Analysis and Implementation of a Precise Paging Mode in Co-LAC for 2G/3G Convergence Core Networks with Path Diversity

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Abstract. Nowadays the 2G/3G interoperability has been enabled over the real networks. However, as there are many 2G/3G borders in the same area, especially in the same location, too much extra network traffic is caused by paging signals and location updates within the 2G and 3G networks. In this paper, we propose a new method to reduce the traffic of both paging signal and update messages by path diversity. Theoretical analysis is shown and implementation results are also given.

Keywords: Precise paging, Update message, Path diversity.

1 Introduction

In the early phase of TD core network construction, macro coverage and indoor coverage have not been optimized. When 2G/3G interoperability is enabled on the network, there are many 2G/3G borders in the same area, especially in the same location area (LA). As a result, a great number of location updates and paging signals occur between 2G and 3G networks [1]-[4].

Users are unreachable during location update. Therefore, the voice call completion rate of the TD network decreases badly, and user experience is also affected. It is possible to set location area codes (LACs) of 2G and 3G networks uniformly in areas in which this problem is rather severe to enable co-routing. In this manner, terminals in idle state do not perform immediate routing area update after cell reselection within the same routing area. Terminals initiate routing area update only when the network side initiates paging or terminals initiate services. This can reduce routing area update signaling caused by reselection. In the actual networking, however, when the core network performs paging based on LACs, paging messages are delivered over the 2G and 3G networks concurrently. Extra invalid paging messages bring paging congestion on the 2G network and radio side of the TD network, therefore affecting the paging success ratio.

As a result, in this paper we determine to adopt precise paging mode based on co-LAC for 2G/3G to meet network requirements and improve user experience. We make an analysis of the reduction of paging signals and update messages by path diversity. And the implementation is also done, where the results prove the efficiency of our proposal.

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2 Concept and Principle

2.1 Concept of LAC

On a cell-based mobile communications network, a great number of base transceiver stations (BTSs) are deployed, and mobile stations are not fixed. When mobile users are in the service area regardless of where they move, the mobile communications network must perform the switching control function to implement location update (registration), cross-cell handover, and automatic roaming. The following figure shows the definition of areas in a GSM network.

An LA can consist of one or several cells (or BTS areas). To call a mobile station, all the BTSs in the same LA can send paging signals concurrently.

The identity of an LA is referred to as location area identity (LAI). An LAI consists of three parts: mobile country code (MCC), which is of three numbers and identifies the country to which a mobile user belongs; mobile network code (MNC), which identifies the mobile network to which a mobile user belongs; LAC, which identifies an LA on a GSM Public Land Mobile Network (PLMN). The LAC is the most important portion of an LAI. Therefore, an LA is often referred to as an LAC, and co-LAC means co-LA.

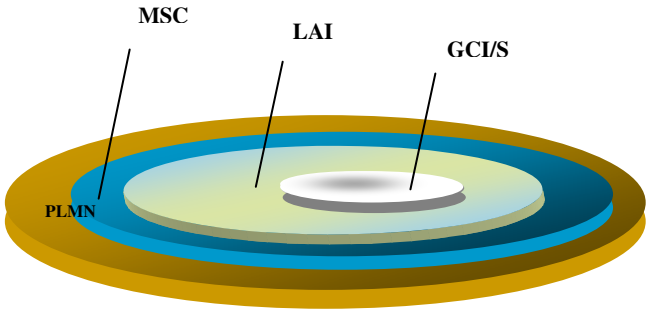

Fig. 1. Areas in a GSM network

2.2 Concept of Location Update

Due to MS mobility, it is important to locate an MS. Only after the current location of an MS is known, connection to the called MS can be set up.

Roaming refers to the feature that a mobile user requests changing of the connection to the cell and network during movement. Location update refers to changing of an LA during roaming and LA confirmation. A mobile switching center (MSC) does not need to be informed of movement within the same LA but movement between cells of different LAs. Location update is primarily composed of the following:

When an MS detects that its LAI is to be updated, the MS sets up a connection with the MSC/visitor location register (VLR) proactively. Then, the MS sends a request, and data on the VLR is updated. If the LAI belongs to different MSCs/VLRs, data on the home location register (HLR) also needs to be updated. After update, the connection between the MS and the BTS is released.

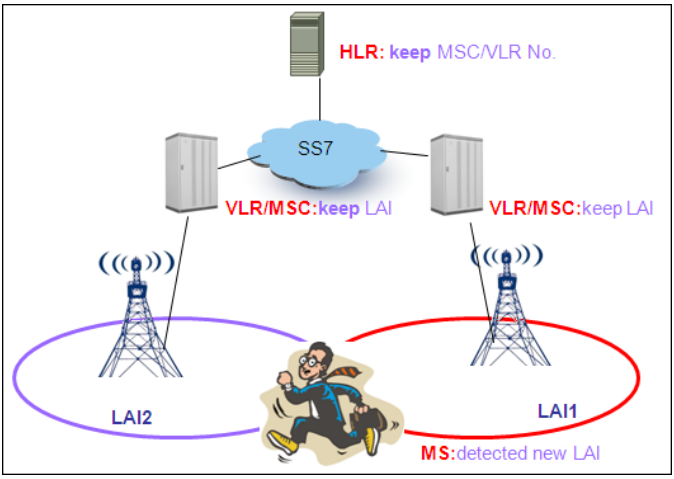

Fig. 2. Location Update

Users are unreachable during location update (a mobile phone cannot listen on paging channels during location update. Therefore, the mobile phone cannot respond to paging requests), that is, users cannot be called during location update. Therefore, the call completion rate of them is greatly affected when their locations are frequently updated. In addition, communications are badly affected.

3 Problem Description

3.1 Problems of Update Message

1) Different LACs for 2G/3G
As shown in the preceding figure, in the scenario of different LACs for 2G/3G, the chance of TD-to-GSM cell reselection is limited in the area covered by the TD network continuously. Therefore, location update messages for the GSM network do not increase significantly. TD cells are preferred. Therefore, the chance of GSM-to-TD cell reselection is also limited. Consequently, location update messages for the TD network do not increase significantly, either.

At the coverage edge of the TD network, dual-mode terminal users who enter TD network coverage all initiate location update and register with the TD network because TD cells are preferred. Users who leave the TD network need to initiate location update on the GSM network and register with the GSM network. Compared with GSM and TD networks, location updates increase greatly at the TD network border.

The GSM network provides an extensive coverage, and GSM users seldom need to switch to the TD network. During the early phase of the TD network, there is a big gap between the coverage of the TD network and that of the GSM network, and TD users often need to reselect cells or switch to the GSM network. In this case, location updates occur. Especially in the same geographical area where different LAs are used for GSM and TD, TD users are more likely to reselect cells or switch to the GSM network. Therefore, a great number of location updates occur.

Paging to users is performed on the basis of LAs on the GSM or TD network. LAs are set separately. Therefore, the TD network is responsible for only paging users who really register with the TD network. Users are unreachable during location update. A mobile phone cannot respond to paging messages during location update. Therefore, in the preceding scenario in which location updates increase, the voice call completion rate of the TD network decreases badly, and user experience is also affected. Therefore, the solution of co-LAC for 2G/3G needs to be introduced to solve this problem.

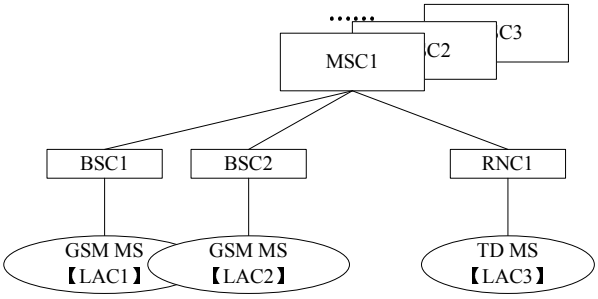

Fig. 3. Different LACs for 2G/3G

2) Co-LAC for 2G/3G

See the preceding figure. At the coverage edge and areas without coverage or weak coverage of the TD network, dual-mode terminal users who enter the TD network coverage initiate inter-RAT cell reselection and select the TD network. This is because the TD network is preferred. The core network, however, is not informed of the reselection. Users who leave the TD network also initiate inter-RAT cell reselection and reselect the GSM network. The core network is not informed of the reselection either.

Advantages of co-LAC: When a user performs cell reselection between 2G and 3G wireless systems, the user does not need to initiate location update to the core network. This is because the LAC does not change and the core network does not need to be informed of LAI change. In addition, the delay of system reselection is very short. Therefore, the possibility that paging and system reselection (including location update) occur concurrently can be minimized. In this manner, the paging success ratio increases and the completion rate of calls can be improved.

There are three types of location updates: normal location updates (cross-LA), periodical location updates, and International Mobile Subscriber Identity (IMSI) attachment (corresponding to the process of terminal power-on). In the case of

co-LAC for GSM and TD networks, the number of periodical location updates and IMSI attachments do not change greatly. This is because mobile phones complete these two types of location updates within their own networks. The major change is that normal location updates decrease. This is because in the same LAC, location updates do not occur just because a TD user reselects cells or switches to the GSM network due to weak signals or insufficient coverage. This also excludes the possibility of call drop due to location update. In the early phase of TD network construction, this can greatly improve the service experience of TD users.

Because the LAC is shared, when the core network pages a piece of user equipment (UE), the core network needs to perform paging over the entire LA, including the coverage areas of both TD and GSM networks.

The GSM network needs to serve users who register with the TD network. Although these paging messages are not responded to, they occupy the paging channels of the GSM network. Considering the small number of users in the early phase of the TD network, the impact on the GSM network is limited after co-LAC deployment. With the increase in the number of TD users, the paging capability of the GSM network may decrease inevitably.

The TD network needs to serve users who register with the GSM network. Although these paging messages are not responded to, they occupy the paging channels of the TD network. The impact to the TD network is great because the number of GSM users is multiple times that of the TD network. To prevent invalid paging in the scenario of co-LAC, the solution of precise paging for co-LAC needs to be introduced.

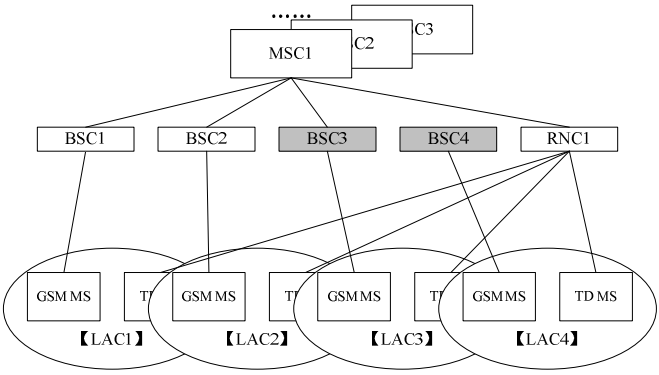

Fig. 4. Co-LAC for 2G/3G

3.2 Problems of Paging Signal

When a mobile phone performs location update in a co-LAC area, the core network obtains parameters of the mobile phone, including classmark1 and classmark3, and saves the parameters to the data area of the VLR.

During paging delivery in the LA for the mobile phone, the MSC determines whether the mobile phone is a GSM-only one. If yes, the paging is sent to only the BSC in Fig.5.

If the mobile phone is not a GSM-only one or the terminal type is not reported, the MSC sends paging to both the BSC and the RNC concurrently in Fig.6.

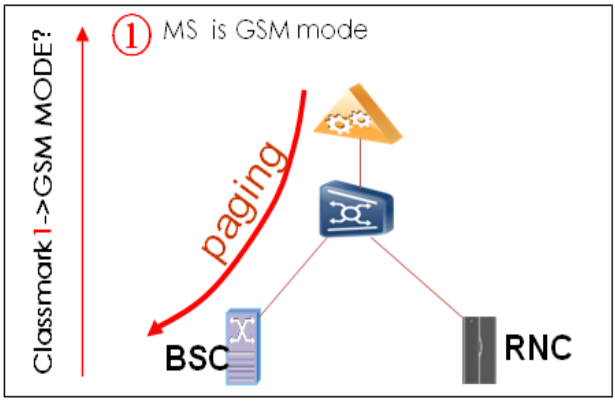

Fig. 5. Conventional method for paging signal

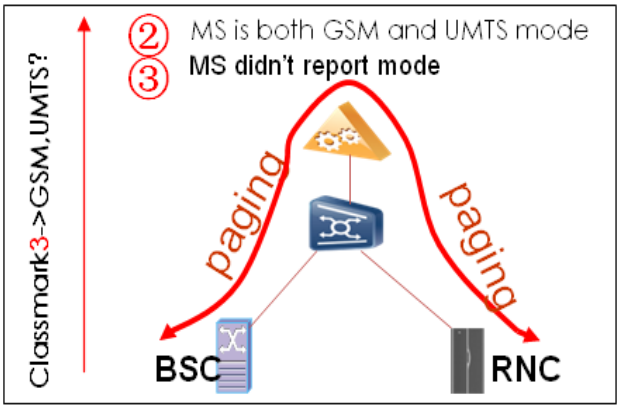

Fig. 6. Proposal to determine the type of a mobile phone

During location update, the MSC obtains the revision level from classmark1 in the location update message sent from the mobile phone. Revision level is a two-bit parameter. When its value is 01 (GSM PHASE 1) or 10 (GSM PHASE 2), the mobile phone is a GSM-only one.

When its value is not 01 (GSM PHASE 1) or 10 (GSM PHASE 2), you can determine the mobile phone type based on the following parameters in classmark3 reported by the mobile phone. If the mobile phone does not report classmark 3, the MSC can send the classmark update message to obtain this parameter proactively.

UMTS FDD Radio Access Technology Capability
CDMA 2000 Radio Access Technology Capability
UMTS 3.84 Mcps TDD Radio Access Technology Capability
UMTS 1.28 Mcps TDD Radio Access Technology Capability

The preceding parameters represent a special 3G radio access technology. If the preceding bits are 1, the mobile phone supports this radio access technology. If the

preceding bits are all 0, the mobile phone is a GSM-only one. Otherwise, the mobile phone is not a GSM-only one.

4 Implementation Results

4.1 Tests and Verification for Various Scenarios

Regression test for typical services after co-LAC deployment to test the validity and consistency of each typical service

Test of the precise paging function for the core network

Comparison and analysis of network indexes in scenarios such as different LACs, co-LAC with TD LAC not being divided, and co-LAC with TD LAC being divided.

The LA of a TD network is greater than that of a GSM network. LA division refers to dividing a large LA into several smaller LAs so that the LA of the TD network is of the similar size with that of the GSM network.

Change in delay of 2G/3G interoperability before and after co-LAC deployment

Compatibility of PBP parameters for terminals, and test of TD paging capacity

Effect of co-LAC configuration on the ARD function of the core network

4.2 Problems of Update Message

The incoming completion rates of the RNC within six days before and after co-LAC deployment are as follows. The average incoming completion rate of the RNC within six days before co-LAC is implemented is 90.92%. The average incoming completion rate of the RNC within six days after co-LAC deployment is implemented is 93.06%. This value is 2.14% higher than the previous value

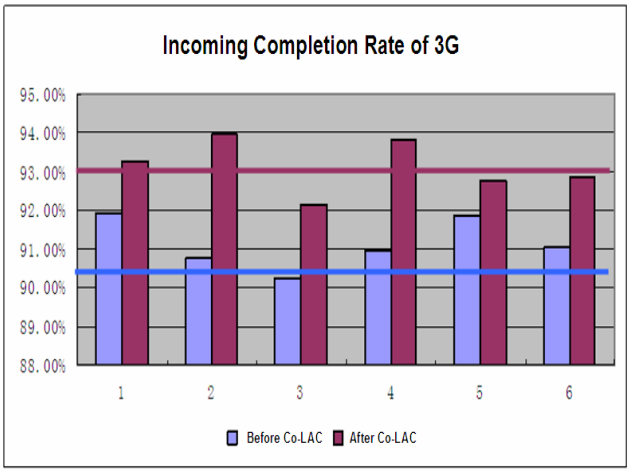

Fig. 7. Incoming completion rates of the RNC within six days before and after co-LAC

The paging success rates in the entire region in four scenarios within six days are collected. The preceding data indicates: The average paging success rate in the entire region within six days is 95.74% in scenario 1, 97.26% in scenario 2, 95.32% in scenario, and 96.46% in scenario 4.The success rate in scenario 2 is 1.5% higher than that in scenario 1. The success rate in scenario 2 is 0.8% higher than that in scenario 4.

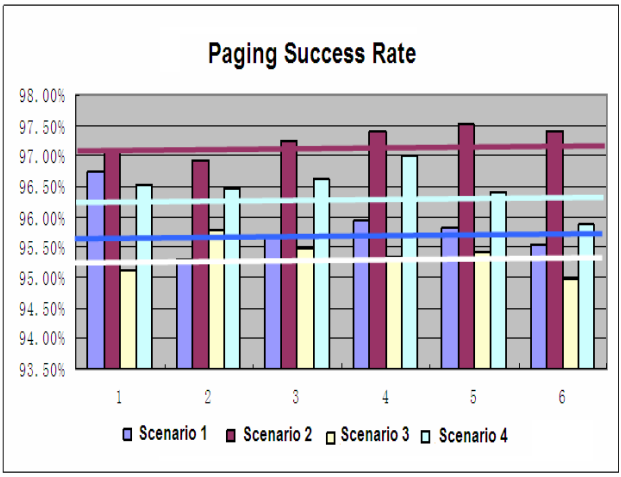

Fig. 8. Paging success rates in the entire region

The success rates of location update in the entire region in four scenarios within six days are all higher than 97%.

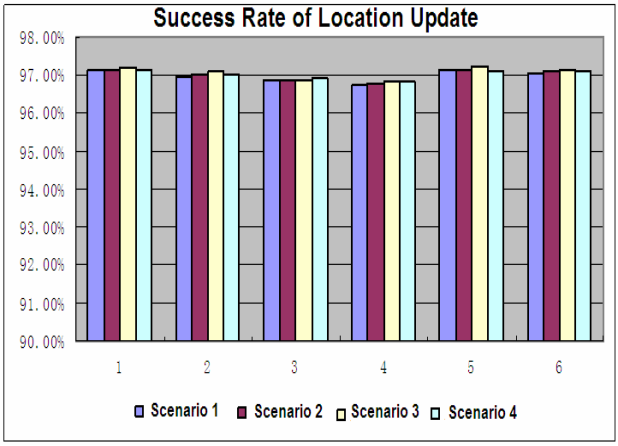

Fig. 9. Success rates of location update

Times of location update in the entire region in four scenarios within six days are collected. The average value is 3094353 times in scenario 1, 2887721 times in scenario

2, 3102822 times in scenario 3, and 3048604 times in scenario 4. The number of location update times in the entire region in scenario 2 is the smallest, which is 160883 (about 5.3%) smaller than that in scenario 4, 206632 (about 6.7%) smaller than that in scenario 1, and 215101 (6.9%) smaller than that in scenario 3.

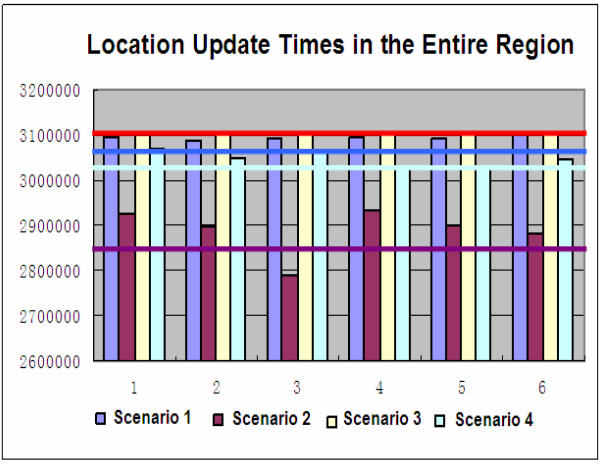

Fig. 10. Times of location update in the entire region

5 Conclusions

The proposed precise paging technology can eliminate the bottleneck of co-LAC. The precise paging technology has been implemented o. According to actual test, when precise paging is started in co-LAC, the paging success rate of the live network is not affected. The study of situations before and after precise paging is started shows that precise paging can eliminate invalid paging messages of the 2G network upon the 3G network and realize the expected target. Invalid paging messages decrease from 78432 to 705, and the ratio of valid paging increases to 48.23% from 47%.

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