Reducing Handoff Blocking Probability in Fourth Generation Wireless Networks

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Abstract—**In this paper, we propose new methods to reduce the handoff blocking probability in next generation wireless networks. This reduction is based on an adaptive resource reservation scheme that provides quality of service (QoS) guarantees, and handoff priority in admission and in scheduling. To this purpose, the proposed schemes employ received signal strength (RSS) and speed to reserve available resources for a user from its adjacent cells according to its current position. The Performances of the proposed schemes are compared with others methods by simulation. Our new scheme reduces not only the handoff blocking probability, but also maintains a low new call blocking probability.**

I. INTRODUCTION

The evolution of wireless network technologies has led to different generations of wireless systems referred to as nG (1G, 2G, 2.5G, and 3G). Current wireless systems only provide limited services. The wireless 4G network will be a heterogeneous network consisting of different access networks, which may overlap [7]. This will enhance and extend the mobility concept by providing continuous and ubiquitous accessibility, IP mobility, privacy and security of communications. The provision of different multimedia services (video-conferencing, teleconferencing, on-demand services, etc.,) to mobile users, while at the same time meeting some specific QoS requirements (loss rate, delay, bandwidth, security), is one of the main goals of the next generation wireless networks [1].

Therefore efficient bandwidth reservation schemes are needed to ensure better QoS. Recently, several resources reservation schemes for cellular networks have been proposed [2, 3, 4, 5, 6]. All strategies available in the literature to reduce the handoff blocking probability aim at putting some resources in each cell that are exclusively devoted to handoff cells [5]. In [2], a reservation algorithm provides quality of service guarantees by reserving resources from all of the neighboring cells simultaneously. This scheme is apparently too conservative and wastes large amount of resources, resulting in low bandwidth utilization and a high new call blocking probability. In [6], authors propose a predictive and adaptive handoff bandwidth reservation scheme based only on the user received signal strength (RSS). In this paper, first we propose a new Handoff Resource Reservation (HRR) scheme. It is adopted to reduce unnecessary resource reservation for mobile stations (MSs) near the base stations (BS). The amount of bandwidth to be reserved is dynamically adjusted to reflect the mobility condition of MSs. Second, an admission control scheme is also adopted to achieve lower dropping probability, better usage of the reserved bandwidth, and better bandwidth utilization. Finally, we propose a generic scheduling scheme that assigns dynamically the priority of handoff request in scheduling queues.

The rest of this paper is organized as follow: In Section 2, we present our approach to reduce handoff blocking probability in next wireless generation. This probability is reduced by the processes: resource reservation, and giving the priority to the handoff requests in admission and in the scheduling. In section 4, we provide numerical results of the above sections and highlight the efficiency of the proposed handoff reservation resource. A conclusion is given in Section 5, where some perspectives are given.

II. HANDOFF RESOURCE RESERVATION

A. Reservation decision

In order to maintain a low handoff blocking probability, we choose to reserve a maximum bandwidth in all neighboring cells of the serving cell. To maintain a low new call blocking probability, this reservation should be optimal. In this subsection, we propose a new handoff resource reservation that uses RSS measurements to determine when channel reservations are to be made. In the HRR scheme, resource reservation decisions are made based not only on each MS' RSS, but also on the relative moving speed with respect to its next target cell. Each MS estimates its speed using RSS variations. The decision for reservation is based on the values of RSS. If the RSS of one neighboring cell i of the serving cell j is greater than RSS_{RESV} for exceeding time, it is necessary to reserve resources in it. During its normal status, the mobile is continuously checking for better radio links.

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During this checking, the mobile measures the pilot signals received from neighboring cells and compares them to the reservation threshold (RSS_{RESV}). Then the mobile sends measurement reports to the serving cell if the signal received exceeds RSS_{RESV}. A period of time called exceeding time is used to maximize the probability that a reservation request, once established, will operate without the reservation rejection procedure. If a mobile finds a neighboring cell with pilot signal strength exceeding the RSS_{RESV}, then it sends a reservation request to its serving cell in order to reserve bandwidth in this neighboring cell. Afterwards, if the pilot strength drops and stays below RSS_{RESV} during the exceeding time, the mobile sends a release request. On the other hand, if the pilot strength reaches RSS_{add}, then the mobile initiates a handoff. RSS_{RESV} is not an absolute value, but is rather a relative value to RSS_{add}. When RSS_{add} is dynamically determined according to the current wireless link status and network load condition, RSS_{RESV} can also be adaptively modified because of the distance separating the mobile from the cell center and its motion in the cell. Therefore, RSS_{RESV} should be smaller than RSS_{add}. Moreover, RSS_{RESV} should be higher than RSS_{drop} because low reservation threshold value can cause excessive unnecessary reservations.

B. Resources Reservation Optimization

This subsection presents the vertical handoff resources reservation triggers analyses. To find the optimal dynamic threshold values, we set up a test to relate RSS and speed. We use the following variables to determine reservation thresholds:

- RSS_i^t and RSS_i^{t-1} denote the RSS of a MS *i* at time *t* and *t-1*, respectively.

- ΔRSS_i the average of absolute value of the RSS variation of mobile *i* in unit time.

We define the average absolute value of RSS of mobile *i* in cell *j* as a weighted scheme:

$$\Delta RSS_i^j = \alpha_1 \left| RSS_i^{t-2} - RSS_i^{t-3} \right| + \alpha_2 \left| RSS_i^{t-1} - RSS_i^{t-2} \right| + \alpha_3 \left| RSS_i^{t} - RSS_i^{t-1} \right| \quad (1)$$

Where $\sum_{i=1} \alpha_i = 1$

We use the average of at least three absolute values in order to resolve the problem of moving in transition from cell to cell. Each MS_i in cell *j* measures it's ΔRSS_i^j at regular time interval. If the ΔRSS_i^j is large, it means that the RSS changes rapidly. A possible reason may be that the mobile is moving at a very fast speed.

According to the average mobiles speeds, the mobility in a cell *j* (M_j) is classified as two modes, high and low. This classification is updated periodically by using two thresholds, as given by:

$$M_j = \begin{cases} fast\ , \ if \ \ v_j \geq V_{Thr} \\ slow\ , \ if \ \ v_j \prec V_{Thr} \end{cases} \quad (2)$$

where v_j denotes the average speeds in a cell *j*.

V_{Thr} is the speed threshold.

Because the user speed is related with the slope of the RSS, the equation 2 is equivalent to:

$$M_j = \begin{cases} fast\ , \ if \ \Delta RSS^j \geq \Delta RSS_{Thr} \\ slow, \ if \ \ \Delta RSS^j \prec \Delta RSS_{Thr} \end{cases} \quad (3)$$

where ΔRSS_{Thr} denote the mobility threshold.

ΔRSS^j is the mobility in cell *j*

If the ΔRSS^j of a MS is larger then ΔRSS_{Thr} , it means that it is keeping moving at reasonable speed. Its mobility is classified as fast mobility. In contrast, if the ΔRSS^j of a MS is lower then ΔRSS_{Thr} , it means that it is keeping moving at low speed. Its mobility is classified as slow mobility. If the mobility in cell *j* is classified as fast, the reservation threshold of mobile *i* is the RSS of a MS *i* at time *t* plus the resident time in cell *j*. $RSS_{RESV} = RSS_i^{t+T_{resident}}$

Where *t* is the time when the mobile *i* enters in the cell *j*,

$T_{resident}$ is the average resident time in cell j.

If the mobility of cell *j* is classified as slow, we have to find the dynamic reservation threshold satisfied the following equation:

$$RSS_{RESV} = RSS_{add} - \Delta RSS^j \times T_{res\_prep} \quad (4)$$

where T_{res_prep} is handoff reservation prepare time between two cells divided by unit time of the computation of ΔRSS .

The HRR integrates the features of threshold time, reservation queuing, reservation cancellation and reservation pooling to minimize the false reservations and to improve the channel utilization of the cellular system.

- *Reservation cancellation:* If a reservation request is invalid after a later time (because the MS may change its moving direction, slow down its moving speed or because the call may terminate before the MS reaches the candidate cell), the false reservation will be canceled.

- *Reservation Pooling:* Once a handoff is needed, the BS will randomly choose a reserved channel from the reservation pool and assign it to the handoff call. So when one BS sends a reservation request to another BS, it does not need to send the MS' identity.

III. HANDOFF PRIORITY

Since dropping a handoff call is more annoying than blocking a new call from user's perspective, handoff calls should be given higher priority than new calls. The handoff priority is given by two processes: Admission thresholds, and scheduling handoff requests.

A. *Admission thresholds*

In this subsection, priority is given to handoff requests in admission test by defining two admission thresholds.
Priority is given to handoff requests by defining two bandwidth thresholds, say BW_n and BW_h, satisfying $BW\_n \le \mathrm{BW}\_h$, where BW_n is the new call admission threshold and BW_h is the handoff admission threshold. As resources are passively reserved for mobiles that are maintained connected to their old cells, it is possible to over allocate the soft capacity by stating that handoff reservation could be performed until a threshold BW_p is reached. Threshold BW_p is controlled by $BW\_n \le BW\_h \le BW\_p$.

The proposed call admission control algorithm is described below:

Algorithm 1.

```
Initialization
Wait for call request arrival
If the incoming call is a new access then
  If ($used\_BW \le BW\_n$) for the new user and
    ($used\_BW \le BW\_h$) for the existing users
  Then ADMIT REQ
  Else REJECT REQ
  End if
End if
If the incoming call is a reservation call then
  If ($used\_BW \le BW\_p$) for the new user and
($used\_BW \le BW\_h$) for the existing users
  Then ADMIT REQ
  Else REJECT REQ
  End if
End if
If the incoming call is a handoff call then
  If ($used\_BW \le BW\_h$) for the new users
  Then ADMIT REQ
  Else REJECT REQ
  End if
End if
```

B. *Scheduling handoff requests*

Handoff queuing schemes discusses how to line up the handoff requests. In this subsection we propose a novel scheduling handoff requests scheme that gives priority to handoff and maximizes the bandwidth utilization. Scheduling algorithms determine which request is served next among the requests waiting for service in queues at a BS. In most wireless networks [6], priority scheduling maintains control packets and data packets in separate queues and serves them in a FIFO (First In First Out) order. In the next generation wireless networks, the requirements of applications differ based on QoS requirements set by the users. For this reason, our scheduling algorithm must assign dynamically the priority according to the local information and instantaneous wireless channel quality. When a MS enters the handoff zone, it issues a handoff request to the target cell. If the target cell cannot provide adequate bandwidth for requested service, the MS is put into the *handoff queues*, and hopefully the requested bandwidth can be satisfied by later released bandwidth.

In our system, we assign different priorities to handoff calls of each class depending on their QoS profile, such as latency tolerance and bandwidth. For determining the priority for each handoff call, we define a term service class priority factor (SCPF), which depends on QoS parameters such as delay tolerance and bandwidth.

Before inserting the MS into the handoff requests queue, the initial priority, P_i, is computed by using (5), where RSS_i and $SCPF_i$ denote the received signal strength, and the service class priority factor of MS_i, respectively.

$$P_i = \frac{SCPF_i}{RSS_i} \qquad (5)$$

Then, the mobility of MS_i is determined by (3). If M_i is fast the handoff request of MS_i is inserted into high handoff queue; if M_i is slow the handoff request of MS_i, it is inserted into low handoff queue. To timely reflect the erratic mobility of a MH, its priority needs to be periodically adjusted by the equation 6.

$$P_i^0 = \Delta RSS_i^j \times P_i \qquad (6)$$

Scheduling scheme periodically updates its handoff priority according to the dwelling time (DT_i^t) which indicates how soon a MS is expected to be handoffed to the target cell. A MS which has shorter dwelling time should have higher probability to handoff into the target cell, and thus should be given a higher handoff priority.

$$P_i^t = \frac{P_i^0}{DT_i^t \times RSS_i} \qquad (7)$$

Regardless of instantaneous channel quality, the packets are served following the order of their priorities. To improve the scheduling scheme, the new scheme combines signal quality (carrier-to-interference ratio) and local information defined in the request. The scheduler is equipped by three queues: service queue *S* is used to store *ID* of selected packets for service; *R* queue is used to store packets *ID* which not respect real-time connection specification; *B* queue is used to store packets *ID* which will be retransmitted (Bad channel).

IV. PERFORMANCE EVALUATION

We used the simulation analysis to test the performance of the system. The simulation goals are: (a) to highlight the influence of resource reservation on new call blocking probability and (b) to highlight the influence of reservation thresholds on handoff blocking probability.

A. Simulation Parameters and Environments

The simulated system is assumed to consist of 3*3 UMTS base stations, and 10 Access Points as depicted in Figure 1. Each WLAN subnet controlled by a UMTS base station constitutes one network domain. The WLAN is utilized as an access network complementary to UMTS access network. AP and base station parameters are chosen similarly to what is made by [9]. We assume that the arrival rate of new calls follows a Poisson process with parameter λ. The duration of a call is exponentially distributed with mean value 1/η. Also we assume that nodes move according to the random waypoint mobility (RWM) model. The pause time is 20 seconds with a uniformly random speed between 0-15 m/s. The scheduling algorithm used at APs assigns the priority dynamically according to the local information and instantaneous wireless channel quality [16]. For UMTS, the assumed propagation model that we use in this simulation is the "cost 231 indoor office model" without floor losses and is given by [9]:

$L_{i,j}(dB) = 37 + 30\log(d_{i,j})$ where $d_{i,j}$ is the distance between *i* and *j*. The path loss in WLAN and Bluetooth is given by: $L_{i,j}(dB) = 40 + 35\log(d_{i,j})$.

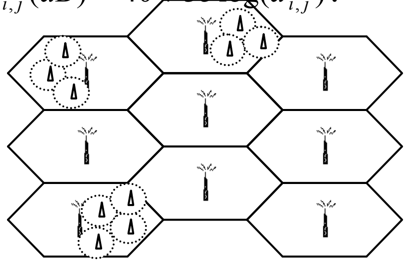

Figure 1. Simulated network

A. Results

The simulation results depicted by figure 2 show the influence of resource reservation on new call blocking probability. We remark that the new call blocking probability observed for reservation based on the static RSS is higher than the new call blocking probability observed in simulation without reservation. The main reason for this is that the system that doesn't consider a resources reservation scheme assigns an equal priority for both a new call and a handoff call and consequently, the new call blocking probability and the handoff blocking probability will be relatively equals. However, the resources reservation scheme based on the static RSS gives the priority to the handoff calls. In this case, the new call blocking probability increases especially when the number of admitted users per cell increases.

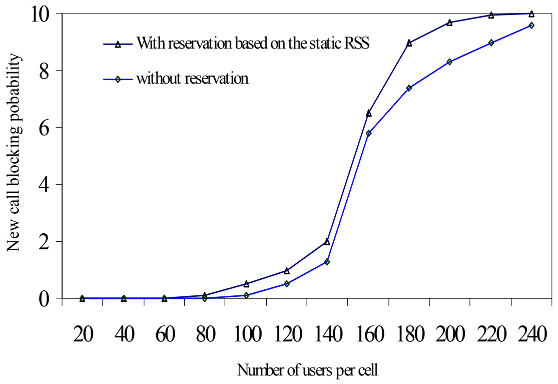

Figure 2. New call blocking probability with static reservation

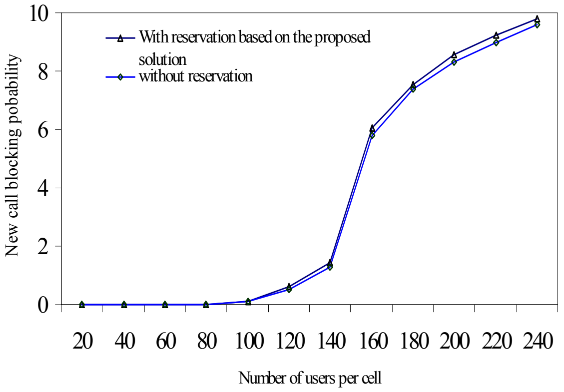

Figure 3. New call blocking probability with dynamic thresholds management

Figure 3 shows the influence of the resources reservation based on our proposed solution on the new call blocking probability. We remark that our proposal method keeps a similar new call blocking probability than the method without resources reservation. Except when the number of admitted users increases, the proposed solution privileges the handoff call than a new call. This increase (of about 0.2%) is observed for simulations involving more than 200 mobiles. This result can be explained by the fact that our proposed solution uses an optimized threshold that improves the handoff blocking probability independently of the new call blocking probability.

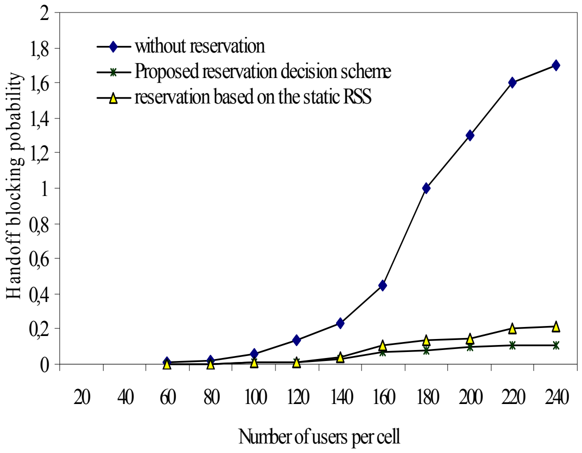

Figure 4. Handoff blocking probability

Figure 4 shows the influence of resources reservation on the handoff blocking probability. Thus, we observe the following:

- The handoff blocking probability either without reservation or with resources reservation increases when the number of users increases. This can be explained by the increase of the number of admitted users, while the resources for handoff are kept static.
- The handoff blocking probability observed without reservation is higher than the handoff blocking probability observed with resources reservation (static RSS or dynamic RSS). The main reason for this is that resources reservation schemes give the priority to the handoff call than a new call and consequently the handoff blocking probability decreases considerably.
- The handoff blocking probability observed with the proposed reservation decision scheme is lower than the reservation based on the static RSS. This is explained by the fact that the proposed solution uses a dynamic threshold that can manage efficiently the handoff mechanism.

V. CONCLUSION

To conclude, we have proposed a new resources reservation scheme for handoff that uses a dynamic threshold based on the RSS and the mobile station speed. This optimized threshold can achieve an improvement on the handoff blocking probability while keeping the new call blocking probability unchanged.

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