

HANDOVER REQUESTS QUEUING IN LOW EARTH ORBIT MOBILE SATELLITE SYSTEMS

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ABSTRACT

This paper deals with a study on resource management strategies in Low Earth Orbit Mobile Satellite Systems (LEO-MSSs). A suitable mobility model has been proposed. Fixed Channel Allocation (FCA) and Dynamic Channel Allocation (DCA) have been considered. Moreover, we have foreseen that inter-beam handover requests, which do not immediately find service, can be queued in order to reduce the handover failure rate. Two different queuing disciplines have been assumed. An analytical approach has been developed to compare these queuing strategies and its results have been validated through simulations.

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1. INTRODUCTION

Future global-coverage Mobile Satellite Systems (MSSs) will be able to provide the users with communication services anytime and anywhere. MSSs will cover impervious or scarcely populated areas where the implementation of terrestrial cellular systems would be infeasible or too expensive. MSSs will also support terrestrial cellular networks when these will be congested or malfunctioning [1-3].

This paper is focused on Low Earth Orbit (LEO) satellites. The study here presented is kept general and illustrated numerically in the case of the IRIDIUM system [4].

A channel request in a beam x (=cell of the satellite system) may be due to either a new call arrival or a handover request from an adjacent beam (i.e., an active Mobile Station -MS- that moves from a cell towards an adjacent cell); if no channel is available in x , the channel request fails and the relative user respectively experiences the blocking of the call attempt or the dropping of a call in progress. For a user oriented service, it is more unacceptable the interruption of a conversation than the blocking of a newly arriving call. In addition to this, inter-beam handover requests are extremely frequent in LEO-MSSs during call lifetime and every time that a call has a beam change there is the risk that it may be dropped owing to a lack of available resources in the destination cell of the mobile user. Therefore, techniques that prioritize the service of handover requests with respect to the service of new call attempts are deemed as essential in order to reduce as much as possible the call dropping probability. A handover prioritization strategy based on the queuing of handovers, that do not attain immediately service, is considered here [5, 6]: any handover request, that occurs in a congested cell, can be queued for a maximum time, t_{wmax} . Elapsed t_{wmax} , if no channel becomes available in the cell, and the call is still in progress, the handover procedure fails. In this study, two different queuing disciplines for handover requests have been proposed and compared in terms of

- the blocking probability for new call attempts, P_{b1}
- the handover failure probability, P_{b2}
- the call dropping probability, P_{drop}
- the probability P_{ns} that a call is not completely served due to either the initial blocking of the call attempt or the failure of a subsequent handover request.

According to ITU-T requirements, the values of P_{drop} and P_{bl} should not exceed 5×10^{-4} and 10^{-2} , respectively [8].

In the following, FCA NPS (DCA NPS) will denote the Fixed (Dynamic) Channel Allocation with No Prioritization Scheme (NPS) for handover requests; whereas, FCA-QH (DCA-QH) will denote the Fixed (Dynamic) Channel Allocation with the Queuing of Handover requests [5, 7].

2. PRELIMINARY CONSIDERATIONS AND ASSUMPTIONS ON LEO-MSSs

Let us assume that, due to beam-forming, spot-beam footprints are disposed on the earth according to a hexagonal regular layout (side R) and they have a circular coverage with radius R' . Possible values for the ratio R'/R range from 1 to 1.5 [9]. Obviously, the greater this ratio is, the larger the overlap area¹ is and, then, the better the queuing technique performance is. In this paper, the minimum possible overlap area extension has been considered (Fig. 3.1): $R = R'$. In the IRIDIUM case under examination, it has been used $R = 212.5$ km.

The cellular network irradiated on the earth by a multi-spot-beam antenna from a satellite has been considered parallelogram shaped. This parallelogram network of cells has been folded onto itself [10], in order to take into account the interference produced by the presence of adjacent spot-beams belonging to neighboring satellites.

Due to the high value of the satellite ground-track speed, V_{trk} (about 26,000 km/h in the LEO case) with respect to the other motion component speeds (i.e., the earth rotation around its axis and the user motion relative to the earth), the relative satellite-user motion can be approximated by only vector V_{trk} .

Two different cells on the earth may reuse the same channel provided that they are at a suitable distance, called *reuse distance* D , that allows tolerable levels for the co-channel interference. In this paper, it will be assumed that $D = \sqrt{21} R$.

Only voice traffic has been considered; as in the classical fixed telephony, new call attempts that do not immediately find free resources are blocked and lost.

¹ An overlap area between two adjacent cells is a region where the MS can receive the signal from both cells.

3. THE LEO MOBILITY MODEL AND ANALYSIS OF ITS STATISTICAL PARAMETERS

Let us denote by *source cell*, the cell where the MS call starts and *transit cell* any subsequent cell reached by the MS with the call in progress. Let us consider an MS that crosses a cell at a height $z \in [-R, R]$ (Fig. 3.1). Let $r(z)$ denote the length of the circular cell with radius R at a height z (Fig. 3.1):

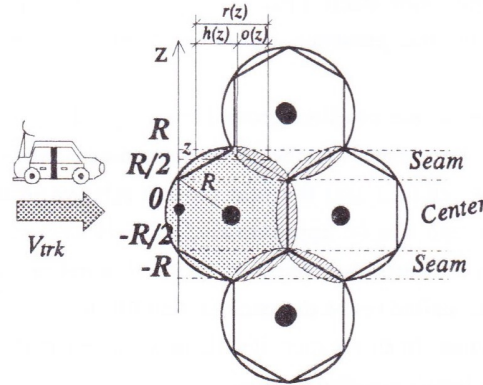
$$r(z) = 2\sqrt{R^2 - z^2} \quad (3.1)$$

The circular cell is divided into two regions: the overlap area between adjacent cells in the direction of the relative motion and the part of the cell that is called *curvilinear cell* (whose area is equal to $3\sqrt{3}R^2/2$); this cell is represented by the shaded area in Fig. 3.1. The MS crosses a distance $h(z)$ in the curvilinear cell and a distance $o(z)$ in the overlap area:

$$h(z) = r(z) - o(z) \quad (3.2)$$

and

$$o(z) = \begin{cases} 2\sqrt{R^2 - z^2} - \sqrt{3}R, & \text{if } |z| \leq \frac{R}{2} \\ \sqrt{R^2 - z^2} - \frac{\sqrt{3}}{2}R + \sqrt{R^2 - \left(|z| - \frac{3}{2}R\right)^2}, & \text{if } R \geq |z| > \frac{R}{2} \end{cases} \quad (3.3)$$






-  - curvilinear cell, where the avg. arrival rate of new attempts is λ
-  - hexagonal cellular layout with side R
-  - overlap area between adjacent cells

Fig. 3.1: The geometry assumed for the overlap areas

Once the position of the MS at the call arrival instant is defined, a height z is assigned to this call in its source cell. Then, the distance $o(z)$ covered in the overlap area is obtained from (3.3) and, due to the geometry of the problem (see also the following assumptions on mobility), this value is valid for any subsequent handover request. The LEO mobility model proposed in this paper is as follows:

- MSs cross the cellular network with a relative velocity, vector V_{mk} , "orthogonal" to the side of the cells (Fig. 3.1).
- When a handover occurs, the destination cell is the neighboring cell in the direction of the relative satellite-user motion.
- Calls are uniformly generated all over the network.
- From the call outset in a cell, an MS travels a distance (depending on z) defined as:
 - uniformly distributed between 0 and $h(z)$, if the call is in its *source cell*;
 - deterministically equal to $h(z)$, if the call is in a *transit cell*.

According to these assumptions, the probability density function (pdf) of the height z of a call arrival in a cell is $f_i(z)$, where $i = 1$ for a call in its source cell and $i = 2$ for a call in a transit cell:

$$f_i(z) = \begin{cases} \frac{h(z)}{3\sqrt{3}R^2}, & \text{if } i = 1 \\ \frac{u[z+R] - u[z-R]}{2R}, & \text{if } i = 2 \end{cases} \quad (3.4)$$

where:

$$u(x) = \begin{cases} 1, & x \geq 0 \\ 0, & \text{otherwise} \end{cases} \quad (3.5)$$

We introduce the following dimensionless parameter that characterizes the MS mobility in a cell, according to the height z :

$$\alpha(z) = \frac{h(z)}{V_{trk} T_m} \quad (3.6)$$

where T_m is the average call duration.

For $|z| \leq R/2$, $h(z) = \sqrt{3} R$ and $\alpha(z) = \sqrt{3} R / (V_{trk} T_m)$; this quantity will be denoted by α . For the IRIDIUM satellite constellation ($R=212.5$ km, $V_{trk}=26,600$ km/h), if $T_m=3$ min, α is about equal to 0.27.

The unencumbered call duration, t_d , has been assumed a random variable exponentially distributed with mean T_m . Let t_{mc1} (t_{mc2}) be the time interval elapsed from the arrival instant of a call in its source cell (transit cell) to the instant in which the related MS exits the cell. From [11], the handover probability for a call from a cell, where the related MS crosses (from the call arrival instant)

- a distance uniformly distributed between 0 and $x V_{trk} T_m$, is:

$$P_{h1}(x) = \frac{1 - e^{-x}}{x} \quad (3.7)$$

- a fixed distance equal to $x V_{trk} T_m$, is:

$$P_{h2}(x) = e^{-x} \quad (3.8)$$

Handover probabilities P_{H1} and P_{H2} respectively from the source and the transit cell are obtained through the following formula:

$$P_{Hi} = \int_{-R}^R P_{hi}(\alpha(z)) f_i(z) dz \quad (3.9)$$

The handover probability from a transit cell is (from (3.9) with $i = 2$):

$$P_{H2}(\alpha) = \frac{P_{h2}(\alpha)}{2} + \frac{1}{R} \int_{R/2}^R P_{h2}(\alpha(z)) dz \quad (3.10)$$

The handover probability from a source cell is (from (3.9) with $i = 1$):

$$P_{H1}(\alpha) = \frac{2}{3} P_{h1}(\alpha) + \frac{\frac{4}{3R} \int_{R/2}^R \alpha(z) P_{h1}(\alpha(z)) dz}{\alpha} \quad (3.11)$$

Handover probabilities P_{H1} and P_{H2} only depend on the mobility parameter α . It is evident that as α approaches 0 (∞), P_{H1} and P_{H2} approach 1 (0), i.e., the mobility increases (decreases). In the IRIDIUM case, $P_{H1} \approx 89\%$ and $P_{H2} \approx 81\%$.

The channel holding time in a cell can be derived as:

$$t_{Hi} = \min [t_d, t_{mci}] \quad (3.12)$$

where: $i = 1$, for a call in its source cell, $i = 2$, for a call in its transit cell.

From [12], the expected value of t_{Hi} , $E[t_{Hi}]$, results in:

$$E[t_{Hi}] = T_m (1 - P_{Hi}) \quad (3.13)$$

Let us consider an MS that starts a call in the source cell at a height $z \in [-R, R]$; z is a random variable with probability distribution function $f_z(z)$ given by (3.4).

If $|z| \leq R/2$ (Fig. 3.1), the MS motion is centered with respect to the cellular network. In such a case, $P_{h1}(\alpha)$ is the handover probability from the source cell (see (3.7)) and $P_{h2}(\alpha)$ is the handover probability from a transit cell (see (3.8)) [10]. Then, the mean number of handover requests for $|z| \leq R/2$ [11] is:

$$n_{h|z} = \frac{P_{h1}(\alpha)(1 - P_{b1})}{1 - (1 - P_{b2})P_{h2}(\alpha)} \quad , \quad \text{for } |z| \leq \frac{R}{2} \quad (3.14)$$

If $R \geq |z| > R/2$ (Fig. 3.1), the MS is moving across the seam of the cellular network; the maximum distance covered in the source cell is $h(z) = 2\sqrt{3}(R - |z|)$, whereas the distance crossed in the subsequent transit cell is $\sqrt{3}R - h(z)$. In the next transit cell the distance covered is again $h(z)$, and so on, alternately. Let us denote:

$$\alpha_1(z) = \frac{h(z)}{V_{trk} T_m} \quad , \quad \alpha_2(z) = \frac{\sqrt{3}R - h(z)}{V_{trk} T_m} \quad (3.15)$$

$$\text{then: } \alpha_1(z) + \alpha_2(z) = \alpha$$

The handover process is shown in Fig. 3.2. According to this diagram, the average number of handover requests per call for $R \geq |z| > R/2$ is given by:

$$n_{h|z} = (1 - P_{b1}) \frac{P_{h1}(\alpha_1) + (1 - P_{b2}) P_{h1}(\alpha_1) P_{h2}(\alpha_2)}{1 - (1 - P_{b2})^2 P_{h2}(\alpha)}, \text{ for } R \geq |z| > \frac{R}{2} \quad (3.16)$$

The average number of handover requests can be obtained by removing the conditioning on z in formulas (3.14) and (3.16): it is necessary to integrate $n_{h|z}$ weighted by the pdf of z , i.e., $f_1(z)$, from $-R$ to R ; the result is as follows:

$$n_h = (1 - P_{b1}) \frac{2}{3} \left\{ \frac{P_{h1}(\alpha)}{1 - (1 - P_{b2}) P_{h2}(\alpha)} + \frac{\gamma(\alpha) + (1 - P_{b2}) \zeta(\alpha)}{1 - (1 - P_{b2})^2 P_{h2}(\alpha)} \right\} \quad (3.17)$$

where:

$$\zeta(\alpha) = \frac{2}{\alpha} (P_{H2}(\alpha) - P_{h2}(\alpha)) \quad (3.18)$$

$$\gamma(\alpha) = P_{h1}(\alpha) - \zeta(\alpha) \quad (3.19)$$

From (3.17) we can note that if $P_{b1} = P_{b2} = 0$, $n_h = 4 / (3\alpha)$: in this case, n_h is a parameter that only depends on the geometry of the problem. For the IRIDIUM system ($\alpha \approx 0.27$), $n_h \approx 4.82$ handovers/call.

The average number of handover requests per served call, n_h' , can be obtained from n_h through the following formula (Fig. 3.2):

$$n_h' = \frac{n_h}{1 - P_{b1}} \quad (3.20)$$

If a served call originates an average number n_h' of handover requests and at each request the call may be dropped according to probability P_{b2} , then the overall call dropping probability is given by:

$$P_{drop} = n_h^i P_{b2} \quad (3.21)$$

Probability P_{ns} can be obtained as follows [6, 11]:

$$P_{ns} = P_{b1} + (1 - P_{b1}) P_{drop} = P_{b1} + n_h P_{b2} \quad (3.22)$$

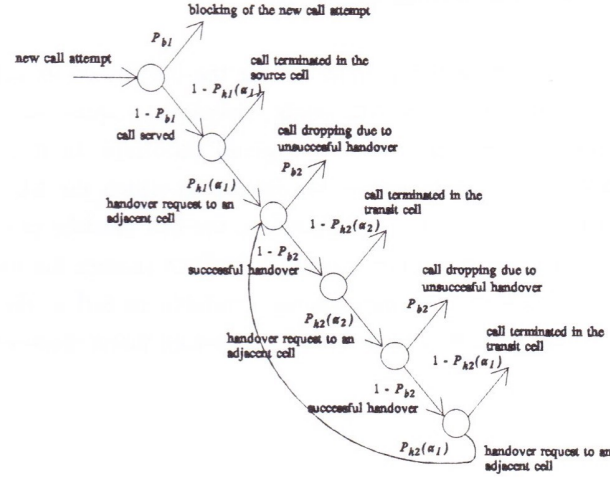


Fig. 3.2: The handover process across the seam of the cellular network.

λ_h is the average arrival rate of handover requests towards a generic cell. Whereas, λ is the average arrival rate of new call attempts in a generic cell. We can use the following formula which is valid for any mobility model:

$$n_h = \frac{\lambda_h}{\lambda} \quad (3.23)$$

4. HANDOVER QUEUING POLICIES

In order to meet the specified requirements for the call dropping probability, an inter-beam handover strategy is here considered that requires the Queuing of Handover requests (QH) when no channel is free in the destination cell of the mobile at the handover request instant.

4.1 The description of the queuing technique

Let us assume that an active MS is approaching the borders of its cell x and is going into an adjacent cell y . The MS sends a handover request as soon as the level of the received signal drops below a given threshold. In this paper, we consider that this event corresponds to the instant in which the MS enters the overlap area between cell x and cell y . In cell y , the MS must be provided with a new channel to carry on the communication. The MS crosses the overlap area in a time t_{wmax} . If no channel is immediately available in cell y , the handover request can be queued for a maximum time t_{wmax} , to wait that a resource becomes free [10, 11].

4.2 Statistics of the maximum queuing time

According to the assumptions used, t_{wmax} , is derived as the time spent by the associated MS to cross the overlap area at a given height z (Fig. 3.1) with a speed V_{trk} :

$$t_{wmax} = \frac{o(z)}{V_{trk}} \quad (4.2.1)$$

The average value of the maximum queuing time, $E[t_{wmax}]$, results in:

$$E[t_{wmax}] = \frac{E[o(z)]}{V_{trk}} = \alpha T_m \beta \quad (4.2.2)$$

where the dimensionless parameter β is given by:

$$\beta = \frac{4}{9} \left(\frac{\sqrt{3}}{3} \pi - \frac{3}{2} \right) \approx 0.1394 \quad (4.2.3)$$

In the IRIDIUM case, we have:

- $E[o(z)] \approx 52 \text{ km}$,
- $E[t_{wmax}] \approx 7 \text{ s}$.

4.3 Queuing disciplines

Depending on the order according to which the handover requests are served in the queue, two schemes have been considered in this paper: the First Input First Output (FIFO) and the "*Last Useful Instant*" (LUI) technique. In the FIFO scheme [6, 10, 11], handover requests are queued according to their arrival instants. Whereas, the idealized queuing discipline called "*Last Useful Instant*" (LUI) requires that, when a handover request is queued, the system exactly knows its maximum queuing time (t_{wmax}). This new request is placed before the other ones found in the queue that have a greater residual maximum queuing time. In such a way, the system serves first the most critical handover request. This queuing policy is not dynamic: the relative ranking of queued handover requests does not change while they are waiting for the service. In the LEO-MSS case, where the mobility is dominated by the satellite motion, it is also possible to propose an implementation of the LUI strategy. The system may estimate the time spent by the MS to cross the overlap area, t_{wmax} , by measuring the position of the MS at the call arrival instant in the source cell with a sufficient accuracy (for example, by resorting to use a positioning system integrated into the MSS).

5. ANALYSIS OF FCA-QH WITH DIFFERENT QUEUING STRATEGIES

In performing the analysis on FCA-QH, we have assumed that:

- S channels are assigned per cell with FCA;
- new call arrivals and handover attempts are two independent Poisson processes, with mean rates λ and λ_h , with λ_h related to λ by (3.17) and (3.23);

- whether handover requests are queued or not, the channel holding time in a cell is approximated as exponentially distributed with mean $1/\mu$, expressed as:

$$\frac{1}{\mu} = \frac{\lambda(1-P_{b1})E[t_{H1}]}{\lambda(1-P_{b1}) + \lambda_h(1-P_{b2})} + \frac{\lambda_h(1-P_{b2})E[t_{H2}]}{\lambda(1-P_{b1}) + \lambda_h(1-P_{b2})} \quad (5.1)$$

where $E[t_{H1}]$ and $E[t_{H2}]$ are derived from (3.13);

- the maximum waiting time is approximated by a random variable exponentially distributed, with expected value equal to $1/\mu_w = E[t_{wmax}]$, where $E[t_{wmax}]$ is given by (4.2.2);
- the handover queue has an infinite capacity.

From the above assumptions it follows that in case of the FCA-QH technique each cell can be modelled as an $M/M/S$ queuing system (Fig. 5.1) with non-homogeneous arrival rates [6, 11] (M : Poisson arrival process / M : service time exponentially distributed / S : number of channels assigned per cell).

The status of the queuing system under consideration (= a cell) has been defined as sum of the number of calls in service and the number of queued handovers. Whenever the system is in a status n less than S , the gross arrival rate is $\lambda + \lambda_h$; while, if the status is greater or equal to S , i.e. all channels are busy, the gross arrival rate is λ_h (Fig. 5.1). When the system is in the state $S+i$, for $i=1,2,\dots$, we have added $i\mu$ to the departure rate with respect to the queuing model shown in [11] (Fig. 5.1), because a call may end in the overlap area before obtaining service. The model shown in Fig. 5.1 is valid for both FIFO and LUI queuing disciplines.

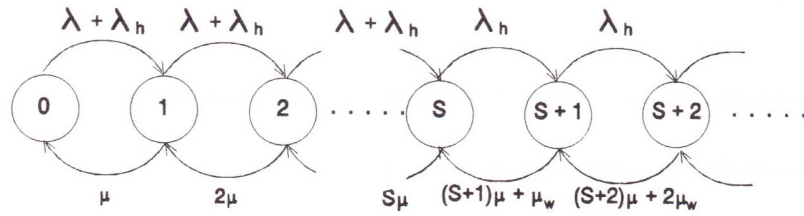


Fig. 5.1: The Markov chain model for a cell with FCA-QH.

Let us analyze the state probabilities for the Markov chain in Fig. 5.1; by following the same approach proposed in [11], the probability of state n , P_n , can be derived as:

$$P_n = \begin{cases} \frac{(\lambda + \lambda_h)^n}{n! \mu^n} P_0, & 1 \leq n \leq S-1 \\ \frac{(\lambda + \lambda_h)^S \lambda_h^{n-S}}{S! \mu^S \prod_{j=1}^{n-S} ((S+j)\mu + j\mu_w)} P_0, & n \geq S \end{cases} \quad (5.2)$$

where the idle system probability, P_0 , is given by:

$$P_0 = \left\{ \sum_{n=0}^{S-1} \left[\frac{(\lambda + \lambda_h)^n}{n! \mu^n} \right] + \sum_{n=S}^{\infty} \left[\frac{(\lambda + \lambda_h)^S \lambda_h^{n-S}}{S! \mu^S \prod_{j=1}^{n-S} ((S+j)\mu + j\mu_w)} \right] \right\}^{-1} \quad (5.3)$$

New arrivals are blocked when all the available channels (servers) are in use in the cell, i.e. when the queuing system is in the state $n \geq S$. Therefore, P_{bl} results in:

$$P_{bl} = \sum_{n=S}^{\infty} P_n \quad (5.4)$$

The blocking parameter P_{bl} does not depend on the queuing discipline, whereas P_{b2} depends on the assumed queuing policy (i.e., FIFO or LUI). Simulation results have confirmed that P_{bl} values are almost the same in both cases (see Fig. 6.3 in the next Section).

5.1 P_{b2} with FIFO queuing policy

In this case, P_{b2} can be derived by following the same approach proposed in [6, 11] and by considering these new aspects:

- P_{b2} must contain a multiplying factor $P_{uh} = \mu_w/(\mu + \mu_w)$ which represents the probability that the queued handover request is related to a call that does not end before its time t_{wmax} has expired.
- State probabilities are derived according to the new queuing model (Fig. 5.1).
- We take account of the additional departure rates $i\mu$ for states $S + i$ for $i = 1, 2, \dots$

P_{b2} results in:

$$P_{b2} = \frac{\mu_w}{\mu + \mu_w} \sum_{n=S}^{\infty} P_n \left\{ 1 - \frac{S\mu}{S\mu + \mu_w} \prod_{j=1}^{n-S} \left[1 - \frac{\mu_w}{S\mu + \mu_w} \left(\frac{\mu_w}{\mu + \mu_w} \frac{1}{2} \right)^j \right] \right\} \quad (5.1.1)$$

5.2 P_{b2} with LUI queuing policy

In case of the LUI strategy, each handover request in the queue reaches anyhow the head of the queue before dropping the associated call, unless the request leaves the queue because of a call termination. Only the call whose handover request is at the head of the queue may be dropped. Therefore, the probability of handover failure for a handover request, that is queued since it does not find any free resource among the S , $P_{b2/S}$, does not depend on the position that this request initially has in the queue. Then, by taking also into account eq. (5.4), the following result is obtained:

$$P_{b2} = \sum_{n=S}^{\infty} P_n P_{b2|S} = P_{b2|S} P_{b1} \quad (5.2.1)$$

$P_{b2/S}$ takes into account two joined and independent events:

- the call, whose handover request is at the head of the queue, does not end before exiting the overlap area; the probability of this event is P_{uh} .
- None of the S channels of the cell becomes free before the maximum queuing time has expired; let us denote the probability of this event by P_f

By using the exponential distributions for the maximum queuing time and the channel holding time, we obtain the following result:

$$P_{uh} = \frac{\mu_w}{\mu + \mu_w}, \quad P_f = \frac{\mu_w}{S\mu + \mu_w} \quad (5.2.2)$$

Hence, in the LUI case, P_{b2} is given by:

$$P_{b2} = P_{b1} \frac{\mu_w}{\mu + \mu_w} \frac{\mu_w}{S\mu + \mu_w} \quad (5.2.3)$$

5.3 Numeric methods

An iterative method based on parameter n_h is used to compute P_{b1} and P_{b2} (for both queuing disciplines), because λ_h is related to P_{b1} and P_{b2} , through (3.17). In the next Section, Figs. 6.1 and 6.2 compare simulation and analytical results for FCA-QH with FIFO and LUI schemes in the IRIDIUM case under examination.

6. SIMULATION RESULTS

The following assumptions have been made for the simulations:

- the call arrival process is Poisson independent from cell to cell with average rate per cell equal to λ ,
- the call duration is exponentially distributed with average value equal to $T_m = 3$ min,
- the simulated cellular network is parallelogram shaped and folded onto itself with 7 cells per side,
- 70 channels are available to the system ($S=10$ channels per cell with FCA),
- the IRIDIUM mobility case is considered ($\alpha \approx 0.27$),
- an infinite queue capacity is assumed.

The comparison between simulations and analytical predictions for FCA-QH with FIFO and LUI queuing disciplines are respectively shown in Fig. 6.1 and 6.2 in terms of parameter P_{ns} .

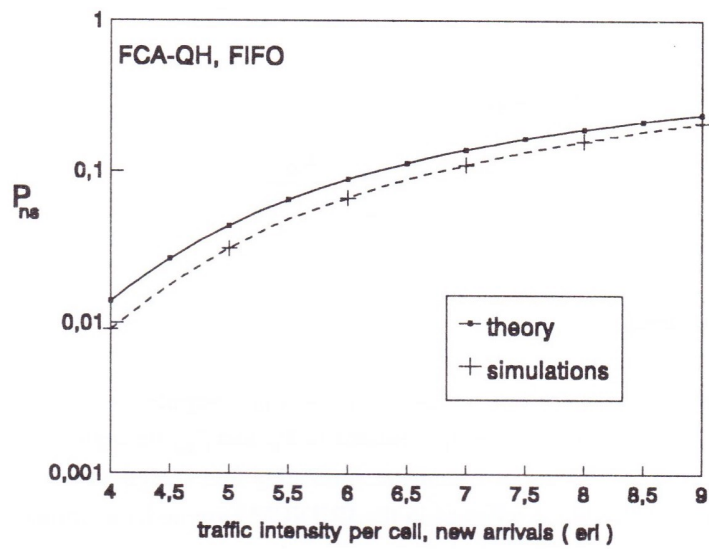


Fig. 6.1: FCA-QH with the FIFO queuing discipline (IRIDIUM case).

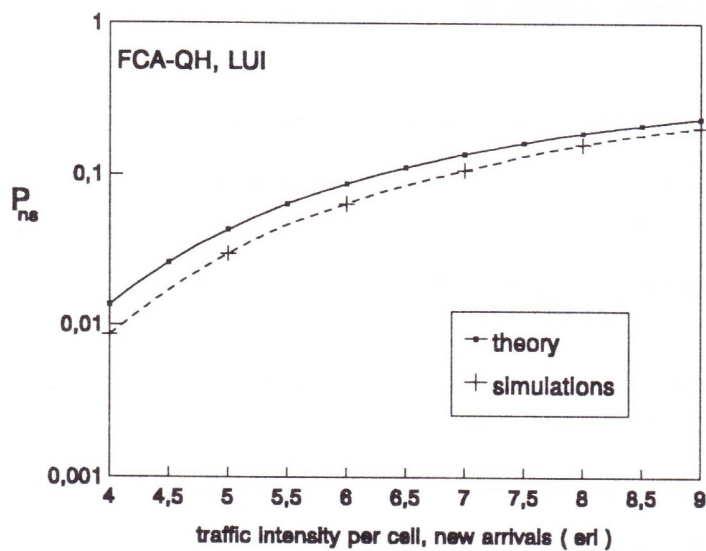


Fig. 6.2: FCA-QH with the LUI queuing discipline (IRIDIUM case).

In Figs. 6.1 and 6.2, we may note that the theoretic approaches for both queuing disciplines give a conservative estimate of the P_{ns} performance obtained by simulations.

Figs. 6.3, 6.4 and 6.5 show simulation results for all the techniques considered in terms of P_{b1} , P_{b2} and P_{ns} . In these graphs the curves for FCA NPS and DCA NPS have been also presented. The following considerations arise:

- As regards the NPS scheme, the QH strategy (with both FIFO and LUI and regardless of the channel allocation technique used, i.e., DCA or FCA) allows a significant reduction of P_{b2} at the expenses of an increased value of P_{b1} . These advantages are particularly evident in terms of P_{ns} (see Fig. 6.5).
- DCA techniques allow better results with respect to the corresponding FCA strategies. This result highlights that DCA strategies will be particularly suitable for high mobility systems such as the LEO-MSSs under consideration.
- The LUI strategy permits to reduce P_{b2} with respect to the FIFO one both in the FCA-QH and DCA-QH cases (Fig. 6.4), but this difference is very little. Moreover, LUI and FIFO solutions have practically the same performance in terms of P_{b1} and P_{ns} (see Figs. 6.3 and 6.5). Therefore, the FIFO scheme has to be preferred since the possible advantages of the idealized LUI discipline do not justify its implementation complexity.

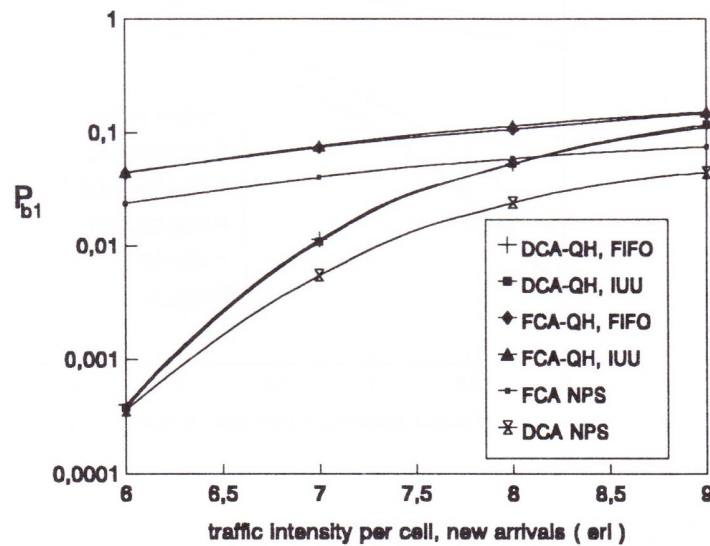


Fig. 6.3: P_{b1} performance (IRIDIUM case).

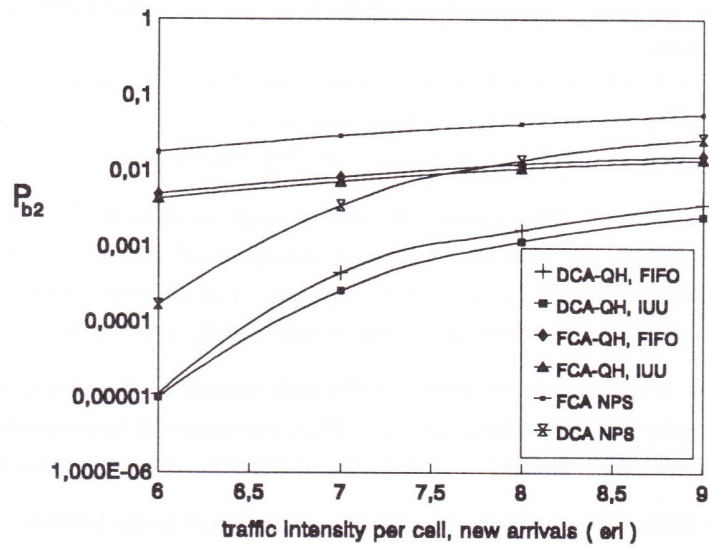


Fig. 6.4: P_{b2} performance (IRIDIUM case).

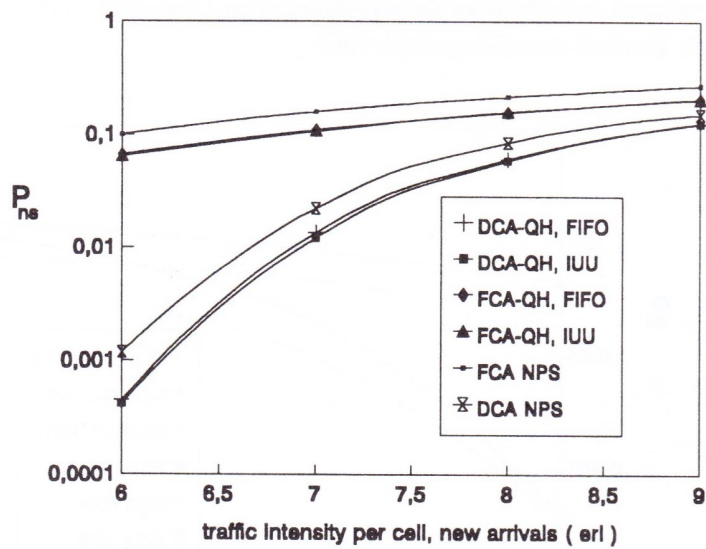


Fig. 6.5: P_{ns} performance (IRIDIUM case).

7. CONCLUSIONS

An LEO-MSS has been assumed and a suitable mobility model has been proposed. Both FCA and DCA have been considered with the Queuing of Handover requests. Performance comparisons among the techniques presented have been carried out by simulations. Moreover, an analytical approach has permitted to obtain an upper bound to the FCA-QH performance.

Two handover queuing disciplines have been compared: the simple FIFO scheme and the idealized LUI technique.

It has been proved that the queuing of handover requests is essential in order to improve the performance of high mobility systems such as LEO-MSSs.

Moreover, the simulation results have shown that the FIFO policy attains good results very close to those given by the LUI technique. Therefore, the FIFO solution has to be preferred to the LUI one, which has a greater implementation complexity.

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