

A Location-Aware Resource Reservation Algorithm with User Class Differentiation in WCDMA

J. Sánchez-González, J. Pérez-Romero, O. Sallent
Universitat Politècnica de Catalunya (TSC)
c/ Jordi Girona 1-3, Campus Nord, 08034 Barcelona, Spain
email: [juansanchez, jorperez, sallent @ tsc.upc.edu]

Abstract— This paper proposes and evaluates a radio resource reservation algorithm that takes advantage of location-aware techniques in order to facilitate handovers in a WCDMA system, specially for users following straight trajectories. The mobility characteristics of these users may provide certain information about the instant of time when they will require a handover process. The proposed resource reservation algorithm takes into account the user location information in order to manage the available radio resources in a more efficient way. The proposed algorithm optimizes the existing trade-off between the blocking probability of new connection requests and the dropping probability of users in handover. This optimization is obtained by minimizing the system Grade of Service (GoS). Moreover, the algorithm includes a prioritization of business users over consumer users. The obtained results are compared to a reference algorithm and the impact on the most important performance indicators has been analyzed, including the influence of call duration and service bit rate

Keywords: WCDMA, blocking probability, dropping probability, handoff prioritization, resource reservation, location-aware.

I. INTRODUCTION

The demand of wireless multimedia services is growing in recent years. For that reason, the efficiency in bandwidth utilisation has become an important objective in the development of mobile communication systems. On the other hand, recent developments in the positioning technology in the context of WCDMA systems (e.g. based on Time-Difference-of-Arrival [1] or using the Global Positioning System GPS [2]), provide strong assurance that accurate position measurements will become a viable reality in the near future. The location information obtained by these techniques may provide better predictions of future resource availability, and therefore, it can be exploited to develop more advanced RRM (Radio Resource Management) strategies that increase the system efficiency.

RRM algorithms (admission control, congestion control, power control, etc. [3]) determine how the available radio resources of the system must be used and shared in an efficient way among the different users. In particular, the admission control must decide whether to accept or reject connection requests depending on system load estimation. In a given cell, an admission request may come either from a user that generates a new connection or a user connected to a neighbouring cell that demands a handover to this cell. In wireless networks, it is well-known the existence of a trade-off

between minimizing the blocking probability (i.e. the probability of rejecting a new connection request) and minimizing the dropping probability of users in handover, i.e. the probability of cutting down a current connection because the user QoS (Quality of Service) requirements cannot be guaranteed. In terms of quality of service perceived by the user, it is better to reject an admission request instead of dropping an established connection. Therefore, certain priority in the assignment of the radio resources must be given to handover users in order to reduce the dropping rate. Several works dealing with this problem can be found in the open literature. In [4] a call admission control is proposed in order to reduce the number of dropped calls. The algorithm defines a certain reservation region in order to reduce the dropping probability rate at expenses of increasing the blocking probability. Similarly, [5-9] propose reservation algorithms in order to assure service to users in handover. In particular, [5][6] propose adaptive reservation algorithms to control the size of the reservation capacity according to the number of soft handover attempts. By doing this, the reservations are carried out in a more efficient way with respect to fixed reservation strategies [7].

The knowledge of the location and mobility pattern of the users will provide certain information to estimate the future need and availability of the radio resources. In particular, in scenarios with users moving along a road, these location estimations can be more accurate because main road users have usually a straight mobility pattern. Therefore, more accurate predictions of handover requests can be done, and consequently, certain radio resource mechanisms can be triggered in order to assure available resources for the handover procedure, increasing the efficiency in the use of the system resources. In this respect, [8][9] propose handoff prioritization algorithms based on predictions and estimations of the future mobile locations.

On the other hand, another feature of WCDMA systems is the ability to support different types of services and user profiles. Then, it is usual that some users (i.e. business users) should receive from the system a certain degree of priority with respect to other users (i.e. consumer users) because of contractual commitments. Under this framework, in this paper we propose a location-aware radio resource reservation algorithm that, by making use of location information, is able to provide an efficient use of the radio resources to ensure the QoS constraints of business users while introducing, in case,

minimum degradation in the performance of consumer users. The results obtained with the proposed resource reservation algorithm will be compared to the case where no reservation is carried out in terms of blocking probability and dropping probability. In order to optimise the existing trade-off between blocking and dropping probabilities, the impact of the main parameters of the proposed algorithm on the system grade of service (GoS) will be analysed. Within this context, the rest of the paper is organised as follows. Section II presents the proposed resource reservation algorithm. In section III the simulation model is described. The obtained results are shown and discussed in section IV and the conclusions are summarised in section V.

II. RESOURCE RESERVATION ALGORITHM

The scenario considers a main road with different base stations close to it, as shown in Figure 1. Users are distributed both in the main road and in the rest of the scenario. Moreover, two kinds of users will be considered: business users (higher priority) and consumer users (lower priority). The main objective of the proposed reservation algorithm is to assure service to business users moving along a main road while at the same keeping the service of consumer users at a satisfactory level. To this end, the proposed algorithm defines a certain reservation region around each station, starting at the reservation distance D [meters], as shown in Figure 1. The reservation distance D is always higher than the cell radius R . When a business user in the main road with an established connection reaches the reservation point (i.e. the distance between the user equipment UE and the Base Station BS is lower than D), certain resource reservation will be made to this user. The proposed algorithm considers accurate positioning measures to determine that the user enters the reservation region, which could be obtained with any of the existing location techniques.

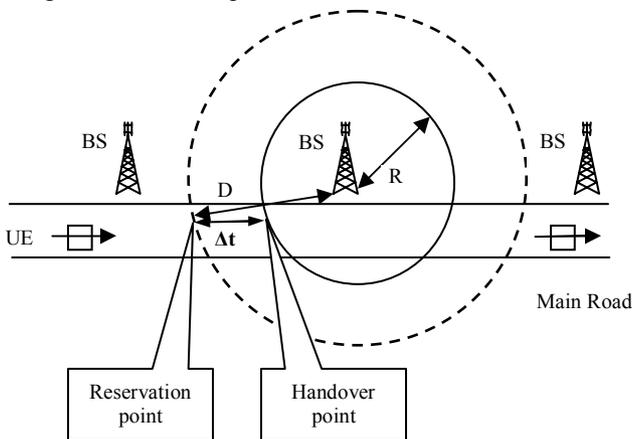


Figure 1. Example of resource reservation

Although the algorithm developed hereinafter could be easily extended to include other radio resources, the proposed algorithm makes the reservation in terms of the number of

required downlink OVSF (Orthogonal Variable Spreading Factor [10]) codes, which are the “hard” physical resources consumed in a WCDMA system, and therefore they should be available at the new cell in order for a handover to be admitted. On the contrary, the availability check for other “soft” resources like e.g. transmitted power can be relaxed for handover users in a natural way recalling the soft-capacity in WCDMA systems. The reason is that a handover rejection may lead to a power increase in the new cell, due to an increase in interference, if the user remains connected to the old cell [3]. For that reason, the proposed algorithm illustrated in Figure 2 and Figure 3, considers only code availability check.

Each transmission in the downlink direction makes use of a channelisation code selected from the OVSF code tree. The number of available codes coincides with the Spreading Factor (i.e. there are 4 codes with $SF=4$, 8 with $SF=8$, and so on). When a main road business user reaches the reservation distance of a given cell, OVSF code availability check ($C_i + \Delta C < C_{max}$) will be carried out in this cell as shown in Figure 2. C_i is the total amount of codes already used by all the i users connected to this base station, ΔC denotes the resource that must be given to the user which is being reserved and C_{max} is the maximum number of codes. All the quantities refer to the number of codes with $SF=512$ (i.e. the minimum bit rate), so that if a user transmits with higher bit rate, in terms of code occupation, it is equivalent to occupying a higher amount of codes (e.g. if a user transmits with $SF=32$ it is equivalent of occupying 16 codes with $SF=512$). If there are enough available codes in this cell, (i.e. $C_i + \Delta C < C_{max}$), a code reservation ΔC is carried out for the current user in order to assure resources for the future handover request. When the user finally requests the handover, it is accepted in the new cell, as shown in Figure 3.

On the other hand, if there is no code availability to make the code reservation to this user, the algorithm will firstly reduce the admission threshold C_{max}' for users demanding a new connection request in this base station, as shown in Figure 2, in order to make room for the reservation in the future during the time Δt before the handover, see Figure 1. Due to the dynamics of the system, a reduction in the admission threshold C_{max}' may provide enough available codes for the incoming user by blocking certain number of new connection requests, as long as some users end their connections.

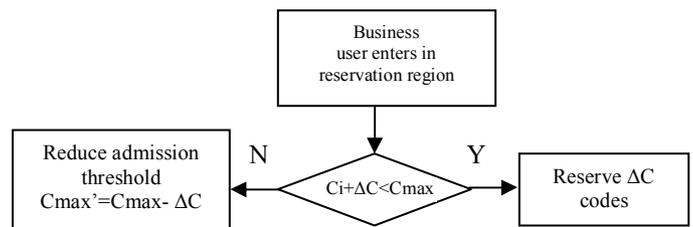


Figure 2. Reservation algorithm for Business users

Finally, when the handover is requested, the user will be accepted, either if there are ΔC available codes or if it is possible to make room for the user by dropping some less priority users (i.e. consumer users), as shown in Figure 3.

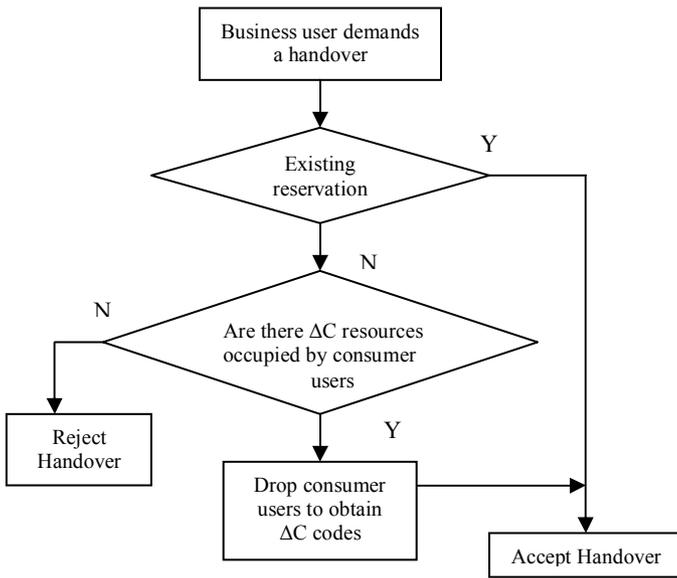


Figure 3. Handover algorithm for business users.

III. SIMULATION MODEL

The considered cell layout consists of 7 cells located along a main road with base spacing of 1800m. The base stations have been numbered as shown in Figure 4. Two types of users are considered. On the one hand, a group of conversational consumer users (64kbps CBR) have been located in a rectangular region (i.e. a building) whose position and user mobility pattern can be chosen at the beginning of the simulation. In our simulations, these users will move randomly at 3km/h inside the building. On the other hand, several business conversational (64kbps CBR) or streaming users (384kbps CBR) will be considered. These users have been distributed uniformly along a main road, as shown in Figure 4. These users move following a straight trajectory (from left to right in Figure 4) with speed 50km/h. The main simulation parameters are shown in Table I.

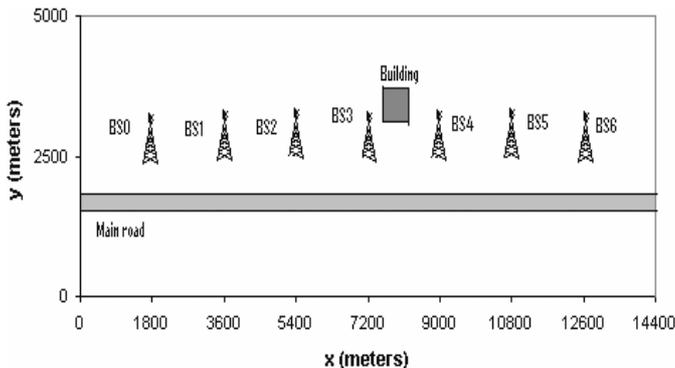


Figure 4 Cell layout

TABLE I. SIMULATION PARAMETERS

Parameter	Value
Chip rate W	3.84 Mcps
Frame duration	10 ms
BS parameters	
Cell type	Omnidirectional
Maximum DL power P_{\max}	43 dBm
Pilot and common control channels power P_c	30 dBm
Thermal noise	-106 dBm
Orthogonality factor	0.4
Handover parameters	
Active Set maximum size	1
Replacement hysteresis	1dB
Time to trigger HO	0.5 s
QoS parameters	
E_b/N_0 target	4.36dB

IV. RESULTS

In order to evaluate the proposed reservation strategy, different algorithms are presented for comparison purposes:

- *Reference algorithm*: In this case, no resource reservation for business users moving along the road is done. Moreover, the dropping of consumer users is not considered when there are not available resources to accept the handover of a business user.
- *Consumer dropping based algorithm*: In this case, no resource reservation for business users moving along the road is done. However, when there are not enough resources to accept the handover request of one of these users, a number of consumer users are dropped to make room for the business users.
- *Resource Reservation algorithm*: In this case, a reservation to business users moving along the main road and reach the reservation point is done. If necessary (see Figure 3) a number of consumer users are dropped to make room for business users.

In Table II, a comparison of the different algorithms is presented in terms of blocking and dropping probability for business and consumer users. A total number of 125 conversational users (64kbps CBR) have been considered. 15% of these users are hotspot users (inside the building). The rest of users move along the main road. As shown, the *Consumer dropping based algorithm* is able to reduce the dropping of business users, with respect to the *Reference algorithm* at the expense of a high increase in the dropping of consumer users. This dropping can be reduced with the proposed reservation strategy. Moreover, the impact of the reservation distance in the *Resource Reservation algorithm* is analysed. As shown in Table II, a too low value of the reservation distance will cause a high dropping probability of consumer building users. On the other hand, for high values of the reservation distance D (m), high number of users will fall in the reservation region, which will reduce the admission

threshold C_{max} . This will reduce the dropping probability of consumer users at expenses of increasing the blocking.

TABLE II. COMPARISON OF THE DIFFERENT ALGORITHMS WITH 125 USERS

		Blocking probability (%)	Dropping Business users (%)	Dropping Consumer users (%)
Reference Algorithm		2.01	2.13	≈ 0
Consumer dropping based algorithm		2.08	≈ 0	5.32
Resource Reservation algorithm	D=920	2.69	≈ 0	3.9
	D=1100	5.84	≈ 0	2.19
	D=1300	10.44	≈ 0	≈ 0
	D=1500	13.09	≈ 0	≈ 0
	D=1700	22.03	≈ 0	≈ 0

In order to account for the trade-off between blocking degradation and dropping improvement, let define the grade of service as $GoS(\%) = Pb(\%) + 10 * Pd(\%)$ where $Pb(\%)$ is the blocking probability and $Pd(\%)$ is the dropping probability. As shown in Figure 5, there is an optimum value for the reservation distance that minimises the system GoS. For comparison purposes, the GoS obtained with the *Reference Algorithm* (considering 125 users) is 23.31% while in the *Consumer dropping based algorithm* is 55.28%. Notice that this value is higher than the obtained with the *Reference Algorithm* because of the increase in the dropping of consumer users as a consequence of the reduction of business users dropping. By comparing these values with Figure 5, it can be observed that a reservation distance between 1300 and 1700 metres provides lower GoS than the *Reference Algorithm*.

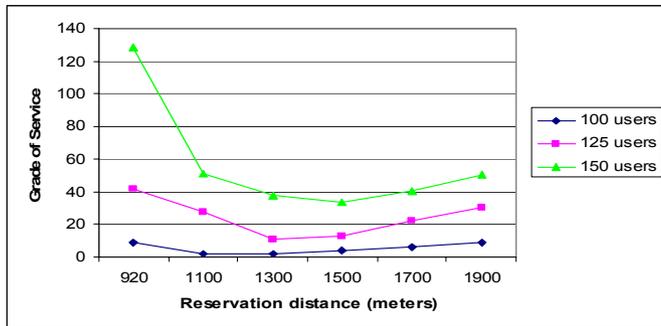


Figure 5. Grade of Service for different reservation distance (mean call duration 120seconds)

Further, certain user characteristics such as the mobile speed or the user call duration will impact on the optimization of the reservation distance. For example, the higher the mobile speed is, the sooner the reservation must be done in order to have enough time to obtain available resources for a main road business user before the handover process starts. Similarly, and focusing on the impact of the call duration, Figure 6, shows the obtained GoS for different reservation distances when the mean call duration is reduced to 20 seconds. In this case, the minimum GoS is obtained for lower values of reservation distance with respect to the case when the mean call duration is 120 seconds (see Figure 5). It is worth noting

that a too high value of reservation distance may cause that a main road business user with reservation for a given cell may end its current connection before the handover is eventually made effective (i.e. false reservation). In this situation, the reserved resources for this user have been wasted, reducing the system efficiency. The false reservation probability is shown in Figure 7. Higher reservation distance causes a higher false reservation probability, particularly for short call durations.

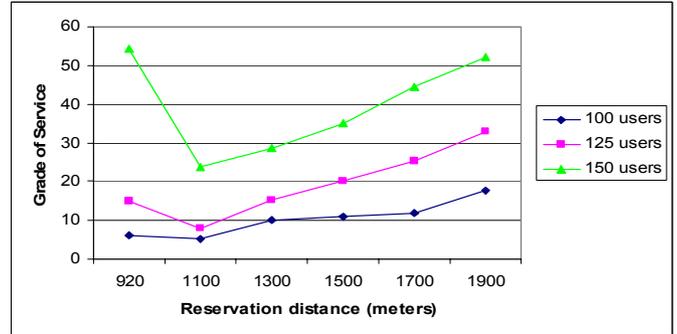


Figure 6. Grade of Service for different reservation distance (mean call duration 20seconds)

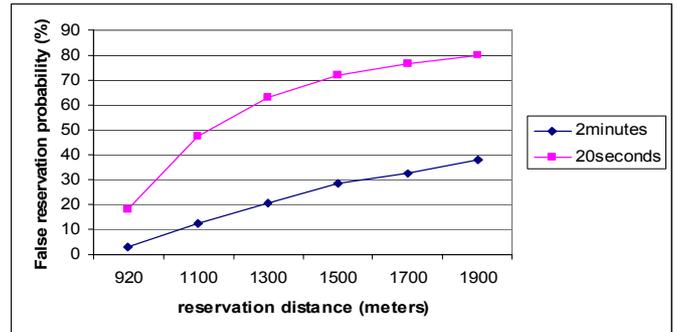


Figure 7. False reservation probability for different reservation distance

In the following, the impact of the service bit rate is presented. To this end, the main road business users are considered to be streaming (384kbps CBR). Consumer building users are conversational (64kbps CBR). When the 384kbps users moving along the main road reach the reservation region, they will demand a higher resource reservation than in the previous scenario, where main road users transmitted at 64kbps. Then, in order to optimise the system efficiency, the resource reservation must be carried out sooner (farther from the base stations) in order to have more time to make room for the high bit rate users before they demand the handover. Figure 8 and Figure 9 show the optimisation of the reservation distance in order to minimise the system GoS. 20 and 30 streaming users (384kbps) have been distributed along the main road. As shown, higher values of the reservation distance are needed with respect to the case of services of 64kbps for the main road users. Moreover, the impact of the call duration is presented, by comparing Figure 8 and Figure 9. As mentioned before, higher mean call duration requires higher reservation distance. Finally, Table III summarises the optimization of the reservation distance for different call duration and service bit

rate. As stated before, higher call durations require higher reservation distances. Also, the gain $G(\%)$, in terms of GoS, of the proposed algorithm with respect to the *Reference Algorithm* is presented in brackets. It can be observed that significant gains are achieved. The gain is even higher for shorter call durations, since the reservation procedure blocks new call attempts for a shorter period of time.

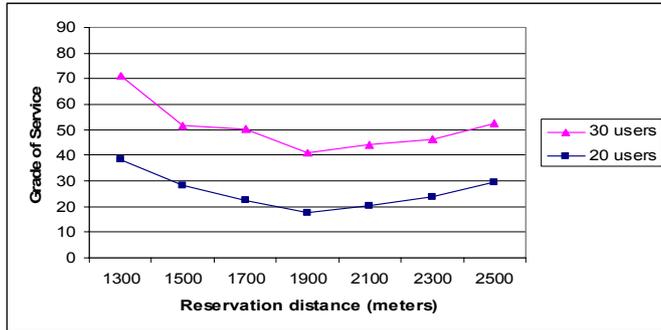


Figure 8 Grade of Service for different reservation distance (call duration 20seconds)

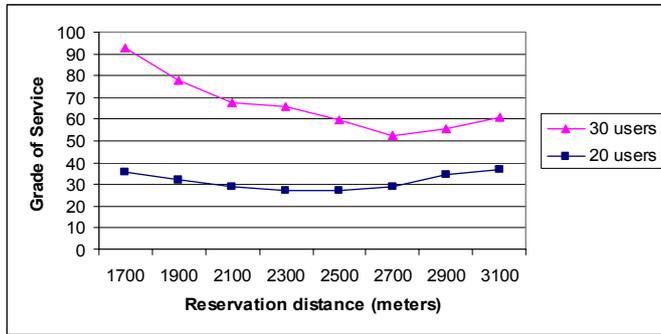


Figure 9 Grade of Service for different reservation distance (call duration 2minutes)

TABLE III. OPTIMUM VALUE OF THE RESERVATION DISTANCE

	64kbps	384kbps
20 seconds	1100m [G=71%]	1900m [G=67%]
2 minutes	1300m [G=55%]	2700m [G=49%]

V. CONCLUSIONS

This paper has proposed a resource reservation algorithm that makes use of location-aware techniques in order to assure service to high priority users. The proposed algorithm optimizes the existing trade-off between the dropping probability and the blocking probability in a WCDMA system. The reservation of certain resources for handover users reduces the number of dropped connections at expense of certain increase in the blocking probability of new connection requests. The proposed algorithm takes advantage of the predictability in the movement of users along a main road in order to determine the most adequate instant of time when the resource reservation for handover users should be made. A too large reservation region may cause that a handover user ends its connection before starting the handover procedure, resulting in a high false reservation ratio. Moreover, the blocking probability of new connection requests would

increase because a large number of resources would be devoted to reservations for users inside the reservation region. On the other hand, a too small reservation region increases the number of handover failures (i.e. the dropping ratio) because there is not time enough to obtain the available resources. Then, an optimization of the reservation distance has been made by minimizing the system GoS. Moreover, the impact of the user call duration and service bit rate on the proposed algorithm has been discussed. It has been shown that, for shorter call durations, the reservation distance must be lower in order to reduce the false reservation probability. Similarly, higher service bit rate require higher reservation distance because more time is needed in order to obtain the required resources.

ACKNOWLEDGMENTS

This work is part of the EVEREST project, partially funded by the European Commission under the IST framework and by the Spanish Research Council (CICYT) under COSMOS grant TEC2004-00518 and TEC2004-0053.

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