PERFORMANCE EVALUATION OF PRIORITIZED HANDOVER MANAGEMENT FOR LEO MOBILE SATELLITE SYSTEMS WITH DYNAMIC CHANNEL ASSIGNMENT

Vladimir Obradovic, Sascha Cigoj
Communication Networks,
Aachen University of Technology, 52074 Aachen, Germany;
Phone: +49.241.80.7916, Fax:+49.241.8888.242,
e-mail: vob@comnets.rwth-aachen.de and sc@comnets.rwth-aachen.de

Abstract

This paper presents a handover prioritization scheme based on the usage of guard transceivers in a capacity limited Low-Earth-Orbit (LEO) mobile satellite systems with dynamic channel assignment (DCA). Simulation tests were carried out in order to evaluate the performance of this scheme. The results show that, in the LEO satellite systems with non-uniform traffic the system performance parameters as call blocking, handover failure and grade of service (GoS) are significantly better by DCA then by fixed channel assignment (FCA) strategy. Another achievement is the improvement of the handover blocking probability and GoS by systems using guard transceivers for prioritized handover attempts. The most efficient percentage of the channels reserved for handover has been determined.

I Introduction

Being already in commercial use LEO satellite systems are a useful mean for providing mobile communication services. Unbeatable advantages of these systems are their global coverage and presence on every place world-wide. They are already partly integrated with the similar terrestrial cellular systems but a full integration with seamless service providing is an issue for the 2nd and 3rd generation systems, expected in year 200x.

Beside mentioned advantages, capacity that LEO mobile satellite systems (MSSs) offer is much smaller than one in the terrestrial systems. Capacity is not limited only due to the available spectrum but, as a matter of fact, more because of the restricted power and number of transceivers that are at the disposal for every satellite. In [4] the interference and capacity limited MSSs have been defined. This paper is dealing with capacity limited systems. These systems generally have enough frequency spectrum available, i.e. almost at every moment there are enough carriers for new users that are requesting service, but due to the limited satellite or antenna panel power (limited transceiver number) a new call or a handover blocking could occur. Beside 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. Together with, from terrestrial system already known, handover because the quality of service (QoS) reasons, the whole number of handover procedures trouble system performances. Especially GoS is getting worse with increasing handover blocking rate.

Aim of this paper is to propose the handover managing strategy which will improve GoS by LEO MSSs. This strategy is based on assignment schema where so called guard channels, are exclusively reserved for handover attempts. In investigated capacity limited systems it means that amount of available power or transceivers is to be used exclusively for handovers. The reservation scheme is combined with DCA.

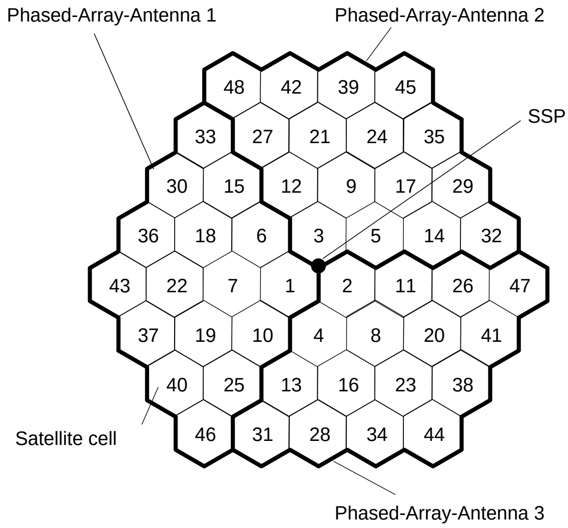

Figure 1: The structure of the satellite foot-print

Nearer description of the investigated LEO MSSs could be found in section 2 of this paper. Proposed strategy to be used for radio resource management is described in section 3. The 4th section enfolds clarification of the proposed prioritization scheme for handover attempts which should contribute to the GoS betterment. In the section 5 simulation assumptions and results are presented and discussed. Finally, section 6 concludes the paper.

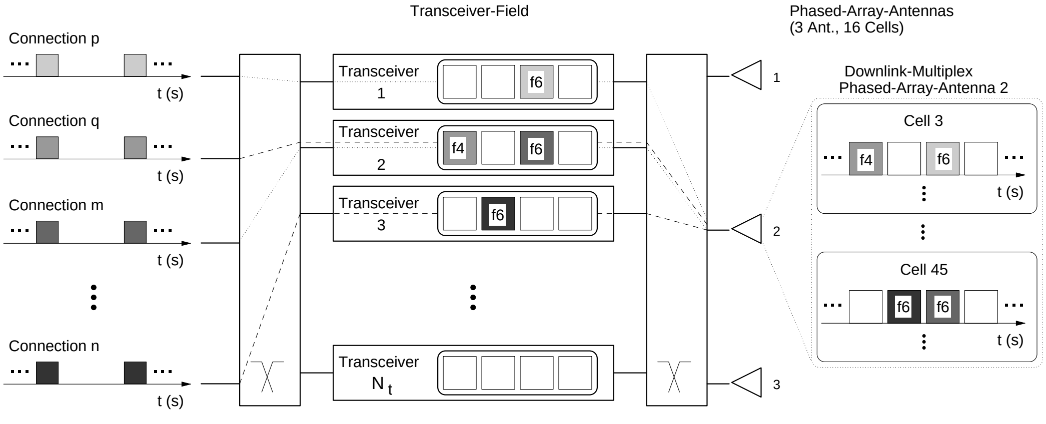

Figure 2: Transceiver field structure

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 (Fig. 1), is divided into spot-beams. Spot-beams of the same satellite as well as neighboring satellites are overlapped on the edge areas. 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. 3). 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

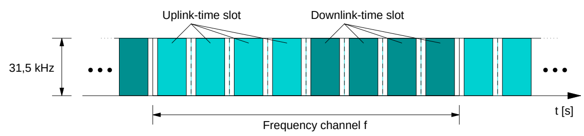

Figure 3: Frame structure

frequency from the given set of carriers in every time slot and 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 (Fig. 2).

III Handover management scheme

In LEO MSSs occur more handovers 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 constellation, only a few minutes (e.g. IRIDIUM around 10 min) it is clear that user very often changes satellites which control him. When this change happens during a connection that is what we call inter-satellite handover (Fig. 4). 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 spot-beam is many times smaller than the satellite foot-print, a spot-beam 'overflies' the user position for shorter time than a 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 [1] the mean number of inter-beam-handovers during a connection could be up to 4 (average connection duration is 180s).

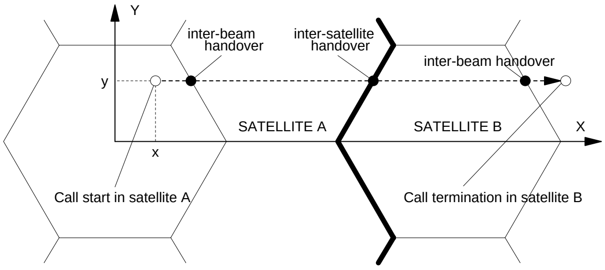

Figure 4: Inter-satellite and inter-beam handovers

Since each handover evokes a new channel assignment, the resource management becomes more important due to their large number. The first generation of LEO MSSs uses mostly FCA strategy. As known from GSM systems this strategy requires a set of channels to be allocated for a given number of connections.

A Dynamic Channel Assignment

The investigated DCA strategy has two components. The first is the dynamic slot assignment, which is important for optimizing 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 equally occupied, as much as possible. Proposed strategy considers current slot occupation. 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. It should be noticed that if the situation is more critical with antenna panels than with satellite the slot priority list is made according to the antenna panel power usage.

The second component of the DCA strategy is the carrier assignment. The chosen strategy is based on the estimation of the Carrier to Interference Ratio (CIR). The basic idea is to choose a carrier which maximizes 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 [2].

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

Here *ch'* represents a set of all channels including the new proposed channel and *ch* is the same set but without new channel. Also chosen carrier has to fulfil other two basic assumptions:

$$CIR_{up}(ch') > CIR_{up\_\min} \qquad (2)$$

$$CIR_{dn}(ch') > CIR_{dn\_\min} \qquad (3)$$

B Description of the handover management

As the GoS depends much more on the handover than on the new call blocking probability (9) it is proposed to prioritize handover attempts. The strategy with guard channels reserved for the handover attempts is investigated. In this strategy *R* of the maximal channel number *MAX_CH* is reserved for handovers. It simply means that if the number of available channels is less then *R+1* or, in other words if *MAX_CH-R* channels are occupied, a new arrived call request will be rejected. On the other hand, a wish for a handover will be accepted. The handover will be rejected only if all channels are occupied. This strategy is represented in the Figure 5. When a handover request occurs first an attempt is made to assign a non-reserved

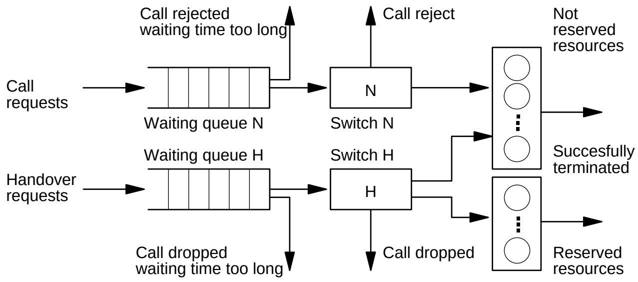

Figure 5: Resource management strategy by prioritizing

channel and only in the case of failure the reserved channel is assigned. After assignment of a reserved channel the system is trying in uniform time intervals to hand over the connection to a non-reserved channel. As already tested in terrestrial communication systems, schemes based on the similar procedures are applicable in most communication systems where the running connections should have prioritized treatment compared with new one.

As further improvement the waiting queues for call requests, as well as for handover requests, are foreseen. This means that in the case of a busy system new calls and handover attempts are not automatically rejected. The timer is set on the time allowed for the delay of one of the requests. After this time the new call is finally lost or in the case of a handover the connection is dropped. The evaluation by simulation was simplified by setting the waiting queue length to zero. Specific for the carried out analysis was that the channel reservation was actually transceiver reservation. Therefore the power amount, as a critical parameter, was allocated exclusively for the handover purposes. The mentioned *R* allocated channels are in this sense *R* transceivers. If the system is interference limited it would be more useful to reserve frequency carriers.

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 using the in house developed simulation tool. 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°. With such constellation the whole Earth is covered. 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 (Fig. 1).

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 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]

The uniform user distribution is not in contradiction with the assumption that offered traffic is non-uniform. Due to the satellite movement traffic load varies from 0, when the satellite is not serving the simulation area, to the max value when the satellite foot-print maximally covers the simulated area. From the satellite point of view this traffic could be characterized as highly non-uniform.

In order to validate the performance of the proposed scheme, the following system parameters have been determined:

- new call blocking probability;
- handover blocking probability;
- GoS.

The *new call blocking probability* P_{new} , is defined to be the ratio of the number of (new call) connect rejects and the number of connect requests.

$$P_{new} = \frac{rejected\_connections}{requested\_connections} \quad (4)$$

The *handover blocking probability* P_{ho} is defined to be the ratio of the number of rejected handovers and the number of requested handovers.

$$P_{ho} = \frac{rejected\_handovers}{requested\_handovers} \quad (5)$$

From the users point of view, lost connections (caused by rejecting handover attempt) are worse then new call rejects. Since the GoS criteria takes both new call and handover blocking probabilities into account, weighted with the appropriate factors, this parameter has been used for the evaluation of the system performance [5]:

$$GoS = \frac{rejected\_connections + 10 \cdot rejected\_handovers}{requested\_connections - rejected\_connections} \quad (6)$$

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.

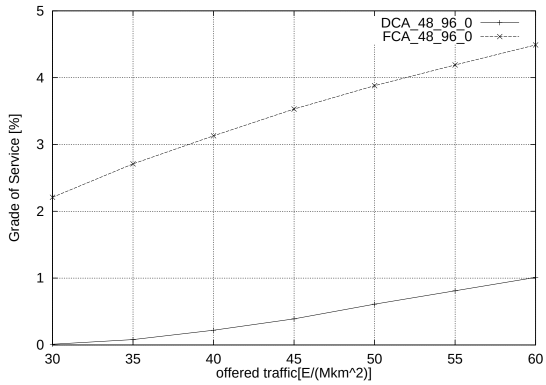

Figure 6: GoS (FCA vs. DCA)

Before examining the prioritized resource management schemes, FCA and DCA strategies without channel reservation have been compared. Simulation results have shown that regarding the new call and handover blocking probability DCA strategy has performed much better then FCA. Consequently, for the GoS criteria DCA strategy shows much better results (Fig. 6).

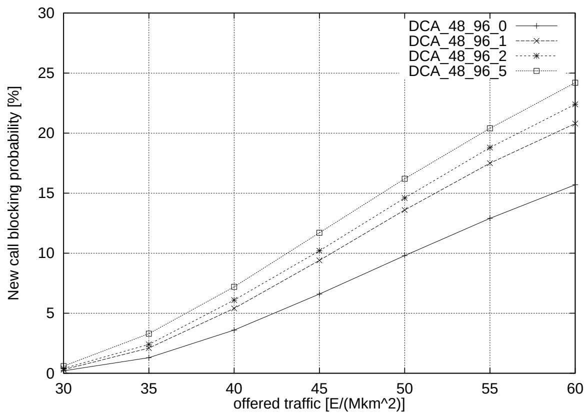

Figure 7: New call blocking probability

In consecutive simulations, only for DCA strategy 0, 1, 2 and 5% of all transceivers have been reserved exclusively for handover purposes. Figure 7 shows that the reservation of resources implies increase of the new call blocking probability. The most significant difference is in the case of changing from non-reservation strategy to strategy with 1% of the reserved resources. Further, the deterioration of the new call blocking is approximately linear with the increase of the reserved channels. On the other hand, in Figure 8 can be seen that the strategy with transceiver reservation significantly improves the handover blocking probability. As the traffic load increases, the difference between non-reservation and reservation strategies is more evident. In addition, the increase of the reserved system resources brings further betterment.

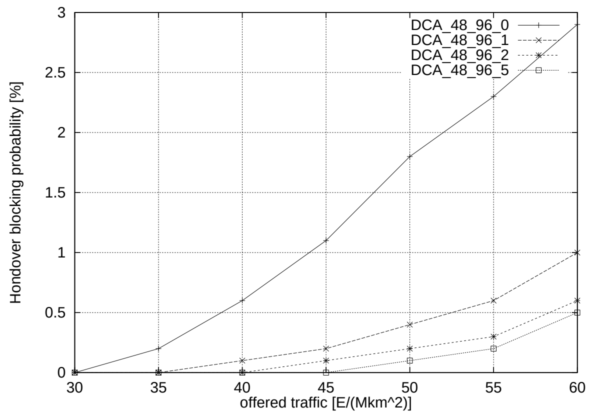

Figure 8: Handover blocking probability

The handover blocking probability becomes better with each reserved transceiver, but, this is a slow improvement. In order to validate the system performance correctly and balance the influence of the new call and handover blocking, GoS has been calculated and presented in Figure 9. It shows that one percent of the reserved transceivers significantly improves performance of the system.

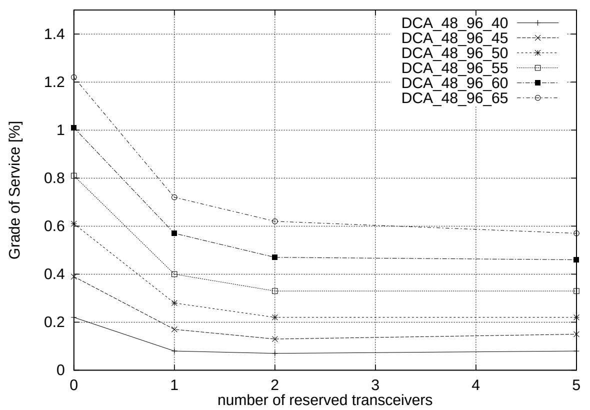

Figure 9. Grade of Service

Reservation of the second percent of transceivers has an additional positive effect. Analyzing further, it is concluded that, regarding the GoS, the increase of reserved transceivers has no effect on the system. An exception are the systems with very high traffic density. In that case a slight enhancement of GoS could be noted.

V Conclusions

This paper presented a new resource management scheme for the capacity limited LEO MSSs. The evaluation criteria used for testing the scheme was the GoS. To begin with, it was proved that DCA strategy has significantly better performances compared to the FCA. The resource management scheme which was proposed is based on the prioritization of handover attempts by reserving a power amount which should be used only for the channel allocation caused by a handover.

The performance evaluation of handover prioritization scheme was validated by means of simulation. It was noted that reserving of 1%-2% of transceivers brings the best improvement of the GoS by low and medium traffic loads. In this cases the GoS is up to 50% better then in the case without resource reservation. On the other hand, when high traffic loads are considered, it is more reasonable to reserve up to 5% or more of the resources. In unlikely situations, when the system is burdened and there is an extremely high new call reject probability, it is reasonable to reserve more resources for the handover attempts. This will partly ‘close’ the system for new calls by increasing the already bad call rejection probability, but running connections will be saved. Simulations showed that even if the new call blocking probability rises up to 25% the handover blocking probability remains in a reasonable boundary of 1%.

VI REFERENCES

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