EVALUATION OF LOCATION TRACKING SCHEMES FOR SATELLITE UMTS

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ABSTRACT

An adaptive location tracking scheme is proposed for satellite UMTS (*S-UMTS*). This scheme uses combination of *spotbeam based paging* (*SBP*) method, *footprint based paging* (*FBP*) method and dynamic location update method. Performance of this scheme is evaluated against bandwidth, location update rate (*LUR*), processing time, consumption of satellites and mobile terminals (*MT*) power and fixed network traffic.

INTRODUCTION

Location information of *MT*s is maintained and updated regularly by the network for call routing purposes. Hence, coverage area of the network is divided into number of location areas (*LA*). Size and layout of the *LA* may be fixed for all users, or vary with time and users mobility. The first one is called as Fixed Location Area (*FLA*) and the second one is called as Dynamic Location Area (*DLA*). Whenever a *MT* crosses the *LA* boundary, the *MT* does the location update. When a call arrives to a *MT*, the system searches all or subset, of the cells or spotbeams (*spots*), called paging area (PA). Selecting the cells or *spots* for paging according to the mobility statistic of the *MT* and paging the *MT* through the selected cells or *spots* is called intelligent paging by Lyberopoulos (4). This paper initially concentrates on current location tracking scheme for terrestrial system and then moves on to the selection of location tracking scheme for *S-UMTS*. Afterward the method of implementing intelligent paging in *S-UMTS* is described and the impact of intelligent paging in processing time and power of the satellite is considered. The simulation results are discussed and conclusions are drawn in the last section.

CURRENT LOCATION TRACKING SCHEMES FOR TERRESTRIAL SYSTEM

The conventional method, proposed in the past, has the following problems.

- Switching between two *LA*s, due to the random walk of *MT*s at *LA* border.
- Traffic due to the location management is concentrated in the *LA* border cells.
- High *LUR* due to cell selection switching caused by radio propagation.

In order to overcome these problems, multi-layer location update method is proposed by Okasaka et al (7). However it is not fully optimised for all parameters, which are changing with time and individuality. Therefore, *DLA* method was proposed by Xie et al (10), where the size of *LA* for a user is not fixed, but optimised according to its current call arrival rate (λ) and mobility. *DLA* method was investigated by Bar-Noy (1) with three different approaches called time based, movement based and distanced based and shown that distance based is the best. Lyberopoulos (4) and Tabbane (9) introduced intelligence in paging to further reduce signalling load due to location management. In this methods, recent interaction, degree of mobility, *MT* attraction points, time zone and base station for paging topology were used to find the proper paging area for step paging. Chin-Lin (2) presented a location tracking scheme called *reverse virtual call* setup (*RVC*) to reduce the *LUR*, paging load, signalling cost in fixed network and call setup delay. In which, *MT* is found using a global paging sub-network based on terrestrial or satellite systems.

SELECTION OF LOCATION TRACKING SCHEME FOR *S-UMTS*

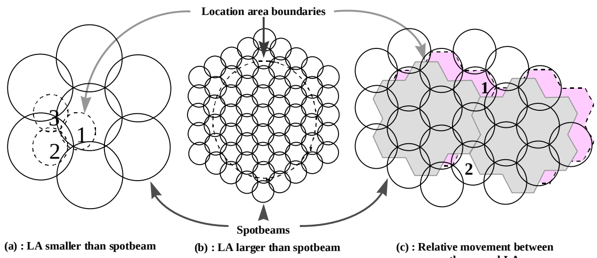


Figure 1 : *FLA* using location area *ID*

In *FLA* method, set of *LA*s should be defined on the earth as in Figure 1, by transmitting *LA* identity (*ID*) using a broadcast control channel (*BCCH*) for each spot. Three different cases are illustrated in Figure 1 to explain the difficulties in implementing the *FLA* method in *S-UMTS*. In the first two cases, one *spot* overlap with 3 or 4 *LA*s. Hence, there is difficulty in defining *LA* using *LA ID*. The last one illustrates the impact of moving *spot*s on defining the *LA*. Thus, *FLA* method is not suitable for *S-UMTS* and it has been identified that the *DLA* method is the suitable candidate for *S-UMTS* with real distance measurement using GPS or the method proposed by Narenthiran (6) or Zhao

(11). In *DLA* method in *S-UMTS*, the *MT* provides its position information in terms of latitude and longitude. To define the possible location of a *MT* after certain time, a circle is defined, where its radius increases with time at a certain rate according to the *MT*s speed. The centre of this circle has the co-ordinates of the last mobile position. The *MT* needs to update its position after travelled pre-defined distance. A combined footprint based paging method and spotbeam based paging method is proposed for the *S-UMTS*. *SBP* refers to paging the *MT* through spotbeam signalling channel whilst *FBP* refers to paging the *MT* through the single footprint size beam as shown in Figure 2. Therefore, the satellite should have a special antenna arrangement to produce footprint size beam for paging purpose.

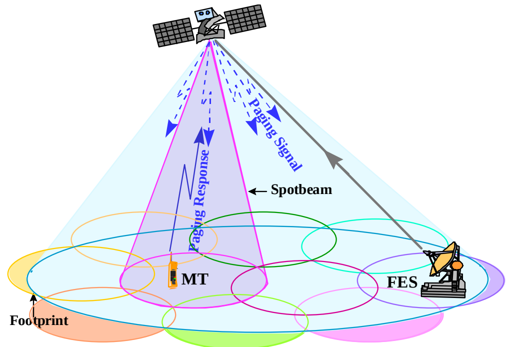


Figure 2 : Paging and Response in *FBP* method

SIGNALLING COST IN LOCATION TRACKING

Only Air interface signalling is considered for cost calculation. Total cost C_T for location update and paging can be given by equation (1).

$$C_T = N_{sp} \times \lambda \times NB_{PAGE} + LUR \times NB_{LUP} \qquad (1)$$

Number of bits for paging in one spot NB_{PAGE} and number of bits for location update NB_{LUP} are 152 and 1196 respectively. Number of *spots* required for paging N_{sp} can be found using the corresponding constellation model. The method of finding *LUR*, is explained in the next sections.

LUR for FLA method

LUR in the *FLA* method depends on the flow of *MT*s among the *LA*s. The number of incoming terminals to a *LA* ($N_{\text{Incoming } MTs}$) in unit time is given by (2). *S* is perimeter of the *LA*, ρ is density of *MT*s per unit area, E[υ] is mean velocity of *MT*s and υ is velocity of individual users.

$$N_{\text{Incoming } MTs} = \rho S E[\upsilon]/\pi \qquad (2)$$

Assuming that, the number of incoming and outgoing *MT*s is equal and *LAR* is location area radius,

$$LUR = 2 \times E[\upsilon]/(\pi \times LAR) \qquad (3)$$

LUR for DLA method

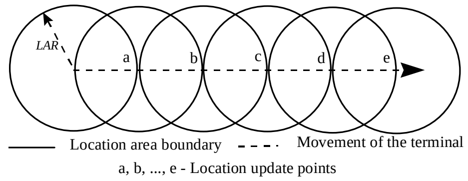


Figure 3 : Location area for *DLA* method

Assuming, there is no update on call arrival and the *MT* is moving in a straight line (Figure 3), *LUR* = υ/*LAR*. In the case of update in call arrival, the derivation for *LUR* is given below, assuming that PDF of originating and terminating calls is Poisson distributed $P(N)=\frac{(\lambda_{mean}t)^N}{N!}e^{-\lambda_{mean}t}$. The probability of not receiving a call within *t* hours is $P(0)=e^{-\lambda_{mean}t}$.

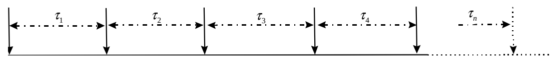


Figure 4 : Time diagram for Call Arrival

Referring to Figure 4, inter-call arrival times $\tau_1 ...... \tau_n$ should be greater than *T*, in order to have location update, only after a call. The number of location updates followed by calls in unit time is given by (4).

$$N_{lup only after calls} = \lambda_{mean} e^{-\lambda_{mean}\left(\frac{LAR}{v}\right)} \qquad (4)$$

Location update may be after a call or after a previous location update. Hence,

$$P_{lup\text{-}after\ call} + P_{lup\text{-}after\ lup} = 1 \qquad (5)$$

$P_{lup\text{-}after\ call}$ and $P_{lup\text{-}after\ lup}$ are probabilities of location update after call and after location update respectively.

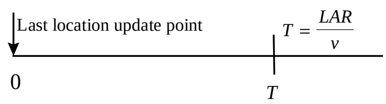


Figure 5 : Location Updates with time

Referring to Figure 5, there should be no call within time interval *T*, to have location update only after a previous location update. The probability of doing a location update only after a location update is $e^{-\lambda T}$. From (5), the probability of doing a location update after a call is given by $P_{lup-after\ call} = 1 - e^{-\lambda_{mean}\left(\frac{LAR}{v}\right)}$. Then, number of location updates only after calls in unit time is given by (6).

$$N_{lup\ only\ after\ calls} = LUR * \left(1 - e^{-\lambda_{mean}\left(\frac{LAR}{v}\right)}\right) \qquad (6)$$

By combining (4) & (6) $LUR = \dfrac{\lambda_{mean} e^{-\frac{\lambda_{mean} * LAR}{v}}}{1 - e^{-\frac{\lambda_{mean} * LAR}{v}}}$

Paging Load

This section explains, the way of reducing paging load using intelligent paging, and the implementation of intelligence in *S-UMTS*.

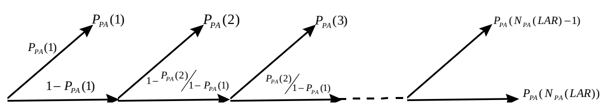


Figure 6 : Tree diagram for probability distribution of step paging

Referring to Figure 6, in order to make the initial paging steps successful, $P_{PA}(i-1)$ should be greater than $P_{PA}(i)$. Assuming that $N_{cells}(LAR)$ is number of cells in a *LA*, $N_{PA}(LAR)$ is number of PAs in a *LA*, N_{Page} is average number of cells for step paging, $K_{cells}(i)$ is number of cells in i^{th} PA and $P_{PA}(i)$ is probability of a *MT* being in i^{th}, the average number of cells required for paging and delay are given by (7) and (8) respectively.

$$N_{Page} = \sum_{i=1}^{N_{PA}(LAR)} p_{PA}(i) \sum_{1}^{i} K_{cells}(j) \quad (7)$$

$$Delay_{page} = \sum_{i=1}^{N_{PA}(LAR)} i \times p_{PA}(i) \quad (8)$$

Therefore, for large value of $N_{PA}(LAR)$, the average number of cells for paging is reduced to half while the paging delay increases. Using equation (7), the number of spots (N_{sp}) required for paging can be found.

IMPLEMENTATION OF INTELLIGENT PAGING IN *S-UMTS*

In order to adopt the intelligent paging in *S-UMTS*, a method was proposed by Meenan (5) to calculate the probability distribution among the *spots* called *Virtual Paging Cell (VPC)* method. *LA* is divided into number of *VPC* as shown in Figure 7 and the probability of being *MT* in i^{th} *VPC* p(i) is found using mobility pattern of *MT*. The footprints overlap with the *LA* are found with probability of being the *MT* in that footprint and the redundant ones are removed by comparison of *VPC IDs* of each footprints. Then, the redundant *spots* belonging to the selected footprints are removed using the same method applied for footprints. The selected *spots* will be in the descending order of the probabilities according to the sorting mechanism applied for selection of *spots*.

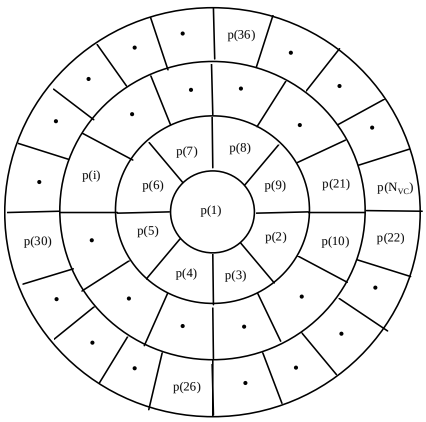
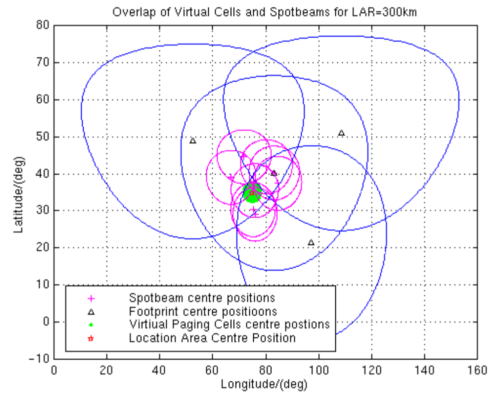
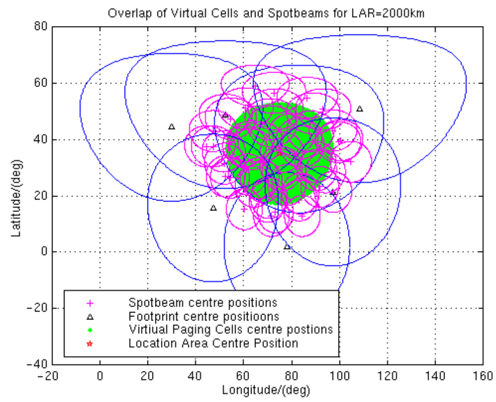


Figure 7 : Virtual Cells

Footprint, spot and *VPC* layout of LEO-48 is shown in Figure 8 for two different *LAR*. Referring to Figure 8(a), the *LA* can be covered by two different single *spots* from different satellites separately. But only one is enough for paging. Considering Figure 8(b), only one footprint can cover whole *LA*. Still, few *spots* of the other footprint have higher probability. This may lead to selection of two satellites attached with different FES and it makes paging more complicated and higher traffic as well in fixed network. Therefore the redundant footprints and *spots* should be removed considering immediate spot or footprint handover, FES handover and call routing easiness.



(a)



(b)

Figure 8 : *VPC*s in *LA* and spotbeams and footprints

PROCESSING TIME FOR PAGING

Spots selection time and time for sorting the *spots* in probability descending order are involved in intelligent paging. In order to have good result from the paging, *VPC*s should be as high as possible. But processing time puts limitation on it. Heapsort from Press (8) book is selected for sorting, because it required very low processing time ($N_{Data}\log_2 N_{Data}$, where N_{Data}-Number of data). The processing time for spot and footprint are given in Figure 9.

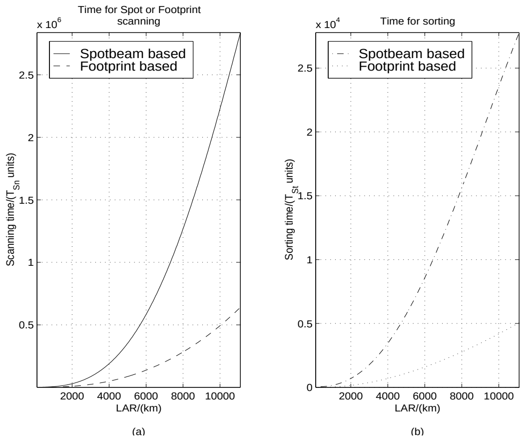


Figure 9 : Processing time

POWER COMPARISON

From Larson book (3), gain of the antenna is given by the following equation.

$$G \cong 44.3-10\log(\theta^2)-12(e/\theta)^2 \quad (9)$$

Where θ is antenna beamwidth (beam half angle) *e* is pointing error. Here only the edge of the spot and footprint is considered for the analysis. Assuming that number of spot required to page is N_{Spot} and number of footprints required to page N_{foot}, the power ratio between these two cases is given by (10). The simulation result for different paging methods is shown in Figure 10.

$$\frac{N_{Foot}\times P_{Tx-Footprint}}{N_{Spot}\times P_{Tx-Spotbeam}}=\frac{N_{Foot}\times G_{Spotbeam}}{N_{Spot}\times G_{Footprint}}=\frac{N_{Foot}\times \theta^2_{Foot\,Half\,angle}}{N_{Spot}\times \theta^2_{Spot\,Half\,angle}} \quad (10)$$

$P_{Tx-Footprint}$, $G_{Footprint}$ and $\theta_{Foot\ Half\ angle}$ are footprint level power, gain and half angle respectively. $P_{Tx-Spobeam}$, $G_{Spotbeam}$ and $\theta_{Spot\ Half\ angle}$ are spotbeam level parameters like footprint.

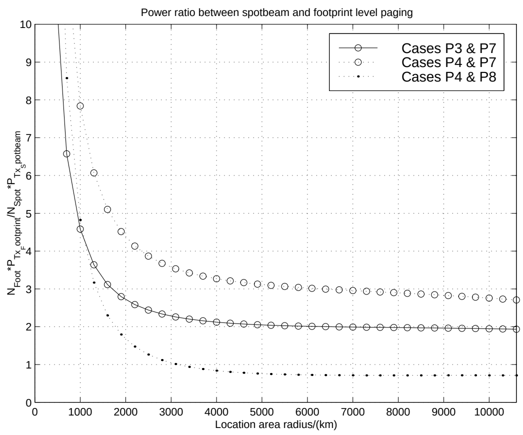


Figure 10 : Power comparison

COMPARISON OF SIMULATION RESULTS

Eight different case (P1-P8) for paging, two different cases (D1-D2) for *DLA* method and only one case (FA) for *FLA* are considered for simulation with two values of λ, CR1=0.01 and CR2=1.0 calls/hour and LEO-66 street of coverage constellation.

P1 : Page all *spots* overlap with the *LA*
P2 : Same as P1, but no satellite redundancy.
P3 : Page minimum *spots* for 100% success.
P4 : 2 step paging (90% success in 1st step).
P5 : Step paging with infinite delay via spot.
P6 : Page all footprints overlap with the *LA*
P7 : Page min footprints for 100% success
P8 : Step paging with infinite delay via foot.
D1 : No location update on call arrival
D2 : Location update on call arrival

Referring to the simulation results in Figure 11, the number of *spots* for paging decreases with intelligence in paging for both SBP and FBP methods. The *FBP* always requires fewer number of footprints compare to the *SBP*. The step paging with infinite delay require the lowest number of *spots*, however the delay is very high. Therefore case P5 is not suitable for *S-UMTS*. P1, P2 and P6 are not efficient methods because they require higher number of *spots* or footprints for paging compare to minimum number of *spots* or footprints required for paging. With compromise between delay and number of *spots* or footprints, cases P3, P4, and P7 can be considered for *S-UMTS*.

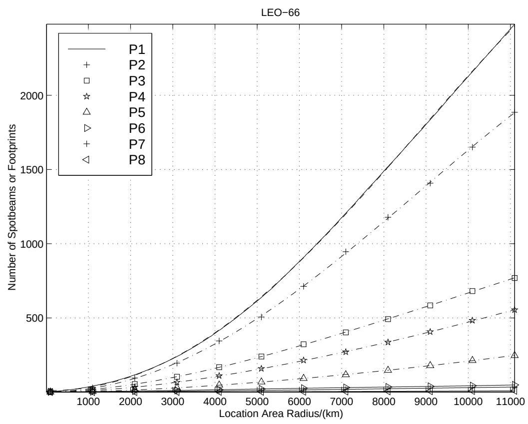
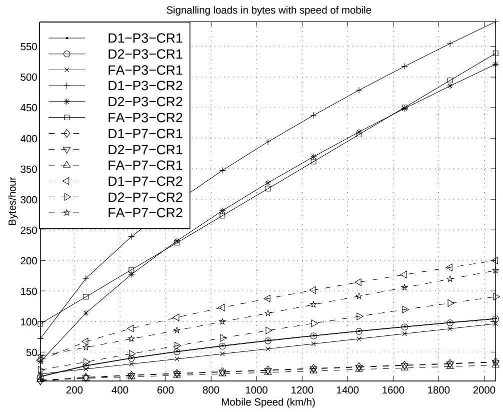
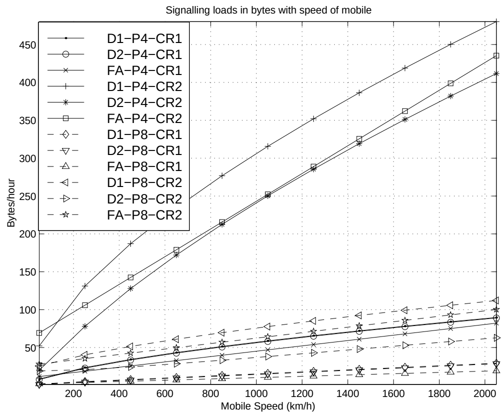


Figure 11 : Number of *spots*

Figure 12 & Figure 13 show the signalling load and *LUR* respectively for some of the paging methods. From Figure 12, the bandwidth requirement increases with λ for both *SBP* and *FBP* methods. Total bandwidth utilisation for location tracking decreases with increased intelligence in paging. *FBP* has much lower bandwidth requirement and *LUR* compare to *SBP*. There is no different in terms of *LUR* and bandwidth requirement between *DLA* with update on call arrival and *DLA* without update on call arrival, at lower λ. Signalling load is always low for *FLA* method compare to *DLA* method at low λ. *LUR* of case D2 is always low compare to D1 and FA at higher λ. The different between *FLA* and *DLA* values for *LUR* and signalling load is small at lower λ even though *FLA* does slightly better than *DLA*.

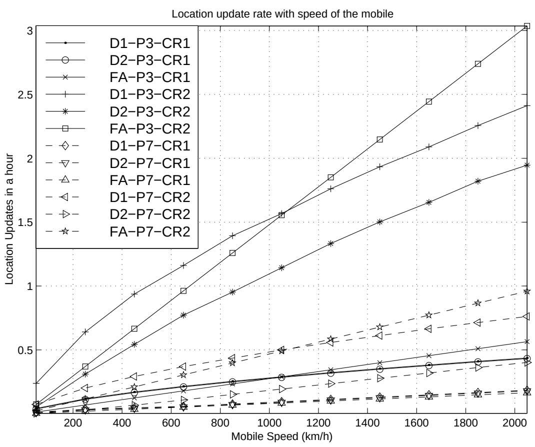


(a) Case P3 and P7

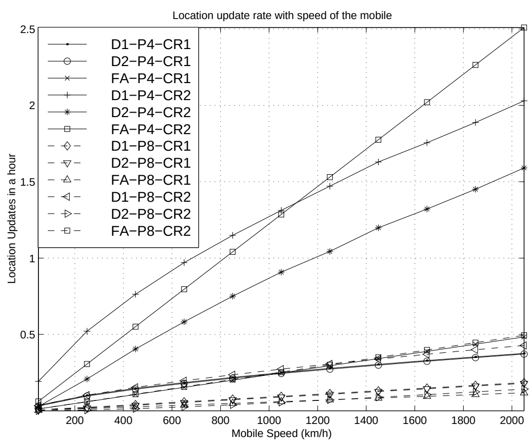


(b) Case P4 and P8

Figure 12 : Signalling load with speed



(a) Case P3 and P7



(b) Case P4 and P8

Figure 13 : Location update rate for different speeds of the terminal

The bandwidth requirement and *LUR* for *FBP* is lower for case D2 compare to cases D1 & FA at higher λ. *FLA* does better than *DLA* (D1&D2) at higher λ, in most of the speed range for *SBP* non intelligent. With intelligent paging, bandwidth requirement is almost same for both *FLA* and *DLA* with update on call arrival or *DLA* does little bit better than *FLA*. Referring to Figure 9, the processing time for *SBP* method increases sharply while the processing time for *FBP* method increases slowly with time. Even though *FBP* intelligent paging performs well in terms of bandwidth and processing time, it consumes higher satellite power compare to *SBP* method as shown in Figure 10. The power ratio increases with intelligence in *SBP* and decreases with intelligence in *FBP*. When same intelligence is applied for both cases, the ratio is above two or remains in two after certain value of *LAR*. Particularly for low optimal *LAR*, *FBP* method is not suitable in terms of satellite power. Hence the decision on using *FBP* method or *SBP* method should be made dynamically with the help of optimal *LAR* and satellite power. If two times higher satellite power is affordable, FBP is the best solution in terms of bandwidth, terminal power, fixed network traffic, processing time, and propagation delay. More ideal solution is to apply adaptive decision making mechanism considering, λ and speed of the terminal with combination of *SBP* and *FBP* methods. Simulation with different mean speed shows that signalling load and *LUR* decrease with increasing mean speed of the mobile population. *FLA* method does better in signalling load compare to *DLA* method at high speed. Still *LUR* is lower for *DLA* with location update in call arrival at higher λ.

CONCLUSIONS

It has been proved that *DLA* with location update in call arrival is the suitable candidate for *S-UMTS*. The performance of the location tracking scheme improves with intelligence in paging while intelligent paging requires more processing time than conventional paging particularly at higher optimal *LAR*. Hence footprint based intelligent paging was proposed instead of spotbeam based intelligent paging. It reduces *LUR*, bandwidth, search time, terminal power and fixed network traffic, while consuming higher satellite power at lower *LAR*. Due to these reasons, adoptive location tracking scheme, with combined spotbeam based and footprint based paging methods, is considered as the best solution for *S-UMTS* to optimise the resources with λ and terminal mobility. It has been also shown by simulation, LEO-48 and MEO-10 have the same performance as LEO-66 for the adoptive location tracking scheme proposed in this paper.

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