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LOCATION MANAGEMENT MODEL USING MULTI-STEP INTELLIGENT PAGING IN GSM

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ABSTRACT: Location management (LM) is a necessity in highly dynamic and large scale mobile network. It is one of the major problems of mobile networks that should be taken into account to enable communication systems provide Quality of Service (QoS) and meet the subscribers demand. Most existing location management schemes such as location update scheme, paging scheme are still faced with the problem of reducing cost, excessive traffic, resource utilization and low quality of service. In this work, a multi-step intelligent paging scheme was developed to monitor and estimate mobile station mobility to address the problems faced by the existing system and to enhance the Quality of Service of the GSM network.

KEYWORDS: Location Management, QoS, Intelligent Paging, Mobile Station, GSM network.

1 INTRODUCTION

Networks today are becoming continuously complex, with the addition of new kinds of services and heterogeneous networks collaborating as whole entities (Onifade et al., 2009). Due to the diverse mobile services and development in wireless networks (e.g. GSM), enormous number of people employs mobile devices as their communication means (Amar, 2010). Global System for Mobile Communication Networks (GSM) is the most widely used mobile network in the world dating back to more than a decade ago, which provides good speech quality, low terminal and service cost, support for international roaming, support for handheld terminal, etc (Onifade et al., 2009).

Location management/mobile management is a necessity in highly dynamic and large scale mobile network. It is one of the major issues of mobile networks that should be taken into account to enable communication, provide quality of service and meet the subscribers demand (Selvan et al., 2011). Mobile stations can move freely within a given location area without updating their location but informing the network only when transitioning to a new location area (LA). If a call is to be forwarded to the mobile station, the network must page every cell within the location area to determine their precise location (Jae-Woo, 2007). The balance of these defines the field of location management incurring network cost. The study of location management aims to reduce the overhead required in locating mobile devices in a cellular network.

While mobile stations perform updates according to their location update scheme, the network needs to be able to precisely determine the current cell location of the mobile station to be able to route an incoming call. This requires the network to send a paging query to all cells where mobile station may be located, to inform the mobile station of the incoming transmission (Furht, 2003).

There is need to determine the location of moving mobile stations (MS) within the network to know when update is needed, when paging is required whenever call arrives, when ping pong and handover effects will be corrected and when to disseminate the mobile station location information to the databases required within the network.

The goal of this work is to propose a tracking strategy that is efficient, reliable and beneficiary. Mobility, tracking and quality-related functions raise new questions as new problems evolved rapidly in personal communications. The aim of this research is to develop location management model using multi-step intelligent paging to reduce registration/paging cost, manages database processing, delivering of services to mobile station under any certain delay bound, tracking mobile stations and also maintains consistency of location information so as to reduce the overhead required in locating mobile stations in a cellular network.

2 Literature Review

Various paging schemes have been proposed to determine the location of the mobile station and identify loopholes. A new paging strategy (alternative strategy) was introduced in which the paging sequence in a location area is optimized based on the location probability of a mobile station (Dong-Jung *et al.*, 2004). Stephan *et al.*, (2010) proposed paging algorithm that registered the location of mobile terminal only when the residence time in the cell is longer than a predefined constant. Hesham *et al.*, (2011) presented caching and two level paging to reduce ping pong effects and paging cost. Mallikarjun *et al.*, (2014) proposed a predefined geographical area such that every base station maintains its geographical database or blocking area and notifying the network whenever the mobile user moves to the blocking area thereby triggering paging. Yang *et al.*, (2013) proposed location management scheme to keep mobile stations location tracking. The approach uses database to predict the future location of mobile station based on the history of the movement pattern. Jiang-Ming *et al.*, (2008) proposed an intelligent approach that combines rule base paging scheme and travelling salesman mobility model to resolve the issue of inherent trade-off between the paging and location update cost in location management system. The proposed intelligent paging approach, Polymers *et al.*, (2000) minimize the paging to one step only. The probability for a successful first paging step is determined using statistic about mobility of the mobile stations stored in the paging relevant information.

3 System Architecture

The combined approach of the reviewed related works has given us an insight into the proposed approach. The proposed intelligent paging strategy is established whenever there is need to communicate with a particular mobile station (MS). Whenever there is call arrival, the system searches for the MS by sending polling signals and would be searched in the paging area (PA) through the home location register (HLR) of the location registration (LR) area concurrently. This approach minimize the paging area to three states to reduce the signaling cost of paging, the delay associated with locating the MS, guarantee efficiency and robustness of the network.

The configuration chosen for the proposed system (multi-step intelligent paging) has been the hexagonal cell layout. Each cell has six directions with equal probability and same size. The proposed system, multi-step intelligent paging in global system for mobile communication network (MSIP-GSM), adopts the threshold-based scheme where each mobile station maintains a particular parameter. The architecture for the proposed scheme is shown in figure 1 below.

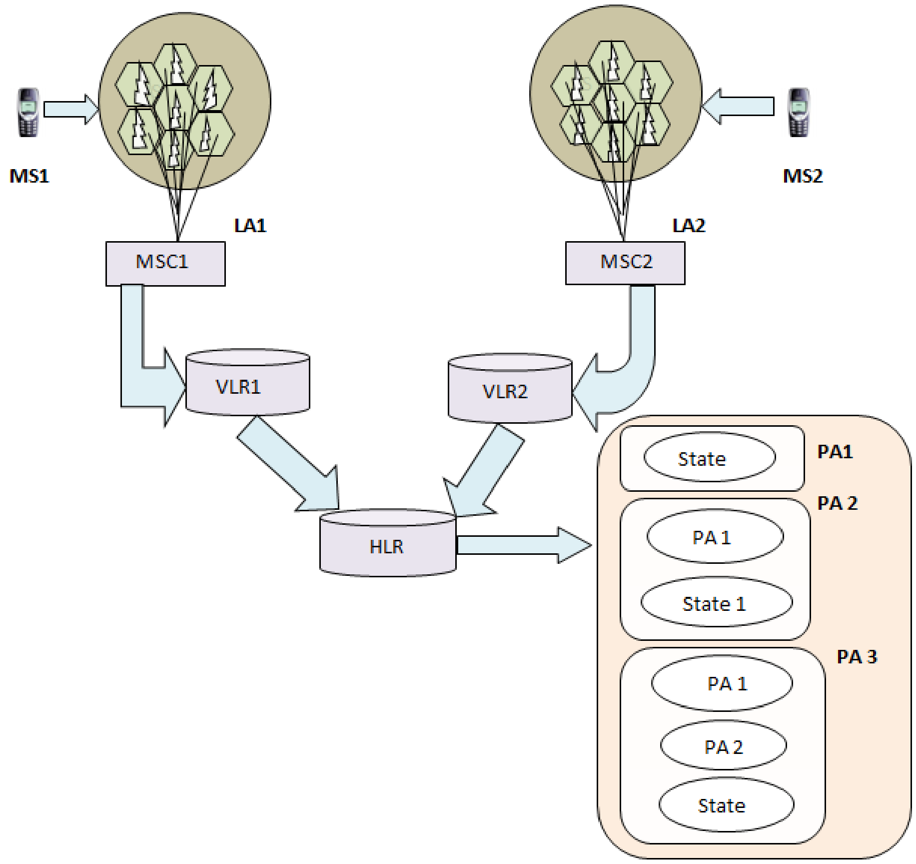

Figure 1: MSIP-GSM Architecture

Legend:

MS= Mobile Station
BS= Base Station
MSC= Mobile Switching Center
VLR= Visitor Location Register
HLR= Home Location Register
PA= Paging Area

The proposed scheme (MSIP-GSM) in the figure 1 above incorporates the database architecture aimed at determining the proper paging area (PA) within which the mobile station currently roams and updates the system whenever the mobile station crosses a preset number of cell boundaries. In order to determine if a mobile station is residing in a particular cell, the network performs the following steps:

i. The location probability density function of MS is known.
ii. The process of movement of MS broadcasted by the base station (BS) triggering location update (LU).
iii. The time elapses since the last known location.
iv. The distance between the location areas when LU is required.
v. The mobility model is classified into three states:

- Start: initial state of mobile station that are registered in a cell residing in a particular location register area. The mobile tag is blue.
- Move: the state of mobile station that is in mobility, triggering update by the base station to inform the system. The mobile tag is green.
- Stop: the last state of the updated location information of the mobile station. The new MS information will be stored in the residing location area visitor location register (VLR) and the master database, home location register (HLR) will be updated. The mobile tag is red.

vi. Depending on the particular requirement of each network, the maximum allowable paging delay for locating mobile station varies. The above listed models are integrated into polling cycle. The polling cycle is grouped into paging list which includes:

- Paging Area 1 (PA1): contains list of registered mobile station in a cell residing in a particular location area.
- Paging Area 2 (PA2): contains list of PA1 and list of the mobile station in mobility determined by a selective update (threshold scheme).
- Paging Area 3 (PA3): enlist the PA1, PA2 and list of mobile station that has been updated.

The flowchart for the proposed scheme is shown in figure 2 below.

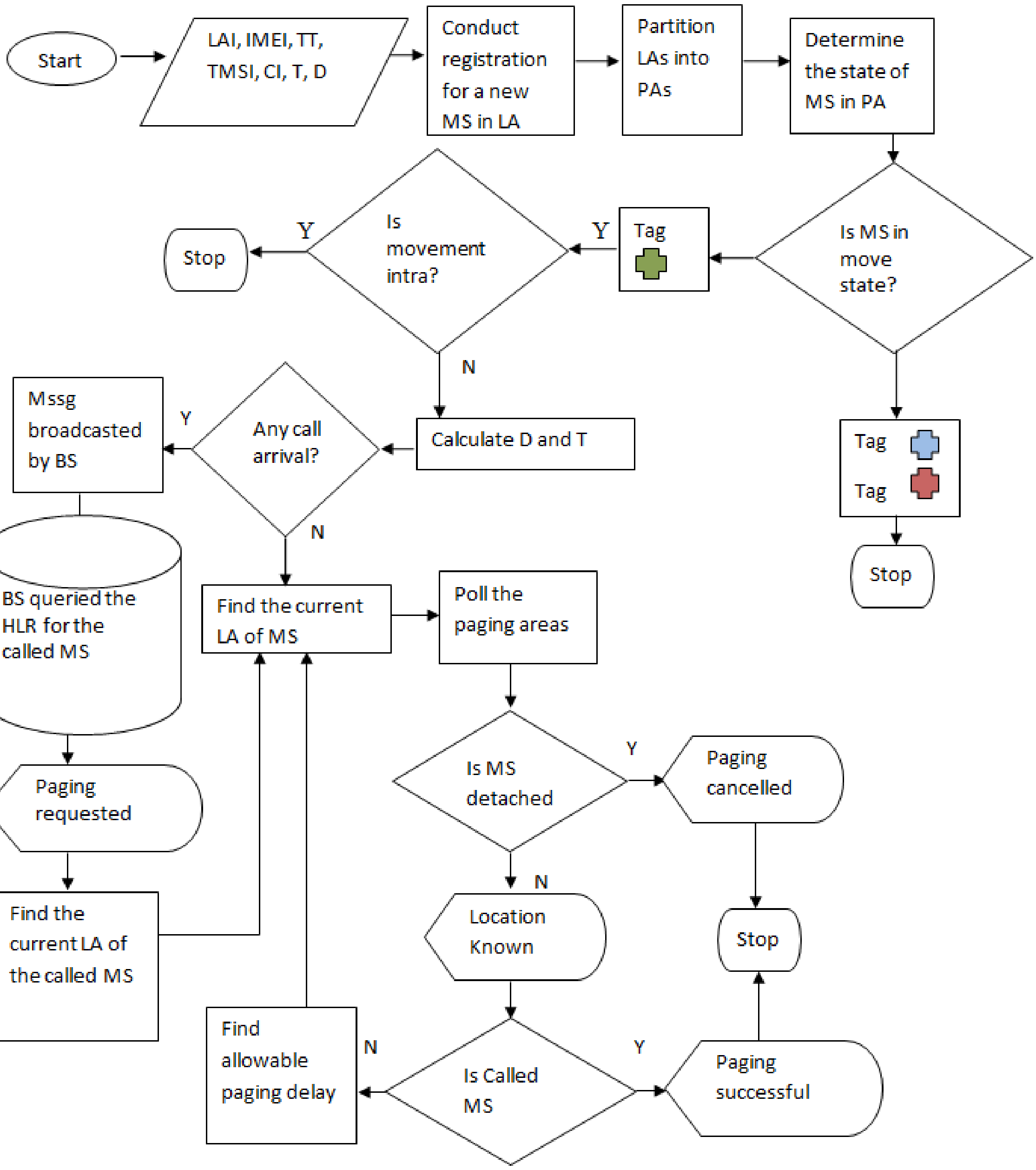

Figure 2: MSIP-GSM PROCESS FLOW

The system is structured into mobile stations (MS); devices that sends and receives calls that is expected to be registered in the location areas; which contains the residing cells, hexagonal shaped, serviced by residing base station (BS); the base station communicate with the mobile switching center (MSC); which manages the location area, supports location registration, paging, call delivery, etc through the base station controller (BSC); which broadcast message whenever mobility of mobile station occurs to the mobile switching center and send request message to the temporary database called visitor location register (VLR). The VLR stores MS information that is currently in the location registration area. It supports registration, authentication and call routing to/from a mobile while it is away from its initial residing area. The VLR forwards the mobile station data to master database called home location register (HLR) to permanently save the mobile station profiles in its database.

The master database, HLR, is partitioned into three paging areas with state 0, state 1 and state 2. Illustratively, the partitioning of the paging area is such that the first paging area, PA1 (state 0), enlist the cells that contain registered mobile station in a location register area. The second paging area, PA2 (PA1 & state 1), enlist the cells that contain registered MS in mobility but not yet updated in the master database. The third paging area, PA3 (PA1, PA2, & state 2) enlist the cells that contains registered mobile station in mobility and has reached the current location registration area.

The algorithm of the proposed model is shown in figure 3 below.

INPUT: $W, K, DIST, T, M$
OUTPUT: MS, LU, P_d, D
Step 1: Start
Step 2: Let W be the function with set of mobile data,
$W = f(LAI, IMEI, TT, TMSI, CI) \in LA$; // LAI = Location Area Identity, $IMEI$ = International Mobile Equipment Identity, TT = Tag type, CI = Cell Identity, $TMSI$ = Temporary Mobile Subscriber Identity, LA = Location Area.
2.1: Let K be set of finite parameters, $K = \{VLR_1, VLR_2, \ldots, VLR_n\} \in HLR$; // VLR_i is the visitor location registers, HLR is the home location register.
2.2: Let D be finite set of partitioned paging areas, $D = \{PA_1, PA_2, PA_3\}$; // PA_i is the paging areas.
Step 3: If $W = \emptyset$, then $FLAG = True$;
$MS =$ "$Unregistered$" // MS = Mobile Station; Else
$FLAG = False$;
$MS =$ "$Registered$";
Step 4: Read Movement, M
If $M =$ "$intra$", then
Declare Location Update, $LU = \emptyset$ Step 7; Else
Determine the state of mobile station in D;
Compute distance $(Dist)$ and time (T);
$Dist = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}$ // X, Y are coordinates points
$T = V \times Dist$ // V is the linear velocity, Dist is the distance covered
Store W into $K \in HLR$;
Declare "Location Update Successful";
Step 5: Read call arrival;
Initialize paging;
If $W \in K$, poll the paging areas, D; Step 6;
5.1: If $MS =$ "$detached$" then
$Paging =$ "$cancelled$";
$MS = \emptyset$;
$FLAG = False$
Declare "Paging unsuccessful" Step 7; Else
$Location =$ "$Known$";
$FLAG = True$
Declare "Paging successful" Step 7;
Step 6: Polling the paging areas;
If called mobile station = "found"
$FLAG = True$
Declare "Paging successful"; Else
Declare "Paging unsuccessful"
Compute paging delay, P_d , GO TO Step 5;
Step 7: Stop.

Figure 3: ALGORITHM OF THE PROPOSED MODEL

4 DESCRIPTION OF MSIP-GSM MODEL

In this MSIP-GSM model, we present an intelligent paging scheme that satisfies the condition of minimizing the paging cost under delay bound. The model is structured in such a way to fulfill the conditions of location probability and boundary so as to minimize the paging cost.

It is assumed that each LA, Q, consist of same number of cells, G, and the cells consists of MS, P. The paging delay is considered as the delay bound, D, for $1 \leq D \leq G$

(Wenye, 2001). Suppose the partitioning of the LAs requires grouping the cells into a series of Paging Areas (PAs), Y, such that all PAs consists of approximately the same number of cells.

Given a finite set of cells, $Q = \{g_1, g_2, \ldots.., g_n\} \forall \; g_i \in Q \exists \{P_1, P_2, \ldots, P_n\}$. Let G be finite set of mobile stations such that $\{P_1, P_2, \ldots, P_n\} \forall P_i \in G \exists$ the following transition state of PA $\{Y_1, Y_2, Y_3\}$, for each $P_i \in Y_i$ and $P_i \in Q$ then

$P_i \in (Y_i \cup Q)$. Thus, $Y_1 \cup Y_2 = Y_3$ then,

$$\bigcup_{i=1}^{n} (Y_i = Y_n) \quad (1)$$

For every set $G \exists B_i$ // B_i is the base station such that $B_i \in M$ // M is the mobile switching center where $M = H_i \cup V_i$ $\forall Q \cap G \exists M$

For $P_i \in Q_i$ and $P_j \in Q_j$, then $LU = \emptyset$ // LU is the location update.

Suppose at an increased threshold, the distance covered at a time interval is

$$Dist = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad (2)$$

// $Dist$ is the distance covered between two coordinate points x and y

$T = Velocity \times dist$ // T is the time (3)

$$\Delta T = T' - T \quad (4)$$

// ΔT = time difference, T' = ideal time, T = measured time

Assume that a subscriber is in cell i at the beginning of time slot t with the threshold distance, d.

The probability that the mobile station remains in cell i in the start state is p, given as:

$$P(S) = p \quad (5)$$

The probability that the subscriber is in the moving state is q, given as:

$$P(M) = q \quad (6)$$

The probability that the subscriber has moved from cell i to cell j in the stop state is r, given as:

$$P(S^*) = r \quad (7)$$

Thus, the probability of finding the MT in *ith* cell is;

$$P(success) = p + q + r = 1 \quad (8)$$

At an increased time $t + 1$ and $d + 1$, the subscriber has moved from cell i to cell $i + 1$, the probability is given as:

$$P(M_i) = (1 - p)/2 \quad (9)$$

At an increased time threshold T and D, the probability that the subscriber moves from cell $i + 1$ to cell $j + 1$ is given as;

$$P(M_{i,j}) = (1 - r)/6 \quad (10)$$

Hence,

$$P(S) + \sum_{i=0\ldots D-1, j=0\ldots.T-1} P(M_{i,j}) + P(S^*) = 1 \quad (11)$$

Additionally, we present an intelligent paging scheme that fulfils the conditions described below. Suppose an LA, Q_n, is partitioned into series of PAs, Y_i, such that all PAs consist of approximately the same number of cells, Q_n.

Suppose each transition state of the paging area, Y_m is denoted by a triplet $PA_r = (m, q_m, n_m)$ under paging scheme, r // m is the sequence number of the PA; q_m is the probability of the called MT being found in the m*th* PA; and n_m is the number of cells contained in the *mth* PA.

Suppose we enumerate the paging location areas by

$$\bigcup_{m=1}^{3} Y_m \qquad (12)$$

such that the mobile station is at location, m, with probability, P_m .

We can associate a mobile station location with a random variable, X, such that

$P = \{X = m\} = P_m$. Then, (13)

$$q_m = \sum_{m \in Q_n} P_m \qquad (14)$$

In the figure 3.1 above, it is assumed that location area, Q_n, is divided into paging areas, Y_m , such that $1 \le Y_m \le Q_n$ for multi-step intelligent paging.

Let the size *mth* paging area (i.e. the number of cells in the *mth* PA) be given as n_m // $n = 1, 2, \ldots Y_m$.

The probability of paging area in *nth* location area, P_n , can be calculated as:

$$P_n = \sum_{m=K_n+1}^{K_n+n_m} q_m \;\; // \;\; K_n = \sum_{m=1}^{n} n_m \qquad (15)$$

where K_n is the number of cells in the *nth* LA. Hence,

$$\sum_{n=1}^{Y_m} P_n = 1 \qquad (16)$$

The average number of cells searched until paging successful is deduced from (15) and (16)

$$Av(G_n) = \sum_{n=1}^{Y_m} P_n \times K_n \qquad (17)$$

Since all locations within a location area, Q_n, are polled simultaneously, the paging delay, D, equals number of LAs searched before the mobile station is found and is given as: $P\{D = m\} = q_m$ and the expected paging delay is:

$$E(D) = \sum_{m=1}^{3} m \times q_m \qquad (18)$$

The number of cells in each PA is given as;

$$n_m = \left[\frac{G_n}{D}\right] \qquad (19)$$

Let variable $L = G_n - n_m D$

Suppose λ_m is the probability that a mobile station resides in the *mth* cell i.e. the user location probability and D is the paging delay, which is the number of paging requests waiting in the *mth* cell ∀ $(m = 1, 2, .., G_n)$ then,

$$\sum_{m=1}^{G_n} \lambda_m = 1 \qquad (20)$$

such that $0 \le \lambda_m \le 1$

Let W_m be unsuccessful paging in the m*th* paging area;

$$W_m = \sum_{n=1}^{Y_m - 1} \left[1 - \sum_{m=1}^{n} P_n \right] \quad (21)$$

Accordingly, the paging cost C_p can be deduced from (17) and (21);

$$C_p = G_n + W_m \quad (22)$$

Eqn (22) can be rewritten as;

$$C_p = \sum_{n=1}^{Y_m-1} \left(P_n \sum_{m=1}^{n} n_m \right) + \sum_{n=1}^{Y_m-1} \left[1 - \sum_{m=1}^{n} P_n \right] \quad (23)$$

5 CONCLUSION

MSIP-GSM model, we present an intelligent paging scheme (MSIP-GSM) that satisfies the condition of minimizing the paging cost under delay bound. The model is structured in such a way to fulfill the conditions of location probability and boundary so as to minimize the paging cost. This study is expected to generate parameters for measuring the performance of intelligent paging scheme in the network such as paging delay, time elapse, distance covered, searching cell, paging cost, location update and database architecture. The result from this research is expected to provide knowledge of how location management can be incorporated with multi-step intelligent paging technique to monitor and estimate mobile station mobility so as to minimize the location paging costs for efficiency of the system in wireless mobile network.

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