A Hybrid Connection Admission Control Scheme for QoS Enhancement in UMTS/WLAN Overlay Networks

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Abstract— In this paper we evaluate the performance of an hybrid and adaptive call admission control protocol for UMTS cellular networks with underlying tunnel-WLANs. either at the cell periphery or elsewhere within the UMTS coverage area. This CAC policy is proposed to limit the occurrence of hard IEEE 802.11 WLAN-UMTS handovers to mobiles using real time applications. It is based on the service class differentiation, the location in the heterogeneous infrastructure and a vertical handoff decision function as well. The results show that our policy achieves significant performance and gains. It maximizes the utilization of the resources available at the WLAN cells, and meets as much as possible the QoS requirement of higher priority users.

Keywords- Heterogeneous wireless Networks, QoS, Call Admission Control, Vertical Handoff, Handoff performance

1 Introduction

In the near future, mobile users will operate in heterogeneous environment integrating different wireless access technologies. Quality of Service (QoS) provisioning in such networks is therefore a challenging task since each access network provides different levels of QoS, bandwidth and coverage to the end user. Further, in the presence of a mix of services characterized by a wide range of QoS requirements in terms of transmission delay, throughput, etc., the system performance can vary considerably, thus rendering QoS provisioning even more difficult. Connection Admission Control (CAC) constitutes a fundamental technique for QoS provisioning that limits the amount of traffic accepted in the network in order to provide better service to accepted connections. This technique is required to maintain QoS contracts and user connectivity in an environment where users are dynamically roaming between different access technologies while supporting heterogeneous traffic.

In heterogeneous wireless access network, selecting the best network to initiate a connection is an important consideration for overall network stability. The access decision can be based on criteria such as the required QoS level, bandwidth requirement, residual capacity in each available network, coverage, power consumption and cost. Moreover, efficient admission control strategies should exploit the adaptability of certain services to give priority to non-adaptive service. Although the real-time service may have higher priority for the use of radio resources, the non real-time services also impose certain QoS requirements in terms of delay and throughput.

In this paper, a hybrid adaptive QoS oriented CAC function is proposed to meet the rapidly increasing demand for providing multimedia services with diversified quality requirements in heterogeneous network. This policy based on service class differentiation aims at maximizing the use of available radio resource while selecting the best access network and meeting the QoS requirement of higher priority users as much as possible while maintaining the minimum requirements of lower priority users, especially when the system suffers from congestion.

This paper is as follows. In the next section, we present recent works devoted to CAC, followed by the architecture of a new CAC function that we propose. After, we describe our simulation platform, and finally, we report some quantitative results followed by concluding remarks.

2 Connection Admission Control investigations: Background and related works

It is envisaged that next generation wireless networks (NGWN) will utilize several different radio access technologies, integrated to form a heterogeneous network. An interesting example is the heterogeneous environment consisting of an UMTS cellular network and a WLAN. These access networks are characterized by their soft capacity and the support of multiple heterogeneous services with diverse quality requirements. In this context, the Connection Admission Control becomes a complex problem. It is responsible for making access decisions in response to a user’s access request,
and then facilitates high capacity and spectrum efficient network usage.

Recent works on radio link management in wireless networks highlights the importance of access control techniques [1]. These techniques have been primarily proposed for the homogeneous networks. Today, they are defined as “Conventional” algorithms. The most representative of them and those designed for NGWN heterogeneous networks will be presented in this section. For example [2] proposed an algorithm based on complete partition using the guarded channel policy to differentiate between new and handoff voice calls. In this scheme, a common dynamic partition (DP) scheme, $K_1$ out of the $C$ channels of a cell are reserved for both new and handoff voice calls and $K_2$ channels are reserved for data calls. The remaining $(C-K_1-K_2)$ channels are shared in a fair manner by both voice and data calls. New voice calls can only use $K_3$ out of the $K_1$ channels.

According to the DP algorithm, when a new voice call arrives, a channel is sought in $K_1$. If a channel is available there, it will be admitted. Otherwise, a channel is sought in the shared area. It will be blocked if there is no channel in both $K_1$ and the shared area. When a handoff voice call arrives, a similar search is done in the voice only area and then the shared area. It will be dropped only if there is no channel available both in the voice only and shared area. A similar decision is made for a data call arrival by first searching in the data only area and then the shared area.

In the DTBR scheme, an algorithm developed a “Non Conventional” CAC scheme in the context of a UMTS-WLAN architecture. Its features are presented in the following.

In DTBR, the C channels of the cell are divided into three regions by two thresholds $K_1$ and $K_2$ ($K_1 > K_2$). When the network occupancy level $L$ is less than the threshold $K_2$, both voice and data calls can be admitted into the system. When $L$ is greater than $K_2$, no data call can be admitted into the system. When $L$ is greater than $K_1$, no data call or new voice call can be admitted to the system. A handoff voice call will be dropped only if there is no channel available.

One of the good features of the DTBR algorithm is that a higher priority call is never rejected while there is a bandwidth available for a lower priority call.

However, the idea of effective bandwidth was used in [5] to assign effective bandwidth to a given multimedia service according to its traffic profile. Admission requests are grouped into different classes and interference from each class is characterized. New users are assigned their effective bandwidth based on QoS targets according to their classes and call admission control admits new users of a particular class if total interference of all the classes is less than threshold. Hierarchical priority schemes have been studied [6] for multimedia services requiring soft and strict QoS requirements to set priorities at call level and burst level. [7] presents two different principles on which the CAC can be based. The first one indicates that admission control is performed according to the type of required QoS. In this case, the CAC is performed only for some types of service, like conversational and interactive. It is not performed for background class since no guaranteed QoS is required. For the second principle, the CAC is based on the current system load and the required service. In this way, if none of the suitable cells can efficiently provide the required QoS, the call should be blocked avoiding that the required service leads to increase the interference level to an unacceptable value. This action ensures that the UE avoids wasting power affecting the quality of other communications. In this case, it is also possible that the network initiates a re-negotiation of resources of the ongoing calls in order to reduce the traffic load.

More recently, CAC algorithms between heterogeneous wireless networks, have been proposed. In [8], authors describe a CAC algorithm with service differentiation for voice and data traffic in a topology where isolated hotspots are meshed into a larger cellular network. In [9], a two-tier architecture for a wire/wireless CAC is proposed. Calls that are likely to perform handovers in the future are given the highest priority of admission. A measurement-based handover decision algorithm is proposed in [10], in a loose coupling architecture between Wide Area Access Networks and isolated WLAN networks. A micromobility management method is proposed to mitigate the impact of handovers on performance. To support heterogeneous networks, adaptive policies based access management systems were also proposed. In [11] for example, a bandwidth adaptation scheme based on per flow degradation was proposed for heterogeneous wireless networks by defining a concept called degrade profile. In the cases where the bandwidth of an access network is full and the ongoing calls are using bandwidth more than the minimum needed bandwidth, degradation is done upon arrival of new or handoff calls. Here, in order to admit calls, this scheme degraded the longest calls in the system with a hope that those flows have bigger probabilities to quit the system and leave fewer degraded connections. The authors in [12] proposed a bandwidth adaptation scheme based on per class degradation. Here, in order to admit a call, the lower possible priority class calls are degraded. Ongoing higher priority class calls are not affected by arrival of lower priority calls. The performance analysis in [12] showed that the per class adaptation scheme is better in terms of fairness (by treating flows of the same class equally) and simplicity. But the per flow scheme is better in terms of resource utilization.

On the basis of the policies presented above, we have developed a “Non Conventional” CAC scheme in the context of a UMTS-WLAN architecture. Its features are presented in the following.

3 A Next Generation Call Admission Control Algorithm: description and Architecture

We propose a hybrid Call Admission Control algorithm for new call requests to limit the occurrence of handover-UMTS handovers that may cause a disruption in the packet flow, if connections could be handled by neighboring WLAN access points. Several parameters are taken into account in the admission decision either into the WLAN hotspot or into the UMTS cell. These parameters include the position in the network, the anticipated direction, the type of service, the available bandwidth, the interference levels, the power consumption and the information security.
On the other hand, this policy is also proposed to reduce the call dropping rates while performing horizontal handoffs within an UMTS cellular network. Its performance on users operating inside the overlapped coverage area between two UMTS cells with underlying border-WLANs (i.e., WLANs deployed at the UMTS cell-periphery) are estimated.

The CAC algorithm evaluation is primarily performed considering two WLAN hotspots with overlapping coverage area integrated inside one UMTS cell coverage area. In this system, users are equipped with dual UMTS and WLAN interfaces and move across cells. In a first step [13], we will identify three categories of users based on the type of handover they are likely to perform. Each of them can use either a real time or a non real time service. The users’ categories 1, 2 and 3 are defined according to the call origination point and the anticipated direction, on which depend in part the priorities assigned to them.

Users of category 1 are connected to WLAN1 and move out its coverage area towards WLAN2 and redirect their connections to its access point AP2. If they are rejected, they perform a handover to UMTS. Users that are establishing new connections inside the WLAN2 hotspot and trying to connect to its access point belong to the category 2. In case they are rejected, they use the UMTS network. The users of this category have the same characteristics of those of category 3 except that they are operating within the overlap zone between two UMTS cells and trying to perform a horizontal handoff.

To accommodate horizontal handoffs of users of category 1 from H-WLAN1 to H-WLAN2, we use the concept of degrade profile and we can effectively degrade the connections of other category 4 users. The use of such bandwidth adaptation scheme can guarantee the satisfied QoS level to the end category 1 user of real time services.

We consider that not all calls likely to perform a handover should be given a higher priority of admission. The priority level will be given according to the user category.

As WLAN technologies are short-range networks and offer lower cost to users than UMTS, the vertical handoff from UMTS to WLAN was defined in [15] as a desirable handoff. On the other hand, the mobile terminal’s connection has to remain seamless as a user connected to the WLAN roams out of the WLAN domain. Thus, the handoff from the WLAN to the UMTS was defined to be a necessary handoff. This type of handover that should be given the higher priority, is then qualified as a hard handover since it may cause a disruption in the packet flow. Users of category 1 are then given the highest priority over all other users. Admission to the WLAN hotspot implies a faster connection set-up time, and thus category 2 users are given an intermediate priority. Users of category 3 are given the last priority since these users are performing desirable handoffs.

In a second step, a fourth category of users will be considered and concerns those operating in the cell periphery within the overlapped coverage area between two UMTS cells as depicted in figure 1. Communicating hybrid users in an UMTS cell access border-WLANs (known as Handoff-cooperative WLAN and denoted H-WLAN [14]) when they are inside their coverage area, as soon as horizontal handoffs are required and no channels are available in the neighboring cells.

The users of this category have the same characteristics of those of category 3 except that they are operating within the overlap zone between two UMTS cells and trying to perform a horizontal handoff.

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The new handover-based CAC scheme we elaborated takes into account both the user category and the class of service differentiation. Thus, it will be designed as “Adaptive and Hybrid” and it will be given the acronym “A-HCACH” for “Adaptive Hybrid CAC scheme for Heterogeneous multimedia wireless networks”. Let \( \alpha_j \) be the percentage of bandwidth assigned to the category “j” of users, \( j \in \{1,2,3,4\} \). \( \alpha_4 \) is equal to \( \alpha_3 \) as users of category 4 are those of category 3 connected to H-WLAN and performing handoffs between UMTS cells.

We define a resource allocation function to which we give the acronym “RAF”. It combines the user category and the priority of the class of service to which belongs the application currently in use, according to the following formula:

\[
RAF_{jk} = \alpha_j / p_k \quad and \quad p_k = k, \quad k \in \{1,2,3,4\},
\]

(1)

Where \( p_k \) denotes the precedence class. It defines the priority assigned to the class of service in use by the mobile node. When a user \( u \) is trying to access the WLAN hotspot and requesting a bandwidth equal to \( B_u \), it will be assigned to category \( j \) and given the priority level \( p_k \).

The mobile node will be admitted in the WLAN only if the following condition applies:
Let $C_{\text{HO}}$ be the amount of channels reserved within a border-WLAN to data users connected to an UMTS base station and have missed their handoffs to neighboring cells. These channels are therefore created to handle vertical handoffs of users when no channels are available for them in the target UMTS cell while their energy per bit to noise density ($E_p/N_0$) in the current UMTS cell becomes below a defined threshold.

Within the same category of users, a voice call have the highest priority over all ongoing connections ($Q_u=1$). However, the power consumption (P) of mobile terminals using short battery lifetime, will have less priority than mobiles with full battery, when they redirect their connections to a higher power consuming network.

As for users of category 4 within the H-WLAN, $C = C_{\text{HO}}$.

When $B_C > RA F_{j,k} \ast C$, then only users having a $RAF$ value superior to $RAF_{j,k}$ are admitted in the WLAN hotspot. For example, when a user A of category 2 ($\alpha_1=0.8$) initiates a voice call and that cannot be admitted in the UMTS network, it will have more priority ($p_1=1$) then a user B of category 1 ($\alpha_1=1$) that requests resources to use the video streaming service ($p_2=2$).

Within the same category of users, a voice call have the highest priority over all ongoing connections ($p_1=1$). However, the WLAN is preferred to be always filled with data calls, and then a new voice call is admitted in the WLAN only if it is not able to be admitted by the UMTS network. This condition is applied for users initiating their calls within the WLAN coverage area as well as for category 3 of users. Users of this category will have lower priority than users starting new calls within the WLAN cell.

Streaming services are very sensitive to access delay and have priority over all other ongoing data packets. They are followed by interactive and after by background traffics.

As A-HCACH scheme is based on the class of service differentiation; the requests belonging to competing mobile stations will be queued according to their class of service. For users of the same category, using the same class of service and therefore the same $RAF$ value, their requests will be served according a priority function that we propose. It provides a measure of the priority level, $Q_u$, given to each user that competes for the resources within the WLAN network. This function is defined as the following:

$$Q_u = \frac{w_1(S_u)}{\max(S_1,...,S_n)} + \frac{w_2(D_u)}{\max(D_1,...,D_n)}$$

This function is derived from the vertical handoff decision function, denoted “VHDP”, originally developed by [16] to make wiser the handoff decisions. The function presented in (4) depends on four parameters:

- The power consumption (P): mobile terminals with nearly exhausted battery or equipped with relatively short battery lifetime, will have less priority than mobiles with full battery, when they redirect their connections to a higher power consuming network.
- The security (S): when the information being exchanged is confidential, a network with high encryption is preferred. Thus, if a WLAN offers a highest encryption performance, mobile nodes exchanging confidential information are given the highest priority.
- The network performance (F): mobile terminals with the strongest signal strength have the highest priorities.
- The required bandwidth (D): Mobile terminals using bandwidth hungry applications are given the highest priority.

$w_p$, $w_s$, $w_t$ and $w_d$ are weights for each of the network parameters and obtained from the user via a user interface. The values of these weights are proportional to their significance to the network access. The larger the weight of a specific factor, the more important that factor is to the user and vice versa. These weights range from 0 to 1, and add up to 1.0.

Each network parameter has a different unit; this leads to the necessity of normalization. The final normalized equations for $n$ users who tempt to access to the network at the same time are then presented by (4).
In [16], VHDF includes another parameter relative to the cost of service in the network. Mobile nodes choose the network to which they will be admitted or redirect their connections according to the VHDF-based priority scheme. It gives a priority level value $Q_u$ to competing users as the following:

$$Q_u = \frac{w_p \left( \frac{1}{P_{u0}} \right)}{\max \left( \frac{1}{P_1}, \ldots, \frac{1}{P_j} \right)} + \frac{w_s (S_u)}{\max (S_1, \ldots, S_n)} + \frac{w_f (F_u)}{\max (F_1, \ldots, F_n)}$$

$$+ \frac{w_C \left( \frac{1}{C_u} \right)}{\max \left( \frac{1}{C_1}, \ldots, \frac{1}{C_n} \right)} + \frac{w_d (D_u)}{\max (D_1, \ldots, D_n)}$$

(5)

$C$ denotes the cost of service parameter and $w_i$ its weight. Mobile terminals offered a low cost service will have more priority over other ongoing mobile nodes.

So, in resume, for the proposed A-HCACH handover-based CAC scheme that we propose the available bandwidth will be shared between users according to their categories that we defined (i.e. depend on call origination point and the anticipated direction) and the application type in use. Users of the same category requiring the same bandwidth will access to the network in an order of priority defined by the function given in (4). In the next section, the performance of this algorithm will be compared to those obtained with a handover-based CAC policy for which mobile nodes access to the networks according to their priority levels given by VHFD.

In order to offer better QoS to users of category 1 while using real time services, we enhance the proposed A-HCACH allocation scheme by using a pre-emption mechanism. Thus, lower priority categories with lower priority services can be pre-empted or forced out of the WLAN hotspot. The first pre-empted users are those having the weakest signal strength. If enough bandwidth is freed, the pre-emption procedure is stopped. Otherwise, the procedure resumes with the next user in the list. The procedure is repeated until the pre-empted bandwidth $B$ satisfies the following condition:

$$B_C + B_a \times (C_{\text{max}} - C_{(i)}) \quad \text{for H-WLAN}$$

(6)

and

$$B_C + B_a \times B < C_{\text{max}} \quad \text{for NB-WLAN}$$

(7)

This proposed A-HCACH protocol has then the benefits to admit more category 1 users in the WLAN hotspot and thus limiting the occurrence of costly WLAN-UMTS handovers.

### 4 Performance Evaluation

#### 4.1 Simulation Platform

We investigate the effect of the A-HCACH policy on the IEEE 802.11g and UTRA-TDD networks performance. The investigation is performed using a flexible discrete time simulator based on the programming language C++ that we have developed. It describes a real world environment. It uses as time unit an equal TDMA framework period duration. Both time and spatial dimensions of the traffic variations are taken into account. Time variation of traffic is represented as arrival process, call duration or packet length for various types of services, and spatial variations characterize the user mobility in the cellular area.

The cellular network consists of 21 micro-cells with 1000m coverage area serving both packet-switched voice and data calls, and the performance evaluation is performed only for mobile nodes operating within only one UMTS cell. This is to evaluate the interference that affect the communication of each user operating within the current UMTS cell. The edges of the whole network system are wrapped around such that the “border effect” is suppressed, as in a real world environment. Within the UMTS coverage area are integrated 2 overlapped IEEE 802.11g cells (cf. figure 1). Their coverage area is 100m radius circle.

In this system the delays introduced by the information exchanges either between the access point and the stationary server or between the base station and the stationary server are neglected.

All users are pedestrians. They move across cells at the velocity of 3 km/h, crossing cells boundaries impacting on the quality of received signal of their resident cell.

For simplicity, we consider that within the WLAN networks, the radio propagation is performed considering the free space model [17]. As in the UMTS network, we have chosen the three stages propagation model which characterizes the main effects which impact the mobile radio channel: path loss, fast fading and shadowing [17]. It aims mainly at estimating CIR ratio for each communicating mobile terminal. For the division of slots within a frame, we have chosen the combination of 8/7 for Downlink (DL)/Uplink (UL).

In our UTRA-TDD system, the power control procedure and the handover management are performed every 0.5 s which acts as the mobility time unit.

For users of category 1 and 2 that are redirecting their connections to the UMTS network, an interference-based CAC scheme is used to control their admission. In such network, each new call increases the interference level of all other ongoing calls, affecting their quality [18].

For each class of service, the interference parameter taken into consideration when the access to the network is controlled varies along simulation and is maintained under defined static threshold. For each user equipment reaching the UMTS network, the energy per bit to spectral noise density ratio target is computed as the following:

$$\left( \frac{E_b}{N_0} \right)_u = \frac{W}{D_0} \times \left( G_0 \times \sum_{i=1}^6 P_0 + \sum_{j=1}^6 G_j \times P_j \right)$$

(8)

where $W$ is the WCDMA chip rate, $P_u (u=1..N)$ is the received signal power from the user $u$ and $N$ is the number of active users’ in the current cell, $P (j=1..6)$ is the transmit power from the current base station, $D_u$ is the transmission rate, $\gamma$ is the orthogonality factor and $G_j (j=0..6)$ is the signal
attenuation between user and the current base station (Node B), computed using the three-stage propagation model [17].

\( G_0 \) is defined as the signal impairment between the user and the current base station.

The inter-cells interference can be approximated by \( G \times P_n \), where \( G \) is the signal attenuation between the current and the interferer base stations, and \( P_n \) is the maximum transmit signal power of all base stations. The formula (8) becomes:

\[
\begin{align*}
\left( \frac{E_s}{N_0} \right)_u &= \left( \frac{W}{D_u} \right) \times \frac{G_0 P_n^0}{\gamma \times G_0 \times (N-1) \times P_n^0 + G \times P_n} \\
\end{align*}
\]  
(9)

For each type of service, the maximum number of users depends on the energy per bit to noise density threshold \( (E_s/N_0)_{\text{threshold}} \). It is defined by:

\[
N_{\text{max}} = \left[ \frac{1}{\gamma + \left( \frac{W}{D} \right) \times \left( \frac{E_b}{N_0} \right)^{-1} \text{Threshold}} \right]^{-1}
\]

\( \lceil x \rceil \) designates the whole part of the variable \( x \).

If the number of admitted users becomes over \( N_{\text{max}} \), the connection will be rejected.

The traffic generated by each user in the system can be of the following types: voice, video streaming, web browsing, and E-mail.

They are modelled respectively as a conversational, real-time streaming, interactive, and background traffics as outlined in [18, 19]. The first three types of services are mapped over guaranteed services (GS), while the E-mail application is best effort (BE) traffic having no delay constraint. In the presented simulation campaigns the system is loaded by the heterogeneous traffic according to the following percentages: voice, 35 percent; video streaming, 20 percent; web browsing, 20 percent, and E-mails, 25 percent.

Since we use a discrete time simulator, the new packet-switched calls are generated with Poisson distributed process either in the WLAN network or in UMTS.

Internet packet data service traffic is based on the model outlined in [19]. The traffic model is intended to represent HTTP browsing session by user. And as we are interested only to the uplink, calls represent the pages downloading requests.

Video streaming model represents an MPEG-4 streaming data. The service bearer is modelled as a constant bit rate circuit switched data service with 100% activity. The packet sizes vary depending on the type of video frame. There are three types of frames, namely I, P and B frames log-normally distributed and having the mean size and the variance of respectively (775 bytes, 97656), (100 bytes, 4727) and (63 bytes, 1405). The frames are produced periodically and in the deterministic IBPBPPBBPBBPBB sequence (15 frames per second). The maximum throughput is 115.2 kbps and the maximum packet delay is 0.25 s. Frame generation is done according to [20] and the video streaming parameters are based on a statistical survey of frame statistics [21]. We assume that the size of the video pictures is: QCIF 176x144 pixels. Like all other considered applications, the inter-arrival of E-mail sessions is Poissonly distributed and varies between 0 and 120 s. The maximum throughput is 64 kbps and the maximum packet delay is 64s. The \( (E_s/N_0)_{\text{threshold}} \) values for the speech, the WWW, the video and the E-mail traffics are respectively 3.8, 3.3, 1.4 and 1.2.

B. Simulation Results

We compare the performance of the handover-based A-HCACH policy with those of VHDF-based CAC scheme that we have simulated for real time video streaming service. To show the advantages of A-HCACH, we evaluate the performance of this algorithm for category 1 users which move from WLAN1 to WLAN2 and try to redirect their connections to the access point AP2.

We performed simulation while neglecting the users power consumptions and the security of the information being exchanged by giving the same weights to all users or simply by considering \( w_p = w_i = 0 \). As we are investigating the performance of the proposed algorithm only for the video streaming service, we consider that the cost of service will be also the same for all competing users. Thus, this parameter could be neglected in this case of simulation.

The two remaining parameters in the function (4) are then the user required bandwidth and the signal strength. As video streaming is bandwidth hungry, i.e. bandwidth must be the most significant parameter, users will be given a weight \( w_d = 0.9 \). The weight \( w_t \) relative to the network performance is therefore equal to 0.1.

In this investigation, the quality measures reported are the percentage of satisfied real time (RT) users, the blocking and the dropping probabilities. Users of video streaming application are satisfied if packets are received in less than 250 ms during 95% of the session duration.

Figure 3 exhibits the blocking probabilities of category 1 users and those performing handoffs from AP1 to AP2 while performing respectively the A-HCACH algorithm and the VHDF-based CAC policy. Figure 4 reports the rates of satisfied users while performing the two algorithms.

The exhibited results obtained while considering only the first three categories, show clearly that A-HCACH enhances the rates of satisfied users by giving more priority to mobiles nodes coming from other WLAN and therefore accepting fewer users of other categories in the cell. This means less hard WLAN-UMTS handoffs and less congestion. When A-HCACH policy is performed, the rate of satisfied users remains over 95% if the system load is below 7.5 Erlangs.

Users of category 1 in the WLAN2 network will intuitively have the lowest blocking probability since they have the highest priority over categories 2 and 3. Due to the limitation of the bandwidths assigned for categories 2 and 3, Figure 5 reports that due to the limitation of the bandwidth assigned to...
categories 2 and 3, the overall blocking probability in WLAN2 is higher than the blocking probability obtained for one block bandwidth scheme ($\alpha_1=\alpha_2=\alpha_3=1$) when a multiple bandwidth reservation is being used for the different categories ($\alpha_1=1$, $\alpha_2=0.8$, $\alpha_3=0.6$ for example). It becomes higher within a H-WLAN from about 5 Erlangs.

In figure 6 we compare the blocking probabilities for each class of service used by the mobile nodes that redirect their connections to WLAN2 while performing A-HCACH. This comparison is done for the two scenarios of bandwidth reservation. Although category 1 users have always the highest priority, this figure shows that instead of confounding themselves, a little gap separates the two blocking probability curves relative to each scenario for the video service users. This gap is due to the fact that in some cases, the $RAF_{ij}$ value assigned to category 2 mobile terminals using voice calls may be higher than the value assigned to video streaming users of category 1.

Users of the best effort traffic (E-mail) have the highest blocking probability since they are assigned the lowest percentage of bandwidth and have the lowest priority. The overall rate of blocked background users in WLAN2 which belong to lower categories will grow up when they are preempted by users of category 1.

Figure 7 exhibits the impact of the border-WLANs on the dropping probability on horizontal handoffs in UMTS networks. With A-HCACH, the dropping probability of horizontal handoffs in UMTS decreases from 4.5% to about 2.9% at a load of 9 Erlangs. As shown in figure 8, this probability depends on the amount of guard channels reserved to users of category 4.

In figure 9 we report only the gain obtained for the category 1 streaming real time traffic when lower categories are preempted by category 1 mobile nodes. At the same load of 9 Erlangs for example, the blocking probability decreases from about 3.9% to 2.4% in NB-WLAN and to 3.2% in H-WLAN. This is because of the guard channel reserved to users of cat 4. The simulation run takes duration of about ($10^6$ * simulation time unit) to achieve a confidence level of 95%. Beyond this time of simulation, the confidence level remains the same. Confidence intervals are shown in figure 6 as red dash lines.

In all curves the arrival rate of voice and data users is varied to study the heterogeneous system under increasing load conditions. The validation of results by analytical model is very difficult since the full details of a dynamic CAC function with users’ mobility and propagation environment cannot be described by formulas usable in practice.
In this paper, we have proposed an efficient CAC scheme for QoS enhancement in integrated UMTS/WLAN networks. The proposed protocol is hybrid, based on the service class differentiation, on a vertical decision function, on the anticipated direction and the originating point of a handover that can occurs between UMTS and WLAN cells as well. The performance evaluation has shown that the proposed scheme, called A-HCACH, provides better service to accepted real-time connections and assures better performance to heterogeneous networks by reducing the sessions’ dropping rates within multimedia cellular networks with underlying tunnel-WLANs. QoS performances of this new policy are shown under real world heterogeneous wireless network traffic conditions. Future work includes performance analysis of the proposed scheme while optimizing the number of dedicated channels within the border-WLANs and considering the cost and the encryption level of the data to be exchanged.

5 Concluding Remarks

References


