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**Paper:** **Improvement of the Performances of the Mobile Satellite Systems by Sophisticated Handover Management**

Contribution to topic : **W4 - Mobile Satellite Systems ...**

# Improvement of the Performances of the Mobile Satellite Systems by Sophisticated Handover Management – Extended Abstract

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**Abstract**

**Comparing Low-Earth-Orbit (LEO) mobile satellite systems (MSSs) with terrestrial mobile communication systems it is obvious that satellite movement causes more frequent handover occurrences. For this reason the system performance generally depends stronger on the handovers management technique. This paper presents a new handover management schemes for capacity limited LEO MSSs with dynamic channel assignment (DCA).**

**The first scheme is based on queuing of the handover requests. According to the FIFO strategy queued requests are tried to be served for a specified time period. As in LEO MSSs a handover is performed more because of geometrical reasons than because of the deterioration in the signal power, it is expected that a short time is available before connection parameters become insufficient. Although the handover queuing is already known from terrestrial systems, its application in very specific environment of LEO MSSs, which is in some aspects tremendously different from terrestrial mobile communication systems, has not been investigated sufficiently.**

**The second proposal is to combine the queuing scheme with handover prioritisation by reservation of an amount of system resources exclusively for handover purposes.**

**Simulation tests were carried out in order to evaluate the performance of these schemes. The results show that, in the LEO satellite systems with non-uniform traffic the system performance parameters as handover blocking probability and GoS are significantly better by systems using handover queuing and even more improved by combining with handover prioritisation. Improvement is noticeable in systems using DCA as well as in those using fixed channel assignment (FCA) strategy.**

## I INTRODUCTION

The LEO satellites are proven to be a useful mean for providing mobile communication services. The main advantages of these systems are their global coverage and presence on every place world-wide. Although they are partly integrated with the similar terrestrial cellular systems, a full integration with seamless service providing is expected in year 200x.

However, capacity that LEO mobile satellite systems (MSSs) offer is much smaller than that of the terrestrial systems. This is due to the available spectrum and even more to the restricted power and number of transceivers that are at the disposal for every satellite. This paper tackles the capacity problem of these systems. Even though there is enough frequency spectrum available, i.e. almost at every moment there are enough carriers for new users that are requesting service, due to the limited satellite or antenna panel power (limited transceiver number) a new call or a handover blocking could occur. Beside the capacity limitation, LEO MSSs are also burdened with large number of handovers compared with terrestrial cellular system. Due to the satellite moving each user suffers two types of handover, inter-satellite and inter-beam handover, which occur every few minutes. These two types together with, the handover because of the deterioration in the quality of service (QoS) trouble the system performances. Especially GoS is getting worse with increasing handover blocking rate.

Aim of this paper is to propose the handover managing strategies which will improve GoS by LEO MSSs. They are based on queuing and prioritising of the handover attempts and are combined with DCA. Very important to stress is that, although, the handover queuing and prioritisation are already known by terrestrial systems, this paper is one of the few which investigate its application in the LEO MSSs. Already mentioned characteristics of LEO MSSs make effect, scope and art of using the handover queuing and prioritising much differently then in terrestrial networks.

This paper enfolds further short description of the investigated LEO MSSs, description of the proposed strategies to be used for handover managing and some of the simulation results proving that the new schemes led to the improvement of the system performances.

## II SYSTEM DESCRIPTION

By Low Earth Orbit satellite systems, satellites divided into orbits cover more or less the whole Earth surface.

Area covered by each satellite, known as satellite foot-print, is divided into spot-beams. Spot-beams of the same satellite as well as neighbouring satellites are overlapped on the edge areas. The overlapping depends on the satellite orbital configuration and antenna characteristics. It is described with factor $\alpha$. This factor, multiplying the beam radius, gives the maximum distance in the overlapping zone (Fig. 2).

Carrier level in every part of a spot beam depends on the propagation loss which in turn depends on the distance from the satellite and on the used wave length. Because of the very large area which satellite foot-print covers, the distances between the satellites and various beams vary a lot. In order to reduce the difference of the carrier level between beams a passive power control scheme is used.

Considered LEO MSSs use for radio access the Frequency Division Multiple Access (FDMA) combined with Time Division Multiple Access (TDMA). The whole frequency band is divided into sub-bands and every one of them is assigned to one carrier frequency. Furthermore, each carrier sub-band consists of eight time slots: four for the up-link and four for the down-link connection (Time Division Duplex – TDD) (Fig. 1). Eventually, it means that every user gets one carrier and one up-link i.e. down-link time slot. At the same time, a transceiver has to be provided for the satellite connection with an user. The first generation of LEO MSSs suffers capacity limitation due to the short number of available transceivers per satellite or antenna panel, or due to the limited maximum power. This capacity shortage could be provided by satellite batteries for the whole satellite or, separately, for the one of the phased array antennas. In order to improve such system and to use available resources more efficiently it is proposed to manage the system dynamically. The transceiver assignment to an user should not be time, frequency or antenna limited. In these circumstances the transceiver pool is managed on the satellite level. It is possible to assign a transceiver from this pool to any antenna panel and therefore to any spot-beam as long as free transceivers are available and power limits are not overflown. Every transceiver could operate on any frequency from the given set of carriers in every time slot. It should be stressed that every slot is grouped with one frequency and one transceiver. That means that one transceiver could supply four different users which could operate on the four different frequencies in any spot beam.

The satellite systems using FCA as well as DCA strategy has been investigated and compared. As known from GSM systems FCA strategy requires a set of channels to be allocated for a given number of connections. The channel assignment and the maximal number of operating users is deterministic. On the other hand, DCA optimises exploitation of the available power. As stated, one satellite, as well as one antenna panel, has limited maximal power on the disposal for one time slot. That is why different time slots should be as much as possible equally occupied. Used strategy takes current slot occupation into account. Before every new channel assignment a slot priority list is made. In this list the highest priority has the time slot during which the satellite power usage is most uncritical. If other conditions are fulfilled this slot will be assigned for the new connection. In opposite the next time slot on the priority list will be considered. The second component of the DCA strategy is the carrier assignment for a connection. The chosen strategy is based on the estimation of the Carrier to Interference Ratio (CIR). The basic idea is to choose a carrier which maximises the minimal CIR on the up-link channel. All co-channel interference of all visible mobile terminals (including new channel) using this traffic channel are taken into account [1].

$$CIR_{up}(ch') = \max_{\forall ch'}\{\min_{\forall ch}[CIR_{up}(ch)]\} \qquad (1)$$

Here *ch'* represents a set of all channels including the new proposed channel, while *ch* is the same set but without the new channel.

## III HANDOVER MANAGEMENT SCHEMES

In LEO MSSs handovers occur more often then in terrestrial systems or Geo-stationary satellite systems. The reason is the movement of the satellites. If we bear in mind that visibility of one satellite lasts, depending on the constellation, only few minutes (e.g. IRIDIUM around 10 min) it is clear that user very often changes satellite which controls him. When this change happens during a connection we are talking about inter-satellite handover (Fig. 2). However, an inter-beam handover happens more often. This type of a handover indicates a change of a spot-beam where the user is located, also during the connection. As the area covered by a spot-beam is many times smaller than the satellite foot-print, a spot-beam ‘overflies’ the user

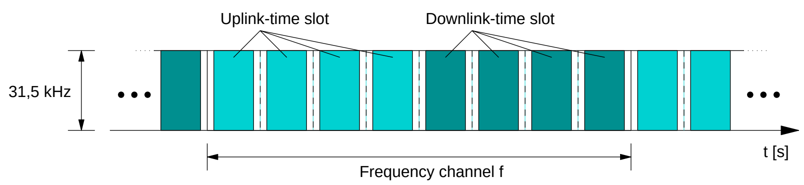


Figure 1: Frame structure

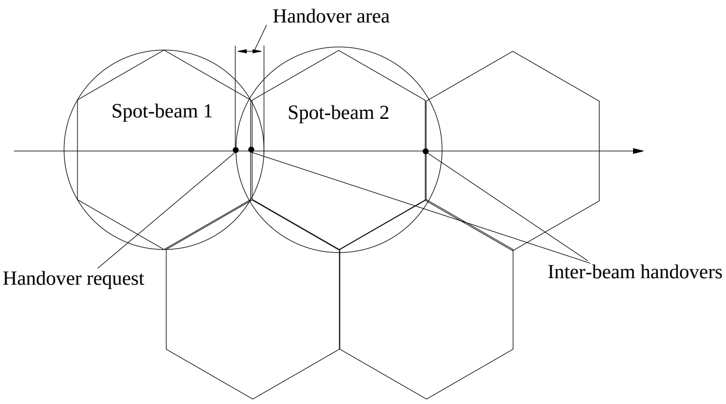


Figure 2: Overlapping of the spot-beams and handover initiation

position for shorter time than foot-print. Therefore, the number of inter-beam handovers is appropriately larger. According to the theoretical analysis and probability curves displaying number of inter-satellite and inter-beam handovers for an reference system similar to IRIDIUM [2], the mean number of inter-beam handovers during a connection is approximately 2 (average connection duration is 180s), while the average number of inter-satellite handovers by connection is around 0,4.

*A Handover queuing*

In LEO MSS the handovers are initiated after the user enters the zone where two beams are overlapping. In this moment the signal level is still strong enough. During the time that the user spends in this zone it is possible that any of the overlapping beams could 'serve' the user because of their sufficient signal levels. Therefore, there is more available time for the handover and it doesn't have to occur immediately as the user enters the zone. The idea to use this time to delay an unsuccessful handover decision and in such a way improve the system performances is enfolded in the common model shown in the Figure 3. Here the new call and handover requests are served by using two waiting queues. In the case when the system is not full and there are available resources the new requests will be immediately served. On the contrary when all servers are busy the requests are queued. This is done separately, for the call and handover queue. Each incoming request will be allowed to wait in the queue for time *t*. This time can take value from (0, $t_{\alpha max}$), where $t_{\alpha max}$. is the maximum possible time spent in the overlap area. In general this time is a random variable that depends on the factor α and on the position of the mobile station. For an mobile station, crossing the overlap area at the "height" *z* (Fig. 2), the crossing time $t_\alpha$. is obtained as

$$t_\alpha = \frac{x(z)}{v_{sat}} \tag{2}$$

where *x(z)* represents the distance that mobile station has passed in the overlap area if the entrance point in the overlap area was on the "height" *z*. It could be noticed that the randomness of the $t_\alpha$. depends only on the *z*, which is related to the mobile station position. The value of the *x(z)* is given by

$$x(z) = \begin{cases} 2\sqrt{R^2 - z^2} - \sqrt{3}R, & |z| \le \frac{R}{2} \\ \sqrt{R^2 - z^2} - \frac{\sqrt{3}}{2}R \\ + \sqrt{R^2 - (|z| - \frac{3}{2}R)^2}, & R \ge |z| > \frac{R}{2} \end{cases} \tag{3}$$

It is possible, as it can be seen on the Figure 2, to calculate necessary parameters for determination of the average value of the crossing time. This value, $E[t_\alpha]$, represents in the same time the average value of the maximum queuing time:

$$E[t_\alpha] = \frac{1}{v_{sat}} \int_{-R}^{R} x(z) f(z) dz \tag{4}$$

Function *f(z)* represents the probability density function of the variable *z*. It can be obtained by taking into account that active mobile stations are uniformly distributed within a cell and that their movement can be neglected compered to the satellite movement. Function *f(z)* is given with

$$f(z) = \frac{y(z)}{3\frac{\sqrt{3}}{2}R^2} \tag{5}$$

where distance *y(z)* is given with

$$y(z) = r(z) - x(z) \tag{6}$$

and *r(z)* with

$$r(z) = 2\sqrt{R^2 - z^2} \tag{7}$$

By replacing the equations (5) - (7) and the parameters *R=339km* and $v_{sat.}$*=7,39km/s*, which is the case of the

IRIDIUM system, it can be calculated by using (4) that the average value of the crossing time is $E[t_\alpha]\approx 11s$. It is reasonable to choose maximum queuing time from *0* to $E[t_\alpha]$.

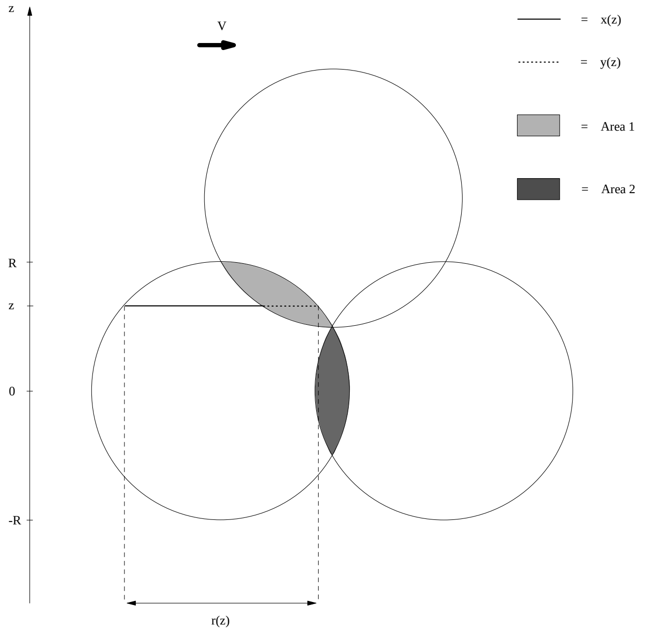


Figure 3: Cells geometry and overlap areas

During chosen queuing time one of the servers could be released and appointed to the waiting request. For serving of the queued requests the FIFO strategy has been applied. However, if the time elapses and none of the servers is released, the call request is lost, i.e. the handover request is rejected which leads to the forced termination. The third possibility is that the call has been regularly terminated during the waiting time. In this case the queuing strategy also leads to the improvement.

If considered that new calls arrival time has Poisson distribution and that serving time is negatively exponentially distributed, the whole system could be treated as a Markoff system. For FCA systems it is possible to calculate new call and handover blockage probability analytically. However, mainly due to the satellite movements, calculations are extremely complicated and require complex numerical methods. Further, in the treated reference system, the calculation is even more complicated, since the DCA component has been added to the FCA. This is the case because of the central management of the transceiver resources. They are taken from the common pool on the satellite level and allocated to the single beam according to the dynamics of the incoming requests.

In the systems with DCA strategies the calculations are getting more difficult and it is not possible to find a closed expressions for wanted system parameters. Both FCA and DCA systems have been successfully analysed by simulation.

### B *Combining of the handover queuing and prioritisation schemes*

The above described resource management scheme based on handover queuing could be combined with a scheme which foresees prioritisation of the handover requests. This, from terrestrial systems known strategy, is based on reservation of system resources exclusively for handover purposes. It leads to the increase of the new call blocking probability, but, on the other hand, to the significant decrease of the handover blocking probability which has more impact on the system performance. ‘Combined’ algorithm functions so that the prioritisation and queuing schemes are applied independently and one after the other. This means that after a handover request it is tried to allocate a new channel from the set of the non-reserved channels. In the case of failure a reserved channel should be allocated. If this operation also doesn’t provide the solution i.e. if the whole system resources are occupied, the handover request is proceeded to the waiting queue. Requests in the queue are served as already described. Additionally by every attempt to allocate a free channel for the in the queue being requests, firstly, it is tried to find a non-reserved channel, but, in the case of failure, allocation of the reserved channel is also a sufficient solution.

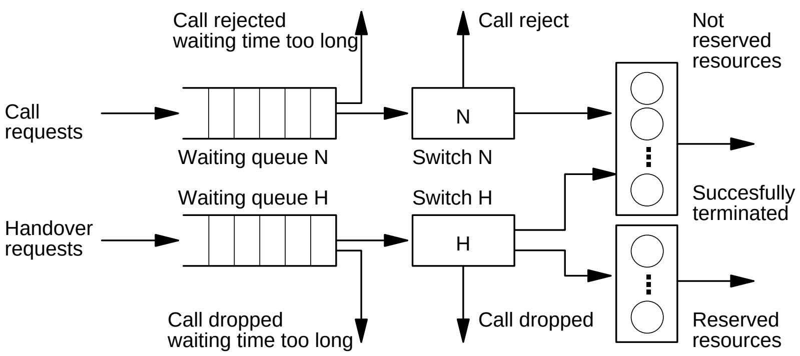


Figure 3: Resource management strategy – queuing and prioritizing

## IV SIMULATION AND RESULTS

### *A System Model*

The performance of the investigated resource management schemes of the capacity limited LEO MSSs has been evaluated by event driven simulations. Most of the system parameters have been chosen similarly as in IRIDIUM system, meaning that a constellation of 66 LEO satellites has been chosen. They are divided into six orbits, in each orbit 11 satellites. The orbits have an inclination of 86°. Satellite foot-print is divided into 48 spot-beams, which are subdivided into three groups, each provided by one of the three phased array antennas.

During the simulation process following assumptions related to the traffic model have been made:

- generated users are uniformly distributed over the rectangular simulation area;
- the disposed frequency band is divided in 24 reusable carriers;
- call duration is exponentially distributed (mean 180 s);
- the guaranteed elevation angle is $\varepsilon = 3°$;
- 96 transceivers per satellite;
- max. panel power = 48 [power units per slot];
- max. satellite power = 96 [power units per slot]

### *B Results*

Analysis and simulations have been performed for different traffic densities, which went from 30 E/Mkm², representing systems with low traffic loads, to 60 E/Mkm², for the very busy systems.

The queuing strategy was firstly examined. It could be stated that both by FCA and DCA strategies the handover blocking probability was decreased and despite the slight increase of the new call blocking probability the GoS improved for up to 20% (Figure 4 - 6). It is to be noticed that by DCA strategy the profit is higher by busier systems. Of course, as expected, for all parameters as well as by all strategies DCA performs much better then FCA.

In consecutive simulations, only for DCA strategy the 'combined' strategy was applied. Respectively 0, 1, 2 and 5% of all transceivers have been reserved exclusively for handover purposes. Simultaneously, the queuing of rejected handover requests was applied. Comparing with queuing strategy, as Figures 7 – 9 show, a significant further improvement of the handover blocking probability and expected small deterioration of the new call blocking probability has been achieved. That led together to the GoS improvement up to a 80%. As a matter of fact, important is to stress that whole mentioned improvement was reached already by reserving of 1% of the resources exclusively for handovers. Further reservation led to the slight decrease of the handover blocking probability but, arbitrative parameter, GoS, was not improved.

## V CONCLUSIONS

This paper presented two new handover management schemes for the capacity limited LEO MSSs. The evaluation criteria used for testing the schemes was the GoS parameter. Firstly, the scheme based on the queuing of the handover requests has been investigated. The waiting queue would delay handover rejecting or forced call termination, while the system tries to find a free channel in a specified time period. It has been shown both by FCA and DCA that the handover blocking probability as well as GoS were significantly improved.

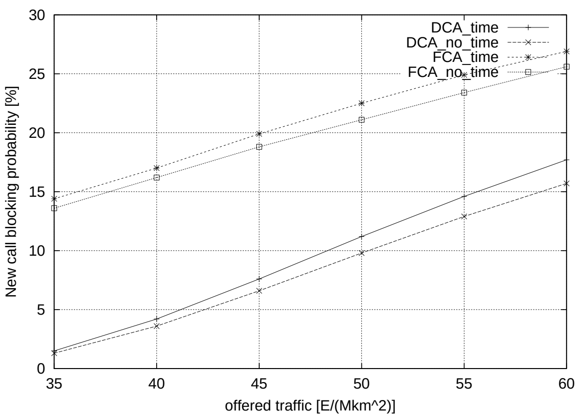


Figure 4: New call blocking probability in strategies with and without queuing

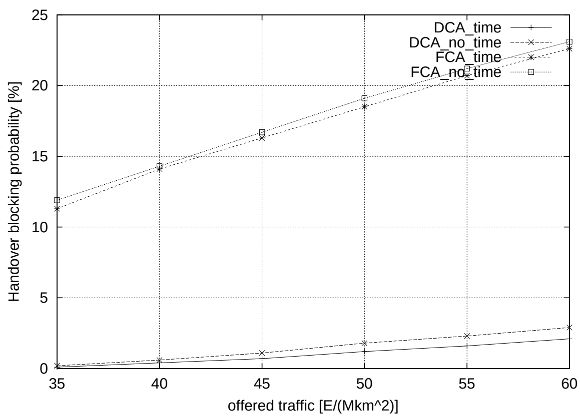


Figure 5: Handover blocking probability in strategies with and without queuing

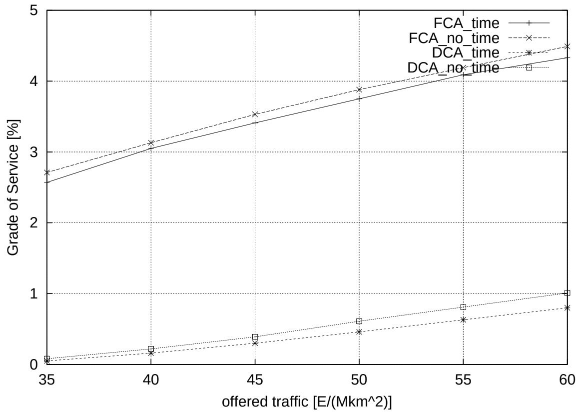


Figure 6: GoS in strategies with and without handover queuing

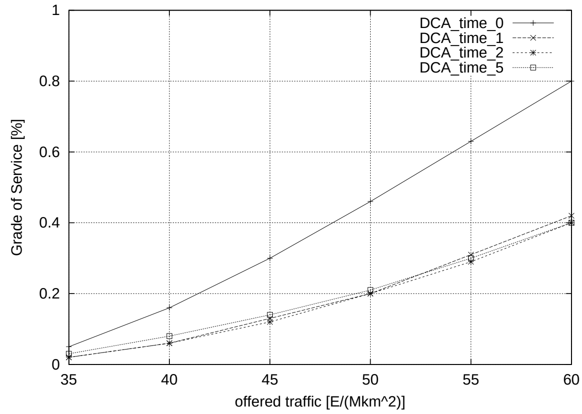


Figure 7: GoS when combining queuing and prioritisation schemes

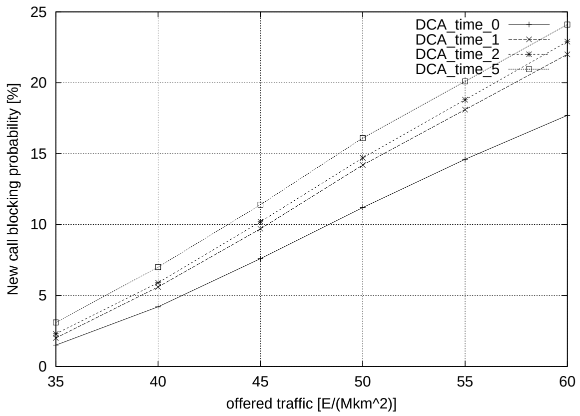


Figure 8: New call blocking probability combining queuing and prioritisation schemes

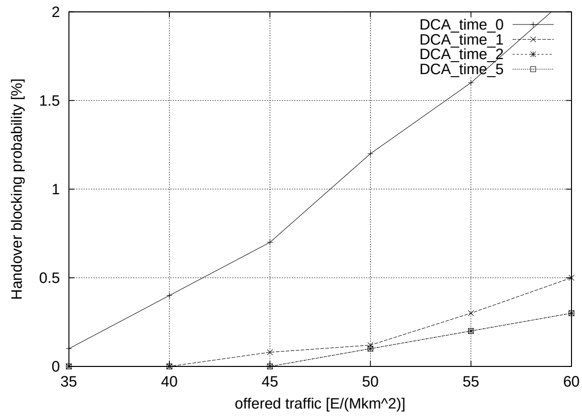


Figure 9: Handover blocking probability when combining queuing and prioritisation schemes

Secondly, the queuing scheme has been combined with the strategy that prioritises handover requests by reservation of the system resources exclusively for handover purposes. The ‘combined’ strategy brought further betterment so that the GoS by DCA was improved up to 80%. It was also noticed that no further improvement was achieved reserving more than 1% of the available system resources.

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