Location Management using Genetic Algorithm Tuned Neural Network in Mobile Networks

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Abstract:

Future mobile systems will be characterized by high user density and high mobility enabling users to communicate regardless of their geographical location. Large number of handovers and registrations will place great demands on radio links. One of the major issues in mobile wireless systems is location management, which is the process that allows a network to identify the exact location of a mobile terminal (MT) for call delivery. In this paper, we present a user pattern learning (UPL) strategy using genetic algorithm tuned artificial neural network (GAANN) to reduce the location update cost. the system maintains a list of places where each user is most likely to be in at each time interval. The intelligence of the location management procedure is increased by updating the profile of each user by users past calling history. Unless the MT detects that it has moved out of the registered profile, it does not perform any other location update. Paging is also done selectively as in the registered profile upon a call arrival for the MT. Experimental results shows that the profile based intelligent system using GAANN performs well than other well known strategies.

Keywords: location management, location update, paging, neural network, genetic algorithm, mobility management.

1 INTRODUCTION

The next generation mobile communications networks should provide not only voice and low-speed data services but also multimedia services requiring high data rate to the users of high density. In a wireless network user can move from place to place while maintaining communication with others. This property is called Mobility of the user. As well known, one of the key issues in cellular mobile communications is how to deliver incoming calls appropriately to the called user roaming from place to place. In the future mobile communications, this issue (especially, the location management) will become more important because of high user mobility [1]. To keep the mobile terminals connected in spite of mobility, the network has to keep track of mobile terminals which will be used to find mobile terminals when incoming calls have to be forwarded towards the mobile terminals.

A network is divided into geographical areas, called location areas (LA) and the location management system keeps track of current LA of a mobile terminal (MT). A location area may contain one or more cells. The location information is stored in the network database for location management. To maintain the consistency of the location information, an update process is triggered whenever a mobile terminal crosses LA boundaries. When a call arrives, a query to the location database is done to obtain the location information of the called MT. Then the location management system pages all the cells in the corresponding LA simultaneously. The same location management system is not possible in present generation mobile communication system, because of the fast growing population.

Location management methods are classified into two major groups: Memory-based and non-memory-based methods. The first group includes methods based on learning processes, which require knowledge of mobile user behavior, while the second group includes methods based on specific algorithms and network architectures. The strategy proposed in this paper belongs to the first group. In North America, the IS-41 standard is used for both the location update and call delivery procedures. This standard deploys a two-level database architecture consisting of a single home location register (HLR) and several visitor location registers (VLR). The HLR for a given network contains the network's subscriber profiles, while a VLR stores the profiles of the users that are currently roaming within LAs associated with that specific VLR. Third-generation mobile networks are characterized by high user density and high mobility (like current 2G systems) and small cell sizes, which will increase the number of location updates and handoff messages, thus limiting the switching capacity and available bandwidth. Reducing the signaling and database access costs of location management introduces significant technical challenges which have to be dealt with and constitutes an important research area. Therefore, more sophisticated schemes were proposed to make the location update and terminal paging operations more efficient. These schemes include the time-based, movement-based [6, 8] and distance-based schemes which locate an MT by paging the LA's ring by ring from its last updated location. Several alternative strategies have recently been proposed to improve the performance of the location management scheme [2-6].

Chien-Hsing Wu et al. [9], used a markov model for Location management. A probabilistic selective paging strategy concept is used for generalizing the selective paging scheme. S.Dasbit et al. (2002) [10], developed a probabilistic location management strategy in a cellular mobile environment. In this scheme the mobile switching center (MSC) maintains an indexed database to keep the frequency of traversals of all the visiting mobile units under it. When a call arrives for a particular mobile unit the MSC performs a location probability of the called MT and performs the best first search to find the cells where the desired MT may be located.

Lo and Chen (2002) [11], describes a dynamic region based location management system for personal communication services system. The strategy described makes use of the users' movement pattern from the set of regions the users is most likely to visit in a time interval. A distributed HLR is used to balance the workload. The call arrival rate and the mobility rate are considered for reducing the registration cost. The strategy used dynamically changes based on the number of regions, the degree of user mobility, and the system parameters such as the signaling cost between HLR and VLR. Yuguang [12], investigated an analytical model for calculating the total cost for pointer forwarding scheme and two-location algorithm. A general model involving various time variables are considered for analyzing the signaling cost. The cost analysis for the move and find are analyzed more analytically for many general cases.

Goo and Yong [13], developed a time based location registration scheme. The MT sends its location update information for every T units of time. If a call arrival occurs within T interval, the system pages the MT and the MT restarts its timer. A ring structure is considered. The inner most ring is ring 0 which is the center cell and it has only one cell. Ring 0 is surrounded by ring 1 and then by ring 2 and so on. When the system routes an incoming call to an MT, it first pages the center cell which is the recently registered location of the MT. If it does not succeed in finding the MT, it pages next surrounded ring. The paging goes on until it finds the MT.

Alejandro Quintero and Oscar Garcia [14], has developed a profile based strategy for managing user mobility in 3G mobile systems. In the 3G mobile systems the power of mobility on network performance must be reduced, mainly due to the huge number of mobile hosts in combination with the small cell size. A profile based strategy is presented to reduce the signaling traffic thereby increasing the intelligence of the location update procedure. User's moving information can be used to assists the user's mobility management, manage network resources and congestion control.

The increasing population of mobile subscribers, smaller sized cells has been used to accommodate the large number of mobile terminals (MT's). Sending paging signals to all cells within a location area (LA) to locate an MT may result in an excessive amount of network bandwidth. In current mobile networks, most users follow regular routines during business hours, residing mostly at their place of work. For these users, it is possible to predict with significant accuracy their location at a particular time of day. The aim of profile-based location prediction schemes is to leverage off this information to reduce location and paging requests [7]. Based on the profile of the user during the last observation period, the location management system generates a list of LA's. When there is a call for the MT, the location management system pages the call to the MT based on the profile of the user.

In this paper, a user pattern learning strategy is followed [8] for location management and the profile of the user is learned using genetic algorithm tuned neural network. In this approach, the MT updates its location only when it's moving direction changes. To locate an MT, paging can be carried out along its moving direction, and hence the paging cost is reduced. Moreover, the MT's moving direction can be determined by simple numerical calculations.

2. OVERVIEW OF THE PROPOSED APPROACH

2.1 Mobility Management in UMTS

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 HLR is a common location information database for both domains. Several area types have been defined in UMTS to handle the location information:

- Location Areas (LA) is dividing the network into geographical areas
- A Routing Area (RA) 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 (URAS) 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.
Cells are related to the provision of radio coverage. The idea of having this diversity is to allow a trade-off between location accuracy and paging

2.2 User Profile Learning Strategy
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.

In the UPL, if the position of a user is always known in advance, then no explicit registration is necessary. Thus, the optimal location area is given by a single cell, which, in turn, minimizes paging costs. Stationary users on fixed schedules exhibit this type of behavior. If mobile users are classified into categories, as was done in [15], the system could treat each category differently to minimize system costs. Furthermore, user mobility information can be used to assist mobility management (traffic routing), to manage network resources (resource allocation, call admission control, congestion, and flow control), and to analyze handoff algorithms in integrated wired/wireless networks.

2.3 GA Tuned ANN
Pattern recognition is one of the fields where neural networks (ANNs) 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. In general, ANN systems are capable of "learning" trends in a given data set and establishing input-output relationships based strictly on a "test" set of data using back propagation algorithm. In particular, the BP is entirely dependent on the initial (weight) settings and most likely gets trapped into a local minimum. In order to address such deficiencies and drawbacks, in this paper, we propose Genetic Algorithm (GA) optimization technique, which automatically designs the optimal ANNs [both network structure and connection weights with respect to the training mean squared error (MSE)] specifically for each user profile.

GA is used to evolve traditional ANNs, and so the focus is particularly drawn on automatic design of the multilayer perceptrons (MLPs). This evolutionary operator makes the proposed system generic, i.e., no assumption is made about the number of (hidden) layers, and in fact, none of the network properties (e.g., feedforward or not, differentiable activation function or not, etc.) is an inherent constraint. The optimum dimension found corresponds to a distinct ANN architecture where the network parameters (connections, weights, and biases) can be resolved from the positional optimum reached on that dimension. Above all, using standard ANNs such as traditional MLPs, instead of specific architectures further contributes to the generic nature of the proposed system, and in short, all these objectives are meant to make it applicable to location management for any user profile without any modifications.

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 GAANN 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 GAANN 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 GAANN, performance is improved over time by iteratively updating the weights in the network as compared to conventional ANN algorithms.

3. GAANN OPTIMAL DESIGN

Genetic algorithms are good at taking larger, potentially huge, search spaces and navigating them looking for optimal combinations of things and solutions which we might not find in a life time. For every mobile user there is a user pattern learning process associated to it. We may classify the users into three different categories depending the predictability of their daily routine: users who have a very high probability of being where the system expects them to be (deterministic users), users who have a certain likelihood of being where the system expects them to be (quasi-deterministic users), and users whose position at a given moment is unpredictable (random users), similar to the classification proposed in [7]. The predictability of deterministic and quasi-deterministic users can be used by the system to reduce the number of location update operations. 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 (Table 1). When a call arrives for a mobile, it is paged sequentially in each location within the list. When a user moves between location areas in this list, no location updates are required. The list is stored at the HLR in the information database (ID) as well as in the user's mobile terminal. 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 location update cost is reduced, even if accesses to HLR are minimized when calls are received from relatively close areas. The proposed strategy increases the intelligence of the location update procedure and utilizes replication and locality to reduce the cost incurred from the paging procedure.

Examples	Di(Day)	Ti(Time)	Ci (Cell Id)	Probability (%)
E1	Monday	02.15	5,1,6	90,50,10
E2	Monday	11.45	5,2,1	95,50,10
E3	Sunday	12.00	5,6,3	40,90,15
E4	Thursday	14.15	5,2,1	95,50,10
E5	Thursday	05.30	5,1,6	90,50,10

Table 1. Sample User Profile

In this problem, the learning process aims to derive a list with which we can find the cell in which the MT locates at any time of every day with high accuracy after observing the behavior of the mobile user for a period, for example, a month.
There are three layers in the Neural Networks: input layer, hidden layer, and output layer. The role of the hidden layer is to remap the inputs and results of previous layers to achieve a more separable or classifiable representation of the data and allow attachment of semantics to certain combinations of layer inputs.
By observing the mobile user's daily behavior, we use the GAANN algorithm to learn the behavior. With some useful data from observation of the mobile user as the input nodes, we can obtain the output as the result we want, which is the cell information of the mobile user on observation, that is to say, the cell list for a mobile user.

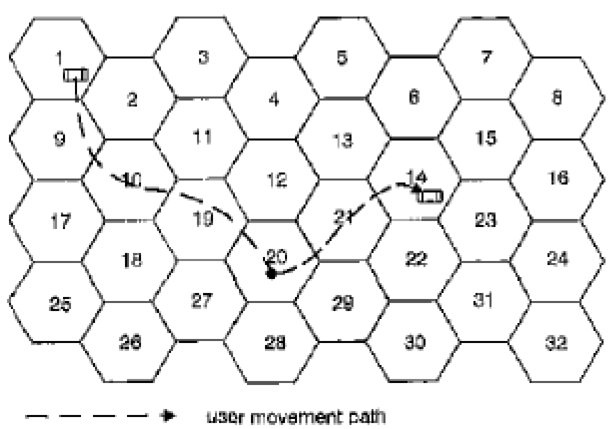


Fig.1 User Movement Path

3.1. GA Optimality Evaluation

In this case, there are three layers, the input layer that contains the values for Day and Time, a hidden layer is optimally designed, and two output units that gives the value of the output values, it's the probability that reside each cell in the user profile i.e Cell ID and probability. In order to determine which network architectures are optimal (whether it is global or local) for a particular problem, we apply exhaustive BP training over every network configuration in the architecture space defined. The number of neurons in the hidden layer in the ANN is determined optimally by the genetic algorithm. As mentioned earlier, BP is a gradient-descent algorithm, and thus, for a single run, it is susceptible to getting trapped to the nearest local minimum. However, performing it a large number of times with randomized initial parameters eventually increases the chance of converging to (a close vicinity of) the global minimum of the fitness function. The fitness function for the Neural Network optimization problem is taken as, $E = MSE$, where MSE is the mean square error between the desired target and actual output of the Neural Network Design.

The optimization of GAANN for the Location Management of MT is performed with the learning rate and the momentum constant varied from 0 to 1 and the hidden neurons varied from 31 to 200. For this training a maximum of 200 generations in GA are performed with a population size of 20 and with 500 training epochs. The crossover rate is 0.8 and mutation rate is 0.01. Using the proposed algorithm an optimized ANN is achieved with Nh =121, Lr = 0.00152 and Mc= 0.8972. Thus, the GAANN algorithm yields a compact network configuration in the architecture space rather than the complex ones as long as optimality prevails.

4. Simulation results

To assess the accuracy of the presented analytical model, in this section a performance evaluation of the Location Management System as well as a detailed model, which captures all relevant aspects of our approach in a concise way is presented. The simulation models both the call delivery and mobility behavior of users offering the ability to consider different service types and different MT groups over a range of cell-layout scenarios. Three different cell layout scenarios have been investigated. The first assumes macrocells only (9 Km^2), the second medium-size cells (1 Km^2), while the third small-size microcells (0.1 Km^2).

In this experiments, 1,000 MTs are simulated and we generated 1,000 samples for each cell layout scenario assuming normal distributions using the statistics estimated from the real data. The simulations are rub for the probability of a user being roaming within his associated list from 0.5 to 0.99. Assuming that a user is within that area covered by its list at least half of time. In practice, it would not do for a performer to have a list of likely positions in which a user is not found at least half of the time. In the case of users whose position at a given moment is unpredictable and the past knowledge of their location cannot predict their future location, our strategy is not applicable.

Assuming that link costs and database access costs are defined by message transmission delays and updating or query delays, respectively. 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;
fi: average number of times the user changes LA per time unit;
UT: average total cost of the location updates procedure;
ST: average total cost of the location search procedure; and
CG: 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 $C_G = \mu U_T + \lambda S_T$

4.1 Cost Comparison

Cayirci and Akyildiz [16] 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;
SUMTS: cost for a location search operation according to the GPRS/UMTS standard; and
CUMTS: 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 $C_{UMTS} = \mu U_{UMTS} + \eta S_{UMTS}$

relative cost of the proposed scheme is defined 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):

$$\frac{C_G}{C_{UMTS}} = \frac{\mu U_T + \lambda S_T}{\mu U_{UMTS} + \lambda S_{UMTS}}$$

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

Where $CMR = \lambda / \mu$

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 [6] 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 $C_{Cayirci} = \mu U_{Cayirci} + \eta S_{Cayirci}$

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

$$\frac{C_G}{C_{Cayirci}} = \frac{\mu U_T + \lambda S_T}{\mu U_{Cayirci} + \lambda S_{Cayirci}}$$

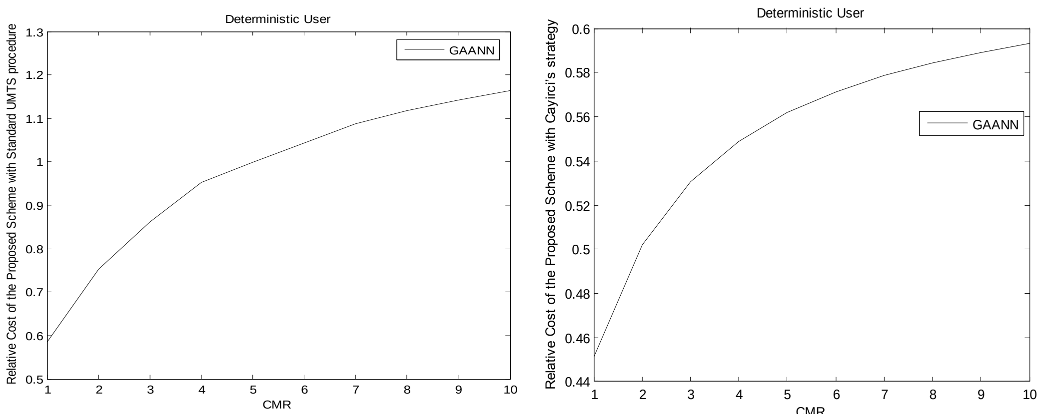
$$\frac{C_G}{C_{Cayirci}} = \mu\left(\frac{U_T + (\lambda / \mu) S_T}{U_{Cayirci} + (\lambda / \mu) S_{Cayirci}}\right)$$

Where $CMR = \lambda / \mu$

Users regularity is taken as (K), is the probability that an MT moves to the next node from the current node according to its current movement pattern. We have categorized the users into three classes by observing the users regularities.

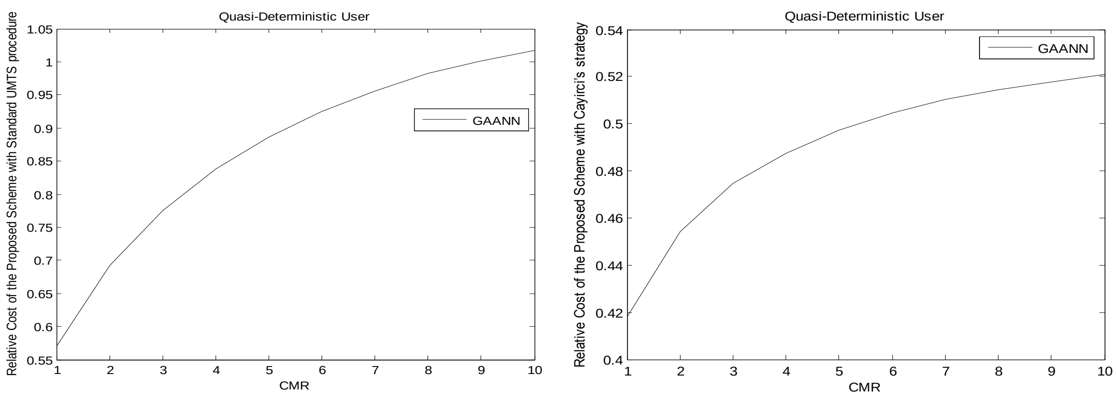
1. All of the people who belong to the deterministic class have regularity close to 1.
2. The regularity Quasi-deterministic users are varying between 0.5 and 0.8.
3. Random users cannot be assigned a list and, thus, their values are below 0.5

Fig. 2 shows the results for a simulation of the scheme that belong to the deterministic users having a roaming probability of 0.9. When considering deterministic users that have a 99 percent probability of roaming within their profile, Cayirci's algorithm achieves a very low cost compared to our scheme. When the user is slightly less deterministic (i.e., a probability around 90 percent of roaming according to its profile), the location update costs for both schemes get closer and the location search procedure decides which algorithm has a smaller cost.



(a) (b)

Fig 2. Deterministic User (K=0.9) (a) Relative cost to standard UMTS (b) Relative cost to Cayrici's strategy



(a) (b)

Fig 3. Quasi- Deterministic User (K=0.7) (a) Relative cost to standard UMTS (b) Relative cost to Cayrici's strategy

Fig. 3 shows the relative cost for quasi deterministic users and this shows how the number of paging trials increases the cost of our scheme when compared to the UMTS standard where the user's location is always explicitly known. However, the proposed algorithm outperforms the UMTS standard for every CMR between 0 and 10 and for a value of n lower than 4. When n reaches 4, the cost of our scheme is higher than the cost for the UMTS standard for high values of CMRs (i.e., location search takes more importance). Nevertheless, for every paging trial that is not completed (from 3 to 2,2 to 1, etc.), the proposed scheme has a 20 percent cost reduction when compared to the UMTS standard.

5. Conclusion

In this paper, a user profile learning using GAANN is proposed to reduce location update signaling cost by increasing the intelligence of the location procedure in UMTS. This strategy associates to each user a list of cells where she is likely to be with a given probability in each time interval. The list is ranked from the most likely to the least likely place where a user may be found. When a call arrives for a mobile, it is paged sequentially in each location within the list. When a user moves between location areas in the list, no location updates are required. The results obtained from our performance evaluation confirm the efficiency and the effectiveness of UPL in comparison with the UMTS standard and other well-known strategy. This improvement represents a large reduction in location update and paging signaling costs.

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