AIAA-2000-1134

SIMPLE POSITIONING METHOD FOR LOCATION TRACKING IN MOBILE SATELLITE COMMUNICATION SYSTEMS

K.Narenthiran, R.Tafazolli and B.G.Evans
Centre for Communication Systems Research
University of Surrey, Guildford, Surrey GU2 5XH, UK
Tel: +44 (0)1483 259844, Fax: +44 (0)1483 259504
Email : K.Narenthiran@ee.surrey.ac.uk

Abstract

A new positioning method for location tracking in mobile satellite communication is described. In this method, terminals use the BCCH channel information about the spotbeams centre position to determine their own location. The advantage of this method is, that there is no great modification required to the hardware or software of the terminals. The effectiveness of this method for location tracking is verified against the Dynamic Location Update method using different type of paging methods.

Introduction

Positioning is a major service nowadays in military, navigation and civil applications and is especially important for multimedia applications in mobile satellite communication systems. Emergency services, geographical dependant services, tariff, guiding a person towards nearest gas station or tourist attraction point etc. in unfamiliar surrounding, crime detection, earth exploration and mobility management in mobile satellite system, are some of the applications of positioning. The terminal positioning technique proposed here, is mainly developed for mobility management applications in mobile satellite systems. In mobile communication systems, the network requires knowledge of the position of the mobile terminal (MT) in order to effectively deliver the calls. In order to locate a MT, a certain number of cells are grouped into a Location Areas (LA) in terrestrial system. Whenever the mobile crosses the boundary of one LA to another, the MT informs the network about its new location with a LA identity (ID). When a call arrives for a MT, the network searches all or subset of the cells, called paging area (PA)[2], belonging to the particular LA by sending a message in the paging channel. The difference between a terrestrial and a mobile satellite system is the movement of the satellites which act as Base Stations (BS) combined with a Fixed Earth Station (FES). The result is movement of the spotbeams which are analogous to the cells in terrestrial system. Therefore, it is difficult to define a Fixed Location Area (FLA) for a mobile satellite system[3]. In order to overcome this problem, a Dynamic Location Update method was proposed[3]. In this method, the LA size depends on each individual user. As soon as a MT is switched on, the location of the MT is reported to the network in terms of its latitude and longitude. The LA of the user is defined as the circle with pre-determined radius, centred around the MT. From time to time, the MT estimates its position and performs a location update, at the edge of the circle defining the LA and the new position becomes the centre of a new LA. Therefore, there is a need for a positioning method. Global Positioning System (GPS) may be a solution, but the hardware and software of GPS would need to be integrated with the MTs. This increases the size and the complexity of the MT and produces dependence on another system for position determination. It is realised that self dependant positioning method will reduce the complexity and cost of the MT design. Even though, the methods given in[4,7] are self dependant, the complexity is considerable due to the requirement of a very accurate oscillator to measure delay and Doppler and very efficient filter to remove the noise. With this in mind, two novel positioning methods are proposed here, Spotbeam Boundary Crossing Method and Averaging Method, which are simple yet effective.

Existing positioning methods

GPS[5,6] provides highly accurate positioning information. The idea behind GPS is, that one's position(x,y,z) can be determined with the distance values from three different known positions by the triangulation method. The distance is measured in terms of delay, where an accurate clock at the receiver measures the time delay between the signal leaving the satellite and arriving at the receiver. Four simultaneous delay measurements from four satellites are required to solve three unknowns and the user's clock offset. Some proposals for positioning, using one or two satellites, were presented in [4,7] based on recently proposed mobile satellite systems. Errors in positioning due to the inaccuracy in delay and Doppler measurement are also explained in these paper. Precious clock and a stable space platform are the two important aspects of the above mentioned positioning methods.

New Proposed Positioning Methods

In the technique proposed herein, it has been assumed, that the Broadcast Control Channel (BCCH) carries the information about the centre position of each spotbeam in the form of latitude and longitude, spotbeam ID and satellite ID. We present two methods to estimate the position of the terminal using the above three piece of information.

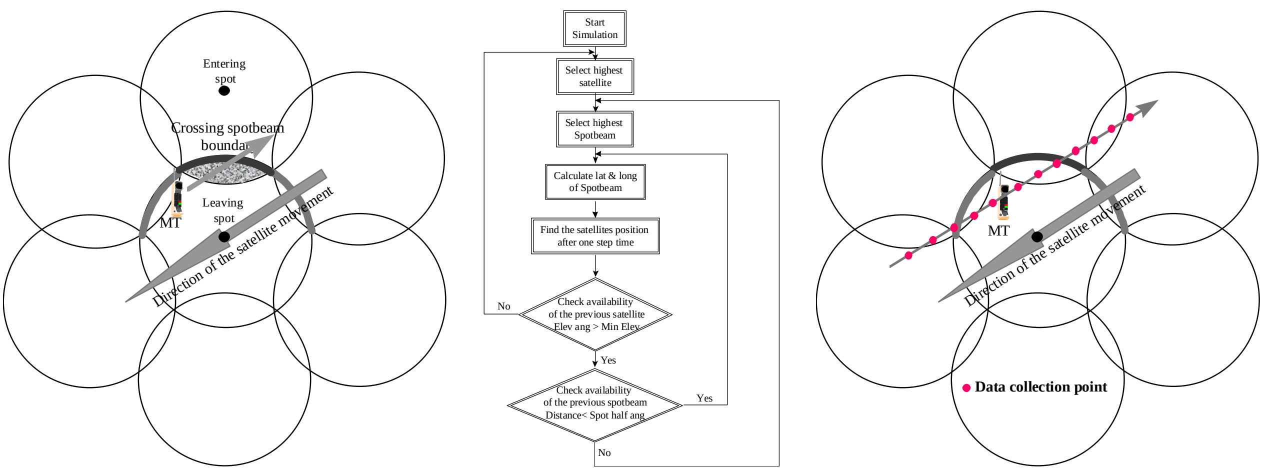
Spotbeam boundary crossing method

In this method, the MT monitors the spotbeam ID and satellite ID at regular intervals (eg. 1second). When the terminal encounters different spotbeam ID or satellite ID, then it stores the current spotbeam position and calculates the previous spotbeam position. Using these two positions, the MT calculates the middle of the spotbeams intersection area as shown by shaded area in Figure 1(a). During the spotbeam boundary crossing time, the MT will be in the shaded area. With this concept, the position of the MT can be determined with an accuracy which is sufficient for location update. Flow chart for selecting the satellite and the spotbeam in simulation is given in Figure 1(b). Using a simulation, the positioning error with Latitudes in this method is calculated for Iridium and Globalstar constellations. The results are given in Figure 2. Maximum error for Iridium is 188km (Diameter of spotbeam 600km) and for Globalstar is 460km (Diameter of spotbeam 1642km). Error levels with percentage of time are also given in Figure 3.

Averaging Method

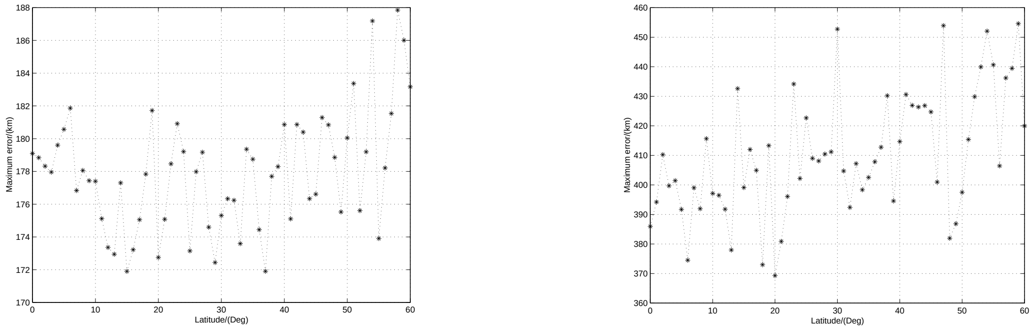
In this method, the MT collects a number of spotbeam centre positions over a certain period of time as shown in Figure 1(c) and averages them. The selection process for the satellite and the spotbeam is shown in Figure 1(b). The position is calculated as the average of the stored positions. The averaging duration has considerable impact on the accuracy obtained. The error for different averaging duration is given in Figure 4 for different latitude positions. For example, the position information is taken from the BCCH channel in 1 second intervals for 120 seconds. At the end of 120 seconds, there are 120 data points for the positions. The values are averaged and the averaged value gives the approximate position of the MT. In 121th second, the first stored data is disregarded and the new value is stored and the average value is calculated again. After the first calculation for position, the position can be calculated in every second. Handling the data for this method is shown in Figure 5. Each box indicates a storage memory in the MT. The required storage memory depends on the averaging duration and the time interval between the two receiving spotbeam position data. The time interval between two position data collection, is considered as one second in Figure 4. It has been found from simulation that the time interval between two position data collection can be as high as 20seconds without significant increase in position error.

From Figure 4, it can be seen that the error decreases with increased average duration. For Iridium, error decreases very sharply up to 200seconds and is slowly decreasing afterward. For Globalstar, error decreases sharply up to 400 seconds and slowly decreases thereafter. Therefore, the averaging duration can be taken as 250s for Iridium and 500s for Globalstar with 5s interval between the two position data collections. Then the required memory locations for the averaging method is 50 for Iridium and 100 for Globalstar.



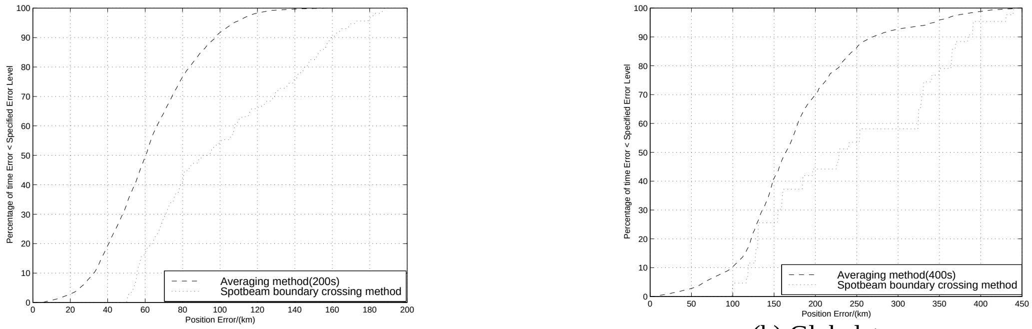
(a) (b) (c)

Figure 1 : Spotbeam boundary crossing and averaging phenomena



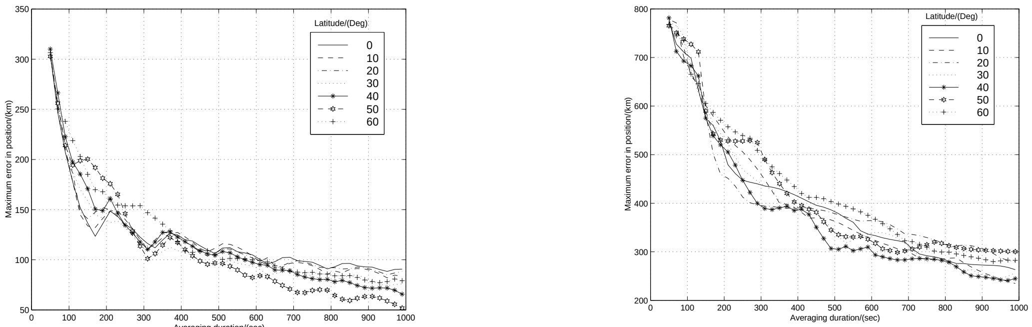
(a) Iridium (b) Globalstar

Figure 2 : Position Error with Latitude for Spotbeam boundary crossing method



(a) Iridium (b) Globalstar

Figure 3 : Percentage of time with Error



(a) Iridium (b) Globalstar

Figure 4 : Position Error with Latitude and Averaging duration for Averaging method

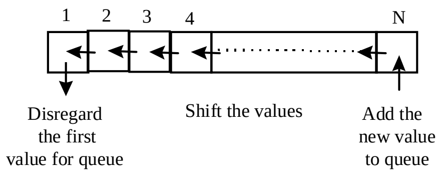
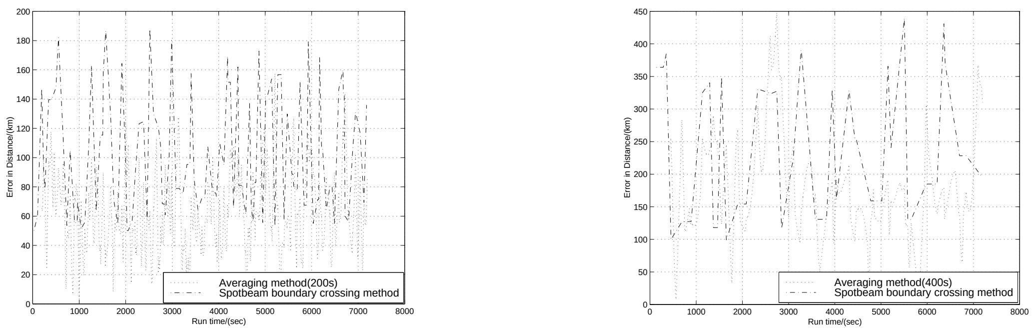


Figure 5 : Way of storing the spotbeam position data



(a) Iridium (b) Globalstar

Figure 6 : Error in Distance

Comparison between the two positioning methods

Figure 6 shows the error variation with time(i:e, different constellation position with respect to a fixed point on the earth) for a duration of 2hours. From this figure, it is evident that the averaging method gives better error performance than the boundary crossing method. This is further strengthened by the result in Figure 3, which shows the percentage of time verses error threshold. For the averaging method, 90% of the time, the error is less than 100km for Iridium and 275km for Globalstar, but for the spotbeam boundary crossing method, only 55% of the time error is less than 100km for Iridium and only 55% time, the error is less the 275km for Globalstar. The performance of the boundary crossing method depends on the power level fluctuation of the signal near to the spotbeam boundary. It needs satellite ID and spotbeam ID information. But the averaging method doesn't require the satellite ID or spotbeam ID information.

Evaluation of Positioning method against Location Update and Paging

Using very simple mobility model (see Appendix A) the actual position of the MT has been calculated with time. The positions of the MT are calculated using the proposed averaging method with the help of constellation software (SPOC[*]). The number of spotbeams per location area has been calculated. Using the number of spotbeams and other data mentioned in Appendix B[1,3] (bit required for paging and location update, call arrival rate and terminal speed) optimal location area size has been calculated as explained in [3]. The calculated optimal location area radius is used for location update. It is also assumed that the MT performs a location update during mobile terminating calls and mobile initiating calls. With the above location update methods, the following paging strategies were investigated with the simulated model for different mobile speeds (four different speeds are considered, car{50km/h}, high speed train {250km/h}, plane{800km/h}, concord{2200km/h}) and call arrival rate. Simulated mobile terminal movement on the earth, location update positions, call arrival positions and paging failure positions are shown in Figure 8 for the following scenarios

- **Case I :-** Whole location area has been paged
- **Case II :-** The paging area grows with time according to the mobile velocity from the location update position if the expected distance of travel of the mobile terminal is greater than positioning error.

If (PosErr[†] *< Time elapsed×Max MT Velocity)*
{
PAR[‡] *= Time elapsed×Max MT Velocity*
}
else
PAR[‡] *= PosErr*[†]

- **Case III :-** The paging area grows with time according to the mobile velocity from the location update position.

PAR[‡] *= Time elapsed×Max MT Velocity*

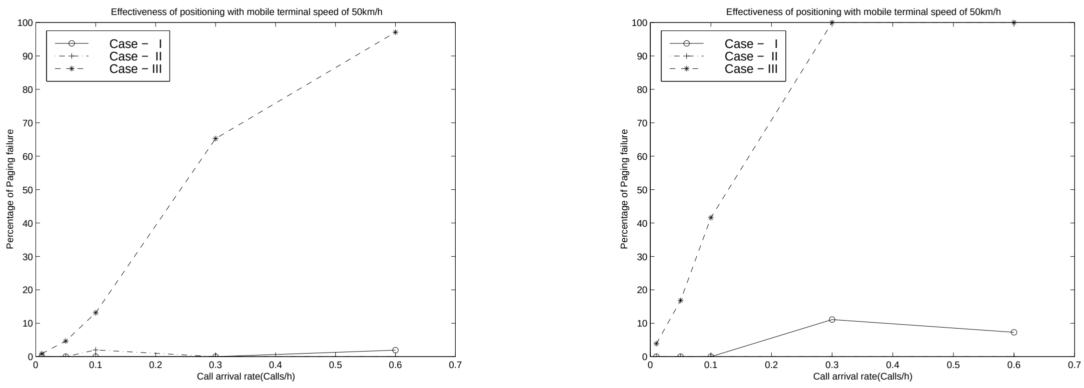
The simulation results for four different speeds are given in Figure 7 for Iridium and Globalstar constellations. The simulation ran for 100 calls arrival time. From the simulation results, Paging failure rate is very low for Case I compare to Case II & III. Paging failure increases remarkably with call arrival rate for Case II & III. Except for a speed of 2200km/h, for all other speeds, paging failure is less than 10% with call arrival rate of 0.1calls/h or less and it is almost zero for Case I. Therefore the proposed positioning method is useful in the new mobile satellite systems when the expected call arrival rate are less than 0.1 calls/h/user. It is possible to observe from Figure 8, that most of the failure happens if calls arrive just after the location update. There will be no paging failure if the PA radius is greater than the notional LA radius plus the position error.

Conclusion

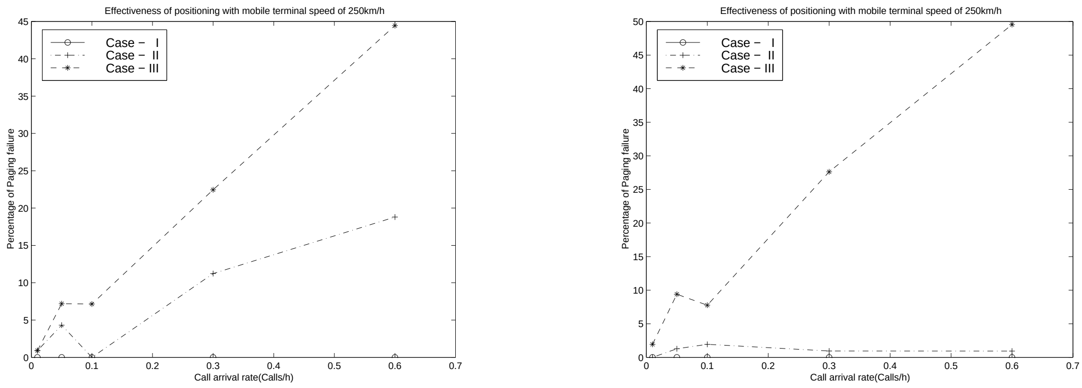
A new application oriented simple positioning method has been proposed for location tracking. It's effectiveness has been verified against the dynamic location update method and it has been found to perform well up to call arrival rate of 0.1calls/h/user except at extremely high speed (MT flies in Concord). It also performs well for higher call arrival rates when the PA is comparable with the LA size. Therefore it can easily be adapted for mobile satellite systems provided the additional bits for transmission of latitude and longitude can be accommodated in the BCCH channel.

[*] SPOC - Simulation Package of Orbit Constellation

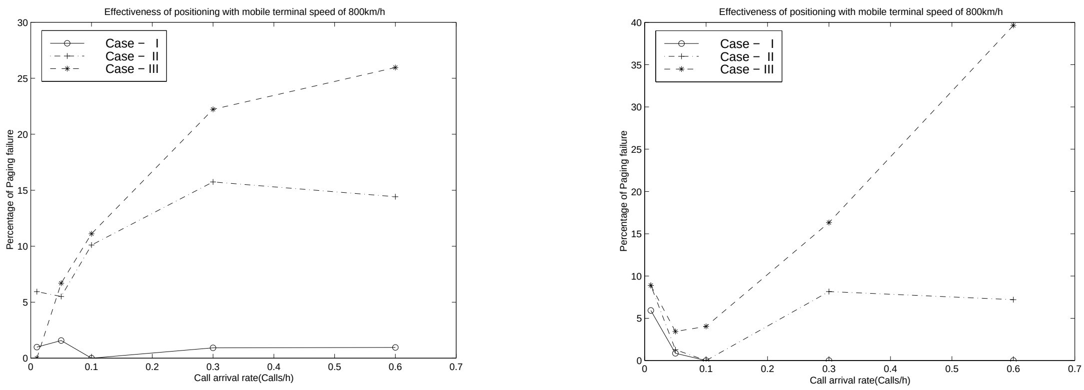
[†] PosErr - Positioning Error
[‡] PAR - Paging Area Radius



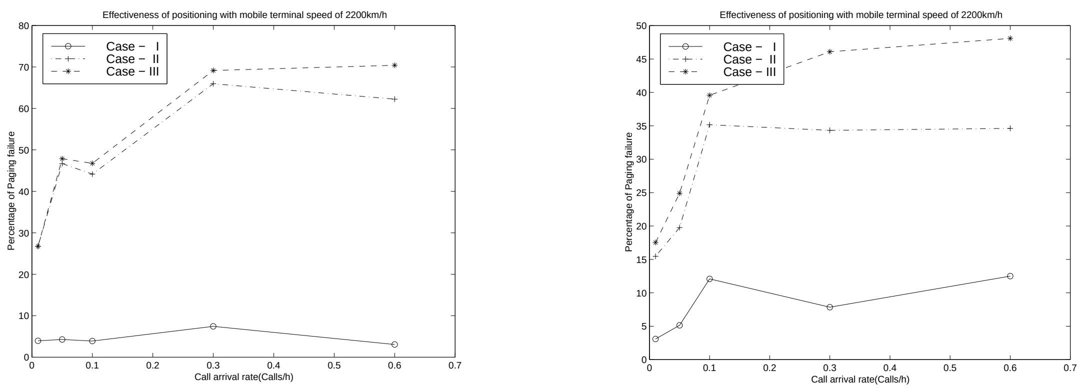
(a) Mobile speed of 50km/h



(b) Mobile speed of 50km/h



(c) Mobile speed of 800km/h



(d) Mobile speed of 2200km/h

Iridium Globalstar

Figure 7 : Paging Failure Rate in First Attempt for the averaging method

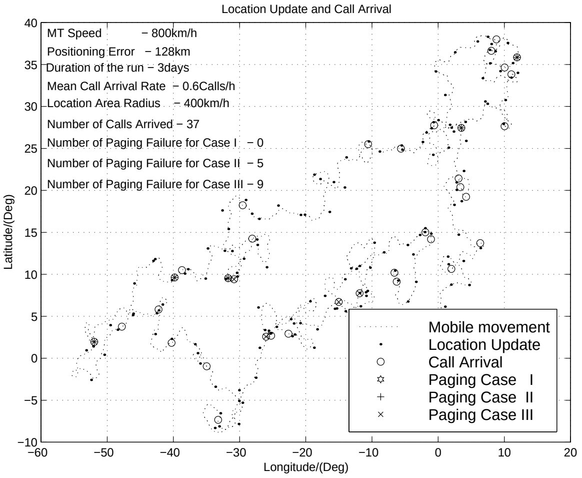


Figure 8: Positions of Location Update, Call Arrival, and Paging failure

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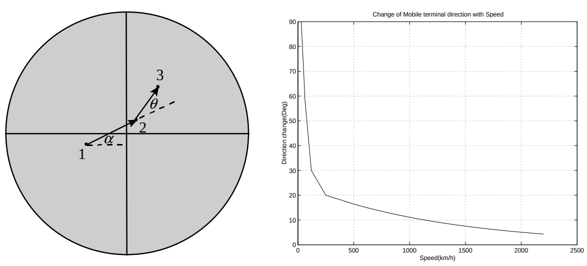
Appendix A : Mobility Model



(a) (b)

Figure A-1 : Movement of the terminal on earth

Assumptions

- The maximum direction change is 90^o and depends on the speed. Velocity of movement is considered from 50km/h(car) to 2200km/h(Concord flight). Possible change of direction (θ) for different speed in shown in Figure A-1(b). For example, considering Figure A-1(a), direction of the terminal from points 1-2 is θ and from points 2-3 is $\theta+\alpha$.
- The terminal can move in the same direction or change direction after certain distance(Called correlation distance). Probability of moving in the same direction, after travelled correlation distance, is 0.2 and probability of changing direction is 0.8.
- It is assumed that mobile can move anywhere on the earth, over ground or sea.

Appendix B : Optimal Location Area

Number of bits for paging /spotbeam(bits) ()	NBPAGE =152
Number of bits for one location update/(bits)	NBLUP =1196
LUR§	$Speed_{MT}$/LAR**
Total Number of bits for paging (TNBPAGE)	NoSpotsLA††× NBPAGE×CAR‡‡
Total Number of bits for location update (TNBLUP)	LUR§× NBLUP
Total number of bits for Location update & Paging	TNBPAGE+ TNBLUP
CAR‡‡ for Terrestrial system	0.6calls/h
CAR‡‡ for Satellite systems	0.1calls/h

Table B 1

It is assumed that number of calls initiating and terminating are equal and has a Poisson distribution.

§ LUR - Location Update Rate
** LAR - Location Area Radius
†† NoSpotsLA - Number of spotbeam in location area
‡‡ CAR - Call Arrival Rate