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Mobility management with the central-based location area policy

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ABSTRACT

In *Long Term Evolution* (LTE), the cells (the radio coverages of base stations) are grouped into the *Tracking Areas* (TAs), and the TAs are further grouped into the *TA List* (TAL). The location of the *User Equipment* (UE) is tracked at the TAL level. To better capture the "movement locality" of the UE, when the UE leaves the current TAL, the UE is assigned a new TAL whose central TA is the TA where the UE currently resides. This paper investigates the performance of the central-based LTE mobility management scheme, and compares this scheme with the previously proposed central-based mobility management schemes: the movement-based and the distance-based schemes. Our study indicates that under some traffic/mobility patterns, the LTE scheme yields the best performance.

1. Introduction

In most commercial *third-generation* (3G) mobile telecom networks, the cells (the radio coverages of base stations) are grouped into *Location Areas* (LAs) [1]. When the *User Equipment* (UE) moves from an old LA to a new LA, the UE executes the location update procedure to inform the network of its new location. When an incoming call arrives, the network searches the UE by broadcasting the paging messages to all cells in the LA simultaneously.

The 3G LA-based mobility management scheme has several disadvantages [2,3]. First, the UE may perform many location updates when the UE resides in the boundary cell of the LA and frequently moves back and forth between two LAs (i.e., the ping–pong effect [4]). Second, when an incoming call arrives, if the LA contains a large number of cells, it may incur large paging traffic to search the UE.

The disadvantages of the LA-based scheme can be avoided in *Long Term Evolution* (LTE). We first describe the LTE mobility management and then show how the aforementioned issues of the LA-based scheme can be resolved in LTE. In LTE, the cells (Fig. 1a) are partitioned into non-overlapped *Tracking Areas* (TAs; Fig. 1b) [5,6]. Every TA has a unique *TA Identity* (TAI). The TAs are further grouped into *TA Lists* (TALs). In Fig. 1c, TAL 1 includes TA 1, TA 2 and TA 3. The *Mobility Management Entity* (MME; Fig. 1d) is responsible for assigning the TAL to the UE through the location update procedure. To mitigate the ping-pong effect, we consider the *central policy* [5] that assigns the TAL where the UE resides in the central TA of this TAL. In Fig. 1(1), when the UE performs the location update in TA 2, the MME assigns TAL 1 to the UE, where TAL 1 = {TA 1, TA 2, TA 3} centered at TA 2. Every base station periodically broadcasts its TAI. The UE detects the location change by searching its TAL for the broadcast TAI. If the broadcast TAI is found in its TAL, it means that the UE still resides in its TAL. Otherwise, the UE executes the location update procedure to inform the MME that it has left the current TAL. In Fig. 1, when the UE moves from Cell 4 (Fig. 1(1)) to Cell 7 (Fig. 1(2)), the broadcast TA 4 identity is not found in TAL 1, and the UE executes the location update procedure to inform the MME that the UE has moved out of TAL 1. Then the MME allocates a new TAL to the UE. In Fig. 1, the allocated TAL is TAL 2 = {TA 3, TA 4, TA 5}. Note that the TAL is assigned on a per-user basis (i.e., the different UEs may have different TALs), and the newly assigned TAL may overlap with the previously assigned TAL. In Fig. 1, TA 3 is included in both TAL 1 and TAL 2.

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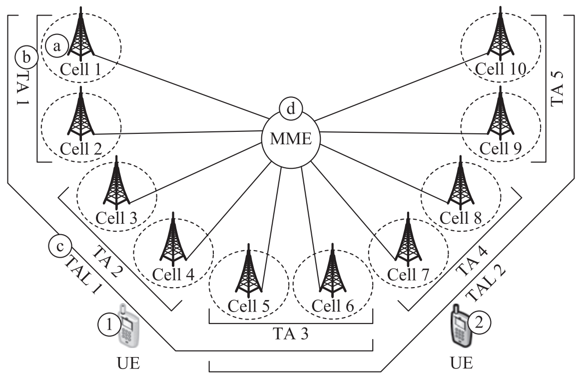

Fig. 1. LTE mobility management architecture.

We also note that the 3G LA-based location update is a special case of the LTE TAL-based location update when the size of an LA is equal to that of a TAL and the TAL only contains one TA. When an incoming call arrives, the cells of the UE's TAL will page the UE. In most commercial 3G mobile networks, all cells in the LA of the UE will execute the paging procedure simultaneously. To reduce the paging traffic, we consider a LTE paging scheme [7] where the MME records the cell where the UE has interacted with the network (e.g., makes call, receives call, or performs location update). This cell is referred to as the interacted cell. When an incoming call arrives, the MME conducts the TAL paging procedure as follows:

Step 1.1. The MME sends the paging message to the last interacted cell. If the MME receives the paging response from the UE, the MME establishes the connection to the UE to deliver the incoming call, and the paging procedure is terminated. Otherwise (i.e., the MME does not receive the response within a timeout period), Step 1.2 is executed.

Step 1.2. The MME sends the paging messages to the TA of the last interacted cell. If the MME receives the paging response, the connection is established, and the paging procedure is terminated. Otherwise, Step 1.3 is executed.

Step 1.3. The MME sends the paging messages to all cells in the TAL to search the UE. After the UE sends the paging response to the MME, the incoming call is delivered to the UE.

We define a *polling cycle* as a period between when the MME sends the paging messages to the cells and when the MME receives the paging response or a timeout occurs. Let N_p be the maximum number of the polling cycles before the UE is found. Steps 1.1–1.3 indicate that $N_p = 3$ in the TAL paging scheme.

Our previous work has proposed an analytic model to compare the performance between the central-based LTE mobility management and the 3G mobility management, which shows that the LTE mobility management outperforms the 3G mobility management [7]. This paper describes a simulation model for the TAL-based scheme, and compares the TAL-based scheme with the movement-based [2,8] and the distance-based [8–10,13] schemes with the *Shortest-Distance-First* (SDF) paging [2,10]. Note that the movement-based and the distance-based schemes with the SDF paging were intensively studied in the literature. However, these schemes have not been exercised in any commercial mobile telecom network because their implementations are not feasible (to be elaborated). The central policy and the TAL paging scheme we described for the LTE mobility management partially implement the distance-based scheme with the SDF paging, and we will show that our approach can capture the advantages of the distance-based scheme with the SDF paging.

This paper is organized as follows. Section 2 introduces the TAL-based, the movement-based, and the distance-based location updates. Then we describe the SDF paging scheme. Section 3 proposes a simulation model for these location update and paging schemes. Section 4 compares the performance of the TAL-based, the movement-based, and the distance-based schemes by numerical examples, and the conclusions are given in Section 5.

2. Location update and paging schemes

This section describes the TAL-based, the movement-based, and the distance-based location update schemes. For the description purpose, we consider a *two-dimensional* (2-D) mesh cell configuration (i.e., Manhattan-street layout) as illustrated in Fig. 2, where a rectangular represents a cell. In this configuration, each cell has eight neighboring cells. Many previous studies assume that the UE moves to one of the neighboring cells with the same routing probability [2,8,10]. We relax this assumption to accommodate heterogeneous routing patterns. In our random walk model, the UE moves to the right-hand side neighboring cell with routing probability p, and moves to one of other neighboring cells with the same probability $(1 - p)/7$. If $p = 0.125$, then the routing pattern is homogeneous (i.e., the UE movement exhibits locality; e.g., a pedestrian or a vehicle in local roads), which is the same as those in [2,8,10]. If $p = 1$, the UE moves to one direction (e.g., a vehicle in highways). Note that in [7], we used the 1-D model to represent the UE movement in highways. On the other hand, this paper uses 2-D model for city layout. We have showed that the effects of the input parameters in 1-D and 2-D models are similar [7]. Based on the 2-D cell configuration, we describe the location updates and the *Shortest-Distance-First* (SDF) paging in the following subsections.

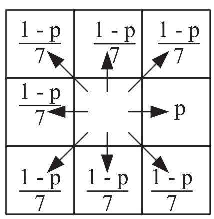

Fig. 2. Mesh cell configuration and the movement directions.