The Handover in the Constellations of Satellites in Low Orbit

Nour el Houda Hedjazi[1], Malika Ouacifi[2], Rachida Bouchouareb[3], Meriem Ourghi[4], Messaoud Gareh[5] and Djamel Benatia[6]

Department of Electrical Engineering, Batna University, Algeria
[1]nour.hedjazi@gmail.com, [6]dj_benatia@yahoo.fr

Abstract

The Handover is one of the key subjects in maintaining the quality of service offered by non-geostationary constellation systems. As the satellite coverage moves according to the satellite motion, the continuity of a call must be maintained from one satellite to another. In case of the Handover fails, the call is dropped, resulting in a quality degradation of service.

In this paper, the performance of several channel assignment strategies for a LEO satellite constellation is evaluated. The FCA method is considered where its advantages and disadvantages are highlighted. Moreover, the Handover process implication in the call blocking probability is assessed via simulation. Strategies able to cope with the high number of Handovers, due to the high speed of the satellites, without affecting strongly the capacity of the system are investigated. Simulation models have been developed to implement all the features evaluated in this paper including the mobility model. An analytical description and interpretation of results are also presented.

***Keywords**: Handover, satellite constellation, the queue, guard channel.*

1. Introduction

Communication's satellites are mobile radio systems for mobile phones such as boats, airplanes, land vehicles, and mobile devices using satellites, we must note that the concept of mobile satellite does not lead necessarily the movement of the satellite.

In this paper, we are particularly interested in the problem of handover in LEO satellite mobile system. Indeed, a call from a fixed or mobile user can be transferred from one cell to another (respectively from one satellite to another) since the call cannot receive a proper communication channel in cell Current (respectively in the satellite system) due to user mobility, the movement of the satellite, and because of the propagation (fading, shadowing, ...). The handover makes the transfer of communication link from the current channel to another.

As the failure of the handover is less desirable for the release of a new connection, a detailed study was made on the various priority strategies of the handover requests for new calls [1, 2, 3, 8]. We also studied some techniques.

2. Mathematical Modeling

In the following, we consider that the arrival of new calls forms a Poisson process with an average λ. The intensity of the Poisson process services is μ. The arrivals of handover requests form a Poisson process of average λh. If a mobile channel in the cell, the call duration (with mean $1/\mu$) is equal to the time during which the call is in progress without having under gone a forced termination due to failure of the handover.

If a channel has been allocated to a mobile, it will be released at the end of the call is due to a handover to a neighboring cell. So the channel occupation time is the minimum duration of the call. We denote by:

- Pb: probability that a new user finds all channels busy in a cell.
- Ph: probability of failure of the handover. Is the probability that a handover call finds all channels occupied on his arrival in the neighboring cell.
- Pf: the probability of forced termination of the call. Is the probability that a call has been accepted by the system is interrupted due to failure of handover.
- Pnc: probability that the call is incomplete. Is the probability that the call either failure (new call) or there is a forced termination of the call....

3. No Priority Strategy

In the no priority strategy, the Handover requests are treated the same way as the original calls [4]. Therefore, the blocking probability of handover is equal to the probability of blocking new call.

The NPS is modeled by a Markov process (Figure 1) with an s+1 states where s is the number of channels present in the cell. The state transition diagram is shown in Figure 1.

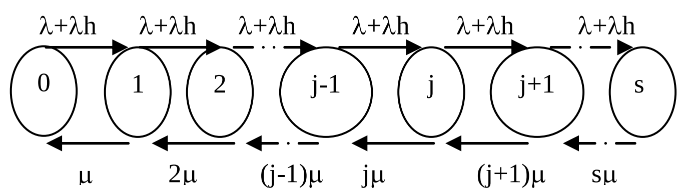

Figure 1. State Transition Diagram

New calls and handover calls use the s channel as they are free.
For $0 \leq j \leq s$, the new call or handover call uses one channel. If s channels are busy and if a call comes, it will be blocked.

The NPS is modeled by a queue M / M / s / s [5]. Pj is the probability of state j. It shows that:

$$P_j = \frac{\frac{\left(\frac{\lambda+\lambda h}{\mu}\right)^j}{j!}}{\sum_{K=1}^{S} \frac{\left(\frac{\lambda+\lambda h}{\mu}\right)^k}{k!}} \tag{1}$$

We get:

$$Pb = Ph = Ps = \frac{\frac{\left(\frac{\lambda+\lambda h}{\mu}\right)^s}{s!}}{\sum_{k=0}^{s} \frac{\left(\frac{\lambda+\lambda h}{\mu}\right)^k}{k!}} \tag{2}$$

This equation is known as Erlang-B formula [5].

4. Priority Strategy

4.1. Handoff Call Queuing Scheme

If no free channels in the neighboring cell, the handover request is inserted into a queue. The mobile continues to use the channel in the current cell [3]. If a channel in the neighboring cell becomes available before the end of the range of degradation, the handover takes place.

If the mobile crosses the surface of the handover and finds no channel available, it is forced termination of the call and release the channel.

If the queue is empty, the released channel is idle. Otherwise, it is assigned to a handover's call in the queue (Figure 2). The Handover's call is served according to the discipline of queue. The state transition diagram is shown in Figure 2.

Allocation type FCA.

The queue disciplines FIFO.

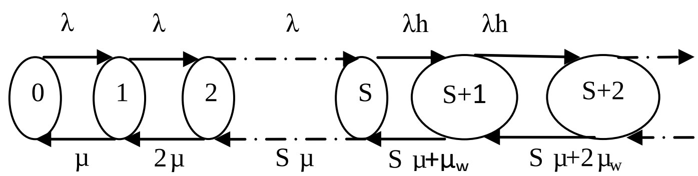

Figure 2. State Transition Diagram

$$P_n = \begin{cases} \frac{(\lambda+\lambda h)^n}{n!\mu^n} P_0 & 1 \le n \le s-1 \\ \frac{(\lambda+\lambda h)^s \lambda h^{n-s}}{s!\mu^s \prod_{j=1}^{n-s}(s\mu + j\mu_w)} P_0 & n \ge s \end{cases} \quad (3)$$

Where $\mu_w = 1/t_{wmax}$ is the residence time in the queue.

$$P_0 = \left\{ \sum_{n=0}^{s-1} \left[\frac{(\lambda+\lambda h)^n}{n!\mu^n} \right] + \sum_{n=s}^{\infty} \left[\frac{(\lambda+\lambda h)^s \lambda h^{n-s}}{s!\mu^s \prod_{j=1}^{n-s}(s\mu + j\mu_w)} \right] \right\}^{(-1)} \quad (4)$$

New calls are blocked if all channels available in the cell are occupied.
So we obtain Pb:

$$Pb = \sum_{n=s}^{\infty} P_n \quad (5)$$

We define $P_{b2|n}$ failure probability of handover in the state n.

$$P_{b2|n} = 1 - \prod_{j=0}^{n-s} \left[1 - \frac{\mu_w}{(s\mu + \mu_w)^{2j}} \right] \quad (6)$$

So Ph is equal to:

$$\boldsymbol{Ph = \sum_{n=s}^{\infty} P_{b2|n} P_n} \quad (7)$$

4.2. Guard Channels Strategy

Guard channels improve the probability of success of the handover by reserving a fixed number of guard channels reserved exclusively for Handover (Figure 3). The remaining channels are used for Handover and new calls [6]. The state transition diagram is shown in Figure 3.

$$\begin{cases} P_j = \dfrac{\left(\frac{\lambda+\lambda h}{\mu}\right)^j}{j!} P_0 & 0 < j \le n \\ P_j = \dfrac{1}{j!}\dfrac{(\lambda+\lambda h)^n \lambda h^{j-n}}{\mu^j} P_0 & n \le j < S \end{cases} \quad (8)$$

$$where \quad \sum_j P_j = 1$$

$$P_0 = \left[\sum_{j=0}^{n} \frac{\left(\frac{\lambda+\lambda h}{\mu}\right)^j}{j!} + \sum_{j=n+1}^{S} \frac{(\lambda h)^{j-n}(\lambda+\lambda h)^n}{j!\mu^j}\right]^{-1} \quad (9)$$

$$or \quad a = \frac{\lambda+\lambda h}{\mu}\ , \quad r = \frac{\lambda}{a\mu}$$

The blocking probability of new calls is given by:

$$P = \sum_{j=n}^{S} P_j = 1 - \sum_{j=0}^{S-n-1} P_j = 1 - \sum_j \frac{(a)^j}{j!} P_0 \quad (10)$$

The blocking probability of handover is given by:

$$\boldsymbol{Ph = P_0 \frac{a^S}{S!}(1-r)^n} \quad (11)$$

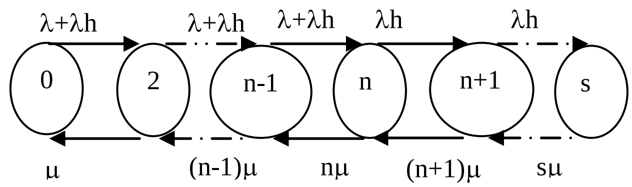

Figure 3. State Transition Diagram

4.3. Guard Channels with Queue for Handoff call

It is a combination of the two previous techniques queuing requests and guard channels strategy reserved exclusively for guards Handover [1]. The state transition diagram is shown in Figure 4.

$$\boldsymbol{P(i)} = \begin{cases} \dfrac{(\lambda+\lambda h)^i}{i!\mu^i} P(0) & 0 \le i \le S_C \\ \dfrac{(\lambda+\lambda h)^{S_C} \lambda h^{i-S_C}}{i!\mu^i} P(0) & S_C < i \le S \\ \dfrac{(\lambda+\lambda h)^{S_C}}{S!\mu^S} \dfrac{\lambda_H^{i-S_C}}{\prod_{j=1}^{i-S}[S\mu + j(\mu_w)]} P(0) & S < i \le \infty \end{cases} \quad (12)$$

Where

$$\boldsymbol{P(0)} = \left\{\sum_{i=0}^{S_C} \frac{(\lambda+\lambda h)^i}{i!\mu^i} + \sum_{i=S_C+1}^{S} \frac{(\lambda+\lambda h)^{S_C} \lambda h^{i-S_C}}{i!\mu^i} + \sum_{i=S+1}^{\infty} \frac{(\lambda+\lambda h)^{S_C}}{S!\mu^S} \frac{\lambda h^{i-S_C}}{\prod_{j=1}^{i-S}[S\mu + j(\mu_w)]}\right\}^{-1} \quad (13)$$

So we get:

$$\boldsymbol{Pb} = \sum_{i=S_C}^{S} \boldsymbol{P(i)} \quad (14)$$

$$\boldsymbol{Ph} = \sum_{k=0}^{\infty} \boldsymbol{P(S+k)\, P_{fh|k}} \quad (15)$$

Where

$$P_{fh|k} = 1 - \left(\frac{\mu_w}{\mu S + \mu_w}\right) \prod_{i=1}^{k} \left\{1 - \left(\frac{\mu_w}{\mu S + \mu_w}\right)\left(\frac{1}{2}\right)^i\right\} \quad (16)$$

Where $P_{fh|k}$ is a probability that a handoff request fails after joining the queue in position k+1.

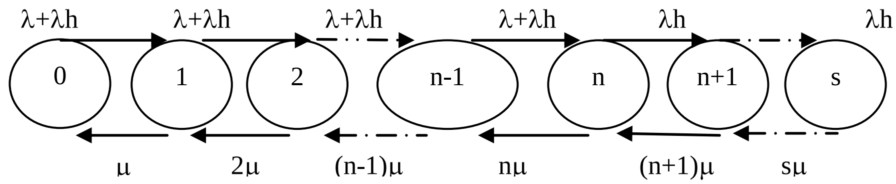

Figure 4. State Diagram

4.4. Originating and Handoff Calls Queuing Scheme

We consider a system with many cells [7], each having S channels. There are two queues, QH and QO for Handover and new calls, respectively. Capabilities for QH and QO are MH and MW, respectively. Handover's call is inserted in QH if it finds no free channel. On the other hand, a new call is inserted into QO if the channels available are less than or equal to (S-Sc). Otherwise the call is blocked.

Handover's call placed in the queue is blocked when it moves out of the cell before obtaining a channel (forced termination).

So this technique is modeled by a two-dimensional Markov process. The state transition diagram is shown in Figure 5.

$$Pb = \sum_{i=S_C}^{S+MH} P(i, M_0) \tag{17}$$

$$Ph = \sum_{j=0}^{MO} P(S + MH, j) \tag{18}$$

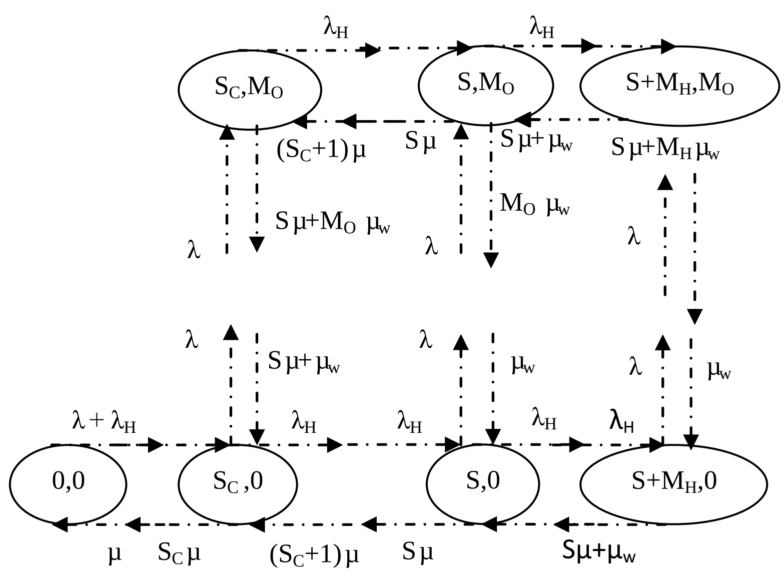

Figure 5. The State Transition Diagram

5. Simulation Results

The curves obtained (Figure 6) show that the blocking probability of new calls is equal to the blocking probability of handover because new calls are treated in the same as the calls of Handover

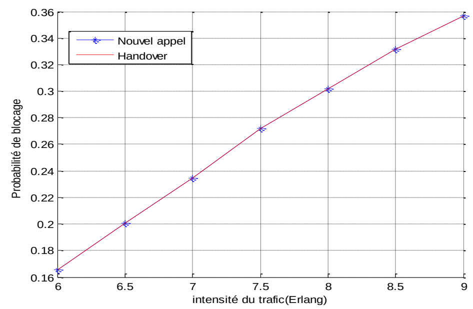

Figure 6. Ph and Pb as Function of Traffic to the Strategy of Non-priority

In the Figure 7 the queue decreases the blocking probability of handover and increases the blocking probability of new calls through its high capacity.

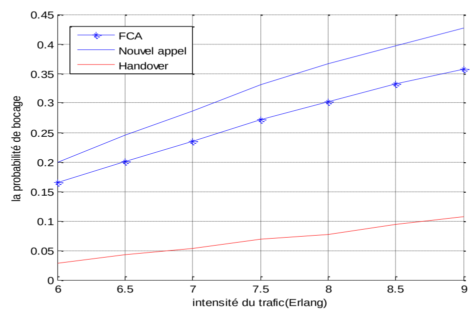

Figure 7. Ph and Pb as Function of Traffic (Erlang) « Handoff Call Queuing Scheme »

The Figures 8 and 9 show that When the number of guard channels increases, the probability of forced termination of the call decreases. The increase of the number of guard channels increases the blocking probability of new calls.

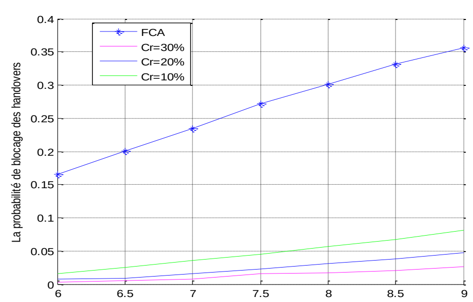

Figure 8. Ph as Function of Traffic (Erlang) «Guard Channels Strategy»

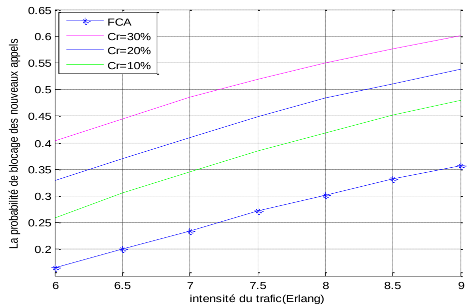

Figure 9. Pb as Function of Traffic (Erlang) «Guard channels strategy»

The Figures 10 and 11 show that the queue and guard channels are an important influence on the blocking probability of handover and the blocking probability of new calls because they are reserved only for handover calls, when increasing the number of guard channels the blocking probability of handover decreases and the blocking probability of new calls increase.

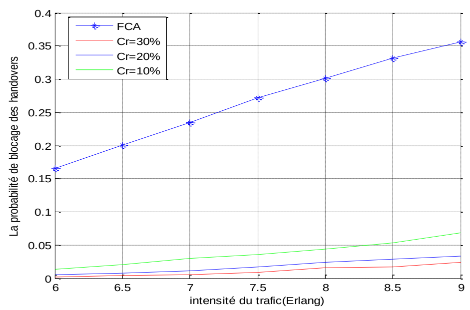

Figure 10. Ph as Function of Traffic (Erlang) «Guard channels with queue for handoff call»

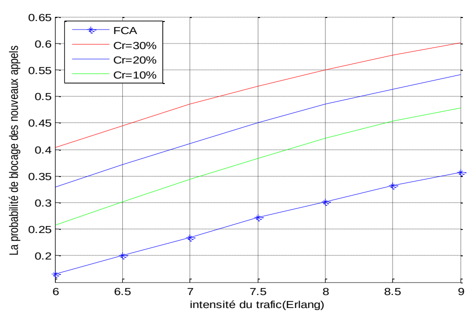

Figure 11. Pb as Function of Traffic (Erlang) «Guard channels with queue for handoff call»

The Figures 12 and 13 show that when the number of guard channels reserved for handover calls increases the blocking probability of Handover decreases and the blocking probability of new calls increases

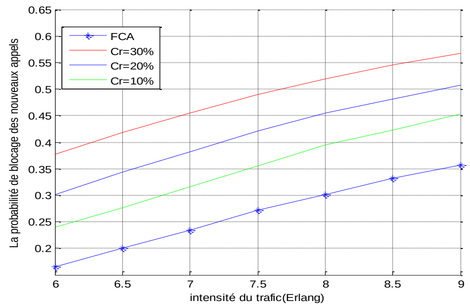

Figure 12. Pb as Function of Traffic (Erlang) «Originating and handoff calls queuing scheme»

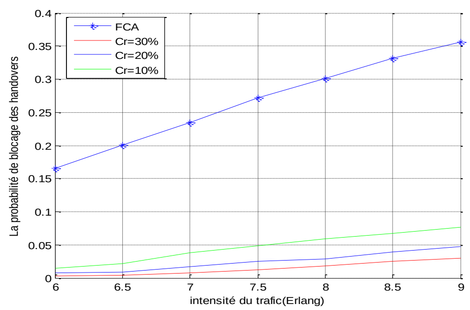

Figure 13. Ph as Function of Traffic (Erlang) «Originating and handoff calls queuing scheme»

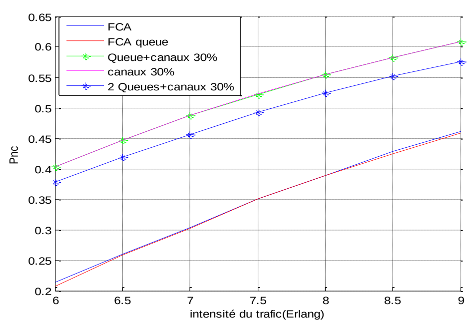

Figure 14. Pnc as Function of Traffic (Erlang)

6. Discussion

From the results obtained, we find that each technique has advantages and disadvantages. In the FCA method, a comparison of performance between the strategies of priority and non-priority technology is evaluated. Reducing the blocking probability of handover is achieved depends on all of the channels reserved exclusively to serve handover requests. This leads to increased blocking probability of new calls and severe degradation of Pnc (Figure 14). If the traffic load increases, more calls will be rejected and this effect is considerable when the number of channels allocated to serve the requests of the handover is very high.

Queuing of handover requests lead to a reduction of Ph when compared with the technique of non-priority; Pnc provides minimum values compared to other systems studied and an increase in system capacity is achieved.

The increase in the blocking probability of new calls is less than the guard channel method, because in the latter there are no dedicated channels to serve the requests of the handover.

7. Conclusion

In these papers, we are interested in satellite networks in the constellations of satellites in low orbit providing mobile communication. The study of these systems has led us to study the problems and assess the performance of the constellations considered. The problem that we addressed in this work is the problem of handover (automatic transfer intercellular). In LEO systems, the Handover are inevitable and they occur mainly by the high mobility of satellites. To prevent degradation and establish quality of service, a priority algorithm that supports the request of the handover should be used.

The handover has important features that encourage designers in the field of satellite communications. This suggests studying analytical models to optimize the handover problem without reducing system reliability.

References

[1] G. Maral and J. J. De Ridder, ''Basic concepts of low earth orbit satellite systems for communications'', Ecole Nationale Supérieure des Télécommunications, Paris-Toulouse **(1991)**.

[2] R. Steele and M. Nofal, ''Teletraffic performance of microcellular personal communication networks,'' IEEE Proc. I, vol. 139, no. 4, **(1992)** August.

[3] Y. B. Lm, S. Mohan and A. Noerpel, ''PCS channel assignment strategies for hand-off and initial access,'' IEEE Personal Communications, vol. 1, no. 3, pp. 47-56, Third Quarter, **(1994)**.

[4] S. Tekinay and B. Jabbari, ''A measured-based prioritization scheme for handovers in mobile cellular networks,'' IEEE Journal on Selected Areas in Communications, vol. 10, no. 8, **(1992)** October.

[5] D. Bear, ''Principles of telecommunication traffic engineering,'' Institution of Engineering and Technology, 2Rev Ed edition IEEE Series 2, Revised 3rd Edition, **(1988)**.

[6] E. D. Re, R. Fantacci and G. Giambene, ''Handover and dynamic channel allocation techniques in mobile cellular networks,'' IEEE Trans. Vehicular Technology, vol. 44, no. 2, pp. 229-237, **(1995)** May.

[7] S. A. El-Dolil, W. C. Wong and R. Steele, ''Teletraffic performance of highway microcells with overlay macrocell,'' IEEE J. Select. Areas in Commun, vol. 7, no. 1, pp. 71–78, **(1989)** January.

[8] M. Gareh and D. Benatia, "Handover prioritizing scheme for reducing call failure probability in cellular wireless network,", Wireless Communications and Mobile Computing, vol. 9, pp. 1660-1667 **(2009)**.