

TAC Reconfiguration for Paging Optimization in LTE-Based Mobile Communication Systems

Hyung-Woo Kang¹, Seok-Joo Koh^{1,*}, Sang-Kyu Lim², and Tae-Gyu Kang²

¹ School of Computer Science and Engineering, Kyungpook National University, Korea
hwkang0621@gmail.com, sjkoh@knu.ac.kr

² Electronics Telecommunications Research Institute, Korea
{sklim, tgtkang}@etri.re.kr

Abstract. In LTE-based mobile communication systems, a Tracking Area Code (TAC) is defined by a group of cells for paging operation. The existing TAC configuration has been made manually by considering only the geographical location of cells, and thus it tends to induce an imbalanced TAC configuration and a low paging success rate. In this paper, we propose a reconfiguration of the existing TAC configurations to get a more balanced TAC configuration and to increase the paging success rate. The proposed TAC reconfiguration scheme is designed by considering the mobility (handover) ratio of mobile users between cells as well as the number of users in cells. From the performance analysis with real traffic data of SK Telecom in Korea, we see that the proposed scheme can provide more balanced TAC configurations and also improve the paging success rates by 8%, compared to the existing TAC configurations.

Keywords: LTE, TAC, reconfiguration, handover ratio, paging optimization.

1 Introduction

In the design of mobile communication system [1, 2], the paging performance is one of the important factors to be considered. The paging operation is initiated to locate a mobile user who is currently in the idle mode. In the LTE-based mobile systems, a paging area is defined by a Tracking Area Code (TAC) [3, 4], and the paging request message will be broadcast to all of the cells in the TAC so as to locate the mobile user.

Most of the mobile operators have so far configured the TACs manually in an arbitrary way, in which only the geographical location of cells in the network is considered. However, such scheme may induce imbalanced TAC configurations and low paging success rate. In this paper, we propose a TAC reconfiguration scheme to get more balanced configurations and also to improve the paging success rate by considering the mobility (handover) ratio between cells as well as the number of users in cells.

This paper is organized as follows. In Section 2, we discuss the existing TAC configuration and paging operations. Section 3 proposes a new TAC reconfiguration scheme with the relevant mathematical optimization model. Section 4 analyzes the performance of the existing and proposed TAC configurations with the real traffic data of SK Telecom. Section 5 concludes this paper.

* Corresponding author.

2 Existing TAC Configuration and Paging Operations

Figure 1 shows an example of TAC configuration in a mobile network. In this figure, there are 11 TACs in a network area, and a group of cells are assigned to a TAC. TAC is encoded with 2-byte hexadecimal digit (e.g., 240A), in which the first byte (e.g., 24 in the example) represents the associated network area, called the Tracking Area List (TAL), and the second byte (0A) is used to identify the TAC in the TAL area.

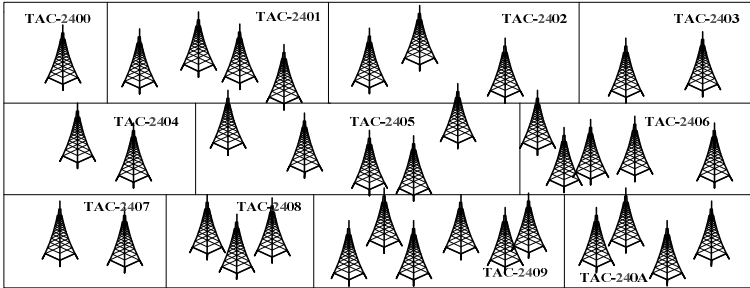


Fig. 1. Example of TAC Configuration in TAL

When a mobile user is connected to a cell, the user is assigned to the TAC in which the cell belongs to. Given a TAC configuration, when a paging is required for an idle-mode mobile user, the paging operations are performed as follows. If the user was registered with a TAC, then a paging request message will be broadcast to all of the cells in the TAC. This is called the *first* paging. If the first paging request fails (i.e., there is no response to the paging request from the user), then the *second* paging is performed. In the second paging, the paging request will be broadcast to all of TACs in the TAL area, and thus a large amount of paging messages will be generated in the network, and the paging response time will also get larger. Thus, we need to increase the paging success rate for the first paging by optimizing the TAC configuration.

At present, most of the mobile operators tend to configure the TACs in an arbitrary way. In this TAC configuration, only the geographical location information of cells in the network is considered, and the network manager manually configures a group of cells as a TAC. This is, the handover ratio between cells has not been considered in the TAC configuration, which may increase the failure probability for the first paging. Such a configuration scheme also tends to generate an imbalanced TAC configuration. By this, the first paging is likely to fail in the paging operation, and thus the paging success rate is decreased.

To improve the paging success rate and thus to reduce the paging delay, in this paper, we propose a reconfiguration scheme of the existing TAC configuration. The proposed TAC reconfiguration scheme is designed by considering the handover ratio mobile users between cells and the number of users in cells, so as to get more balanced TAC configurations and also to enhance the paging success rates for the first paging process.

3 Proposed TAC Reconfiguration Scheme

3.1 Optimization Model

We first construct a mathematical optimization model for TAC reconfiguration. Given a mobile network, the objective is to find an optimal TAC configuration to maximize the paging success rates by considering the handover rates between cells, while the number of users in a TAC does not exceed the given paging traffic capacity.

To derive the associated optimization model, we define the following notations:

- ◇ N : a set of cells in the area, with the size of n ;
- ◇ M : a set of TACs in the area, with the size of m ;
- ◇ λ_i : average number of users (paging traffic load) for cell $i \in N$;
- ◇ h_{ij} : handover ratio of users from cell i to cell j , where $\sum_{j \in N} h_{ij} = 1$;
- ◇ C_{TAC} : the maximally allowable traffic load (number of users) for each TAC;
- ◇ x_{ik} : a decision variable, $x_{ik} = 1$ if cell i is assigned to TAC k , $x_{ik} = 0$ otherwise.

Based on these variables and parameters, we can derive an optimization model for TAC configuration, as shown in Fig. 2. In the model, the objective function represents the *paging success rate* (PSR) for the first paging, which is calculated as the sum of $\lambda_i \times h_{ij}$. That is, the paging process will be successful, if cell i and cell j were assigned to the same TAC k , after a user in cell i moves into cell j .

Maximize $\sum_{k \in M} \sum_{i \in N} \sum_{j \in N} \lambda_i \times h_{ij} \times x_{ik} \times x_{jk}$

Subject to

$\sum_{i \in N} \lambda_i \times x_{ik} \leq C_{TAC}$, for all $k \in M$ (1)

$x_{ik} = 1$ or 0 , for all $i \in N, k \in M$ (2)

Fig. 2. Optimization Model for TAC Reconfiguration

3.2 Reconfiguration Algorithm

As an input to the TAC reconfiguration, we consider the current TAC configuration with n cells and m TACs. Given the traffic distribution (number of users) in cell (λ_i) and handover ratio between cells (h_{ij}), we first select the TAC ($k1$) with the smallest number of cells among m TACs. Now, we consider the other TAC ($k2$), and calculate the handover ratio h_{ij} between each cell $i \in TAC(k1)$ and each cell $j \in TAC(k2)$. In this way, we will consider all of the TACs other than TAC($k1$). Then, we will choose the TAC(k^*) that has the largest handover rate from a cell in TAC($k1$) to a cell in TAC(k^*). Now, the associated cell j in the selected TAC(k^*) will be assigned to the TAC($k1$), if such the assignment satisfies the constraint (1) in Fig. 2.

These operations will be repeated until no more improvement of PSR is obtained. It is noted that this algorithm requires the worst-case time complexity of $O(mn^2)$. The proposed scheme can be summarized in Figure 3.

Step 1. The current TAC configuration is given with n cells and m TACs.
 Step 2. Select the $TAC(k)$ with the smallest number of cells among m TACs.
 2-1. For each cell $i \in TAC(k)$, calculate h_{ij} for all $j \in TAC$ other than $TAC(k)$.
 2-2. Let $TAC(k^*)$ be the TAC that contains the cell j with the largest h_{ij} .
 2-3. Assign the cell j from $TAC k^*$ to k , if the constraint (1) is satisfied.
 2-4. If PSR is improved, go to Step 2. Otherwise, go to Step 3.
 Step 3. Consider $TAC(k)$ with the next smallest number of cells among TACs.
 Perform Step 2-1 through Step 2-4.
 Step 4. Perform Step 2 and Step 3, until no more PSR is improved.

Fig. 3. Proposed TAC Reconfiguration Algorithm

4 Experimental Results and Discussion

In experiment, we use the real-world traffic data of SK Telecom in Korea. The proposed TAC reconfiguration scheme was applied to a total of 10 network (TAL) areas, and we compare the balance factor (standard variation for the number of cells and the number of users in each TAC in the network area) and the paging success rates for the existing and proposed configurations. For the paging success rate, we calculate the paging success probability (PSP) = $PSR / \sum_{i \in N} \lambda_i$, which represents the ratio of successfully paged traffics over total paging traffics in the network.

Table 1 shows the existing TAC configuration and result of the proposed TAC reconfiguration scheme for the area 11, which has m (total number of TACs) = 15.

Table 1. Comparison of TAC Configurations (for Area 11)

TAC index	Existing Configuration		Proposed Reconfiguration	
	# of cells	Traffic Load (# of users)	# of cells	Traffic Load (# of users)
1100	121	514	115	479
1101	75	351	77	380
1102	74	440	78	481
1103	93	819	93	806
1104	107	701	113	761
1105	93	344	90	348
1106	261	2090	257	2017
1107	132	1098	139	1185
1108	191	1609	188	1552
1109	215	1802	208	1690
110A	146	365	147	364
110B	7	1	7	1
110C	3	2	3	2
110D	149	310	153	350
110E	127	175	126	159
Cell Number Variation	67.27		65.89	
Traffic Load Variation	633.03		606.48	
PSP	82.89%		87.24%	

For the existing TAC configuration in Table 1, we can see that TAC 110C contains only 3 cells, whereas TAC 1106 have 261 cells. This implies that the existing TAC configuration is severely imbalanced in terms of the number of cells in the TAC. This leads to a lower paging success rate. The paging traffic load variation value is 633.03. Overall, the existing configuration gives the PSP of 82.89%.

On the other hand, we can see that the proposed scheme provides more balanced TACs and much higher PSP, compared to the existing configuration. The proposed TAC reconfiguration scheme gives the traffic load variation value of 606.48. The PSP of the proposed scheme is 87.24%, which is greater than the existing configuration.

Figure 4 shows the existing and proposed TAC configurations for total 10 network areas (TALs). From this figure, we can see that the proposed TAC reconfiguration improves the PSPs of the existing TAC configuration by 4.72% on the average and 7.88% in the maximum.

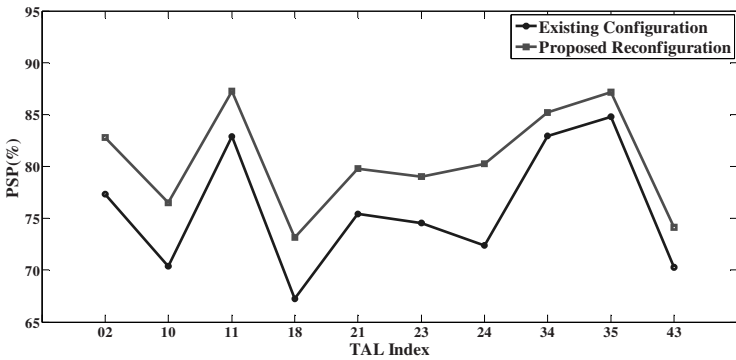


Fig. 4. Comparison of PSPs for the Existing and Proposed Schemes

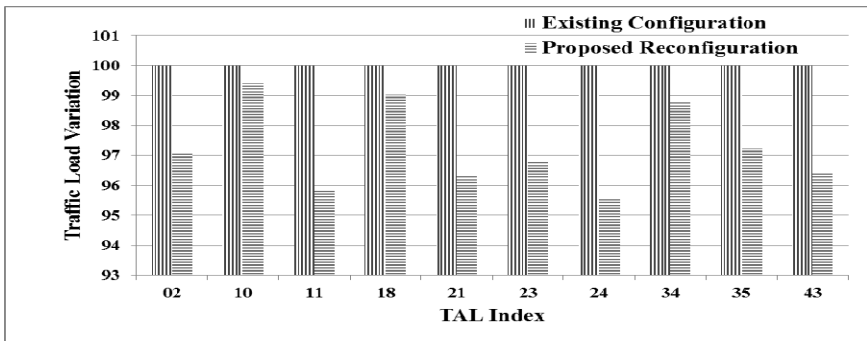


Fig. 5. Comparison of Traffic Load Variations

Figure 5 compares the traffic load variations of 10 TAL areas for the existing and proposed schemes, in which the traffic load variation of the existing configuration is set to 100. In the figure, we can see that proposed TAC reconfiguration can reduce the traffic load variations of the existing TAC configurations by 3 ~ 4% approximately.

This implies that the proposed TAC reconfigurations are more balanced than the existing TAC configurations in the viewpoint of the traffic load variations.

Figure 6 shows the cell number variations (standard derivation of cells) among TACs in the 10 areas for the existing and proposed configurations. From the figure, we can see that the proposed scheme provides more balanced TAC reconfigurations than the existing scheme.

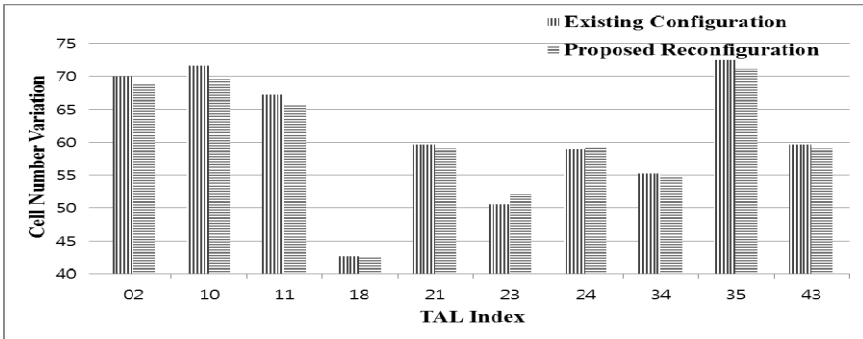


Fig. 6. Comparison of Cell Number Variations

5 Conclusions

In this paper, we propose a new TAC reconfiguration scheme to maximize the paging success rate and to get a more balanced TAC configuration in LTE-based mobile communication networks. The proposed scheme considers the mobility ratio between cells as well as the number of users in cells.

By experimentation with real-world data of SK Telecom, the proposed scheme was compared with the existing scheme in terms of the paging success rate and the balance factors of the cell number and paging traffic loads. From the results, we can see the proposed scheme provides more balanced TAC configurations with higher paging success rate than the existing scheme.

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