g \lambda_{nu} + \rho_2 S_c \lambda_{nu} \qquad (1.)$$

where g denotes the average number of MTs in a moving group, λ_g denotes the expected value of arrival rate of the moving group.

$\gamma_{h2} = \rho_2 \bar{v}_2 L_c / \pi$ is the average number of MTs crossing the cell boundary in unit time [17]. The handoff arrival rate of the MTs with 2-D mobility model in the cell λ_{h2} can be obtained as follows:

$$\lambda_{h2} = \gamma_{h2} * \lambda_{nu}(1-P_b)\bar{t}_{cd} = \frac{\rho_2 \bar{v}_2 L_c \lambda_{nu}(1-P_b)\bar{t}_{cd}}{\pi} \qquad (2.)$$

where $\bar{t}_{cd}$ is the average duration of a call, P_b is the call block probability, and L_c is the perimeter of a cell.

When a high capacity vehicle passes through a cell, all the MTs in the vehicle connecting to the network must be handed off to the new cell. Let g_h denote the number of MTs in the connected states in one group. It can be derived by:

$$g_h = g \lambda_{nu} \bar{t}_{cd} \qquad (3.)$$

The handoff arrival rate of one group, denoted as λ_{hg}, is given as:

$$\lambda_{hg} = g_h * \frac{\bar{v}_1}{l} = \frac{g \lambda_{nu} E[t_{cd}] \bar{v}_1}{l} \qquad (4.)$$

The handoff arrival rate of all MTs with 1-D mobility in the cell λ_{h1} is given as:

$$\lambda_{h1} = g \lambda_{nu} \bar{t}_{cd} * \frac{\bar{v}_1}{l} * \lambda_g \qquad (5.)$$

where l is the length of the large capacity vehicle.

The equations (4) and (5) indicate that the high group mobility and the large size of groups both result in heavy handoff load.

In the cellular systems, the periodic location update (PLU) is used to track MTs. Let λ_{plu1} and λ_{plu2} denote the arrival rates of the PLU requests initiated by the MTs with 1-D mobility model and by the MTs with 2-D mobility model, respectively. So the PLU arrival rate in the cell λ_{plu} is given as:

$$\lambda_{plu} = \lambda_{plu1} + \lambda_{plu2} = \frac{(d/\bar{v}_1)\lambda_g g}{T_p} + \frac{\rho_2 S_c}{T_p} \tag{6.}$$

where T_p is the interval of PLU.

According to the fluid-flow model [17], the NLU request arrival rate λ_{nlu2} for 2-D mobility model in the target cell can be expressed as:

$$\lambda_{nlu2} = \frac{\rho_2 \bar{v}_2 L_{la}}{\pi} * \frac{1}{6K} = \frac{\rho_2 \bar{v}_2 R_c (2K+1)}{\pi} \tag{7.}$$

where L_{la} represents the perimeter of the LA.

When the vehicle passes through the cell, all the MTs moving with the vehicle in the idle states must update the location when they enter the edge cell. The NLU arrival rate of one moving group, denoted as λ_{nlug}, can be obtained as:

$$\lambda_{nlug} = g\left(1 - \lambda_{nu}\bar{t}_{cd}\right) * \frac{\bar{v}_1}{l} \tag{8.}$$

The NLU arrival rate of all MTs with 1-D mobility in the cell λ_{nlu1} is given by:

$$\lambda_{nlu1} = g\left(1 - \lambda_{nu}\bar{t}_{cd}\right) * \frac{\bar{v}_1}{l} * \lambda_g \tag{9.}$$

The equations (8) and (9) indicate that the high group mobility and the large size of group both result in heavy NLU traffic load.

IV. DETERMINATION OF THE KEY PARAMETERS

A. *The minimal delay* $t_{\min}$

In order to ensure the MIT MTs to handoff successfully, it is better to let $t_{\min}$ long enough to avoid group handoff requests. The lower bound can be expressed as follows:

$$t_{\min} = t_0 + t_1 \tag{10.}$$

where t_0 is the time period within which the MT group (i.e., the time the HCT spends in the handoff area) and t_1 is the time spent for the BS to complete the last handoff request from this MT group. For the MTs moving with an HCT, t_0 can be estimated by $t_0 = l/\bar{v}_1$.

Based on the access mechanism of cellular systems, t_1 [19] consists of three parts t_{11}, t_{12} and t_{13}. Here t_{11} is the total waiting time for the responses from the access network corresponding to all the access requests, which can be estimated as:

$$t_{11} = h^r_{\max} * N_{w1} * T_f \tag{11.}$$

where $h^r_{\max} = h_{\max} - 1$ represents the maximum number of retransmissions, N_{w1} denotes the number of frames between two consecutive attempts on RACH, and T_f is the radio frame length. t_{12} is the total time for one handoff request to spend on the random backoff over RACH. Let $N^b_{\max}$ denote the maximum number of backoff frames to avoid the collision on RACH in one attempt. Therefore, t_{12} can be calculated by:

$$t_{12} = h^r_{\max} * N^b_{\max} * T_f \tag{12.}$$

t_{13} is the total time used for persistence check in one access. When the backoff counter reaches zero, an MT determines whether or not to initiate another attempt according to the persistence check probability P_p, which is uniformly distributed over $[0,1]$. Therefore, t_{13} can be estimated by:

$$t_{13} = h^r_{\max} * (E[N^p] - 1) = h^r_{\max}\left(\frac{1}{P_p} - 1\right) * T_f \tag{13.}$$

From (11), (12) and (13), $t_{\min}$ is given as:

$$t_{\min} = h^r_{\max} T_f \left(N_{w1} + N^b_{\max} + \frac{1}{P_p} - 1\right) + \frac{l}{\bar{v}_1} \tag{14.}$$

B. *The maximum delay* $t_{\max}$

The maximum delay $t_{\max}$ to initiate NLU requests ensures that the access channel RACH operate in the non-congested state and the NLU failure probability is low. We will discuss how to estimate this value.

For the classical slotted-ALOHA, the throughput S with the offered load G and n access resources is obtained by $S = Ge^{-G/n}$. The randomized slotted-ALOHA adopted by WCDMA has more advantages in radio environment than classical slotted-ALOHA. Its throughput is analyzed in [20] .

Although the normalized throughputs are different between classical slotted-ALOHA and randomized slotted-ALOHA, the average transmission times h for both mechanisms are the same and can be estimated by $h = G/S$. Let T_c denote the average transmission time for an access request (slot size in this case) and λ^n_{nlug} represent the adjusted NLU arrival rate of the moving MT group with GHA/RALU. The normalized offered load is then given as:

$$G = h\left(\lambda^n_{nlug} + \lambda_0\right)T_c \tag{15.}$$

where λ_0 denotes the arrival rate of the rest of the service requests other than NLU requests initiated by the group moving MTs, which share the access channel RACH. Those MTs moving with 2-D mobility model are assumed to have moderate speeds. In GSM/WCDMA systems, MTs at moderate speed can avoid the contention on RACH and transmit handoff requests via DCCH directly. In such scenarios, λ_0 can be calculated by:

$$\lambda_0 = \lambda_{nlu2} + \lambda_n + \lambda_{plu} \tag{16.}$$

As we know, the maximum throughput is attained when $G = n$ either for classic slotted-ALOHA or for randomized slotted-ALOHA. Under the following condition, RACH congestion can be avoided and can work on maximum throughput

$$h\left(\lambda^n_{nlug} + \lambda_0\right)T_c = n \tag{17.}$$

Let $T_d = t_{\max} - t_{\min}$ denote the time period in which those MTs initiate location updates controlled by the GHA/RALU scheme. From the equation (3), λ^n_{nlug} is given as:

$$\lambda^n_{nlug} = \frac{g - g_h}{T_d} = \frac{g(1 - \lambda_{nu}\bar{t}_{cd})}{T_d} \tag{18.}$$

From equations (17) and (18), T_d is expressed by

$$T_d = \frac{hg(1-\lambda_{nu}\bar{t}_{cd})T_c}{n-h\lambda_0 T_c} \qquad (19.)$$

From the equations (14) and (19), we obtain

$$t_{\max} = T_d + t_{\min}$$

$$= \frac{hg(1-\lambda_{nu}\bar{t}_{cd})T_c}{n-h\lambda_0 T_c} + h^r_{\max} T_f (N_{w1} + N^b_{\max} + \frac{1}{P_p} - 1) + \frac{l}{\bar{v}_1} \qquad (20.)$$

C. Performance analysis

The normalized throughput of ALOHA, S , also indicates the access probability on RACHs. Retransmission can improve the success probability of channel access and prevent the performance from falling sharply when congestion occurs. Because every retransmission is independent, the success probability of channel access can be expressed as:

$$P_s = \sum_{i=1}^{h_{\max}} S(1-S)^{i-1} = 1-(1-S)^{h_{\max}} \qquad (21.)$$

The value of S varies for different ALOHA protocols, different access resource, or different traffic load. In order to let RACH operate at the point when its throughput S_0 is close to the maximum throughput, GHA/RALU adjusts NLU arrival rate initiated by the moving MT groups according to Eqn. (18), where $h = G/S_0$. For WCDMA networks [20], in case of $n = 10$, if we let RACH operate at $S_0 = 0.4$, the NLU access success probability of moving MT groups reaches 92.2% according to (21).

V. NUMERICAL RESULTS

In this section, we provide some numerical evaluation to the performance of GHA/RALU. The main parameters, such as group size, group speed and access bandwidth, are chosen, as listed in Table I, to investigate two key performance metrics, service success probability and service delay.

TABLE I
VALUES FOR THE INPUT PARAMETERS

Parameter	value
Cell radius R_c	4km
LA radius K	4
Path length of the vehicle passing through the LA d	6km
Length of the large capacity vehicle l	200m
Density of the 2-D mobility MTs ρ_2	1000/sq.km
Average speed of the 2-D mobility MTs $\bar{v}_2$	10km/h
Period of PLU value T_p	1h
Expected of arrival rate of the moving group λ_g	12/h
New call arrival for a user λ_{nu}	3call/s/user
Duration of a call t_{cd}	120s
Minimal backoff frames $N^b_{\min}$	3
Maximum backoff frames $N^b_{\max}$	20
Maximal attempt number of a MT on the RACH $h_{\max}$	5
Persistence probability P_p	0.5
Default group size	500
Default $\bar{v}_1$	300km/s
Default access bandwidth n	10

Fig. 4 shows that success probability of handoff, P_s^{ho} , and success probability of location update, P_s^{nlu} , decrease rapidly as the group speed increases in the same way as in traditional cellular networks because the two types of requests have the same priority in accessing the RACH. However, the degradation is limited by the system with the maximum transmission times $h_{\max}$ with approximately 40%. For GHA/RALU, P_s^{ho} and P_s^{nlu} have been improved significantly. In case of $g = 500$ and $n = 10$, P_s^{nlu} is more than 92%, which means that the failure probability of location update can be as small as one sixth of the traditional cellular system. In Fig. 4, the value of P_s^{ho} is a little smaller than P_s^{nlu} because the group handoff requests are more likely to be affected by the group location update requests.

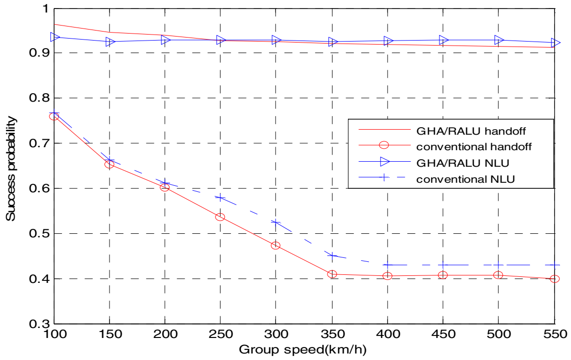

Figure 4. Success probability of handoff/NLU vs. group speed

Fig. 5 shows that the success probability is significantly affected by the group size in the traditional system. In the case $v_1 = 300$ and $n = 10$, P_s^{ho} decreases from 90% to 30% with the group size changing from 100 to 1000. The GHA/RALU is less affected by the group size, which is intuitively expected. In the case $v_1 = 300$ and $n = 10$, P_s^{ho} only decreases from 95% to about 90% and P_s^{nlu} almost stays unchanged at about 92%. The simulation result is consistent with the analytical result, which is 92.22%.

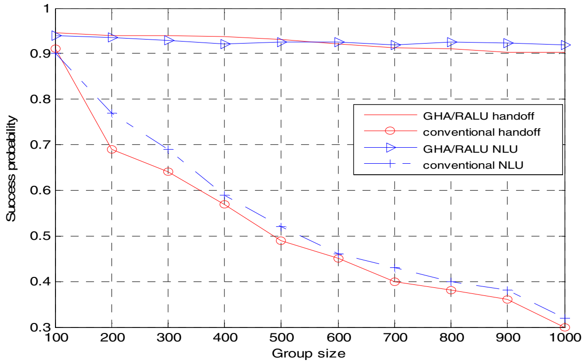

Figure 5. Group size vs. Success probability of handoff/NLU

Fig. 6 shows that the success probability is heavily affected by the number of access channels in the traditional network. The GHA/RALU scheme can save access channels evidently. For example, in case of $v_1 = 300$, and $g = 500$, 8 access channels are enough to ensure the success probability of handoff and success probability of NLU above 90% in GHA/RALU. However, in the traditional network, the service success probability is only about 65% even though 14 access channels are used.

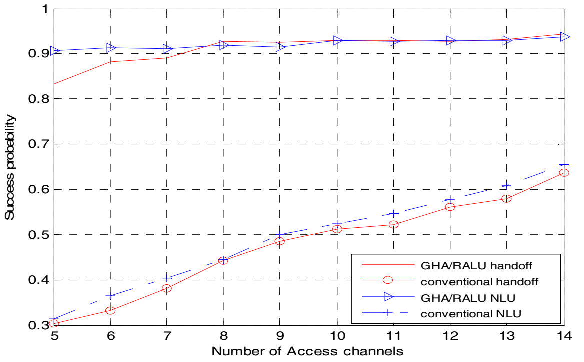

Figure 6. Number of Access Channels vs. Success probability of handoff/NLU

Fig. 7 shows the handoff access delays and LU access delays with respect to group size. In the traditional network, the access delays for handoff and location update are almost the same and they slowly increase when the group size is increased. However, they are limited by the maximum transmission times $h_{\max}$ used in analysis. Fig. 7 also shows that the new scheme reduces the access delay of handoff which is very important to high speed moving group. However, the access delays of location update increase as expected.

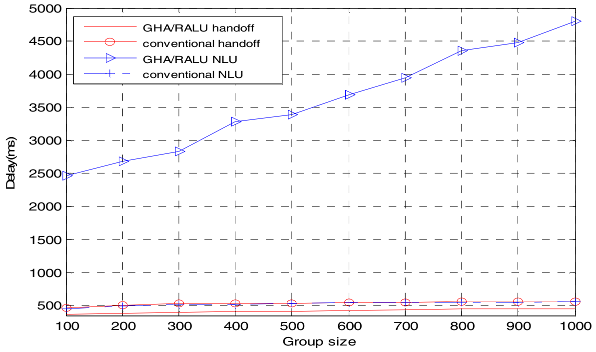

Figure 7. Group size vs. Delay

VI. CONCLUSIONS

In this paper, we investigate the major cause of handoff failure and location update failure when cellular users take the high speed transportation systems. By observing the group mobility causes bursty handoffs and location updates, we propose a novel scheme to avoid the time-sensitive group handoff requests by delaying less time-sensitive location update requests. Using a mixed mobility model of both normal cellular users and vehicular cellular users, we show the effectiveness of our proposed scheme, which indeed provide a solid solution to the mobility issues of moving MT groups based on the traditional network architecture.

REFERENCES

[1] J. G. Markoulidakis, G. L. Lyberopoulos, D. F. Tsirkas and E. D. Sykas, “Mobility modeling in third-generation mobile telecommunications systems,” *IEEE Personal Commun*., pp. 41-56, Aug. 1997.

[2] X. Hong, M. Gerla, G. Pei, and C.-C. Chiang, “A group mobility model for ad hoc wireless networks,” *Proc. ACM Intern. Workshop on Modeling, Analysis, and Sim. of Wireless and Mobile Systems (MSWiM)*, Seattle, WA, 1999.

[3] G. Pei, M. Gerla, X. Hong and C.-C. Chiang, “A wireless hierarchical routing protocol with group mobility,” *IEEE WCNC*, 1999.

[4] G. Pei, M. Gerla and X. Hong , “LANMAR: landmark routing for large scale wireless ad hoc networks with group mobility,” *ACM Mobihoc*, 2000.

[5] H.Y. Lach, C. Janneteau and A. Petrescu. “Network mobility in beyond-3G systems,” *IEEE Communications Magazine*, vol.41, no.7, pp.52-57, July 2003.

[6] http://www.3gpp.org/ftp/tsg_sa/WG2_Arch/TSGS2_63_Athens/Docs/S2-081280.zip,Ericsson

[7] IEEE 802.16j/D1 "IEEE Standard for Local and Metropolitan Area Networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access System Multihop Relay Specification," Aug. 2007.

[8] I. Han and D.-H. Cho, “Group location tracking based on representative identity and virtual VLR for transportation systems,” *IEEE Communications Letters*, vol. 5, no.8, pp.349-351, Aug 2001.

[9] I. Han, S.-K. Jung and D.-H. Cho, “Hierarchical group location tracking for transportation systems inh wireless personal communications networks,” *Wireless Personal Communications,* vol.26, pp.17-31, 2003.

[10] J. Tsiligaridis and R. Acharya “A clustering prediction scheme for wireless cellular network”, *Proc. of the 2005 International Symposium on Collaborative Technologies and Systems*, 2005.

[11] J.-Y. Chang and H.L. Chen, “Dynamic-grouping bandwidth reservation scheme for multimedia wireless networks,” *IEEE Journal on Selected Areas in Communications*, vol.21, no.10, pp.1566-1574, December 2003.

[12] Y. Zhang and M. Fujise, “Location management congestion problem in wireless networks,” *IEEE Transactions on Vehicular Technology*, vol. 56, no. 2, pp. 942-954, March 2007.

[13] K. Kastell, S. Bug, A. Nazarov and R. Jakoby, “Improvements in Railway Communication via GSM-R,” *IEEE VTC Spring*, 2006.

[14] N. Abramson, (ed.), *Multiple Access Communications*, New York: IEEE Press,1993

[15] A. Brand and H. Aghvami, *Multiple Access Protocols for Mobile Communications GPRS,UMTS, and Beyond*, John Wiley&Sons,2002.

[16] I.F. Akyildiz and W. Wang, “A dynamic location management scheme for next-generation multitier PCS systems,” *IEEE Transactions on Wireless Communications*, Vol.1, No. 1, pp. 178–189, Jan 2002.

[17] H. Xie, S. Tabbane, and D. J. Goodman, “Dynamic location area management and performance analysis,” *Proc. 42nd IEEE Vehicular Technology Conf.*, pp. 536–539, May 1992.

[18] 3GPP TS 25.321 V8.3.0 (2008-09) Technical Specification 3rd Generation Partnership Project; “Technical Specification Group Radio Access Network; Medium Access Control (MAC) Protocol Specification (Release 8)”.

[19] 3GPP TS 25.214 V8.2.0 (2008-05) Technical Specification 3rd Generation Partnership Project; “Technical Specification Group Radio Access Network; Physical layer procedures (FDD) (Release 8)”.

[20] I.N. Vukovic and T. Brown, “Performance Analysis of the Random Access Channel (RACH) in WCDMA,” *IEEE Vehicular Technology Conference (VTC)*, pp. 532{536, Spring 2001.