

Configuration of Tracking Area Code (TAC) for Paging Optimization in Mobile Communication Systems

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Abstract. Recently, the mobile telecommunication traffics have been rapidly increasing due to the growth of smart phone services. In this paper, we propose a new scheme for configuration of TAC (Tracking Area Code) to maximize the paging success rates in the LTE-based mobile communication networks. The proposed scheme includes the initial configuration of TAC, the local optimization algorithm, and the re-clustering algorithm for further improvement of the TAC configuration. From the performance analysis with real traffic data of service provider, we see that the proposed TAC configuration scheme can improve the paging success rates in the LTE networks, compared to the existing TAC configuration scheme.

Keywords: LTE, Tracking Area Code, Paging, Optimization.

1 Introduction

With the popularity of smart phones, mobile communication has been rapidly changes from 3GPP to Long Term Evolution (LTE). Recently, LTE is emerging as the new mobile communication technology [1-3].

A mobile user typically moves around in a zone that is composed of many cells in a mobile communication system. When a call request to a specific user arrives, the cellular system should page the user in the cells to locate the user in the network. It is noted that the cellular systems require efficient methods to find a specific mobile user in the paging process [4-6]. In particular, the paging success rate is a very important factor in the design of the paging areas. A paging area is defined by a Tracking Area Code (TAC).

In this paper, we propose a new scheme for configuration of TACs to improve the paging success rates in the paging process. A TAC consists of a group of cells to which a paging signal is broadcast in the paging process. The proposed TAC configuration scheme can be used to increase the paging success rate and to reduce the overhead of paging traffic in the LTE networks.

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This paper is organized as follows. In Section 2, we discuss the TAC optimization issue and how to configure the TAC in the mobile communication system. In Section 3, we describe the proposed TAC configuration algorithm. Section 4 describes the experimental analysis and comparison with the existing scheme. Finally, Section 5 concludes this paper.

2 TAC Optimization in Mobile Communication System

2.1 TAC Configuration

At present, most of the mobile operators configure the TAC in an arbitrary way, in which only the topological location information of all cells are considered and the network manager manually configures a group of cells as a TAC. TAC is defined as a group of cells. The TAC is coded into a 2-bytes hexadecimal digit, in which the first byte represents the area code, called the Tracking Area List. When a call request is required for a specific user, if the user was registered with a TAC, then a paging signal will be broadcast to all of the cells contained in the TAC.

Usually, when a mobile user is connected to a cell in network attachment phase, the user is assigned to the TAC that the cell is associated with. If the user moves to a new cell in the dormant mode, the TAC of the user may be changed, if the TAC of the new cell is different from that of the old cell. Accordingly, the TAC should be configured by considering the mobility and traffic of users in the mobile network.

The Self-Organizing Network (SON) system is used in the LTE-based mobile communication in order to configure and manage a mobile network. For TAC configuration, the TAC optimization S/W provides the information of optimized TAC configuration to the SON system. Figure 1 describes the overview of SON system [7].

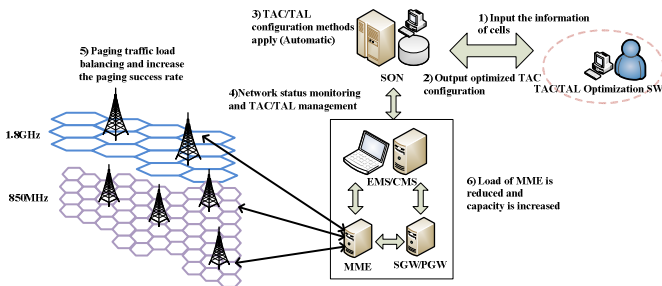


Fig. 1. SON system and TAC Configuration

With such TAC configuration, when a paging request to a specific user arrives, the paging operations are performed as follows. In the first paging, the paging request message (or signal) will be broadcast to the cells contained in the TAC. If the paging request fails (i. e., no response to the paging request from the mobile user), then the second paging is performed, in which the paging request will be broadcast to all of the cells in the area. Therefore, it is important to optimize the TAC configuration so as to

maximize the paging success rate of the first paging and thus to reduce the paging traffics generated in the network.

3 Proposed TAC Configuration Algorithms

3.1 TAC Optimization Model

For TAC optimization, we first make a mathematical optimization model for TAC configuration. Given a network area with many cells, the goal is to find an optimal TAC configuration (mapping from a group of cells to a TAC) by considering traffic and user mobility between cells. The Paging Success Rate (PSR) is used as the objective function of the optimization model. The PSR represents the success probability of the first paging.

Figure 2 shows the mathematical model of TAC optimization.

<p>Objective function: Maximize PSR</p> $PSR = \sum_{k \in M} \sum_{i \in N} \sum_{j \in N} \lambda_i \times P_{ij} \times X_{ik} \times X_{jk}$ <p>Constraints: feasibility conditions</p> $\sum_{k \in M} X_{ik} = 1, \text{ for all } i \in N \text{ (TAC assignment condition)}$ $\sum_{i \in N} X_{ik} \leq S_{TAC}, \text{ for all } k \in M \text{ (TAC size condition)}$ $\sum_{i \in N} \lambda_i \times X_{ik} \leq C_{TAC}, \text{ for all } k \in M \text{ (PTL condition)}$ $d_{ij} \times X_{ik} \times X_{jk} \leq D_{TAC} \text{ for all } i, j \in N, k \in M \text{ (distance condition)}$ $X_{ik} = 1 \text{ or } 0, \text{ for all } i \in N, k \in M$
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Fig. 2. TAC Optimization Model

In the optimization model, we use the following variables and parameters:

- P_{ij} : mobility ratio that user moves from cell i to cell j ;
- λ_i : sum of paging traffics in cell i ;
- d_{ij} : distance between cell i and j ;
- N : a group of cells in TAL, with the size of n ;
- M : a group of TAC in TAL, with the size of m ;
- S_{TAC} : the maximum number of cells that a TAC can contain;
- C_{PTL} : the maximum paging traffic load allowable for a TAC; and
- D_{TAC} : the maximum distance between two cells allowable for a TAC.

On the other hand, we consider the following feasibility conditions:

- TAC assignment condition: each cell should be assigned to at least one TAC;
- TAC size condition: the number of cells assigned to a TAC cannot exceed S_{TAC} ;
- Paging Traffic Load (PTL) condition: the paging traffic load for a TAC cannot exceeds C_{PTL} ;
- Distance condition: the distance between two cells in TAC cannot exceed D_{TAC} .

3.2 Proposed TAC Configuration Schemes

Based on the TAC optimization model described in Section 2, we propose the TAC configuration algorithms in this section. The proposed algorithms consist of initial configuration of TAC, local optimization algorithm, and re-clustering algorithm for further improvement of the TAC configuration.

Figure 3 shows the overall sequence of the proposed algorithms.

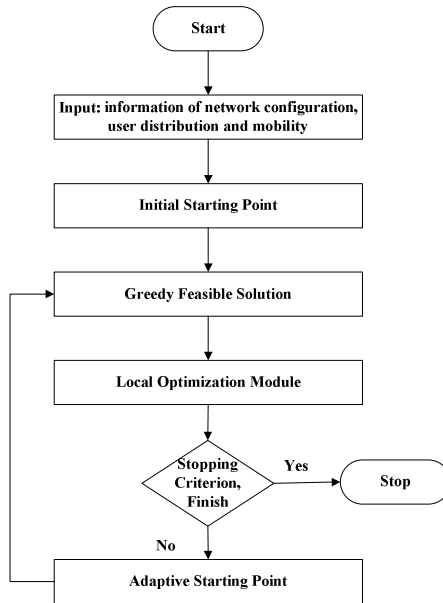


Fig. 3. Overall Algorithm for TAC Configuration

As input to TAC configuration, we consider the mobility ratio and paging traffic per cell and the distance between cells. The Initial Starting Point (ISP) algorithm is used to select an initial cell for each TAC as the starting point to overall algorithm. Based on these initial points, the Greedy Feasible Solution (GFS) algorithm is used to obtain a feasible TAC configuration, in which all of the cells are assigned to one of the TACs in the network. In the GFS algorithm, each cell will be assigned to a TAC in a stepwise way so as to maximize the PSR objective function while satisfying the feasibility conditions.

After the GFS algorithm is performed, we apply the Local Optimization Module (LOM) algorithm to find a more optimized solution. In LOM, we try to optimize the TAC configuration by changing the TAC of a cell to the other TAC. Finally, the Adaptive Starting Point (ASP) algorithm is used to explore the other solution space for further optimization, in which an initial starting cell per TAC will be re-calculated and then the optimization algorithms (GFS and LOM) are performed again. Such procedures are repeated until the stopping criterion is satisfied. The details of each algorithm are described below.

3.2.1 Initial Starting Point (ISP)

The ISP algorithm is the first step of overall optimization algorithm, in which an initial cell is randomly selected for each TAC.

3.2.2 Greedy Feasible Solution (GFS)

In GFS, a feasible TAC configuration is obtained, based on the initial cells of ISP. For each TAC, we select the cell with the largest mobility rate moving from the initial cell among the other cells that have not assigned to any TAC. The selected cell will be assigned to the TAC, if the feasibility conditions are still satisfied by this assignment. GFS will be repeated until all cells are assigned to one of the TACs.

3.2.3 Local Optimization Module (LOM)

The LOM algorithm finds more optimized configuration of TAC. Based on the configuration obtained by GFS, we try to change the TAC of a cell to another TAC. If the PSR value is improved by the TAC change, we perform the change of TAC for the cell. Otherwise, if the PSR value is not improved or the feasibility condition is not satisfied, we do not change the TAC of the cell. These procedures are performed until no improvement of PSR is made for all cells.

3.2.4 Adaptive Starting Point (ASP)

After LOM is completed, the ASP algorithm is used to explore much more solution space in the optimization process. For each TAC given by LOM, we find the 'center' cell, which is obtained by calculating the distances of the other cells from a candidate center cell within the TAC. We define the center cell as the cell with the minimum distance to the other cells.

In ASP, a center cell is calculated for each TAC and it is used as an initial point to GFS and LOM. This ASP algorithm is performed until a pre-specified stopping rule (e. g., totally 10 times)

4 Experimental Results and Analysis

4.1 Test Network Environment

In the experiments, we use the real-world data of network topology, user traffic, and the mobility rates to neighboring cells, which are based on the information of SK Telecom in Korea. The proposed TAC configuration scheme was applied to a target area, and we calculate the PSR value.

For all of the experiments, the default values for parameters are set as follows: N is different for TAL, $M = 11$, $S_{TAC} = (N / M) + 10$, $C_{TAC} = 2100$, $D_{TAC} = 1/2 * \text{the maximum distance between cells in TAL}$.

4.2 Results and Discussion

In experiments, the distance between two cells is calculated by using the Euclidean distance. The probability of moving from a cell to another is assumed to be 20%,

which is represented as α . That is, a mobile user remains within the current cell with a probability of 0.8. Then, the Paging Success Probability (PSP) can be calculated as follows, as shown in Figure 4.

Paging Success Probability (PSP)

$$\text{PSP} = (1-\alpha) + \alpha \times \text{PSR} / \lambda,$$
 where $\lambda = \sum_{i \in N} \lambda_i$, α = the probability of moving from a cell to another

Fig. 4. Calculation of PSP

Table 1 shows the comparison of the existing and proposed schemes for TAC configuration, which is applied to the target area that is coded 19.

Table 1. Comparing the Existing and Optimization TAC configuration of target area

TAC Index	Existing TAC Configuration			Optimized TAC Configuration		
	# of cells	maximum distance	PTL	# of cells	maximum distance	PTL
1900	51	12624	684	64	9565	968
1901	56	4041	829	63	5990	688
1902	48	4629	671	64	9624	264
1903	44	2714	680	64	4489	710
1904	72	6325	1083	62	6436	524
1905	68	6789	943	64	5673	787
1906	53	6138	494	65	6917	904
1907	55	3797	569	61	6236	584
1908	5	4002	60	57	6795	685
1909	5	1152	73	71	8115	401
190A	193	7995	571	5	4002	60

In the table, we can see that the original (existing) TAC configuration is composed of a total of 642 cells and is made up with a number of 11 TACs. It is noted that the TAC 190A contains 193 cells, which violates the feasibility condition of S_{TAC} , whereas the TAC 1908 and 1909 have only 5 cells. This implies that the existing TAC configuration is not balanced in the viewpoint of the TAC size. This leads to a lower Paging Success Rate. The standard deviation of PTL is 91268. Overall, the existing TAC configuration gives the Paging Success Probability (PSP) of 89.39.

On the other hand, the optimized TAC configuration assigns the total 642 cells to 11 TACs. Most of the TACs have the TAC size of a minimum 61 cells and up to 71 cells, except for TAC 190A. This is because the TAC 190A is a subway TAC, and thus this TAC cannot be further optimized. Note that all TACs give the nearly equal size, except the subway TAC, in the proposed optimization scheme. The standard deviation of PTL is 67268, which is lower than the existing configuration. The PSP of the proposed scheme is calculated as 91.58, which is greater than the existing scheme.

Figure 5 compares the PSP values of target area for the existing and proposed schemes as phases of optimization. From the figure, we can see that the proposed scheme provides higher PSP than the existing scheme. That is, the proposed optimization scheme improves the PSP compared with the original configuration.

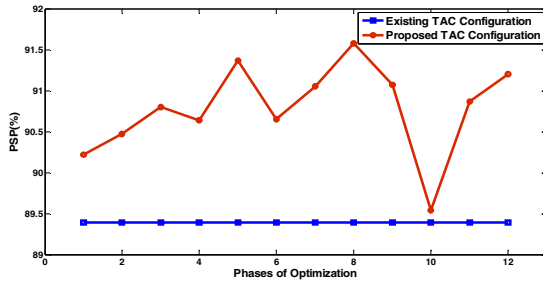


Fig. 5. Paging Success Probability of target area

Figure 6 and 7 shows the distribution of TACs for the target area, in the viewpoint of physical location, for the original and optimized TAC configuration schemes.

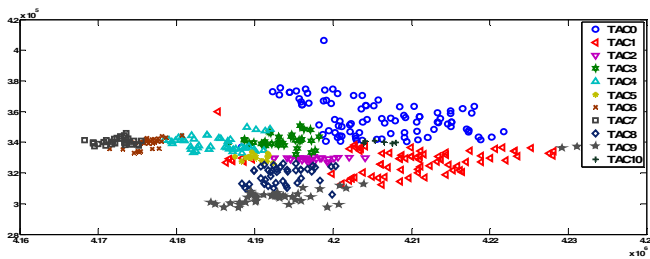


Fig. 6. Existing TAC configuration

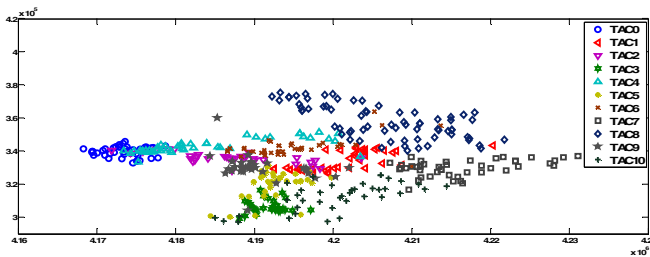


Fig. 7. Proposed TAC configuration

From the figure, we can see that the proposed scheme gives more compact and balanced TAC configurations than the existing scheme. This is because the proposed scheme applies the feasibility conditions for TAC configuration, and the PSP is maximized by including the neighboring cells into the same TAC.

5 Conclusions

In this paper, we presented a new scheme for configuration of TAC to maximize the paging success rates in LTE-based mobile communication networks. The proposed scheme is composed of a set of sub-algorithms: Initial Starting Point (ISP), Greedy Feasible Solution (GFS), Local Optimization Module (LOM), and Adaptive Starting Point (ASP). In the TAC optimization, we also considered the feasibility conditions to get a balanced configuration of TACs.

By the experimentations for real-world data of network topology and user traffic, the proposed optimization scheme is compared with the original existing scheme in the perspective of paging success probability. From the results, we can see that the proposed scheme provides more optimized TAC configurations than the existing scheme by maximizing the paging success probability. It is also noted that the proposed scheme gives a more compact and balanced TAC configuration than the existing scheme by using the feasibility conditions. It is expected that the proposed TAC optimization scheme can be used in the real-world mobile communication networks to maximize the paging success rates and to reduce the paging traffic load.

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