# “Adaptive Individual Location Areas for PCS systems”

* A location area is a group of locations(cells) where the user is currently likely to reside
* GSM use a fixed LA strategy for everyone. The major problems with this strategy are that the fixed LA chosen based on the aggregate mobility and call statistics is not optimal individually, and that the scheme cannot adapt to the changing mobility and call characteristics
* Dynamic Location Area Management Scheme proposed previously intended to solve these problems, which introduces an Individual LA concept. Rather than using fixed Las for all users, this scheme uses a different LA for a different user. The performance of this scheme is in general significantly better than the fixed LA scheme.
* Most previous problem work in mobility management discussed only the sizing problem of Las – how many locations should be put into an LA. However, the problem of LA shape with respect to different movement and call patterns had not been studied.
  + We found that the LA shape plays an important role in signaling cost reduction
* Goal: to minimize the combined average signaling cost due to both paging and registration for each individual mobile user, such that the overall system-wide signaling cost for location tracking can be minimized.
* The signaling cost for registration depends on the average registration rate of a user which is inversely proportional to the mean user dwell time within the LA. While the cost for paging is proportional to the mean rate of incoming call arrivals and the number of cells inside the LA.
  + To reduce the overall cost, registration procedures require the LA to expand while paging procedures want the LA to shrink. Those conflicting requirements form an LA optimization problem.
* Mobility modelling for an individual user requires a model that describes the time-varing motion of an individual and has motion parameters readily available for analysis.
  + A basic mobility characteristic is the increase in user location uncertainty with time since the last user-network interaction.

# “Dynamic Location Area Management”

* To enhance the system performance, many researchers propose using the optimum size of location areas to minimize the signaling traffic
  + All these previous studies are based on the system with a fixed size of location areas
  + The fixed size can be optimized such that the combined signaling traffic for location updates and paging consume the minimal radio bandwidth
  + When the cell size is given, the optimum size of location areas depends on the arrival rate of incoming calls and mobility of the users
  + However, different kinds of users may not have the same arrival rate, and furthermore the arrival rate of a user many not be constant from time to time.
  + THUS!!! Any system with fixed size of location areas is unable to perform optimally for all users.
* IN this paper:
  + Dynamic location area scheme
  + The size of location areas for a user is not fixed but optimized according to **its current arrival rate and mobility**
  + Thus: under the user-variant and time-variant arrival rates, it performs much better than the fixed scheme does.

# “Dynamic Location Management with Variable Size Location Areas”

1. Proposed location management algorithm uses the mobility history of individual subscribers to dynamically form individual Las based on his previous movements from cell to cell
2. It defines the size of Las based on subscriber’s speed and call arrival probability(WE COULD LEARN FROM THIS BY MODELING THE CALL ARRIVAL PROBABILITY TO BE MORE REALISTIC !)

* There is an inherent tradeoff between the costs of LU and paging
  + Existing LM schemes can be broadly categorized into two types:
    - Static & Dynamic
    - Fixed LA based, grid based and dynamically defined LA based
* In this paper, a LM scheme where with each LU message from a MS, a LA is defined for the MS based on subscriber’s mobility history
  + As long as a mobile moves within its current LA, no update message is triggered
  + Only when a mobile moves out of its present LA, a LU is triggered and a new LA is defined for the MS
  + This algorithm also considers speed and call arrival probability of subscriber to define the LA size

Previous work summarize:

* Dynamic location management algorithm:
  + Attempts to utilize the mobility history of the subscriber to dynamically create Las for individual subscriber and to dynamically **determine the most probable paging area**
* Grid-based location management
  + Mobile updates its location only when it changes its grid(LA), which is a collection of cells where the cell to which mobile is registered, is at the center of the grid
    - Not so useful where the user is moving in one direction (highway)

Process:

Speed : (cells\_crossed/(E\_Time-S\_Time))

SpeedDiffRatio= (Curr\_speed-Prev\_speed)/Prev\_speed

CallArrDiffRatio=(CurCallArrProb-PrevCallArrProb)/PrevCallArrProb

LAp = LAp-1\*(1+SpeedDiffRatio-CallArrDiffRatio)

1. The user profile will be stored as a graph where the nodes represents visited cells and the link represents transition between cells
2. The value of the node indicates the traversal frequency of that node
3. If the user traverses a new cell but the new node can’t be added to the graph, then a replacement policy can be used like least traversed node can be replaced by the newly visited node.
4. A LU is triggered whenever a subscriber enters a new cell, which is not part of previous LA or when the mobile station is first powered on, in a cell, then a new LA is formed as described in the algorithm below:

# “Probability Criterion Based Location Tracking Approach for Mobility Management of Personal Communications Systems”

* Goal
  + Seeks to minimize the average signaling cost due to both paging and registration for individual mobile users
* Method
  + A time-based location update and a single-step dynamic paging procedure are used.
  + Each user-network interaction resets the timer and modifies location record
    - The user registers when the timer expires
    - The size of these area(paging area) is an increasing function of the time since last user-network contact.
  + The shape of the paging area depends on the particular probability distribution of user location
* Advantage:
  + The problem formulation is applicable to arbitrary motion models assuming the associated user location distribution is available or can be estimated

# Modeling and Performance Analysis of Tracking Area List-Based Location Management Scheme in LTE networks

--前面写的很具有介绍性,所以可以重点观察

Distinguishes:

1. This paper follows LTE technical specifications, that is, the number of TAs in a TAL can vary and furthermore is upper-bounded, whereas existing studies partially or completely ignore this stipulation
2. As for the dependency among the **cell residence time, TA residence Time, and TAL residence time**, this paper proposes to use a fluid flow model to describe this dependency, which is simple but does not compromise the accuracy.

论证为什么使用individual user specific TAL?

* **These static LA & RA schemes are cost ineffective, being that they neglect the mobility and traffic characteristics of individual UEs. It is intuitive that UEs with high mobility should perform LUs less frequently, as in this case the LU cost dominates the total signaling cost.**
* Whereas for UEs with low mobility, frequent LUs are beneficial in reducing the paging costs, because in this case the paging cost dominates the total signaling cost.
* These static schemes will produce a ping-pong effect. Suppose that a UE moves back and forth between two neighboring Las / RAs. In this scenario the UE will perform repetitive LUs.
* These schemes will bring about the issue of uneven signaling distribution, because all the LUs occur in the border cells of an LA/RA. When massive UEs (e.g. the UEs on a train) in a short time pass through the border cells of an LA/RA, in the new cell which these UEs are moving in a huge number of LU requests will be generated toward the network. Sometimes this situation may lead to signaling congestion and affect the QoS in the cell.
  + Therefore, a cost-effective scheme needs to take into account the mobility and traffic characteristics of individual UEs.
    - To overcome the drawbacks of static LM schemes, LTE adopts a novel LM scheme, called a TA list (TAL)-based LM scheme.
* SO: the performance of the TAL-based scheme is determined by the allocated TAL. IF the allocated TAL is inappropriate to the UE’s mobility and traffic characteristics, the TAL-based scheme may generate adverse effects.

Procedure:

To adapt the mobility and traffic characteristics of individual UEs, the network may allocate different UEs different TALs. When an incoming call to the UE arrives, the UE is paged in all the cells within a TAL. Thus the total signaling cost due to the TAU and paging operations can be abated by allocating a reasonable TAL to the UE. As for the number of TAs in a TAL, it cannot exceed 16.

**Literature Review:**

* Based on the number of TAs in a TAL, the number of cells in a TA, and the study scenario, existing studies can be categorized into four groups:
  1. Assuming that a TAL comprises only one TA.
     + Z.B. when deciding which cells belong to the same LA, the network has to collect the information about massive movement track of UEs.
  2. Assuming that each TA comprises only one cell.
     + Z.B. using concept of a movement-based LU (MBLU) scheme, an optimal movement threshold for TAL allocation based on the mobility and traffic characteristics of individual UEs could be derived.
     + Z.B. 2. Adopting the notion of a distance-based (DBLU) scheme, a self-organization TAL allocation mechanism … derived an optimal distance threshold, however two extra timers is used so as to increase the system complexity.
     + In addition, papers above considered that a TAL is a concentric ring consisting of TAs. In this case, when the optimal movement/distance threshold is large, may even violate the 16-TA upper bound.
     + 瑞典的那些论文可以归类为这边
  3. Considering a one-dimensional study scenario.^
     + In static LA/RA-based schemes, when a large number of UEs cross an LA boundary, e.g. the case in train movement, there is a risk of LU signaling storm in a border cell due to a large amount of LU signaling cost generated in a short time. So an overlapping TALs method to mitigate the uplink signaling congestion.
     + Through this method, the UEs on a train are allocated different TALs so that the risk of LU signaling storm can be avoided.
  4. Assuming that a TAL comprises multiple TAs, each of which is composed of a group of cells.
* Problems so for by literature reviewing:
  1. Some studies assumed that a cell allocates a common TAL to individual UEs. Thus this common TAL may not be cost-effective for all the UEs.
  2. To simplify the analyzing processes, some studies assumed that a TA includes only one cell, which is unreasonable, because a TA generally comprises multiple cells.
  3. All the existing studies neglected the rule that the number of TAs in a TAL cannot exceed 16.
  4. There lacks an accurate mathematical approach to calculate the signaling cost of the TAL-based scheme for **“global UEs. “**

Purpose of this paper: develop a comprehensive mathematical approach to address all these problems.

**Contributions:**

* Bases on the developed approach (embedded Markov approach), **this paper further investigates the impact of the number of TAs in a TAL and the number of cells in a TA on the total signaling cost through numerical studies.** 
  + With these numerical results**, when the number of cells in a TA is fixed, based on the mobility and traffic characteristics of individual UEs, the network can allocate an optimal TAL to the UE that can minimize the total signaling cost**.

System model:

* The structures of a cell, TA, and TAL should be assumed
  + Cell structure: assume that all the cells in a network are regular hexagons of the same size so that each cell has 6 neighbor cells.
  + TA structure: Assume that all TAs in the network **have the same ring structure** consisting of cells. Denote by d the radius of this structure. A TA consists of d rings of cells labeled as ring r’s, r =0,1,… d-1🡪 🡪🡪Number of TAs: 3d^2-3d+1
  + TAL structure: denote by NTA the number of TAs in a TAL. In this TAL structure, all the TAs are identical.
    - To facilitate mathematical analysis, the border TAs in a TAL can be divided into two types: vertex TAs and inner TAs(with more neighbors)
    - There are two configurations to remove vertex & inner TAs so that they satisfy border limitations, 2 vertex + 1 inner OR 2 inner + 1 vertex
    - The signaling of these configurations are compared
    - **This paper considers only a situation where all the removed TAs are adjacent. For nonadjacent situations, the corresponding mathematical analyses are similar.**

User Mobility

* A fluid flow model was proposed to compute the rate at which a UE residing in a closed region moves out of the border of the region. The rate is called the border crossing rate. (characterize the residence times in closed regions, a cell or an LA.)
* In order to apply the fluid flow model to describe the residence times in closed regions, the following two assumptions are necessary:
  + **The velocities of the UE at different places are independent and identically distributed.**
  + **The moving direction of the UE is uniformly distributed over (0,2pi)**

Call handling models

* A call handling model determines whether a TAU occurs after a call:
  + A CPLU: a TAU occurs after a call
  + CWLU: no TAU occurs after a call
* The call handling models are used to investigate the impact of incoming calls on the total signaling cost a location management scheme.

Comparison between the number of TAUs under two TAL configurations (Configuration 1 and configuration 2)

* When in a vertex TA, the probability of moving out of the current TAL is ½, whereas this probability becomes 1/3 when in an inner TA.
* Therefore, it can be anticipated that configuration 2 will have higher signaling cost than configuration 1, because the former has one more vertex TA than the latter.
* This anticipation is validated in Fig, that compares the signaling cost of the two TAL configuration under the CPLU model.

How to construct TAL?

1. The number of TAs cannot exceet 16
2. The TA where the UE performs the last TAU is the center of TA
   1. Therefore, to allocate a TAL to the UE, the network must have the topology information of networks
3. Conclusion: When the radius of a TA is planned by operators in advance, the network can allocate an optimal TAL of size Nta,opt for the UE based on its mobility and traffic characteristics , so as to minimize the total signaling cost of the TAL-based scheme.
   1. Observations: when d<=3, the larger the Nta,opt. When d>=7, Nta,opt =2 for all the … when d is small, e.g. d=2, the larger the number of cells crossed during tc. In order to reduce the TAU cost, the networks can assign a large TAL to the UEs. When d>7, there are a large number of cells in a TAL so that the number of TALs crossed during tc is small, and the paging cost will dominate the total signaling cost. In this case, to reduce the paging cost, a small TAL should be assigned.

# Mobility Management with the central-based location area policy

* Disadvantage of Location Areas (LAs) in 3G is analysed:
* **Important: every base station periodically broadcasts its TAI.** 
  + **The UE detects the location change by searching its TAI 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.**
  + 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.
* **Important also!!!:**
  + **We have to 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.**
  + **In most commercial 3G mobile networks, all cells in the LA of the UE will execute the paging procedure simultaneously.**

Location Update and Paging Schemes:

* Consider a two-dimentional(2-D) mesh cell configuration
* Many previous studies assume that the UE moves to one of the neighboring cells with the same routing probability, here we relax this assumption to accommodate heterogeneous routing patterns.
* Random walk mode.
* IN highways, 1-D model to represent the UE movement is used. On the other hand, this paper uses 2-D model for city layout. But we have showed, that **the effects of the input parameters in 1-D and 2-D models** are similar

Conclusion:

* This paper studies the LTE-TAL-based mobility management scheme by measuring the expected number of TAU of location updates during the inter-call arrival time and the expected number of paging of cells that page the UE when an incoming call arrives.

Central Policy

* When the UE moves out of the current TAL, the entrance TA is reset to the cell in TA at the same relative position.

Movement-based and Distance-based location updates:

* In the movement-based location update, the UE maintains a counter to record the number of cell boundary crossings since the last interaction with the network (**including location update & incoming call**).
  + When the counter value reaches the predefined threshold K, the UE updates its new location and resets the counter value to zero. Also when an incoming call is delivered to the UE, the counter value is reset to zero.
* In the distance-based location update, the UE updates its location when the distance (in terms of the number of cells) between the last interacted cell and the current cell of the UE is K.
  + Note that In the distance-based location update, the UE is required to have the knowledge of the cell topology information (i.e. the distance relationship between cells), which cannot be practically implemented in a real network. Therefore, the distance-based location update is an idealized mechanism, and is considered in this paper for comparison purpose.
* **Define the residing area of the UE as the area which is within the maximum distance K-1 from the last interacted cell.**