Appendix C

Dual Channel Receiver DCA Simulation

This simulation was run assuming dual channel mobile terminals were being used so that a mobile terminal can maintain a communications link on one channel whilst simultaneously measuring interference in target handover channels using the other channel. Since communication is not broken, handover does not need to be so rapid and therefore more channels can be searched, increasing the probability of a successful handover. There still needs to be a limitation on the number of channels searched because handover must occur before the current traffic channel deteriorates to the point where the call is dropped. A limit of twenty different channels was set on the number of channels for which a mobile terminal would measure interference power at handover to limit the time for an intra-satellite handover to complete to 5s. The maximum number of initial requests to FESs made by a mobile was also raised to allow requests through up to twenty different satellites (a limit that could not be reached even at the poles using this satellite constellation). Apart from these two changes, the simulations were exactly the same as those used for the single channel receiver simulations, the results of which are presented in appendix B.

C.1. System Capacity

C.1.1. Blocking Probability

Figure C1 shows all three of the different latitudes coincident at blocking probabilities only slightly lower than the previous simulations' 0° and 30°North curves (which are shown as feint lines for comparison). This justifies the assumption made in B.1.1 that what is seen is a spectral capacity limitation, not any limitation of the assignment scheme itself. Increasing the limit on the number of satellites that can initially be addressed by mobile terminals has brought the 60°North curve into line with the other curves as well as pushing the blocking probabilities down a bit further such that at a traffic intensity of 300 calls per 69,360,000km^2 the blocking probability is now below 2%. As maximum call set-up time can be longer than the maximum handover delay, it is concluded that for call set-up a limit of twenty requests to different satellites (effectively no limit) would be suitable for both single and dual channel receivers.

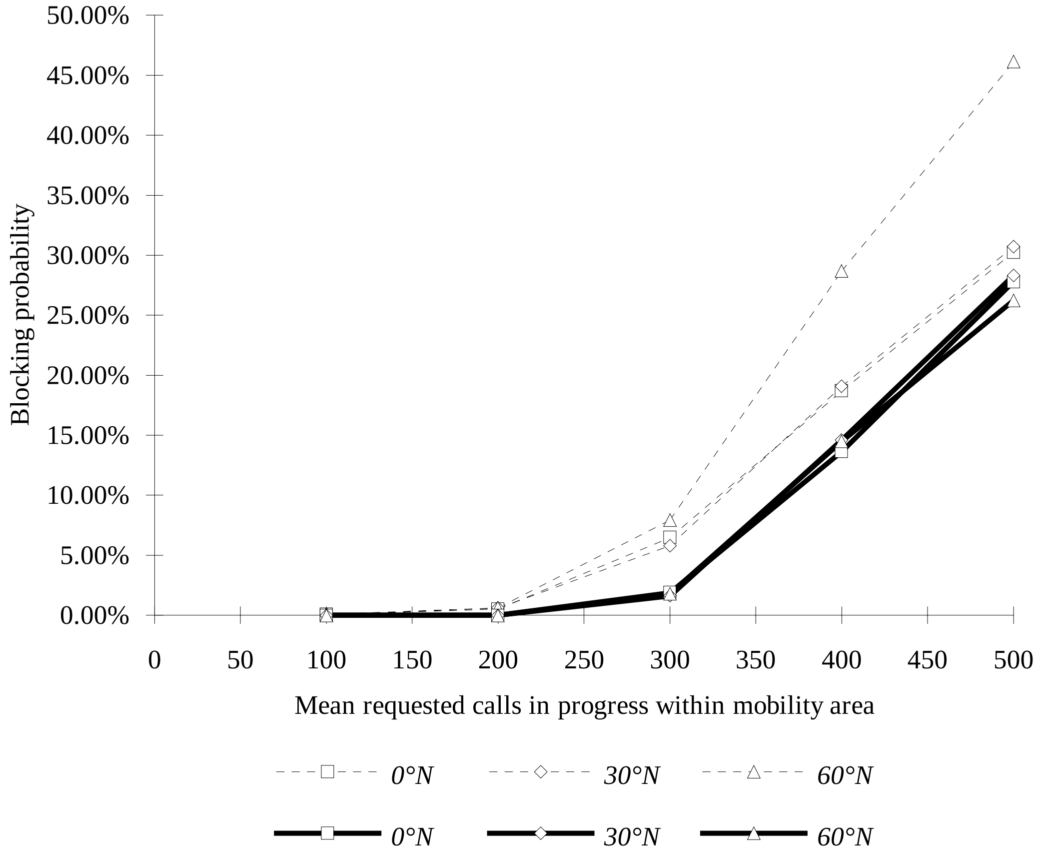

Figure C1 Probability of a call being blocked as a function of traffic intensity for 20 retry simulation (thick lines) and for 5 retry simulation (feint lines)

C.1.2. Call Dropping Probability

Figure C2 confirms the expected result that increasing the number of channels that can be tested at handover results in a reduction in the probability of a call being dropped at operational traffic intensities. Again, the previous simulation's results are shown as feint lines. In the operational area the probability of losing a call that has started is less than 1% for the 20 retry scheme.

Curiously, if the network is overloaded then the 20 retry scheme is more likely to drop calls than the 5 retry scheme. Section C.1.4 shows that this is *not* because it achieves a higher density of calls (which would imply fewer spare channels to hand over to). The channels that are being carried must be causing greater interference to each other than in the 5 retry scheme, where some of the calls would have been dropped before a new channel was found. Perhaps the retention of these existing calls, which cause high levels of interference to other terminals, is causing the reduction in the total number of calls that can be carried on each satellite. A statistic that would be a useful aid to understanding the system would be the distribution of the number of retries required before the mobile eventually manages to complete handover. This could be monitored in any future simulations.

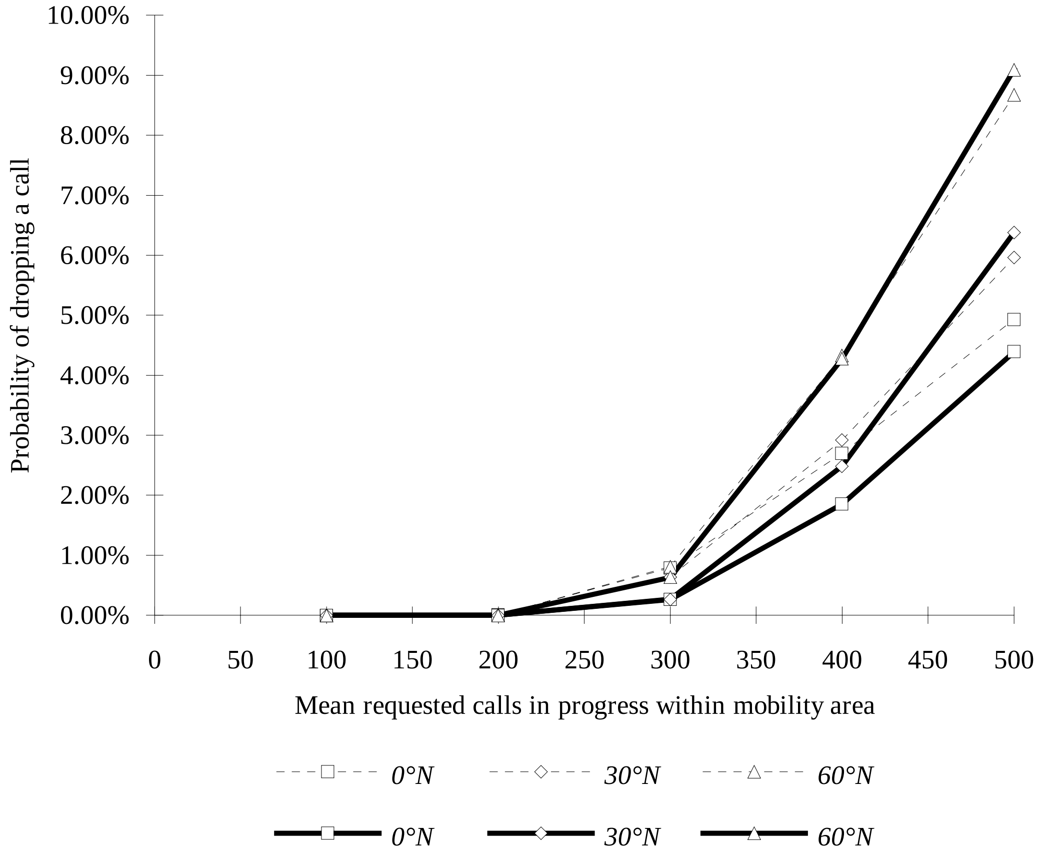

Figure C2 Probability of dropping a call as a function of traffic intensity for 20 retry simulation (thick lines) and for 5 retry simulation (feint lines)

C.1.3. Probability of Channel Suffering Poor Quality

Figure C3 shows the probability of a call suffering from interference and being unable to handover to evade it. This probability is reduced to nearly zero at operational traffic intensities by the increase in the number of attempts that can be made to find a channel. The 60°North curve is reduced the most but because the probability of poor quality is so low, the sample size of events is perhaps too small to read much into these statistics.

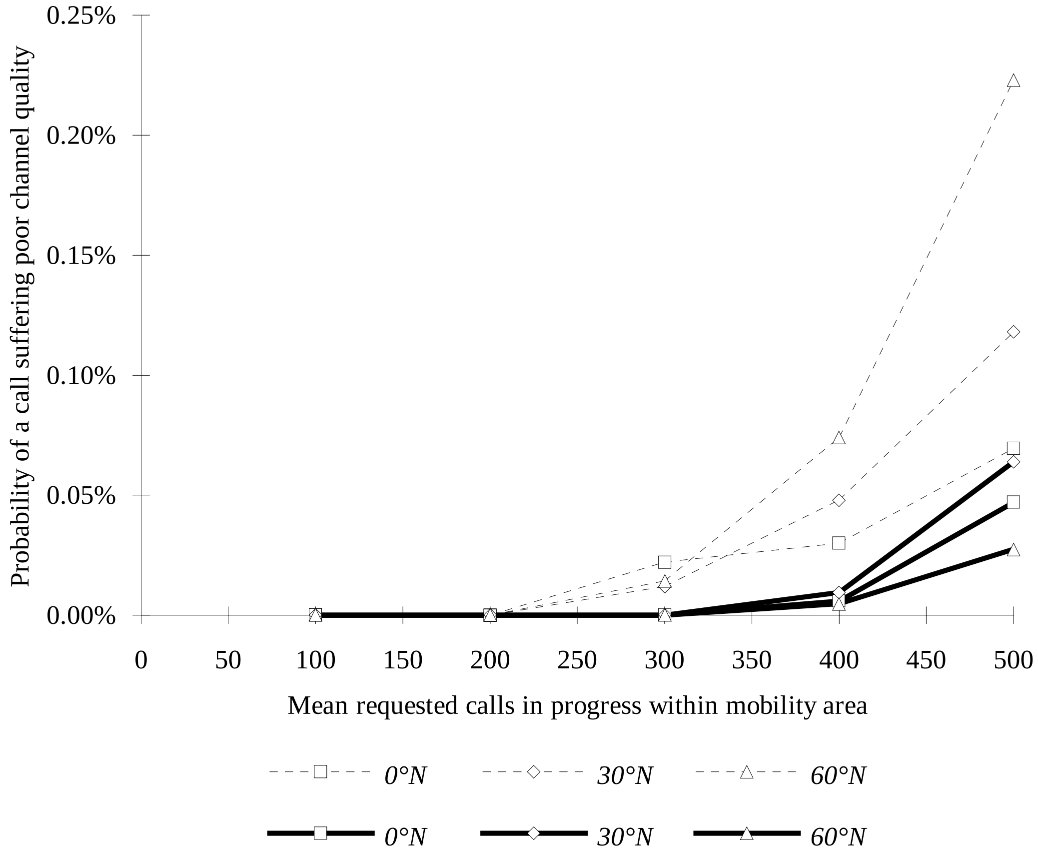

Figure C3 Probability of a call suffering from poor channel quality as a function of traffic intensity for 20 retry simulation (thick lines) and for 5 retry simulation (feint lines)

C.1.4. Actual Carried Traffic per Satellite

Figure C4 shows the mean number of calls carried by the observation satellite. Comparing this simulation's thick curves with the feint curves for the 5 retry scheme shows that less traffic is being carried. This would concur with the increase in dropping probability observed in figure C2 for an overloaded system, bearing in mind that the probability of a call being initially blocked is very similar for both schemes simulated.

The maxima of the curves occur at the same traffic intensity as the 5 retry scheme, approaching 300 calls per 69,360,000km^2, showing that no real gain in the capacity of the system has been made by increasing the number of retries allowable. If there is any change, then the results show that the capacity of the 20 retry scheme is slightly lower than the capacity of the 5 retry scheme.

As for the 5 retry scheme, the proportions of calls blocked, dropped and carried are shown in figures C5, C6 and C7 for the 0°, 30° and 60°North cases.

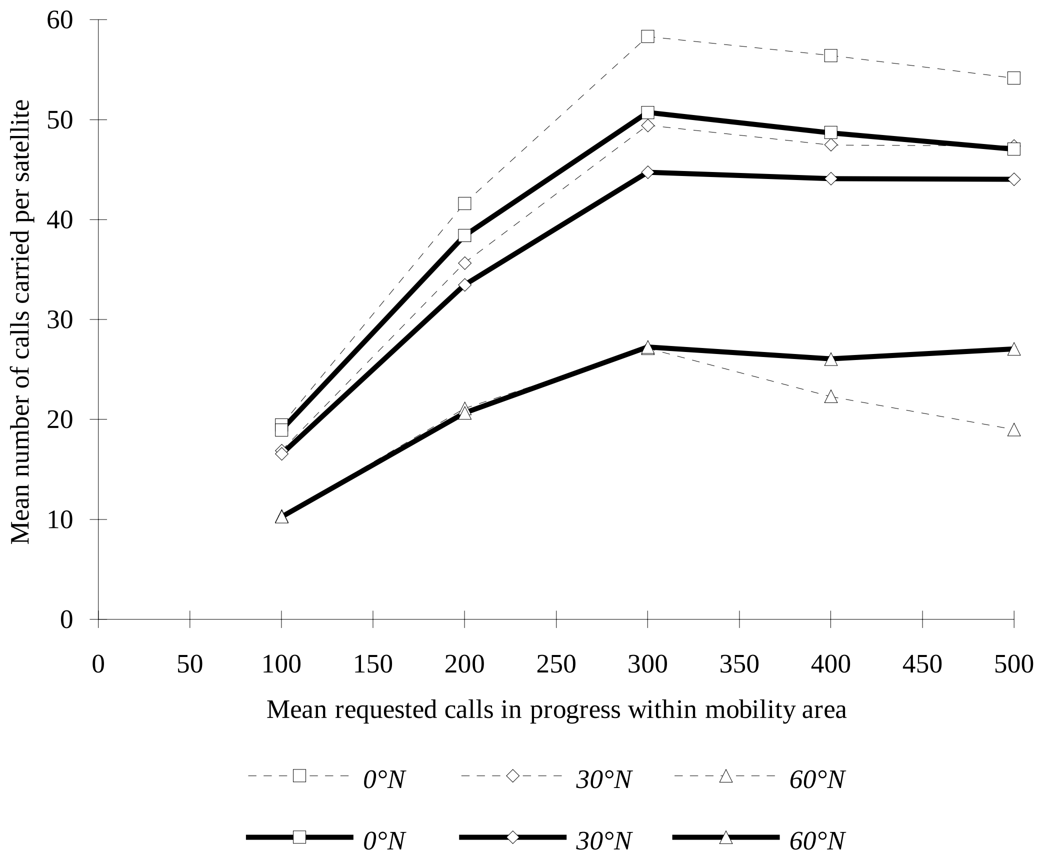

Figure C4 Mean number of calls carried per satellite as a function of traffic intensity for 20 retry simulation (thick lines) and for 5 retry simulation (feint lines)

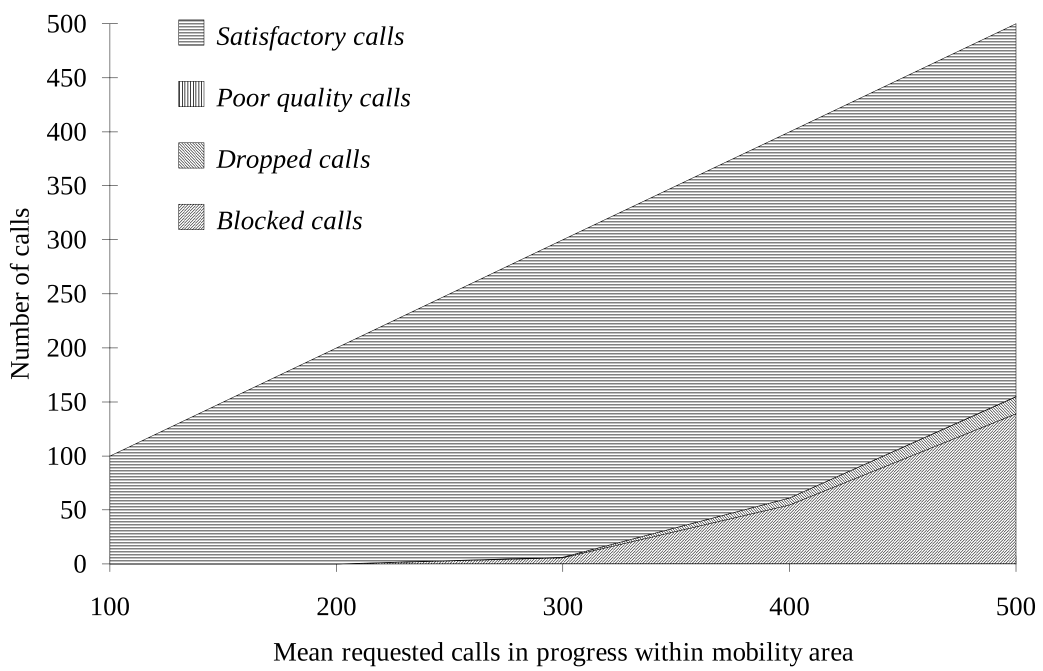

Figure C5 What happens to call requests at 0°North

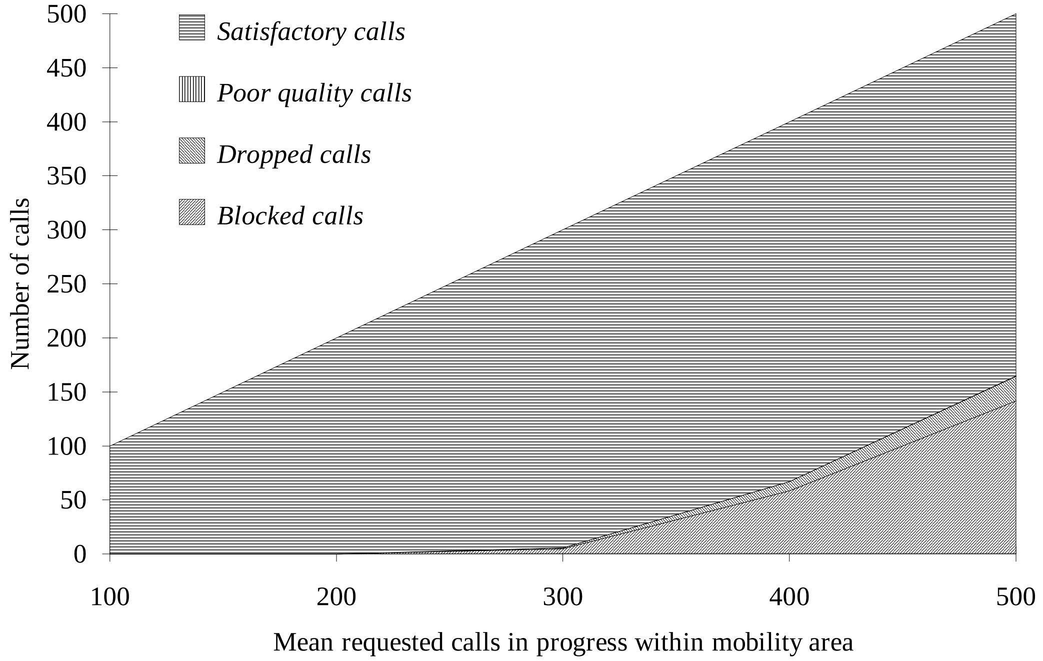

Figure C6 What happens to call requests at 30°North

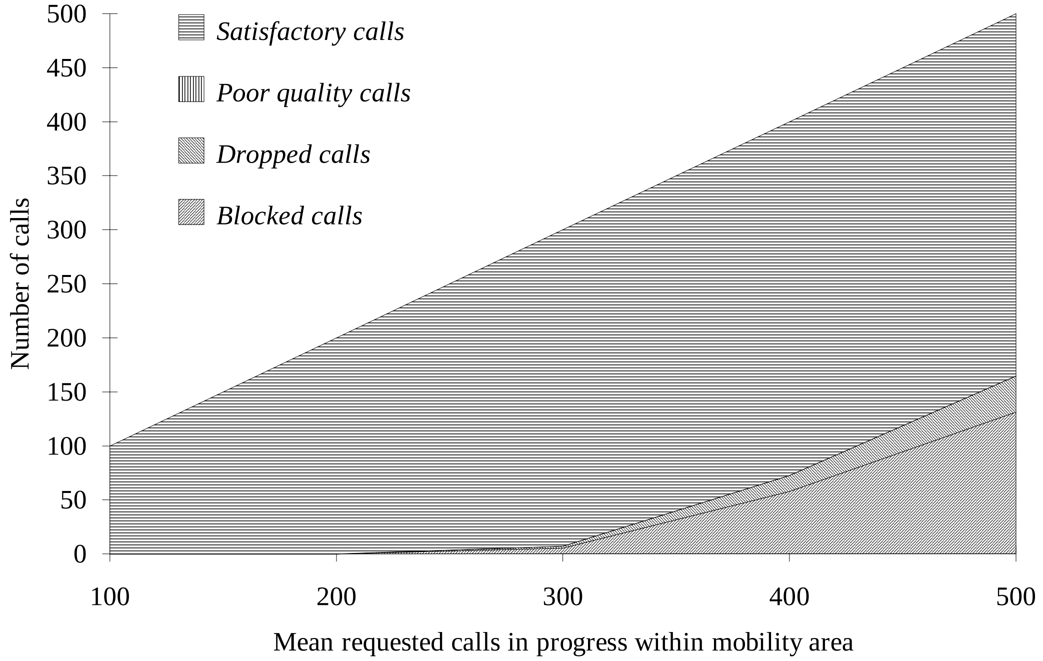

Figure C7 What happens to call requests at 60°North

C.2. Handover Delays

C.2.1. Mean Time Between Handovers

Figure C8 shows that the frequency of handovers in general remains the same as for the 5 retry scheme, dictated by the satellites' orbital movements. However, fewer of the handovers are inter-satellite because with 20 retries intra-satellite handover is more likely to be successful. The constant frequency of inter-satellite handovers for traffic intensities up to 200 calls/69,360,000km² reflects the average time it takes for the satellite to pass from horizon to horizon proving that handovers are not being forced by self-interference but by the satellite falling out of view. At over 200 calls/69,360,000km² the frequency of inter-satellite handovers increases as a result of attempts by mobile terminals to evade interference from other terminals' communications.

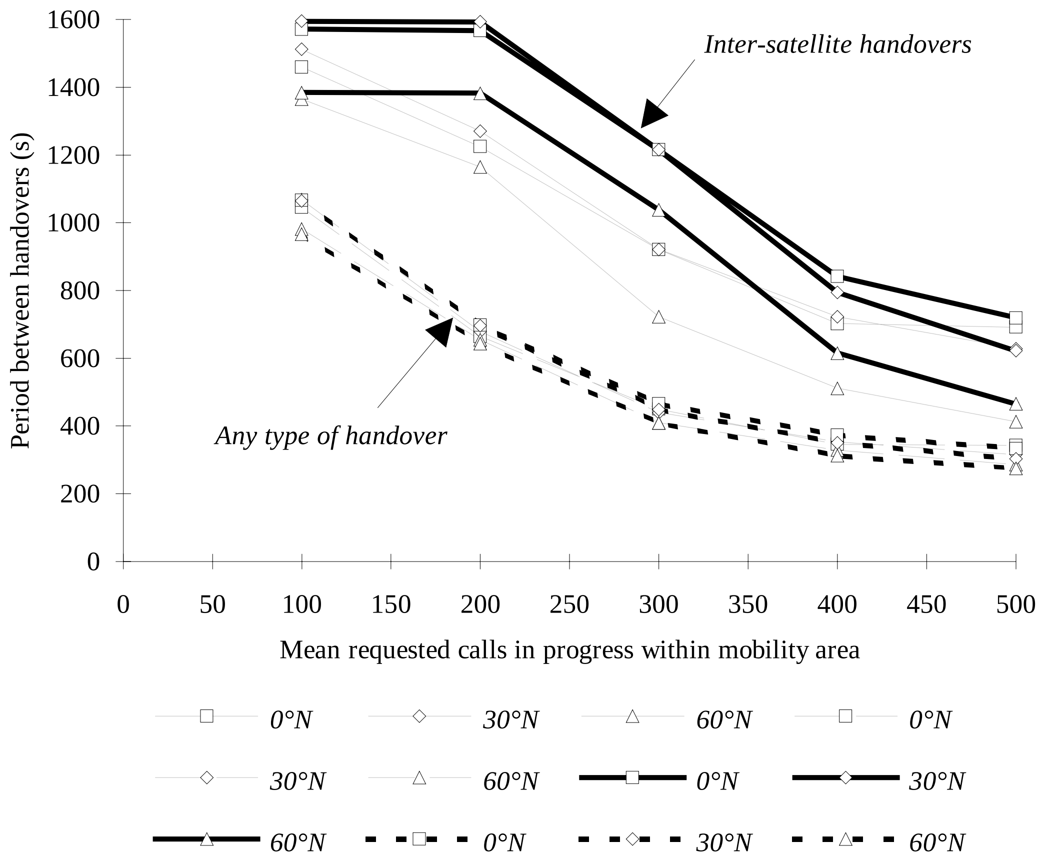

Figure C8 Mean time between handovers as a function of traffic intensity for 20 retry simulation (thick lines) and for 5 retry simulation (feint lines)

C.2.2. Mean Time to Complete Handover

As would be expected, intra-satellite handovers are not as rapid when a larger number of retries is allowed. Figure C9 shows the average delay still below one second, during which time it is unlikely that the communications link would have deteriorated to the point of dropping the call. Communications would continue uninterrupted on the old channel until the new channel is found.

As with the 5 retry scheme, it is found that handover delay reduces as the system gets more heavily overloaded. In the 20 retry scheme the maxima of delay at 0° and 30°North move towards the lighter traffic intensity of 200 calls per 69,360,000km^2 compared with 300 calls per 69,360,000km^2 observed in feint curves for the 5 retry scheme.

Table C1 shows that maximum delay is limited to 5s, corresponding to the 20 retries and that this limit is not met very often.

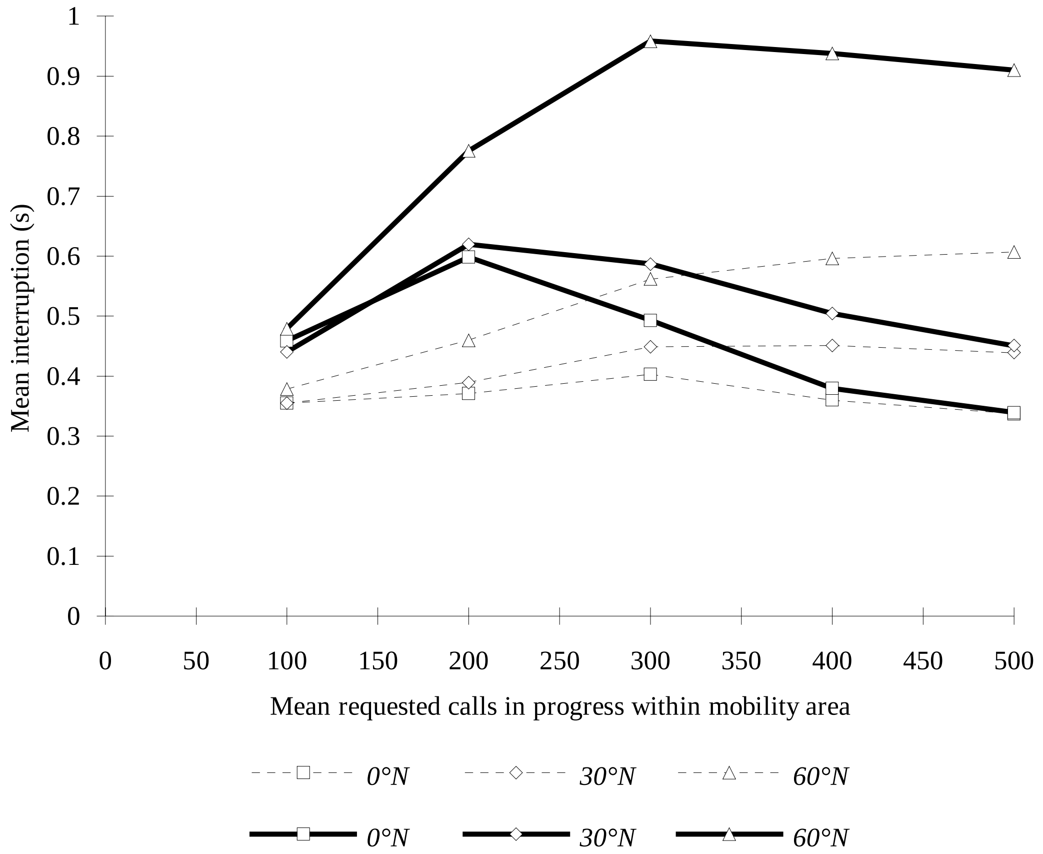

Figure C9 Mean delay before intra-satellite handover occurs as a function of traffic intensity for 20 retry simulation (thick lines) and for 5 retry simulation (feint lines)

Mean requested calls in progress within mobility area	0°North	30°North	60°North
100	4.75	4.75	5
200	5	5	5
300	4.75	5	5
400	3.75	4.25	5
500	2.5	3.25	4.25

Table C1 Interruption (in seconds) at worst case intra-satellite handover events

The starting point of figure C10, 1.2s delay, reflects the average time taken for the FES to recognize that intra-satellite handover is not possible. This means that on average only three channels are suggested before an FES decides that another satellite will need to be used.

At traffic intensities of 200 calls per 69,360,000km^2 and below handover completion times are faster than for the 5 retry scheme. Perhaps this is related to the increased number of successful intra-satellite handovers. At traffic intensities of 300 calls per 69,360,000km^2 and above the mean handover completion time is higher for the 20 retry scheme than for the 5 retry scheme, even though the probability of calls being dropped is worse for the 20 retry scheme.

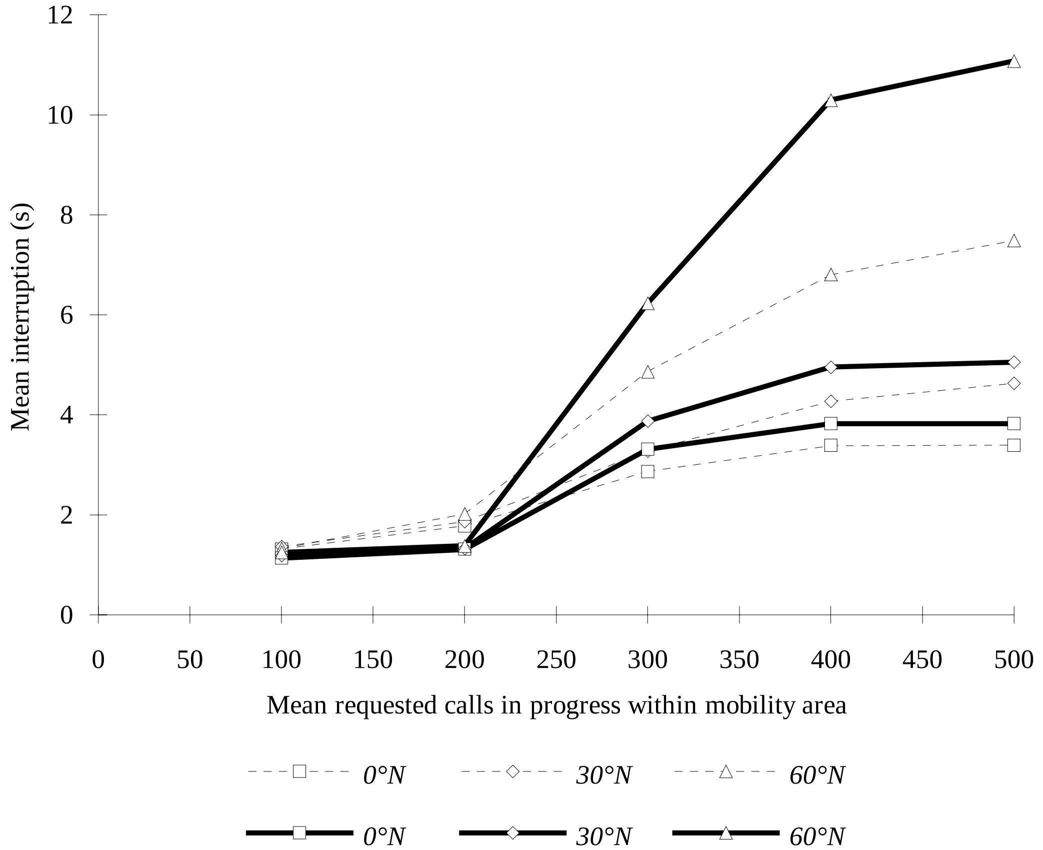

Figure C10Mean time taken to complete inter-FES handover as a function of traffic intensity for 20 retry simulation (thick lines) and for 5 retry simulation (feint lines)

Finally, table C2 shows the maximum handover delay encountered during simulation, 1 minute 20 seconds. As mentioned in section B.2.2 this is good reason to consider the use of multiple satellites working simultaneously through the same FES. During the search for a new channel communication can only continue as long as the old channel's quality remains above the communications threshold. For handovers caused by the movement of the satellite spot beam pattern, this delay is not critical but for handovers caused by fading or shadowing of a moving terminal the degradation of the channel may be very rapid and unless handover were completed in a few seconds the call would be dropped. As fading and shadowing effects dominate the land mobile environment, minimizing the handover delay is a high priority even for dual channel receivers.

Mean requested calls in progress within mobility area	**0°North**	**30°North**	**60°North**
100	20.75	20.75	5.85
200	44.9	32.65	54.8
300	45.95	45.65	77.9
400	39.95	38.5	80.75
500	32.25	39.75	58.2

Table C2 Interruption (in seconds) at worst case inter-FES handover events