On Call Admission Control and Handover Management in Multimedia LEO Satellite Systems

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Low earth orbit (LEO) satellite systems gained considerable interest in the past decade and were expected to be instrumental in future telecommunications systems. Nevertheless, the first two LEO satellite networks that are currently in operation have not come to fruition on account of the limited spectrum of services that they provide. In this context, future LEO satellite networks will be geared towards the provision of multimedia services. In this paper a novel call admission control and inter-satellite handover management scheme tailored for multimedia LEO satellite systems is proposed and evaluated. In addition, the proposed scheme is examined in satellite diversity based systems and two different satellite selection criteria, which can be applied to both new and handover requests, are assessed.

Nomenclature

\[ P_B = \text{blocking probability} \]
\[ P_D = \text{dropping probability} \]
\[ \text{GoS} = \text{grade of service} \]
\[ T_s = \text{call duration (in seconds)} \]
\[ \lambda = \text{call arrival rate in each footprint (in calls/min)} \]

I. Introduction

Due to various economic constrains, terrestrial wireless networks provide communication services with limited geographical coverage. Low Earth Orbit (LEO) satellite networks are deployed as an enhancement to terrestrial wireless networks in order to provide broadband services to users regardless of their location. Since LEO satellite networks are expected to support real-time interactive multimedia traffic they must be able to provide their users with Quality-of-Service (QoS) guarantees including bandwidth, call blocking probability \((P_B)\) and call dropping probability \((P_D)\). However, the limited bandwidth of the satellite channel, the satellite rotation around the Earth and the mobility of end-users makes QoS provisioning and mobility management a challenging task.

Resource management in multimedia satellite networks aims to guarantee the fair distribution of available resources because of the fact that the total link capacity has to be divided among several users as well as to fulfill certain pre-negotiated QoS requirements for the lifetime of the connection. The most important resource management function is Call Admission Control (CAC). A CAC algorithm defines a procedure taken by the network during the call set-up phase in order to determine if the call request can be accepted or not. Generally, the CAC

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function results in call blocking, for new calls, or call dropping in case of ongoing calls when the bandwidth of the requested connection exceeds the available bandwidth.

The coverage area of a LEO satellite, referred to as its footprint, is partitioned into slightly overlapping cells called spotbeams. As their coverage area changes continuously, in order to maintain connectivity, end-users must switch from spotbeam to spotbeam and from satellite to satellite, resulting in frequent intra- and inter-satellite handovers attempts. This fact causes technical problems in which fair sharing of bandwidth among handover connections and new connections is required. Thus, resource allocation and CAC become very important tasks in order to achieve high bandwidth utilization and QoS provisioning for both handover and new connections. This problem is alleviated by implementing new CAC and sophisticated handover control techniques for a better QoS performance.

Several approaches for handover prioritization proposed for terrestrial cellular systems have been studied in the recent literature for mobile satellite systems. The solutions include the guard channel scheme, handover queuing where the highest priority is offered to handover calls, which are organized in a separate queue, and novel CAC algorithms.

In Ref. 2, the authors propose a mobility model and different resource allocation strategies for LEO satellite networks. The queuing of handover requests is proposed aiming to reduce the handover blocking probability. The dynamic channel allocation scheme is expected to be the best scheme to optimize system performance.

In Ref. 3, the CAC strategy is based on bandwidth reservation and priority queues, where the highest priority in the queue management scheme is to reserve bandwidth on behalf of connections that are in imminent danger of being dropped. The authors investigate two types of multimedia traffic, real-time and non-real time traffic.

In Ref. 4, the authors propose a novel call admission and handover management scheme, Q-Win, for LEO satellite networks. A key ingredient in the scheme is a predictive bandwidth allocation strategy that exploits the topology of the network and contributes to maintaining high bandwidth utilization. By introducing priority queues and a new call admission scheme based on the multiple virtual window approach, better overall performance is achieved without knowledge of the exact location of mobile hosts.

In Ref. 5, the authors propose a selective look-ahead strategy, specifically tailored to meet the QoS needs of multimedia connections where real-time and non-real-time service classes are treated differently. The handover admission policies introduced distinguish between these two types of connections. Bandwidth allocation only pertains to real-time handover connections. To each accepted connection, bandwidth is allocated in a look-ahead horizon of $k=2$ cells along its trajectory, where $k$ is referred to as the depth of the look-ahead.

In Ref. 6 a dynamic Doppler based handover prioritization technique (DDBHP) is proposed. This method takes advantage of the Doppler effect in order to estimate the terminal’s location and to reserve channels at an appropriate time in the forthcoming cell. The term appropriate time defines a time interval prior to the handover occurrence during which resource allocation must be completed.

In Ref. 7 an inter-satellite handover scheme is proposed. This scheme is tailored for LEO satellite systems that are geared towards narrowband services, that is the system provides only voice services. As in Ref. 6, this technique takes advantage of the Doppler effect in order to estimate the terminal’s location and to reserve channels at an appropriate time in the forthcoming satellite. That scheme also exploits the satellite diversity that some systems provide. To this end, three satellite selection criteria were proposed and evaluated.

In Ref. 8 the location of users is used for adaptive bandwidth allocation and handover resource reservation. In a spotbeam, bandwidth for handover calls is allocated adaptively by calculating the possible handovers from neighboring spotbeams. A new call request is accepted if the spotbeam where it is originated has enough available bandwidth for new calls. The reservation mechanism provides a low handover blocking probability compared to the fixed guard channel strategy. In Ref. 9, a geographical connection admission control is introduced, based on an adaptive dynamic channel allocation scheme. This technique calculates the future dropping probability of a new call by utilizing the user location information.

In Ref. 10 a guaranteed handover scheme is proposed. According to this method a new call is admitted into the network only if there is an available channel in the current cell and simultaneously in the first transit cell. When the first handover occurs a channel-reservation request is issued to the next candidate transit cell and so on. If all channels are busy the request is queued in a list in a FIFO discipline until the occurrence of the next handover. The call is not forced into termination provided that an available channel has been reserved in the meanwhile.

In Ref. 11 different queuing policies for handover requests are proposed. The handover requests, queued up to a maximum time interval (which is a function of the overlapping area of contiguous cells), are served in a first-input-first-output (FIFO) scheme or in a last useful instant (LUI) scheme (that is, a handover request is queued ahead of any other requests already in the queue that have a longer residual queuing time).
In Ref. 12, CAC is based on the user’s location. The system always traces the location of all the users in each spotbeam and updates the user’s handover blocking parameters. A new call is accepted only if the handover blocking probability of the system is below the target blocking rate at all times.

In Ref. 13, the authors introduce a new metric called “mobility reservation status”, which provides the information about the current bandwidth requirements of all active connections in a specific spotbeam in addition to the “possible” bandwidth requirements of mobile terminals currently connected to the neighboring spotbeams. The key idea of the algorithm is to prevent handover dropping during a call by reserving the bandwidth in a particular number $S$ of spotbeams that the call would be handed over to. The balance between new call blocking and handover call blocking depends on the selection of predetermined threshold parameters for new and handover calls.

In Ref. 14 the authors model the user cell changing process during the call lifetime in LEO systems. The impact of user mobility on the blocking performance of different channel allocation techniques is evaluated taking into consideration the peculiarities of the handover arrival process.

Except for Ref. 7, all the aforementioned works investigated only the intra-satellite handover management. In Ref. 7 an inter-satellite handover scheme was proposed, however, it was tailored for LEO satellite systems that provide only voice services. In our work we investigate inter-satellite handover management tailored for multimedia LEO satellite networks. The main contribution of this work is to propose a novel CAC and inter-satellite handover management strategy for multimedia LEO satellite networks. Our scheme relies upon the queuing of handover requests of different service classes in separate queues. Priority is given to the queue where the handover requests of real-time services are stored. We also investigate two queuing policies for handling the requests in a queue. Additionally, when it is combined with an appropriate satellite selection criterion, the proposed scheme can take advantage of the overlapping coverage area between contiguous satellites.

The remainder of this work is organized as follows. Section II discusses the mobility model assumed in this work. Additionally, the satellite selection criteria and the resulting service schemes are described. Section III provides the details of our CAC strategy and inter-satellite handover scheme. Section IV introduces the simulation model and offers the performance evaluation of our scheme in terms of a cost function that is a combination of $P_B$ and $P_D$ and the mean Bitrate. Finally, Section V concludes the paper.

## II. Mobility Model

Several mobility models have been proposed in the literature for LEO satellite systems. Generally, the mobility model comprises the set of rules that describe the size, the shape and the movement of the satellite footprints. In our study we employ a two-dimensional mobility model in which the footprint of a satellite is modeled as a rectangle. Two-dimensional mobility models have been used in many studies\(^2\)\(^{14}\) and the assumption of rectangular satellite footprints proved valid for polar constellations\(^1\)\(^{10}\). However, these models present a deficiency when they are applied to multimedia LEO satellite systems. In the bulk of the models that have been proposed so far the rotation of the Earth is not taken into account. The rotation of the Earth can be neglected in narrowband systems that provide services with short lifetime such as voice calls. In all that models the visibility period of a satellite depends on its footprint size and its velocity. Nevertheless, this model is not valid for LEO satellite networks that support services with long duration, because in this case a user may be handed over to a satellite of the contiguous orbital plane due to the Earth’s rotation.

To this end, we propose a two-dimensional mobility model for polar constellations that takes account of the Earth’s rotation. The proposed mobility model is depicted in Fig. 1. This model assumes rectangular satellite footprints, and what is more, it takes the overlapping area between contiguous satellites of different orbital planes into consideration. Additionally, the satellite footprints are considered to move with a speed $V_r$. Therefore, the visibility period of a satellite is dependent not only on the satellite footprint’s size and its velocity, but on the Earth’s rotation as well.

The set of rules that comprise the proposed mobility model are the following:

- Users are uniformly distributed over the system’s coverage area.
- Users are assumed to be fixed on the Earth’s surface since terminals in very fast vehicles move with a velocity of 80 m/s at most, whereas the satellite’s velocity (for LEO constellations) can be up to 7400 m/s. However, the rotation of the Earth is taken into account and users are assumed to move with a speed $V_r$ equal to the speed at the equator (this is the maximum speed) since we do not simulate the entire network but just a part of it.
- The overlapping area between neighboring satellites in different orbital planes is taken into account (the dark gray area in Fig. 1). Nonetheless, the common area that contiguous satellites in the same orbital
plane share is not taken into consideration, since in this case, a user should always select the oncoming satellite in order to avoid an immediate handover.

- The constellation is polar and not inclined rosette.

![Figure 1. The proposed two-dimensional mobility model](image)

As can be seen in Fig. 1, there exist some users who are at the center of the footprint, hence, these users will be handed over to the oncoming satellite in the same orbital plane. Nevertheless, there are also some users that are close to the right boundary of some footprints, thus, these users will probably be handed-over to a satellite of the adjacent orbital plane owing to the Earth’s rotation. Furthermore, users that are located in an overlapping area can select one of the two visible satellites. Therefore, satellite selection criteria should be defined for these users. A user will first try to reserve capacity in the satellite indicated by the criterion that is employed. However, if there is not available capacity in that satellite, then the second satellite will be checked.

In Ref. 7 three satellite selection criteria were proposed. The first criterion is named “Maximum capacity”. According to this criterion the satellite that offers the maximum available capacity is selected. This criterion aims to achieve a uniform distribution of the traffic load in the celestial network. The second criterion, named “Minimum Service Time” is based on the satellite’s visibility period. This criterion aims to reduce the number of handovers that a user experiences during a call by selecting the satellite that offers the maximum serving period. Last but not least, according to the “Minimum Distance” criterion the closest satellite is selected, namely the satellite that offers the highest elevation angle. This criterion aims to mitigate propagation impairments and avoid link failures. However, the impact of propagation impairments on the power of the received carrier, and thus on the quality of service, is beyond the scope of this paper.

In this paper we will make use of the “Maximum Capacity” and “Maximum Service Time” criteria but not of the “Minimum Distance” criterion. The rationale behind this decision can be ascribed to the fact that the “Minimum Distance” criterion is not tailored for services with long mean duration since it will result in an increased number of handovers per call, and hence, the dropping probability will be higher (as was shown in Ref. 7). The aforementioned criteria can be applied to either new or handover calls. Table 1 presents the service schemes that are examined in this paper.

<table>
<thead>
<tr>
<th>Service scheme</th>
<th>Criterion for new calls</th>
<th>Criterion for handover calls</th>
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<tr>
<td>CC scheme</td>
<td>Maximum Capacity</td>
<td>Maximum Capacity</td>
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<td>TT scheme</td>
<td>Maximum Service Time</td>
<td>Maximum Service Time</td>
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<tr>
<td>CT scheme</td>
<td>Maximum Capacity</td>
<td>Maximum Service Time</td>
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<tr>
<td>TC scheme</td>
<td>Maximum Service Time</td>
<td>Maximum Capacity</td>
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Table 1. Examined Service Schemes
III. Description of the CAC and Inter-satellite Handover scheme

The proposed CAC and inter-satellite handover scheme has been geared towards LEO satellite systems that provide multimedia services. It aims to reduce dropping probability without increasing blocking probability to unacceptable levels by queuing handover requests. In our work we consider a LEO satellite network that provides six different applications. These applications are categorized into two service classes. Service Class 1 corresponds to real-time multimedia services that have stringent QoS constraints, while Service Class 2 corresponds to non-real-time data services with looser QoS constraints. Each application (hereafter referred to as type of service) is characterized by the minimum source Bitrate, the maximum source Bitrate and its mean duration. Each satellite has two queues where handover requests (that is capacity reservation requests) are placed. The first queue, which we call NR, contains requests of Class 1 calls, while the second queue, which is named NQ, contains the requests of Class 2 calls. The proposed scheme is delineated in the following paragraphs.

The CAC procedure for Class 1 calls is quite different from the one for Class 2 calls. Upon the arrival of a new Class 1 call, the satellite checks the available capacity. The call will be admitted into the network only if at least the minimum capacity that is required for this type of service can be reserved in the satellite. Otherwise, the call is blocked. As soon as a new call is admitted into the network a handover request is sent to the satellite (or satellites) to which the call may be handed over. Terminals that are located in the overlapping area will first try to be served by the satellite that is indicated by the criterion that is used for new calls. If they do not manage to reserve at least the minimum capacity required by the source in that satellite, then they will check the second visible satellite. As was mentioned before, Class 2 calls are subject to looser QoS requirements compared to Class 1 calls. The difference in the procedure that is followed in the case of a new Class 2 call lies in the capacity that should be reserved so that the call will not be blocked. A new Class 2 call will be accepted as long as there exists a residual capacity (>0 kbps) in one of the visible satellites.

We should point out that the satellite should be aware of the terminal’s location in order to be able to derive the time instant of the next handover occurrence as well as the possible satellites to which the call may be handed over. Low complexity techniques that are based on the Doppler effect can be used in order to estimate the terminal’s location and the time instant of the handover occurrence\(^6,7\). However, in that case the satellites should have on-board processing capabilities, a requirement that should be met by all future satellite networks. In the following subsections we spell out the details of the proposed handover management scheme. The scheme will be described for the case where a terminal is located in the overlapping area, and therefore, it is covered by two satellites.

A. Management of Class 1 Handover Requests

Once a Class 1 call is admitted into the network, the serving satellite calculates the time instant of the handover occurrence and the candidate satellites for relaying the call and immediately sends a capacity reservation request to them. Each one of the requests will be placed in the NR queue of the corresponding satellite. The request should be served in the remaining time interval till the handover occurrence. At the handover occurrence the call will not be dropped only if at least the minimum required capacity has been reserved in one of the visible satellites. If capacity has been reserved in both visible satellites, then the satellite that is indicated by the criterion used for handover calls is selected, while the capacity that has been reserved in the other satellite is released. If capacity has not been reserved in a satellite, then the capacity reservation request is removed from its NR queue. As soon as the call is handed over to a satellite the time instant of the next handover occurrence as well as the candidate serving satellites are calculated and capacity reservation requests are sent to them. Then the procedure is similar to the one described above.

B. Management of Class 2 Handover Requests

As in the case of Class 1 calls, when a Class 2 call is accepted, both the time instant of the first handover occurrence and the potential satellites for relaying the call are derived and capacity reservation requests are sent to them. These requests are placed in the NQ queues of these satellites. The call will not be dropped only if some residual capacity has been reserved in one of the visible satellite till the handover occurrence. Therefore, the difference between the procedure that is applied to Class 1 calls and the one that is applied to Class 2 calls lies in the amount of capacity that should be reserved. Concerning Class 1 calls, the minimum required capacity should at least be reserved, whereas as regards Class 2 calls, only some residual capacity is required in order that the call will not be dropped.
C. Queue Management

In order to give priority to Class 1 handover requests over Class 2 handover requests, in the proposed technique, the satellite first tries to serve the requests in the NR queue and then goes to the NQ queue’s requests. However, we had also to decide on the policy that the management of the requests in each queue will be based on. In this work we evaluate two different policies. The first is the well-known FIFO (First Input First Output) policy. In this policy, the requests are queued according to their arrival times. The other policy is called LUI\(^2\)\(^{-1}\) (Last Useful Instant). In this policy, the queuing of the requests is based on the residual time interval till the handover occurrence. Therefore, a request is placed before all the other requests in the queue that have a greater residual queuing time.

IV. Performance Evaluation

The experiments conducted in this work aim at evaluating the performance of the proposed CAC and handover management scheme, as well as assessing the impact of the service schemes and queuing policies on system performance. The tool that was used for these experiments was custom coded in C++. We simulated four orbital planes with four satellites in each one. A wrap-around technique was employed in order to avoid the boundary effects. The proposed scheme was tested in a system that resembled the geometry of the Teledesic system (the Boeing design with 288 satellites). The size of each footprint is \(1790 \times 1790\) km\(^2\) and its velocity is 5.89 km/sec. Moreover, the rotation of the earth is considered to correspond to a speed of 0.46 km/sec. The capacity of a satellite is set to 32 Mbps.

We consider three different types of services for each service class. Their parameters are presented in Table 2. New calls are generated according to a Poisson distribution with mean arrival rate \(\lambda\). The call duration of each type of service is exponentially distributed with mean value \(T_s\).

The schemes have been tested for different percentages of the footprint’s overlapping area. Each scheme is described by three letters. The first letter denotes the queuing policy that has been applied, namely the FIFO policy is denoted by F, while L denotes the LUI policy. The other two letters indicate the service scheme that has been used. We evaluated the performance of each scheme through a cost function which we call Grade of Service (GoS). This cost metric represents the combination of blocking and dropping probability and is given by

\[
GoS = 0.1P_B + 0.9P_D
\]  

(1)

A greater weighting factor has been given to \(P_D\) since dropped calls are considered to be more annoying to users than blocked calls.

Figure 2 depicts the Grade of Service of Class 1 – Type 1 calls. It is evident that the CC service scheme outperforms the other three service schemes. Furthermore, the FIFO policy attains better results than the LUI policy for all the service schemes. As regards the percentage of the footprint’s overlapping area, it seems to be beneficial only to CC and CT service schemes. As can be seen from Fig. 2, the satellite selection criterion that is applied to new calls dominates over the criterion that is used for handover calls. We should also mention that \(P_D\) was in all cases less than \(10^{-4}\), thus, GoS was dominated by \(P_B\).

The Grade of Service of Class 1 – Type 2 calls is illustrated in Fig. 3. Apparently, as the percentage of the footprint’s overlapping area increases, so does GoS. Moreover, this time the LUI policy outperforms the FIFO policy, while the schemes that employ the “Maximum Service Time” criterion for new calls perform better than the ones that use the “Maximum Capacity” criterion. As far as \(P_D\) is concerned, it fluctuated around \(2.4 \cdot 10^{-3}\) and was barely affected by the increase in the footprint’s overlapping area, so \(P_B\) dominated GoS.
The performance metrics of Class 1 – Type 3 calls are presented in Fig. 4 and 5, that is GoS and the mean Bitrate. $P_b$ was around 0.5 for 0% overlapping among contiguous footprints, while it reached 0.9 for 100% overlapping. Concerning $P_D$, it was below 0.1 for any value of the footprint’s overlapping area for all the schemes except for the LCT and FCC schemes for which $P_D$ was higher but only for 100% overlapping. Thus, GoS is mainly dominated by $P_D$. As regards the mean Bitrate of this type of calls, it is obvious from Fig. 5 that it decreases as the percentage of overlapping increases owing to the fact that more capacity reservation requests are sent out, and hence, more capacity is reserved without being used. However, due to the extremely low arrival rate of Class 1 – Type 3 calls, it was not possible to eliminate the statistical error in these results.

Figures 6 and 7 exhibit the performance metrics of Class 2 – Type 1 calls. The differences among the schemes are similar to those depicted in Fig. 2. Therefore, again the FCC scheme presents the best performance. Under further scrutiny, it becomes evident that significant gains accrue when the “Maximum Capacity” criterion replaces the “Maximum Service Time” criterion either as a criterion for new or for handover calls. As for queuing policies, the FIFO policy achieves lower $P_b$ but higher $P_D$ than the LUI policy. Notwithstanding, $P_D$ was very low, less than $8 \cdot 10^{-5}$, and therefore, it does not influence the Grade of Service so much as $P_b$ does. Figure 7 presents fairly interesting results regarding the mean Bitrate. The mean Bitrate for the CC and CT schemes is not affected by the percentage of the footprint’s overlapping area regardless of the employed queuing policy. In addition, the mean
Bitrate of the schemes that make use of the FIFO policy is higher than the one of the schemes that are based on the LUI policy.

Figure 4. Grade of Service of “Class 1 – Type 3” calls

Figure 5. Mean Bitrate of “Class 1 – Type 3” calls

Figure 6. Grade of Service of “Class 2 – Type 1” calls

Figure 7. Mean Bitrate of “Class 2 – Type 1” calls

The next set of figures presents the Grade of Service and the mean Bitrate of Class 2 – Type 2 calls. Regarding GoS, it was dominated by $P_D$ because $P_D$ was less than $10^{-4}$, and the performance disparities among the schemes are more or less similar to those presented in Fig. 6. However, this does not stand for the mean Bitrate. A decrease in the mean Bitrate is observed for all the schemes as the footprint’s overlapping area increases. Furthermore, the LUI queuing policy results in higher Bitrate than the FIFO policy.

Figure 8. Grade of Service of “Class 2 – Type 2” calls

Figure 9. Mean Bitrate of “Class 2 – Type 2” calls
Similar to our comments above are also the comments for the performance metrics of Class 2 – Type 3 calls, which are illustrated in Fig. 10 and 11. $P_D$ was lower than $2 \cdot 10^{-4}$, and therefore, $GoS$ was influenced mainly by $P_{D}$. In order to examine the overall system performance we used the following cost metric (hereinafter referred to as General $GoS$)

$$General\ GoS = \frac{\sum_{i=1}^{2} \sum_{j=1}^{3} a_{ij} GoS_{ij}}{\sum_{i=1}^{2} \sum_{j=1}^{3} a_{ij}},$$

where $i$ indicates the service class, $j$ denotes the type of service, $GoS_{ij}$ is the Grade of Service of Class $i$ – Type $j$ calls and $a_{ij} = \frac{B_{\min_{ij}} \lambda_{ij}}{\mu_{ij}}$. $B_{\min_{ij}}$ is the minimum source Bitrate, whereas $\lambda_{ij}$ and $\mu_{ij}$ are the Class $i$ – Type $j$ call arrival and departure rates respectively. The General $GoS$ is depicted in Fig. 12.

| Figure 10. Grade of Service of “Class 2 – Type 3” calls |
| Figure 11. Mean Bitrate of “Class 2 – Type 3” calls |
| Figure 12. General Grade of Service |
A first observation that can be made is that the FIFO queuing policy performs very similar to the LUI queuing policy. However, the FIFO policy is more appealing than the LUI policy on account of its low complexity. Concerning service schemes, it is evident that the CC service scheme is the best one. On a more careful observation we are led to the conclusion that the “Maximum Capacity” criterion outperforms the “Maximum Service Time” criterion. Moreover, it is apparent that GoS increases commensurate with the percentage of the footprint’s overlapping area. Nonetheless, the overlapping percentage may prove beneficial for some types of services, as it becomes evident from Fig. 2, 6, 8, and 10, and what is more, for a different combination of the call arrival rates of the simulated types of services an increase in the overlapping area may turn out to be beneficial to the overall system performance. Last but not least, we should stress that the proposed scheme accomplished extremely low dropping probabilities for all the types of calls of both service classes, without unacceptably increasing blocking probabilities.

V. Conclusions

In this work, a novel CAC and inter-satellite handover management scheme tailored for multimedia LEO satellite systems was proposed and evaluated. The proposed scheme relies upon the queuing of handover requests of different service classes in separate queues in order to achieve low dropping probabilities, and therefore, enhance network performance. Moreover, we evaluated two different queuing policies. We also examined the performance of the proposed scheme for systems with different percentages of overlapping among contiguous satellite footprints and tested two satellite selection criteria. The good characteristics of the proposed technique were corroborated via simulations, where the most appropriate queuing policy and satellite selection criterion were derived.

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