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Research Article

Location Updating Schemes for High-Speed Railway Cellular Communication Systems

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High-speed railway private cellular network provides voice and data services for passengers. It brings much signaling cost as a great many of mobile subscribers ask for location updating simultaneously. Moreover, it leads to plenty of control signaling channel requests. This paper presents two novel location updating schemes, that is, "clustering location management" and "mobile group location management" to solve the problems caused by the existing location updating scheme in high speed railway cellular private network. These two schemes can realize location updating without occupying more frequency resources. In addition, it does not impact the mobile subscribers' paging. Then it analyses the performance of two improved schemes, such as channel request number of stand-alone dedicated control channel (SDCCH), average waiting time of location updating, cost of location updating, and paging. The result indicates that both schemes can utilize the SDCCH channel resource effectively.

1. Introduction

With the constructing and opening of the high-speed railway lines, mobile users' demand of the voice, data, and other services in the high-speed train is gradually improved. Since the environment of the radio propagation is very complex, and it executes handover frequently during the calling procedure, mobile users have some problems, such as low communication quality, and high call drop rate. Although it can be solved through the construction of private networks for the high-speed railways [1, 2], some new problems are involved correspondingly. For example, there are a large number of mobile users in the same train. All mobile users will send the location update messages to the network at the same time. As a result, the signaling overhead will be increased, and it will even cause the congestion of signaling channel [3, 4]. The field test data also confirmed this. It can be found that most congested base stations locate at the border between the two location areas, and the congestion time is

concentrated within a brief period. Thus, in order to ensure the success of location update, more frequencies should be allocated even if the requirement of voice service in the private network is less. Obviously it is a waste of the network resources. In this paper, to reduce the cost of the location updating and improve the performance of communication system, we propose "clustering location management" scheme and "mobile group location management" scheme used in mobile communication system for passenger dedicated lines, and it may ensure the mobile users to execute location update successfully and not to affect the normal paging process.

There are three types of approaches for location update procedure: time-based, movement-based, and distance-based update schemes [5]. Each type has its advantages suitable for special applications. In order to improve the performance of location management, the improved methods based on those schemes are proposed in the literatures [6–13], such as hybrid location update scheme [6], dynamic location management scheme based on movement-state [7], interoperation of identity management [8], and two-level pointer forwarding strategy for location management in PCS networks [9]. According to the move trend of train, some mobile location management schemes have also been proposed. For instance, a method was proposed in [10], which divided the users into different groups based on their move speed and used the corresponding location management scheme to improve paging efficiency. In [11], a hybrid method based on self-organization mobile network and GSM network has been presented, but the complexity of implementation is increased. According to the characteristics of railway communication, a group location management method based on the group ID (GID) and virtual visit location register (VVLR) is proposed in [12]. To meet the requirement of mobility of base-station in military communication, an enhanced mechanism for relay-based group mobility by extending the IEEE 802.16 m specification on relay is proposed in [13]. However, the methods described in [12, 13] both need to add some mobile base-station equipments, and the internal communication in a group still occupied the network resource, it brings a great challenge to the mobile communication network. Several location management strategies to reduce the cost of location management in mobile networks are presented in [14–16].

For the above reasons, we propose two location update schemes not taking additional frequency resource, and the improved schemes may ensure all the users on the high-speed train to finish location update. For the specific application, we mainly consider two schemes. The first scheme is called "clustering location management" scheme, in which mobile users will be divided into multiple groups to execute location update separately. The second scheme considers the mobile users in a carriage as an integral unit (group), and a particular device (group head) executes location update as the representative of the whole group, which is called "mobile group location management" scheme. This paper is organized as follows: in Section 2, the principles of two improved location schemes are described. In Section 3, the further analysis and performance comparison of the existing scheme and improved schemes are given. Finally the conclusion is obtained in Section 4.

2. Principle Description of Two Improved Schemes

2.1. Clustering Location Management Scheme

The basic idea of clustering location management (CLM) scheme is to divide the mobile subscribers (MSs) with high-speed movement into two or more clusters according to their

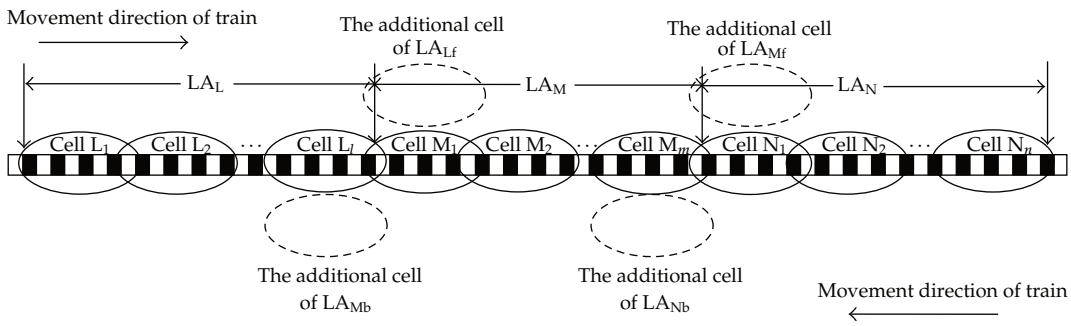

Figure 1: location area and virtual location area.

identification, such as international mobile subscriber identity (IMSI), and then the MSs in each cluster perform location updating in turns. Thus, it can reduce the number of MSs who need location updating in unit time, decreasing the network resource requirement. Meanwhile, through the virtual location area, it can guarantee the paging of those MSs who have not carried out the location updating yet, so as to reduce the call failure probability and improve the reliability of communication.

To take two user clusters clustering in GSM system as an example, according to the difference number of the end bit of IMSI, the odd number MSs is clustering as Cluster 1, the even number MSs is clustering as Cluster 2. When mobile stations find that the current location area code (LAC) is different from the previous registered LAC, they will request a location updating. Considering the different clusters, the network side let the MSs of Cluster 1 carry out the normal location updating procedure, but the updating request of the MSs of Cluster 2 will not be accepted temporarily. After the timer reaches the default time T, then the MSs of Cluster 2 perform the location updating procedure. The value of the default time T is related with the speed of train and the cell radius, T should not be longer than the train travel time for a cell, namely, it should guarantee the MSs of Cluster 1 to complete the location updating within T.

Considering the network coverage along the railway is linear in general, as shown in Figure 1, supposed that LA_L, LA_M, and LA_N are three adjacent location areas, which are l cells in LA_L, m cells in LA_M, and n cells in LA_N. After adopting the CLM scheme, during the location updating phase of Cluster 1, if the MS in Cluster 2 has an incoming call, it will be missed because the MSs in Cluster 2 have not performed location updating yet. Hence, we put forward a concept of virtual location area for paging the MSs in Cluster 2 during Cluster 1 updating phase. The virtual location areas are recorded in the database of network side, and it contains all cells in the original location area and adds an adjacent cell, which is in the target location area. In this case, if the MS in Cluster 2 has an incoming call, it will page MSs in the virtual location area. As shown in Figure 1, when the train travels from left to right, LA_{Lf}, which is the virtual location area of LA_L, is defined as all cells in $LA_L$and cell M_1, and $LA_{Mf,}$ which is the virtual location area of LA_M, is defined as all cells in LA_M and cell N_1. Similarly, when the train travels from right to left, LA_{Mb}, which is the virtual location area of LA_M, is defined as all cells in LA_M and cell L_1, and LA_{Nb}, which is the virtual location area of LA_N, is defined as all cells in LA_M and cell M_m.

By use of the virtual location area, the MSs who are waiting for location updating will not miss the incoming calls. For example, when MSs move from LA_M into LA_N, before the timer time t reaches the default time T, the MSs of Cluster 2 are located in cell N_1, which

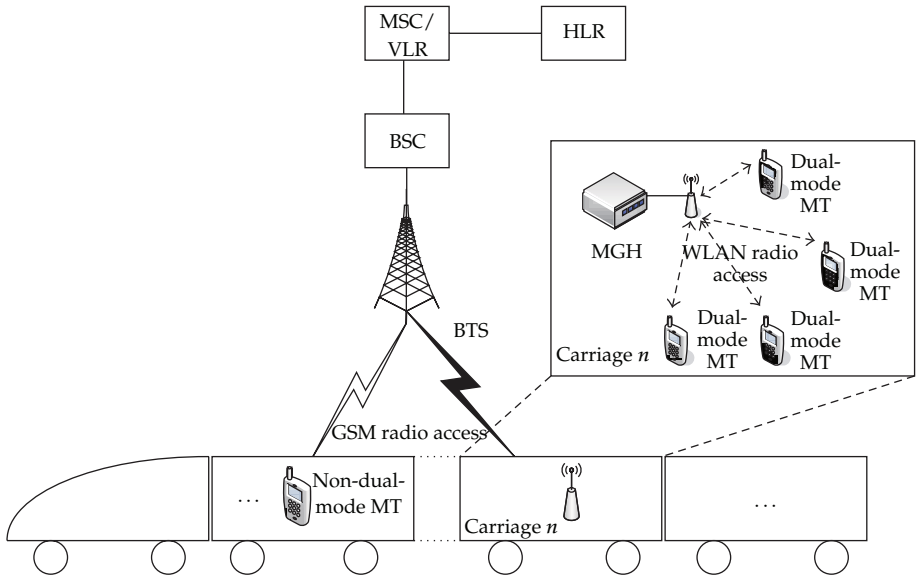

Figure 2: Network architecture of the group location management.

belongs to LA_N, but their location information is still LA_M; when the MS of Cluster 2 has an incoming call, the network will page the MS in the virtual location area $LA_{Mf,}$ including cell M_1, M_2, …, M_m and cell N_1, so the called MS will not miss the incoming call. Note that the paging procedure of the MSs in Cluster 2 is as usual.

If the number of MSs is very large, to avoid the call failure caused by too many location updates, the MSs can be divided into more clusters, each cluster carries out the location updating procedure in turns. However, the virtual location areas for each cluster must be redefined, the specific rules of which can be decided by the network operators.

2.2. Mobile Group Location Management Scheme

To implement the mobile group location management (MGLM) scheme, we need to configure some network devices in each railway carriage to build WLANs, as shown in Figure 2. Each WLAN's coverage range is limited within a carriage, and it should be equipped with a device as the mobile group head (MGH), which is responsible for the management of mobile terminals and performs the integrated location updating with representing the group. MGH comprises a wireless access point (AP), a cellular communication transceiver, and MGH register for storage the registered information of group members, as shown in Figure 3. The mobile terminals have dual mode, which means they support both cellular network wireless transceiver function and Wi-Fi function; hence, they have the ability to access to the WLAN.

In our MGLM scheme, we take GSM network as an example. It includes several processes: the group formation, dissolution and update process, intramobile switching center/visitor location register (MSC/VLR) group location updating procedure, inter-MSC/VLR group location updating procedure. As for the group location updating, it is in relative terms of traditional GSM location updating, the traditional GSM location updating is requested by MSs, each update just updates one MS's information, but the group location updating is

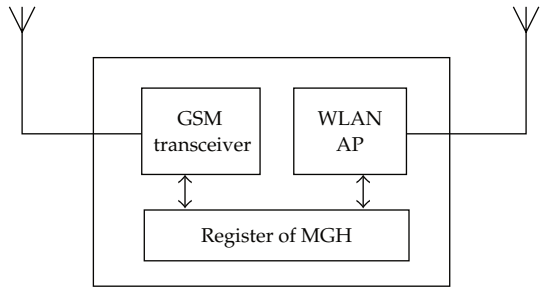

Figure 3: The inner structure of the mobile group head.

requested by the MGH, and it may update the location information of all MSs managed by the MGH. Apparently, the updating efficiency of MGLM scheme is much higher than the traditional ways. The details of those processes are as follows.

2.2.1. Group Formation, Dissolution, and Update Process

As the train sets off from the origin station, the WLANs in the carriages are enabled, the AP in MGH periodically sends member-joining notification message to MSs, the MSs in the carriage establish association with AP through the WLAN and are formed as an integral unit (group). The MGH is taken as the whole group representative, and the ordinary MSs are regarded as the group members. The specific process related to group formation, dissolution, and update includes the following steps.

(1) The AP in MGH sends the checking signal with a period of T_{AP} in the wireless coverage range, usually inside a railway carriage. Mobile group head register stores every MS's IMSI number or temporary mobile subscriber identity (TMSI) number, each TMSI is correspondent to an IMSI;

(2) When the mobile terminals (MTs) within WLAN signal coverage range receives the checking signal, they reply their own IMSI (or TMSI) number, and then apply for joining the group;

(3) After receiving the reply of each MS, the MGH registers the IMSI (or TMSI) number and sequence number of each MS, then returns a confirmation message and sequence number to the MS; when the MS receives the confirmation message, it means that MS has joined the group and knows its sequence number in the group;

(4) MGH checks the change of member in the carriage every T_{AP} cycle regularly, when MGH finds new member joining the group, it registers the new MS information and returns the corresponding message and sequence number;

(5) After sending the period checking signal, if the MGH has not received the IMSI (or TMSI), it thinks that the MS has left the group and then cancels the MS group registration information.

2.2.2. Intra-MSC/VLR Group Location Updating Procedure [17]

The intra-MSC/VLR group location updating procedure is shown in Figure 4.

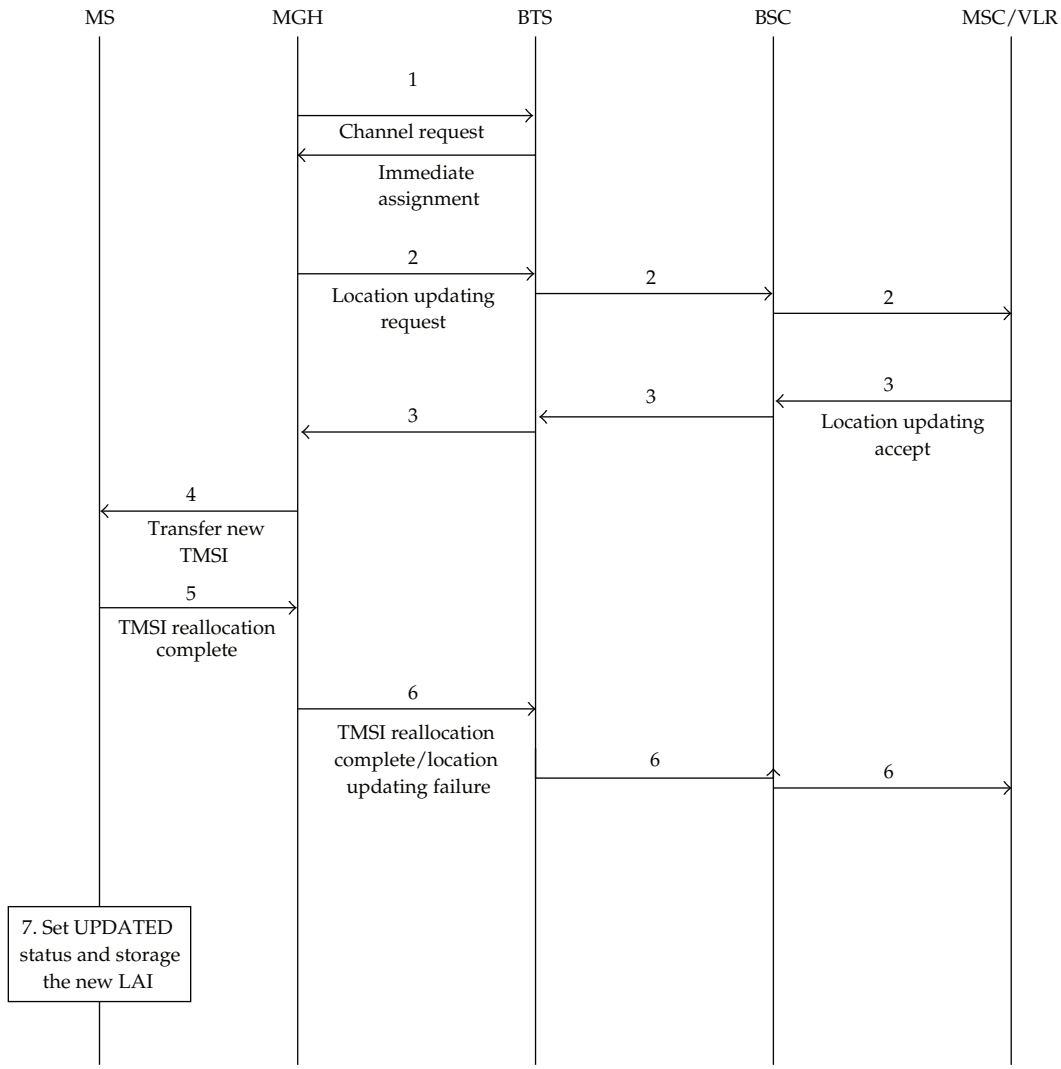

Figure 4: Intra-MSC/VLR group location updating procedure.

(1) The MGH sends the "channel request" message to BTS on random access channel (RACH), the priority of this message is higher than those sent from the ordinary MSs', so the base station (BTS) responds to the "immediate assignment" message on a stand-alone dedicated control channel (SDCCH);

(2) The MGH sends the "location updating request" message to the network, which includes each MS's IMSI (or TMSI) number and old location area identify (LAI) in sequence. The location updating request is forwarded to the MSC/VLR;

(3) The VLR stores each MS's new LAI, assigns a new TMSI to each MS, and then sends the new TMSI table aligned in sequence via "location updating accept" message to the MGH;

(4) The MGH receives the new TMSI table and forwards the message including the new MS's TMSI via WLAN, then each MS updates its location information and TMSI;

(5) The MSs in the group replies the "TMSI reallocation complete" acknowledgement message to the MGH through the WLAN, if the MGH does not receive the acknowledgement message of some MS, the MS location updating failure is considered;

(6) The MGH replies back "TMSI reallocation complete" or "location updating failure" message of each MS to the network in sequence, MSC receives the message and releases the channel link. For the MSs failed in location updating, the network responds their "location updating message" messages sent to the BTS individually, the location updating procedure is the same as the traditional one;

(7) After completing the location updating, the mobile station sets SIM card's update status to UPDATED (latest) and storages the new LAI.

2.2.3. Inter-MSC/VLR Group Location Updating Procedure [17]

The inter-MSC/VLR group location updating procedure is shown in Figure 5, in this case MSs move from VLR1 to VLR2.

(1) The MGH sends the "channel request" message to BTS on random access channel (RACH), the priority of this message is higher than those sent from the ordinary MSs', the base station (BTS) responds to the "immediate assignment" message on a stand-alone dedicated control channel (SDCCH);

(2) The MGH sends the "location updating request" message to the network, which includes each MS's IMSI (or TMSI) number and old location area identify (LAI) in sequence. The location updating request is forwarded to the VLR2 via MSC2;

(3) The new VLR2 inquires to the old VLR1 the authentication parameters and identity of each MS;

(4) The old VLR1 sends the new identity and authentication parameters of each MS to the new VLR2 in sequence, including IMSI, RAND, SRES, and Kc;

(5) The new VLR2 assigns a new TMSI to each MS, then sends the new TMSI table aligned in sequence via "location updating accept" message to the MGH, if necessary, it will send encrypted mode;

(6) The MGH receives the new TMSI table and forwards the message including the new MS's TMSI via WLAN, then each MS updates its location information and TMSI;

(7) The MSs in the group replies the "TMSI reallocation complete" acknowledgement message to the MGH through the WLAN, if the MGH does not receive the acknowledgement message of some MS, the MS location updating failure is considered;

(8) The MGH replies back "TMSI reallocation complete" or "location updating failure" message of each MS to the network in sequence, MSC1 receives the message and releases the channel link. For the MSs failed in location updating, the network responds their "location updating message" messages sent to the BTS individually, the location updating procedure is the same as the traditional one;

(9) The new VLR2 notifies the HLR each mobile resides, then the HLR sends the MS's information to the new VLR2, and the old VLR1is told to delete the data of that MS;

(10) After completing the location updating, the mobile station sets SIM card's update status to UPDATED (latest) and stores the new LAI.

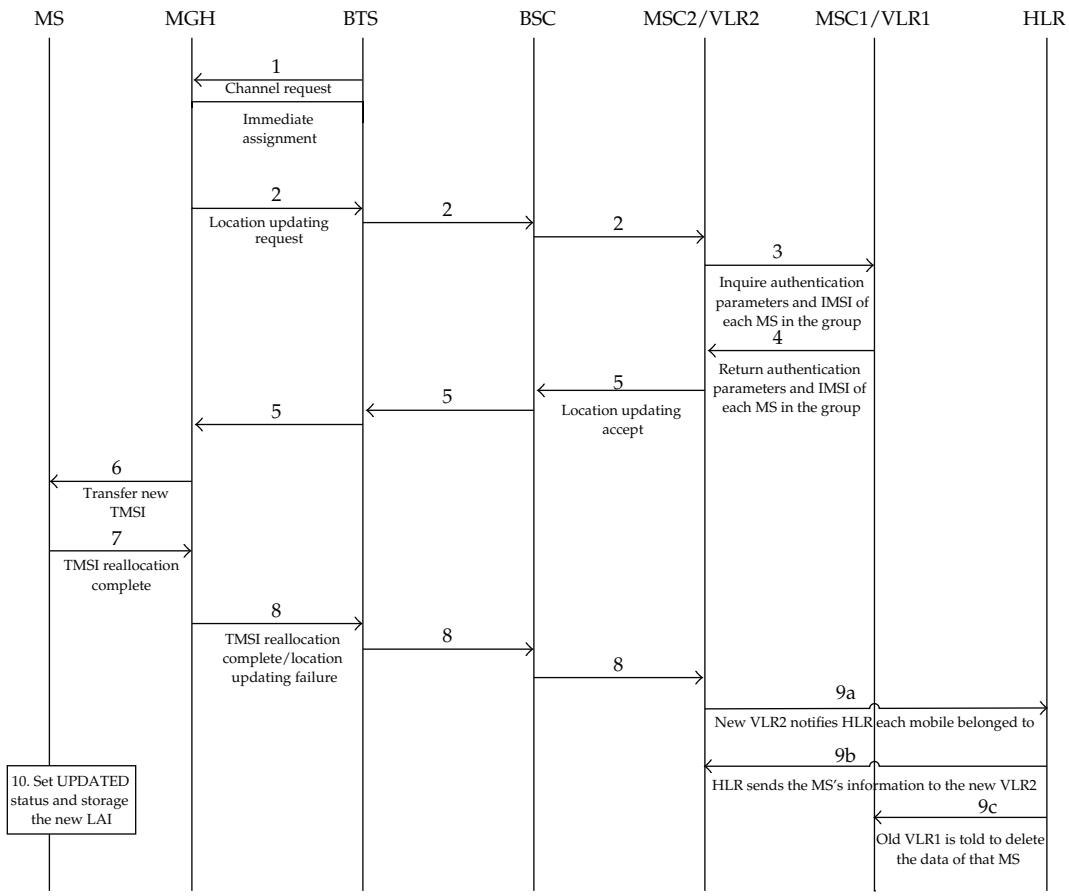

Figure 5: Inter-MSC/VLR group location updating procedure.

3. Performance Analysis

3.1. Parameter Hypothesis

Generally speaking, the minimum interval between two trains in one way is about 10 km. Considering that most of the high-speed railway is double-tracked, there are at most two passenger trains within the 20 km range. Each train has k ($k = 8 \sim 16$) carriages, and each carriage may carry 75 passengers; hence, total number of passengers per train is $Q = 600 \sim 1200$, in which the number of GSM mobile subscriber is about 60%, that is, the biggest number of MSs to perform location updating once is $2 \times Q \times 60\% = 1.2Q$; supposing each line traffic is 0.02 Er1, then the total traffic is $1.2Q \times 0.02 = 0.024Q$ Erl. According to a radio channel call loss rate 2% to design, the least channel number and SDCCH channel number needed per cell is shown in Table 1, due to the LAC boundary of the private network needed to provide enough channel resources to complete location updating and routing updating, consequently the increased number of SDCCHs is 3.2–4 times of the number of traffic channel [1, 2].

Based on the analysis of signaling, a location update occupies SDCCH average 3 s; considering the time from an SDCCH be released (i.e., CHANNEL RELEASE ACK is received) to be reassigned, a normal location updating total time is about 3.5 s.

Table 1: Number of passenger versus the number of TCH and SDCCH.

The number of passengers per train Q	Traffic (Erl)	The number of TCH N (radio loss rate 2%)	The number of SDCCHs S per normal cell	The number of SDCCHs $S_{\mathrm{LAC}} = 4N$ per cell in the private network
600	14.4	22	32	88
700	16.8	25	32	88
800	19.2	27	32	88
900	21.6	30	40	96
1000	24	33	40	96
1100	26.4	36	48	144
1200	28.8	37	48	148

3.2. Performance Analysis of Traditional Location Management Scheme

In the traditional location management scheme, the cost of location updating and paging per MS on the train in a unit time is represented by C_T:

$$C_T = \eta C_{\mathrm{LU}} + \lambda_C C_P, \tag{3.1}$$

where $\eta = v/R$ is the location updating rate; v indicates the speed of train; R expresses the average distance between location boundaries; C_{LU} indicates the average location updating cost of each MS; λ_C is the call arrival rate, that is, the arrived calling number of each MS per unit time; C_P represents the average paging cost of each MS:

$$C_P = x \cdot C_{\mathrm{Pcell}}, \tag{3.2}$$

where x indicates the average number of cells in an LA and C_{Pcell} represents the paging cost of each cell, here supposed the average distance over an LA is about $R = 100\,\mathrm{km}$ including average 10 cells, $v = 300\,\mathrm{km/h}$, $\lambda_C = 0.5/\mathrm{h}$. Supposing that the passengers in a train is Q, $1.2Q$ expresses the total location updating number of MSs at the same time, thus the total cost of all location management per unit time is represented by $C_T{}'$, and

$$C_T{}' = 1.2Q\left(\eta C_{\mathrm{LU}} + \lambda_C C_P\right). \tag{3.3}$$

If SDCCH is congested, the average location updating time is increased, which can be obtained by M/M/C model [18–21]. Supposing the average waiting time per MS is W_q, as shown in (3.4):

$$W_q = \frac{1}{c\mu\left(1 - (\lambda/c\mu)\right)^2} p_c, \tag{3.4}$$

where c represents available SDCCH number and μ represents the number of location updates in a unit time (1 s) completed in one SDCCH. Considering that a normal location updating total time is about 3.5 s, the average service rate is $\mu = 1/3.5$, and λ represents the average arrived rate of location updating. Since the triggering time of the location updating is very

short, we suppose that all MSs start location updating procedure within 1 min, $\lambda = 1.2Q/60$. p_c and the traffic degree ρ are related to SDCCH number c and the steady-state probability p_0:

$$\begin{gathered} p_c = \frac{1}{c!} \cdot \rho^c \cdot p_0, \\ \rho = \frac{\lambda}{\mu}, \\ p_0 = \left[\sum_{k=0}^{c-1} \frac{1}{k!} \rho^k = \frac{\rho^c}{c!(1-\rho_c)} \right]^{-1}, \\ \rho_c = \frac{\lambda}{c\mu} < 1, \end{gathered} \tag{3.5}$$

where k represents the number of MSs, that is, $1.2Q$, from the above equations, the number of MSs is more, the number of SDCCHs is less, thus the SDCCH is more congested, and the average waiting time of MS for location updating is much longer.

3.3. Performance Analysis of CLM Scheme

In the improved CLM scheme, MSs are divided into n clusters. The cost of the location updating is the same as the cost of traditional location management scheme, although the cost of paging is increased, the performance of radio resource utilization rate and the average waiting time of location updating is improved. Please refer to [22–25]:

$$\frac{C_{\mathrm{LU}}}{C_{\mathrm{Pcell}}} = 17. \tag{3.6}$$

As we know, the cost of location updating occupies too much proportion of the total cost of location management; therefore, a little increase of paging cost will bring little effect to the total cost of location management. Supposing C_{Pcell} is the unit cost, we may calculate C_{LU} and C_P via formulas (3.6) and (3.2), respectively; moreover, we may analyze the cost of the location updating and the cost of paging and the total cost.

Through clustering, the number of SDCCHs can be reduced greatly. From Figure 6, we can see that the CLM scheme with 48 SDCCHs can acquire the similar waiting time performance of traditional scheme with 88 SDCCHs, which reduces a great amount of the SDCCH channel consumption. And the more the number of the SDCCH is, the shorter the average waiting time is. Observed in Figure 6, we may choose the appropriate number of SDCCHs to be assigned. When $n = 1$, which means no clustering, it needs at least 88 SDCCHs [1]; when $n = 2$, the number of SDCCHs can be set to 48; when $n = 3$, the number of SDCCHs can be set to 40; when $n = 4$, the number of SDCCHs can be just set to 32. Hence, it can greatly reduce the SDCCH channel resource by clustering and further enhance the QoS quality of MSs. Using the same number of SDCCHs, the more clusters in CLM, the shorter the average waiting time is. For example when SDCCH = 88, the average waiting time of the traditional scheme (i.e., $n = 1$) is 0.215653 s, and when SDCCH = 56, the average waiting time of CLM for $n = 2$ is just 0.15365 s, consequently, the CLM scheme can achieve a better performance.

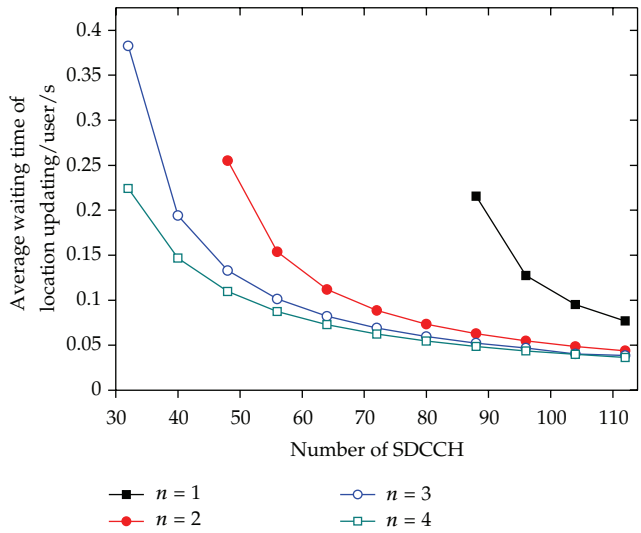

Figure 6: The average waiting time of location updating.

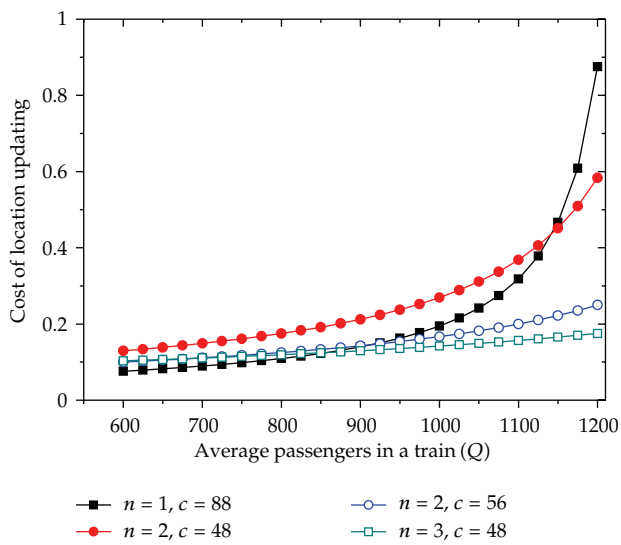

Figure 7: The cost of location updating (n represents the number of clusters, c represents the number of SDCCHs).

Figure 7 describes the performance comparison of the cost of the location updating between traditional scheme and the CLM scheme. Seen from the graph, no matter whether clustering, the general trend of the location updating cost is increased as the number of MSs. When no clustering (i.e., $n = 1$), if the number of MSs is less than 850, the updating cost is a little better than CLM scheme, but its number of SDCCHs far outweighs the CLM scheme; whereas when the total passengers is nearly 1200, the cost of location updating for no clustering increases significantly. When using the same number SDCCH, the more clusters;

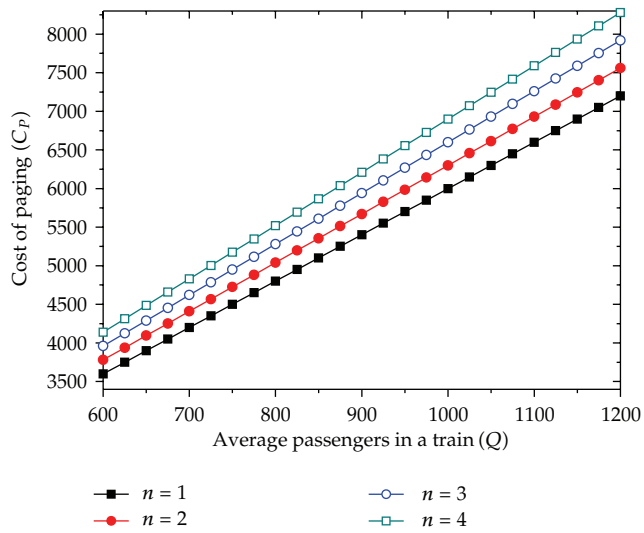

Figure 8: The cost of paging.

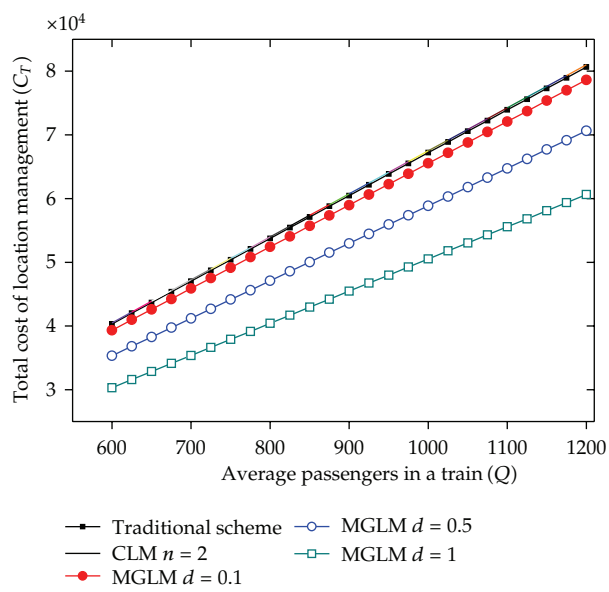

Figure 9: The total cost comparison of the three location management schemes.

the less cost of location updating. When using the same number of clusters n, the more SDCCHs are assigned, the less cost of location updating is.

Figure 8 is the paging cost performance comparison between the traditional scheme and the CLM scheme. We can see that the more clusters, the higher paging cost is increased, but usually the value of n could be 2 or 3 in practical application, and the paging cost only occupies a small proportion of the cost of location management.

Hence, it can be concluded that on the basis of saving SDCCH resource, the CLM scheme can acquire the similar average waiting time and total location management cost performance of the traditional scheme.

3.4. Performance Analysis of MGLM Scheme

In MGLM scheme, we suppose that there are $d * 1.2Q$ $(0 < d < 1)$ MSs with dual-mode terminals joining into the group, the other users cannot join into the group due to mobility or without dual-mode terminals. The definition Q is the same as 3.2; d represents the proportion of MSs in the group. According to the basic principle of the MGLM scheme, the decreasing percentage of SDCCH is in proportion to the percentage of MSs joining in the group, for instance, when $d = 0.5$, the amount of SDCCHs is decreased from 88 to 44. However when $d > 0.5$, to meet the requirement of calling, the number of SDCCHs is not suitable for decreasing. From the specific procedure of the MGLM scheme, we know the overhead of the MGLM scheme includes the overhead of the initial group registration procedure C_g, the overhead of the group location updating procedure $C_{\mathrm{LU\_G}}$, the overhead of paging C_P, and the overhead of group cancellation procedure C_c. Since the group registration does not involve the mobile network resources, it will be neglected, and the group cancellation procedure can be equivalent to the cost of a location updating. Assuming there are 75 passengers in each carriage, where $75d$ MSs with the dual-mode terminal join the group update management, hence the cost of location updating includes two parts: the cost of dual-mode users $C_{\mathrm{LU\_G}}$ and the cost of ordinary users C_{LU}. The calculation of the LA cost for ordinary users is the same as the calculation in traditional scheme, to see (3.6); the LA cost of other dual-mode users can be derived by the signaling:

$$\frac{C_{\mathrm{LU\_G}}}{C_{\mathrm{Pcell}}} \approx 12.36. \tag{3.7}$$

Hence, the total cost of MGLM is

$$C_{T\_G}{}' = 1.2Q \cdot d \cdot (\eta + 1) C_{\mathrm{LU\_G}} + 1.2Q \cdot (1 - d) \cdot \eta C_{\mathrm{LU}} + 1.2Q \cdot \lambda_c C_P, \tag{3.8}$$

where the cost of paging C_p is the same as the one in the traditional management scheme. The cost of the location management comparison is depicted in Figure 9.

Figure 9 shows that the total cost of the CLM is higher than the tradition scheme's, this is because the virtual paging area introduced by CLM leads to the increase of paging cost. Whereas the total cost of the MGLM is relatively low, and with the number increase of MSs joining in the group, its total cost decreases more and more. The reason is that the group location updating may reduce the updating cost greatly. Obviously, we do not consider the equipment cost in MGLM in this paper.

4. Conclusions

In this paper, two kinds of location updating schemes for high-speed railway private network are provided, that is, clustering location management (CLM) and mobile group location management (MGLM). The performance analysis and comparison results of traditional scheme,

CLM and MGLM schemes are also given. From the results we may conclude that both the two improved location updating schemes can reduce the number of SDCCHs greatly. For example, with CLM scheme, it may decrease the number of location updating per unit time more than 50%, and it can acquire much better performance with 56 SDCCHs than traditional scheme with 88 SDCCHs. Consequently, it saves the SDCCH resource greatly. Meanwhile, through adopting the virtual location area, it can guarantee the paging of MSs and reduce the call failure probability and improve the reliability of communication. However, the CLM scheme may increase the complexity of network management. From the view of decreasing radio resource and the cost of location updating, the MGLM scheme is the best choice, in which the decreasing extent of SDCCH is related with the percentage of MSs joining in the group, for instance, when $d = 0.5$, the amount of SDCCHs is decreased from 88 to 44. Since the members of carriage can perform group location updating by the MGH, the cost of the location updating is decreased greatly; but it needs to add the MGH device in each carriage and leads to much change in both the network side and the mobile terminals, the complexity of MGLM is the highest in 3 schemes. In conclusion, the railway private cellular network operator may take a suitable location management improved scheme to decrease the location updating average waiting time and utilize the radio resource effectively.

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References

[1] Y. Wei-guang, G. Hai-ping, and H. Hin-yang, "Discussion about the private network planning and optimazation of high-speed railway," *Telecommunications Science*, vol. 22, no. 3, pp. 94–98, 2008 (Chinese).

[2] L. Fu-xin, X. Ying, and L. Wen-peng, "Study on mobile network coverage scheme of high speed railway," *Designning Techniques of Posts and Telecommunications*, vol. 22, no. 9, pp. 20–24, 2008 (Chinese).

[3] Y. Zhang and M. Fujise, "Location management congestion problem in wireless networks," *IEEE Transactions on Vehicular Technology*, vol. 56, no. 2, pp. 942–954, 2007.

[4] M. Li and W. Zhao, "Visiting power laws in cyber-physical networking systems," *Mathematical Problems in Engineering*, vol. 2012, Article ID 302786, 13 pages, 2012.

[5] N. E. Kruijt, D. Sparreboom, F. C. Schoute, and R. Prasad, "Location management strategies for cellular mobile networks," *Electronics and Communication Engineering Journal*, vol. 10, no. 2, pp. 64–72, 1998.

[6] G. Y. Lee, Y. Lee, and Z. J. Haas, "Hybrid location-update scheme for mobile networks," *IEEE Trans actions on Vehicular Technology*, vol. 58, no. 1, pp. 338–348, 2009.

[7] C. Peng, Y. Xue-jun, and H. Zai-lu, "A dynamic location management scheme based on movement-state," *ACTA Telectronica Sinica*, vol. 30, no. 7, pp. 1038–1040, 2002 (Chinese).

[8] J. Chen, G. Wu, and Z. Ji, "Secure interoperation of identity managements among different circles of trust," *Computer Standards and Interfaces*, vol. 33, no. 6, pp. 533–540, 2011.

[9] W. Ma and Y. Fang, "Two-level pointer forwarding strategy for location management in PCS networks," *IEEE Transactions on Mobile Computing*, vol. 1, no. 1, pp. 32–45, 2002.

[10] Y. W. Chung, "Performance analysis of movement-based group location management for mobile stations riding on transportation systems in cellular systems," in *Proceedings of the 11th IEEE/IPSJ International Symposium on Applications and the Internet (SAINT '11)*, pp. 333–337, Munich, Germany, 2011.
[11] W. Fu-Rong, X. Lai, and W. Hao, "A group location management method based on hybird mobile network," People's Republic of China: ZL101001414A, July, 2007.
[12] I. Han and D.-H. Cho, "Group location management for mobile subscribers on transportation systems in mobile communication networks," *IEEE Transactions on Vehicular Technology*, vol. 53, no. 1, pp. 181–191, 2004.
[13] R. Balakrishnan, X. Yang, M. Venkatachalam, and I. F. Akyildiz, "Mobile relay and group mobility for 4G WiMAX networks," in *Proceedings of the IEEE Wireless Communications and Networking Conference (WCNC '11)*, pp. 1224–1229, Quintana Roo, Mexico, March 2011.
[14] Z. Mao, "An intra-LA location update strategy for reducing paging cost," *IEEE Communications Letters*, vol. 6, no. 8, pp. 334–336, 2002.
[15] P. G. Escalle, V. C. Giner, and J. M. Oltra, "Reducing location update and paging costs in a PCS network," *IEEE Transactions on Wireless Communications*, vol. 1, no. 1, pp. 200–208, 2002.
[16] R. Munadi, M. Ismail, M. Abdullah, and N. Misran, "Location management cost reduction using fuzzy logic in cellular radio network," in *Proceedings of the IEEE International Conference on Space Science and Communication (IconSpace '11)*, pp. 165–169, Penang, Malaysia, 2011.
[17] GSM 03.12, Digital cellular telecommunications system (Phase 2+); Location registration procedures, 1995.
[18] S. V. Subramanian and R. Dutta, "Performance measurements and analysis of M/M/C queuing model based sip proxy servers in local and wide area networks," in *Proceedings of the 2nd International Conference on Advances in Recent Technologies in Communication and Computing (ARTCom '10)*, pp. 306–310, Kerala, India, October 2010.
[19] M. Li and W. Zhao, "Representation of a stochastic traffic bound," *IEEE Transactions on Parallel and Distributed Systems*, vol. 21, no. 9, pp. 1368–1372, 2010.
[20] M. Li, C. Cattani, and S. Y. Chen, "Viewing sea level by a one-dimensional random function with long memory," *Mathematical Problems in Engineering*, vol. 2011, Article ID 654284, 13 pages, 2011.
[21] G. Ren-yong, "A rule of updating position in microscopic pedestrian model," in *Proceedings of the International Conference on Optoelectronics and Image Processing (ICOIP '10)*, vol. 1, pp. 120–123, Haiko, China, November, 2010.
[22] E. Martin, G. Lin, M. Weber, P. Pesti, and M. Woodward, "Unified analytical models for location management costs and optimum design of location areas," in *Proceedings of the 5th International Conference on Collaborative Computing: Networking, Applications and Worksharing (CollaborateCom '09)*, pp. 1–10, IEEE Press, Washington, DC, USA, November 2009.
[23] Z. Liao, S. Hu, and W. Chen, "Determining neighborhoods of image pixels automatically for adaptive image denoising using nonlinear time series analysis," *Mathematical Problems in Engineering*, vol. 2010, Article ID 914564, 14 pages, 2010.
[24] W.-S. Chen, P. C. Yuen, and X. Xie, "Kernel machine-based rank-lifting regularized discriminant analysis method for face recognition," *Neurocomputing*, vol. 74, no. 17, pp. 2953–2960, 2011.
[25] J. Yang, Z. Chen, W.-S. Chen, and Y. Chen, "Robust affine invariant descriptors," *Mathematical Problems in Engineering*, vol. 2011, Article ID 185303, 15 pages, 2011.