CHAPTER 3
SYSTEM MODEL FOR LOCATION MANAGEMENT

The study of location management aims to reduce the overhead required in locating mobile devices in a cellular network. The two sources of network cost involved in location management are location updating, informing the network of devices location, and paging, polling a groups of cells to determine the precise location of a device. Careful application of location update and paging strategies must be made to ensure minimal communication and processing cost. An additional area of consideration in location management is the mobility model used to estimate user movement in the network, aiding in the optimization of location updating and paging schemes. With mobile user subscription increasing rapidly and a continually restricted mobile spectrum available, the problem of effective location management has become one of prime significance. A proper cost model must be chosen to reduce the location management cost.

Location management is the set of functions executed to discover the current attachment point of the MT for call delivery. Location management is a two-stage procedure: location registration and call delivery. In the Location registration (also recognized as Location Update LU) stage, the MT from time to time, notifies the network of its new access point, and the network database (DB) stores the new position, or registration area. In the Call Delivery (CD) stage, the network DB is queried and the current cell where the MT is roaming is found.

The location update procedure (LU) can be further decomposed in two steps. In first step (also called LU), from time to time the MT notifies the
network of its access point, and in the second step (the registration procedure, RG) the network database (DB) updates/stores the registration area according to the LU message received. The first step is supported by the common air interface (CAI) and the second one is supported entirely by the fixed network. A hierarchical DB storing the registration areas of each MT is maintained up to date. Nowadays, a two level hierarchical and centralized DB is used (as in GSM-MAP, or IS-41). In this thesis, we use UMTS network architecture for location management implementation. Two registers per user are updated in the DB used in current systems: the Home Location Register (HLR), and the Visitor Location Register (VLR). In the first level of the DB there are HLRs. Information about each user, such as the types of services subscribed and location information are stored at the HLR. In the lower level of the DB there are VLRs. Each VLR stores the information downloaded from the HLR and location information of the MTs visiting its service area. These registers are updated by the location update messages triggered by the MTs.

The call delivery process (CD) involves the querying of the system DB to determine the current location or registration area where the called MT is actually in. CD can be decomposed in two steps. When an incoming call arrives, the location of the called MT is searched in the system DB Interrogation (IG). The IG procedure is entirely supported by the fixed network (FN), i.e. no radio resources are involved. The output of a successful IG is the registration area (RA) (also location area (LA)) a set of neighboring cells– where the called MT is roaming. After a successful IG, the called MT is searched in the registration area by means of the paging (PG) process. Paging is the process in which a system searches for an MT by sending polling messages to the cells within the last reported LA of the MT. The output of a successful PG is the cell where the called MT is roaming.
3.1 UMTS NETWORK ARCHITECTURE

Universal Mobile Telecommunications Service (UMTS) can be viewed as an evolution of GSM that supports 3G services. Generally, a UMTS network is divided in an access network and a core network (Figure 3.1). The former is dependent on the access technology, while the latter can theoretically handle different access networks.

![UMTS Network Architecture Diagram](image)

**Figure 3.1 UMTS Network Architecture**

The access network is known as the UMTS Terrestrial Radio Access Network (UTRAN). The UTRAN is comprised of two types of nodes, the Radio Network Controller (RNC) and the Node B, which is a base station (BS). It controls the radio resources within the network and can interface with one or more stations (Node Bs). The air interface used between the user equipment (UE) and the UTRAN is WCDMA. The UTRAN communicates with the core network over the lu interface. The lu interface has two components: the lu-CS interface, supporting circuit-switched (CS) services, and the lu-PS interface, for packet-switched (PS) services.
The RNC that controls a given Node B is known as the Controlling RNC (CRNC). For a given connection between a UE and the core network, only one RNC can be in control, the Serving RNC (SRNC). The CRNC controls the management of radio resources for the Node B that it supports. The SRNC controls the radio resources that the UE is using. It is possible for a CRNC and a SRNC to coincide. UTRAN supports soft handovers (where an UE is communicating with a Node B whose CRNC is not the SRNC). The I_{ur} interface's purpose is to support this type of handover, that is, inter-RNC mobility.

3.2 LOCATION DESCRIPTION IN A UMTS NETWORK

In standard UMTS, Mobile Switching Centers (MSCs) are responsible for the circuit switched location management, while Serving GPRS Support Nodes (SGSNs) assume the packet switched location management. Both domains are linked over some interfaces, but the information is kept in separate network entities: The CS location information is in the MSC, while the PS location information is in the SGSN. The HLR is a common location information database for both domains. Several area types have been defined in UMTS to handle the location information

- **Location area (LA)** - The current location area ID is available in home location register (HLR) and visitor locations register (VLR) because an HLR is a centralized database that maintains permanent information of mobile users, whereas VLR keeps the up-to-date locations of visiting mobile terminals.

- **Routing Area (RA)** – It is composed of a group of cells that belong to only one RA. Several RAs can be included in the same LA, but an RA cannot span more than one LA. The PS domain to track the MT's location when in idle mode uses the RAs.
• **UMTS Registration Areas (URA)** – They are an intermediate level between cells and RAs (or LAs). They are similar to RAs and LAs, but are used by the UTRAN to set trade-offs between the MT's location accuracy and signaling load. Furthermore, they are used to track the MT's location while it is in connected mode without using a logical channel. This concept is optional in UTRAN.

• **Cell ID** - In order to maintain an active connection for a mobile user, it is most important to know in which cell the mobile user is located. The network knows in which cell an MT resides by sending polling messages, which can be acquired without additional cost during call origination/termination, or through location client service (LCS) management.

### 3.3 PROFILE BASED STRATEGY

Current cellular systems use geographic-based registration in which a registration occurs when a user crosses the boundary formed by a group of cells, called a location area. If a call arrives for a mobile, the mobile is paged in all cells within the location area where it last registered. As location area sizes increase, the paging cost increases and the location update cost decreases. Depending upon the relative costs of paging and registration, and a parameter often called the call-to-mobility ratio (CMR); there is an optimum location area size which minimizes the total cost.

If the position of a user is always known in advance, then no explicit registration is necessary. Thus, the optimum location area is the one that minimizes paging cost, a single cell. Stationary users and trains on fixed schedules exhibit this type of behavior. On the other hand, a commuter on the way to work will occasionally deviate from a fixed route due to traffic conditions or time of travel. A system might be able to guess, with a certain
probability of success, where to find a user. If a terminal records this information, then it needs to register only when it deviates from the known plan. Thus, by maintaining knowledge of the user’s past behavior, the frequency of location updates may be reduced. It may be possible to group people into classes depending upon the predictability of their daily routine. The system could treat each class differently to minimize the cost to the system. Users may be assigned to a class based on their past call history and their willingness to pay for a higher quality of service.

Three possible classes include the following.

- Deterministic users follow a rigid daily routine that the system knows. The user never needs to register, and the location area should therefore be as small as possible. If the user happens to wander out of the area (a rare event), then the call cannot be completed.

- Quasi-deterministic users can be found in work during a certain time and at home during another time interval. The time intervals vary slightly from day to day. There may be alternate routes on the way to and from work. During lunch, they might be found at different restaurants. These users display a certain likelihood of being in a particular place, but in actuality, they might not be there.

- Random users display no orderly behavior whatsoever. When they are not home, they can be almost anywhere. Past knowledge of their location cannot predict their future location. The profile-based strategy is not applicable to these users. One reasonable strategy would be to page in the vicinity where the user last made or received a call. The size of the paging area could depend on how long ago the last call occurred. In the
profile-based strategy, the system maintains a record of each user’s most likely itinerary.

We assume the following,

- The probability distribution of a user’s location is known exactly. In practice, it will be necessary to either ask the user to provide it or to estimate it using information such as the user’s past calling history.
- The list is stored at the switch that will conduct the search for the user.
- The information required to update the list is found within the mobile switching center’s billing records. This functionality may require change in the network’s billing systems.
- It may be necessary to periodically transfer information between these two fixed network locations (switch and billing database). We assume that this is done using the facilities of the fixed network signaling system.

Based on this Profile based strategy an user’s profile can be learned, we call this strategy as User pattern Learning strategy (UPL). A user pattern learning strategy (UPL) associates with each user a list of location areas (LA) where she is most likely to be located within a given time interval. When a call arrives for an MT, each location within the list is paged sequentially until the MT is found. When a user moves between locations within the list, no location update is required. The list is stored at an intermediate location Database (ILD) associated with a Mobile Switching Centers (MSC) as well as within the user’s MT. The cost reduction depends on the behavior of each class of user. It can be assumed that, when the user follows its expected behavior, the cost of a location update is reduced.
For every mobile user there is a user pattern learning process associated to it. So, after the learning process completes, we get the mobile user’s behavior associated with known location areas. Then, a profile is built for the mobile user. The profile has the cell id, profile number, day, time and the probability where the user remains in a time interval. The UPL strategy increases the intelligence of the location update procedure and utilizes replication and locality to reduce the cost incurred from the paging procedure. An intermediate location database is used, which has the profile of each user. Furthermore, the ILD contains a flag for each registered MT and indicates whether or not the MT is roaming under that particular MSC. Also, the strategy takes advantage of calls placed regularly to a particular user (i.e., a great amount of calls are placed by the MT’s top five callers). Thus, some ILDs will store “location data tables” that contain pointers tracking the called MT’s location which significantly reduces paging costs. When a MT enters a new LSTP that he has never seen before, the MSC creates a basic profile containing a single record with MT’s current LA.

Our strategy differs from the others user profile strategies in the following aspects:

- We use machine learning algorithms to learn about the users’ regular routines. Pattern recognition is one of the fields where intelligent systems have been strongly applied from many years. Pattern learning and classification can be stated as the problem of labeling test patterns derived by a particular application domain.
- A classification system may be trained by a set of data feature, adequately prepared or not.
- We have divided our strategy into two steps: training and application. In general, intelligent systems are capable of "learning" trends in a given data set and establishing input-output relationships based strictly on a "test" set of data.
• It is desirable for the "test" data that the system "learns" from to be as representative of the complete data set as possible; trends not seen in the test data set will not be "learned" by the neural network system.

• After training, the network is ready for application. For satisfactory application, it is essential that the training data contain input sets (and the associated output values) that represent the entire range of possible future inputs; the system will only perform as well as it has been trained. The training examples may contain errors.

The ability to learn is a fundamental trait of intelligence. Although a precise definition of learning is difficult to formulate, a learning process in the context can be viewed as the problem of updating network architecture and connection weights (an elementary structure and functional unit between two neurons) so that a network can efficiently perform a specific task. The network usually must learn the connection weights from available training patterns. Performance is improved over time by iteratively updating the weights in the network. Neural Network's (NN) ability to automatically learn from examples makes them attractive. Instead of following a set of rules specified by human experts, NNs appear to learn underlying rules (like input-output relationships) from the given collection of representative examples. This is one of the major advantages of neural networks over traditional expert systems. Neural networks derive their computing power through their ability to learn and then generalize; generalization refers to the ability of the neural network to produce reasonable outputs for inputs not encountered during training. It is this quality that we utilize to predict the movement of mobile users so that we can predict the position of a user in advance and reduce the paging cost based on the predicted destination cell.

Finally, the impact on the performance of location management with ANN is reduced. The cost of the UPL is decomposed into four components: training procedure, maintenance and update of the user's profile, location
update, and call delivery. Although ANN learning times are relatively long, evaluating the learned network in order to apply it to a subsequent instance (maintenance and update of the user's profile, location update and call delivery) is very fast. In ANN, performance is improved over time by iteratively updating the weights in the network.

The time-normalized cost of the UPL is decomposed into three components.

- Location updating is assumed to occur on a geographic basis. If a user is inside the Location Area (LA), it notifies the system only if it leaves the area covered by the LA. When it is outside LA, it notifies the system whenever it crosses a location area boundary.

- Paging allows calls to be delivered to mobile terminals. When a user is inside LA, it is paged sequentially using the ordering within a list. If it is outside LA, it is paged in the location area where it last registered. In this work, we assume that if a terminal is present, it will be found when paged.

- List maintenance updates the information in the list of likely location areas. This analysis assumes that the list is stored in the switch that will conduct the search. It also assumes that each location area in the list is contained within the coverage area of that switch.

### 3.4 Analytical Model

We assume that link costs and database access costs are defined by message transmission delays and updating or query delays, respectively. The cost involved is a virtual cost calculated per unit time, incurred during the call process. For each mobile terminal, we define the following quantities:

- $A$: average number of calls (i.e., voice or data) to a target MT per time unit;
- $f_i$: average number of times the user changes LA per time unit;
• $U_T$: average total cost of the location update procedure;
• $S_T$: average total cost of the location search procedure; and
• $C_G$: average total cost per time unit for the location update and the location search.

The total cost per time unit for the location search and location update procedures of the proposed scheme is $C_G = \mu U_T + \lambda S_T$ (Refer Appendix 1).

3.5 COST COMPARISON

Cayirci and Akyildiz (2002) [13] proposed a strategy for location management, which we call Cayirci, while the GPRS/UMTS standard proposed another strategy, which we call UMTS, for solving the same problem.

To be able to compare our strategy to UMTS, we have to compute the costs for the location update and location search operations. We define the following costs for the UMTS location management procedure:

• $s$: cost for a location update operation according to the GPRS/UMTS standard;

• $S_{UMTS}$: cost for a location search operation according to the GPRS/UMTS standard; and

• $C_{UMTS}$: total cost per time unit for the location search and location update operations.

The total cost per time unit for the location search and location update procedures is given by $C_{UMTS} = \mu U_{UMTS} + \eta S_{UMTS}$ (Refer Appendix 2)

We define the relative cost of the proposed scheme as the ratio of the total cost of our scheme (per time unit) on the total cost of the standard UMTS procedures. Furthermore, this relative cost is a function of the call-to-mobility ratio (CMR):
\[
\frac{C_G}{C_{\text{UMTS}}} = \frac{\mu U_T + \lambda S_T}{\mu U_{\text{UMTS}} + \lambda S_{\text{UMTS}}}
\]

\[
\frac{C_G}{C_{\text{UMTS}}} = \frac{\mu \left( \frac{U_T + (\lambda / \mu) S_T}{U_{\text{UMTS}} + (\lambda / \mu) S_{\text{UMTS}}} \right)}{}
\]

Where \(CMR = \frac{\lambda}{\mu}\)

The method proposed by Cayirci and Akyildiz is based on a profile similar to the one used in our scheme. There are some differences between the two, but they are mainly structural differences. For example, the short-term events leading to registration are not reflected as they are in our scheme. Furthermore, our profile is more likely to find the user in fewer trials due to the "next nodes" field that provides information on the next visited areas. Both factors compensate each other. Another important difference is the fact that (Cayirci and Akyildiz 2002) [13] sets up a list of cells where no updates are performed while the user roams within this set of cells. Otherwise, a new record is created and another classical location update method is used (i.e., IS-41 or standard GPRS/UMTS).

The total cost per time unit for the location search and location update procedures is given by \(C_{\text{Cayirci}} = \mu U_{\text{Cayirci}} + \eta S_{\text{Cayirci}}\) (Refer Appendix 3)

As we did for the UMTS standard, we define the relative cost of our scheme compared to Cayirci’s scheme as:

\[
\frac{C_G}{C_{\text{Cayirci}}} = \frac{\mu U_T + \lambda S_T}{\mu U_{\text{Cayirci}} + \lambda S_{\text{Cayirci}}}
\]

\[
\frac{C_G}{C_{\text{Cayirci}}} = \frac{\mu \left( \frac{U_T + (\lambda / \mu) S_T}{U_{\text{Cayirci}} + (\lambda / \mu) S_{\text{Cayirci}}} \right)}{}
\]

Where \(CMR = \frac{\lambda}{\mu}\)