Dynamic Time-based Handover Management in LEO Satellite Systems

S. Karapantazis and F.-N. Pavlidou

In this letter, a handover scheme tailored for LEO satellite systems is proposed and evaluated. The proposed algorithm capitalizes upon the deterministic topology of this type of systems in order to increase channel utilization and diminish both blocking and forced termination probabilities.

Introduction: Low earth orbit (LEO) satellites are equipped with multibeam antennas, therefore the coverage area of each satellite is divided into several cells. Notwithstanding the benefits stemming from this design approach, due to the movement of satellites with respect to the Earth's surface, end users must switch between contiguous cells. Thus, an efficient cell handover mechanism is of paramount importance on account of the significant probability of service interruption. As befits a subject of such importance, handover techniques have been the subject of considerable study. The queuing of handover requests (QH) was proposed in [1] with the aim of reducing forced termination probability. A handover request is sent to the succeeding cell as soon as a terminal enters the overlapping area between two adjacent cells. Maral et al proposed a guaranteed handover (GH) technique and particular emphasis was laid on minimizing forced termination probability [2]. Towards this end, when a call handover takes place, a handover request is sent to the next cell thereupon. A time-based channel reservation algorithm (TCRA) was presented in [3]. This algorithm relies on the reservation procedure of the GH scheme. Nonetheless, it aims at attaining a higher channel utilization by reserving channels only for the time interval they are expected to be in use. A dynamic Doppler-based handover prioritization (DDBHP) technique was proposed in [4]. According to DDBHP, a handover request is sent to the destination cell at a specific time instant, prior to the handover occurrence, which is specified by a parameter called handover threshold (t_{TH}). This letter proposes a dynamic time-based channel reservation (DTCR) scheme that aims to keep forced termination probability to a minimum, while diminishing blocking probability at the same time.

Proposed scheme: The proposed handover scheme, namely DTCR, makes use of the key ingredients of the TCRA and DDBHP algorithms. A new call is admitted into the network as long as a channel is available in the current cell. Nevertheless, if the location of the terminal is such that the time interval until the first handover occurrence is smaller than the one defined by the parameter handover threshold (t_{TH}), then a channel must also be reserved in the next cell. However, the channel will be reserved only for the time interval it is expected to be in use, that is, [t_{H1}, t_{H2}], where t_{H1} and t_{H2} are the moments of the first and second handover occurrences respectively. Upon a successful handover, a channel reservation request is sent to the next cell at time t_{TH} prior to the next handover occurrence. If the request cannot be immediately served, then it is stored in a queue on a *first in, first out* (FIFO) basis. Nevertheless, contrary to DDBHP, a channel reservation request of the DTCR scheme rules that the channel will be reserved only for the expected time of use. Consequently, the DTCR scheme aims at enhancing channel utilization and therefore, diminishing blocking probability. In comparison with TCRA, DTCR defers the dispatch of handover requests, therefore new calls, in general, stand a greater chance of being accepted.

Simulation model: In order to evaluate the performance of the aforementioned algorithms, a simulation tool was custom coded by the authors in C++. In the experiments conducted in this work, a fixed channel allocation scheme was employed. In addition, the mobility model adopted in this set of experiments was similar to the one used in [1]-[4]. The altitude of the satellites was set to 780 km and the length of each cell was set to 318.75 km (this is the actual value for Iridium's cells), thus the ground track speed of the satellites is equal to 6.653 km/sec. Moreover, the number of channels allocated to each cell was 20. End-users were uniformly distributed over the network and new calls were generated according to a Poisson distribution. The duration of each call was exponentially distributed with a mean value of 180 sec. Several simulation runs proved that DDBHP exhibits the best performance when t_{TH} is equal to $0{,}4t_{cell}$, where t_{cell} denotes the time interval that takes a user to traverse a cell, while DTCR presents the best performance when t_{TH} is $0.7t_{cell}$. Therefore, for the sake of fair comparison, these values were used in our experiments. Moreover, the performance of the QH scheme hinges on the percentage of overlap between contiguous cells. This scheme was tested for 10% overlap, which is the value used in [1] and holds true for the Iridium system.

Results: Fig. 1 illustrates blocking probability (P_B) as a function of the traffic intensity per cell, while forced termination probability (*PF*) is depicted in Fig. 2.

The QH scheme attains the lowest blocking probability because handover requests do not overcommit the underlying network resources, however, the price to pay is an undue forced termination probability even for moderate traffic loads. At the other extreme, the GH scheme achieves zero forced termination probability. Nonetheless, the corollary of providing a guaranteed handover is an excessive blocking probability on account of the imprudent channel reservation. The TCRA and DDBHP schemes outperform the QH and GH techniques. In particular, they attain null forced termination probability, while keeping blocking probability at acceptable levels. TCRA manages to do so by reserving channels only for the time interval they are expected to be in use, whereas DDBHP does so by deferring the dispatch of handover requests. As far as the DTRC scheme is concerned, it appears to present the optimal trade-off between blocking and forced termination probabilities. Specifically, the blocking probability is well below the ones of the TCRA and DDBHP schemes for any traffic load, whereas the forced termination probability is zero even for high traffic intensity. Last but not least, Fig. 3 depicts another meaningful performance indicator, i.e., Grade of Service (GoS). GoS is defined as P_B+10P_F and accounts for the overall performance of each scheme [1]. The smaller its value, the better the performance of the scheme. Forcing a call into termination is generally considered much more irksome than blocking a new call since it involves breaching QoS (quality of service) guarantees made upon the call establishment, hence the greater weighting factor given to P_F. It becomes evident from this figure that DTCR exhibits the best overall performance for any traffic load.

Conclusions: In this letter, we proposed and evaluated a handover technique for LEO satellite systems. The main mechanism behind the proposed schemes relies on the exploitation of the deterministic network topology. Ample simulation experiments provided corroboration to the enhanced performance of the proposed scheme in terms of blocking and forced termination probabilities.

References

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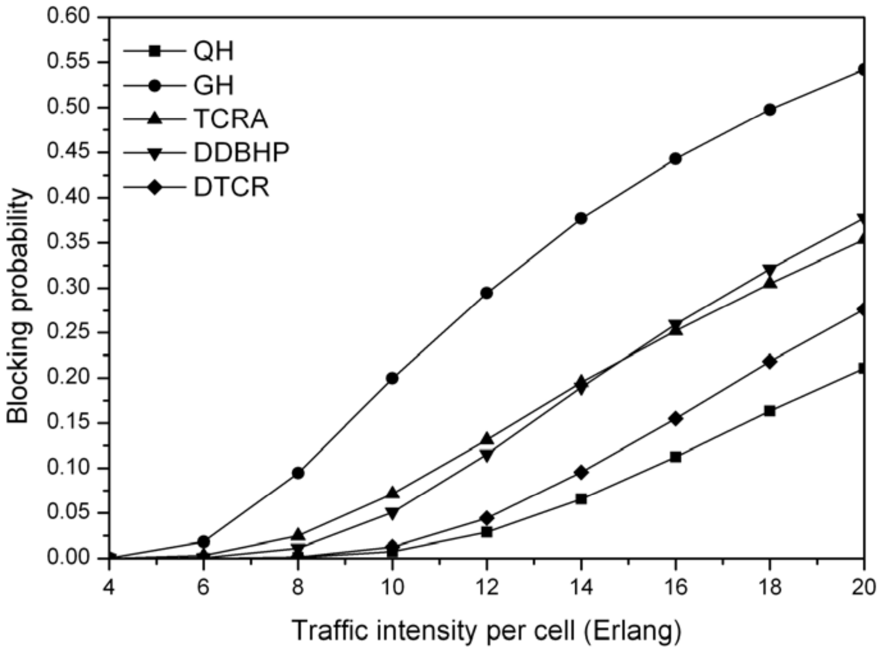
Figure captions:

Fig. 1 Blocking probability vs traffic intensity per cell

Fig. 2 Forced termination probability vs traffic intensity per cell

Fig. 3 Grade of Service vs traffic intensity per cell

Figure 1


QH
GH
TCRA
DDBHP
DTCR
Blocking probability
0.60
0.55
0.50
0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
4
6
8
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12
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16
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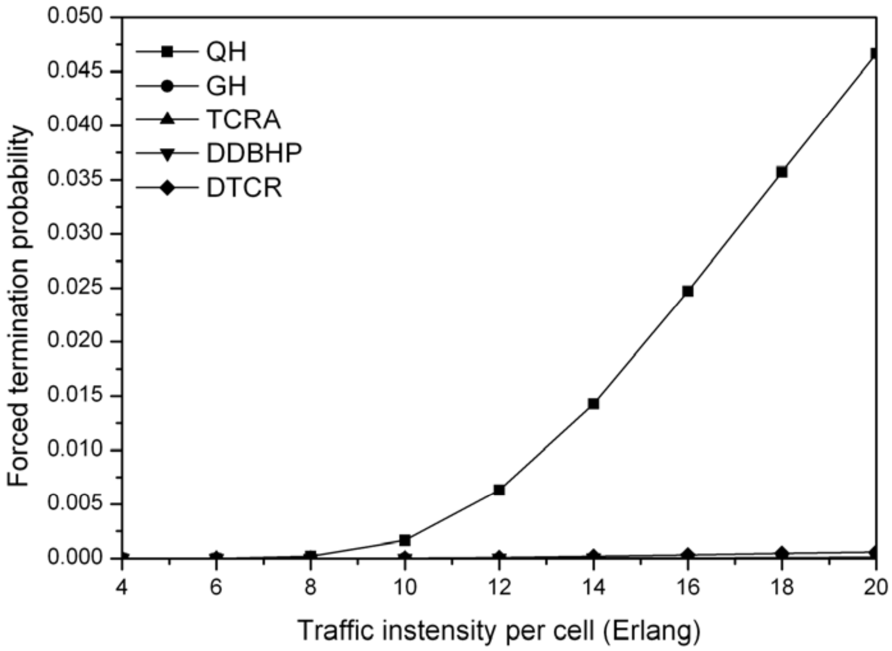
20
Traffic intensity per cell (Erlang)

Figure 2



0.050
0.045
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Forced termination probability
QH
GH
TCRA
DDBHP
DTCR
4
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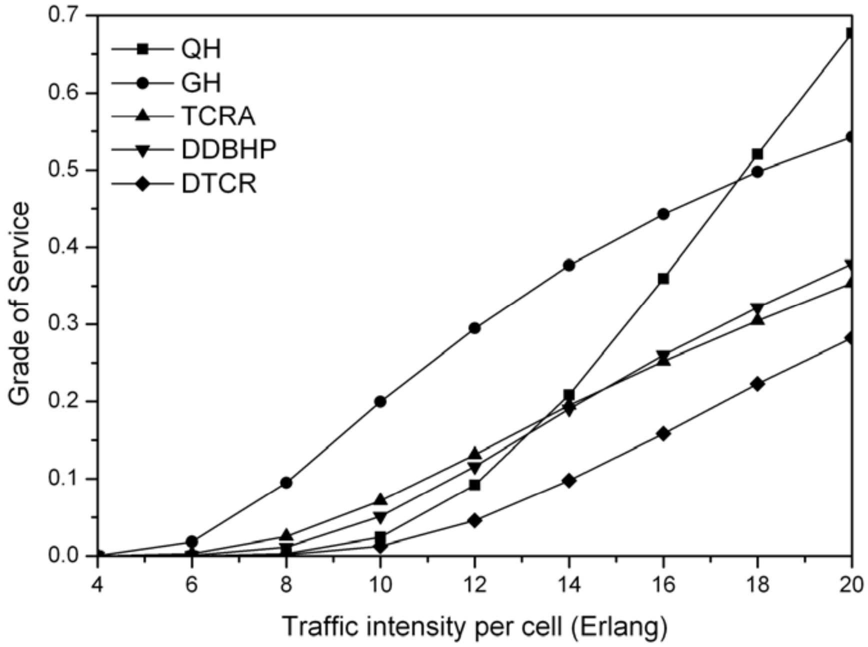
Traffic instensity per cell (Erlang)

Figure 3



QH
GH
TCRA
DDBHP
DTCR
Grade of Service
Traffic intensity per cell (Erlang)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
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16
18
20