A Resource Management Strategy for Interconnected WLAN and UMTS Networks based on User Mobility, Call Renegotiation, and Call Reallocation

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***Abstract*—The users of telecommunications services are demanding access to their subscribed services in mobile contexts. This demand leads to the development of mechanisms that enable the transference of service sessions between networks, seamlessly to the user. These mechanisms allow the operator to jointly manage its networks resources, providing a better service to its customers and, simultaneously, increasing its revenue.**

Starting from the UMTS and WLAN interconnection architecture defined by 3GPP, this paper presents a new strategy for joint radio resource management, suitable for contexts where these networks are interconnected. This strategy bases its decisions on criteria related to user mobility characteristics. The algorithm also introduces the possibility of renegotiating new calls and reallocating running calls from one access network to another.

The new radio resource management strategy is compared with two well-known strategies, the former based on coverage area and the later based on load balancing. The comparison studies show the proposed strategy outperforms the other strategies in what concerns call blocking probability and applications QoS support. Besides, the proposed strategy tends to reduce the handoffs between networks.

I. Introduction

The recent evolutions in telecommunications have been influenced by the crescent need of users to access their subscribed services in mobile environments. This demand has determined two complementary research lines in this area. On one hand, multimode terminals have been developed, being capable to access different network technologies, particularly wireless technologies, such as Universal Mobile Telecommunication System (UMTS), Wireless Local Area Network (WLAN), or Bluetooth. On the other hand, the interconnection of different access networks has been researched and defined, enabling call transference from one interface to another, seamlessly to the user.

In a context where one telecommunications operator administrates different network technologies in the same physical location, a joint and efficient management of those networks resources is desired. This will certainly improve the service offered to the users and, at the same time, will increase the operators' revenue.

The 3rd Generation Partnership Project (3GPP) has defined a generic interconnection architecture between 3G networks and WLAN, illustrated in Fig. 1 [1], [2]. The release 8 of 3GPP promotes solutions for networks interconnection following a seamless mobility approach, characterized by providing the service independently of the technology used to access it.

Starting from the 3GPP architecture, this paper proposes a new strategy, called MTend, for the joint radio resource management (JRRM) in a context where the user is located in a place covered by different radio access technologies. This strategy bases its behavior in criteria related with user mobility. Additionally, in a scenario of low available resources, the strategy introduces the possibility of renegotiating requests of new calls or reallocating existing calls from one network to another.

In the next section, some important related works are presented. Section III proposes the new strategy for joint management of multi-radio resources, based on user mobility and the renegotiation or reallocation of calls; this section also describes the decision algorithm used to define the interface to which a new call should be allocated. Section IV presents the simulation scenario used to validate the strategy proposed in this paper. Section V analyzes in detail the simulation results. Finally, Section VI presents the conclusions and points out directions for future work.

II. Related Work

The joint multi-radio resource management is an well accepted research area in telecommunications. It promotes solutions for the support of Quality of Service (QoS) classes while optimizing the usage of resources.

A strategy based on service classes is proposed in [3], where the authors use two policies: the first policy gives priority to voice calls in GERAN and interactive traffic in UTRAN; the

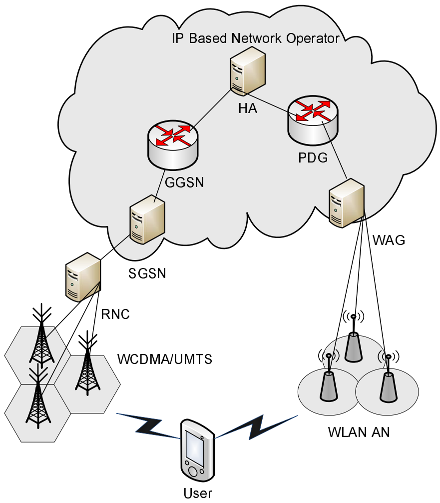


Fig. 1. 3GPP generic architecture for the interconnection of 3G and WLAN networks

second inverts the choice. According to the authors, when the mobile stations are close to the cell there is no difference between both strategies. On the other side, when the distance to the cell increases, more transmission errors occurred due to WCDMA characteristics, leading to a higher degradation in UTRAN users. In this case, the first policy is the most efficient one.

Two other strategies commonly used in this context are the load balancing (LBal) and the coverage area (CovAr) strategies, which will be used for comparison with the strategy proposed in this paper. The LBal strategy is characterized by directing calls to the interface with lowest load, maintaining the interfaces balanced [3], [4], [5].

The CovAr strategy directs calls preferentially to the interface associated to smaller area cell. For example, in hotspots the calls are directed firstly to the WLAN network until it saturates, and then to the UMTS network [4].

III. JRRM Based on User Mobility, and Call Renegotiation and Reallocation

The multi-radio resource management strategy proposed in this paper, called MTend, aims to maximize the use of the radio resources, while satisfying the QoS requirements posed by the applications.

Fig. 2 represents the structure of the decision algorithm used for the joint management of interconnected UMTS and WLAN radio resources under the control of the same operator. When a new call request arrives, the algorithm decides to which interface it should be directed, based on the call characteristics and resources available. In a scenario where both networks have resources available, the strategy is based on the Mobility Tendency of the users, differentiating applications according to their tendency for mobility. For example, voice calls are inherently mobile, since the probability of a user receiving or starting a call in movement is relatively high. Thus, this strategy gives priority to mobile applications in the UMTS network, in order to avoid vertical handoffs between different network technologies. Applications usually used in static contexts (e.g., web browsing and videostreaming) are accepted preferentially in the WLAN network.

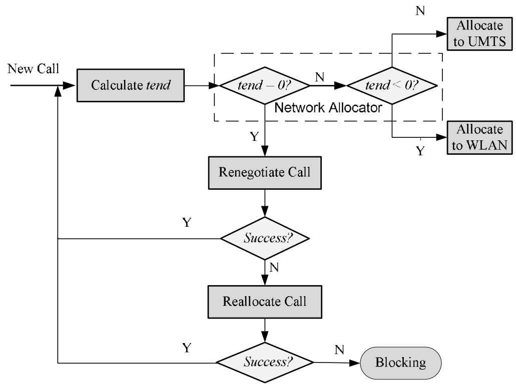


Fig. 2. Joint multi-radio resource management algorithm

In scenarios of insufficient resources, our strategy proposes two complementary mechanisms. The first mechanism consists of renegotiating the resources requested by the new call; the second mechanism considers the possibility of reallocating an accepted call from one network to the other, enabling resources to be freed in the congestioned network. The renegotiation and reallocation mechanisms require the monitoring of each access network so that their level of congestion can be evaluated.

The renegotiation mechanism consists of two renegotiation tries. In a case where the first try does not succeed, the system enables the application to reduce again the resources requested. Table I contains the renegotiation parameters for two applications.

TABLE I
APPLICATIONS BIT RATES AND THEIR RENEGOTIATION ALTERNATIVES

Application	**Mean bit rate (kbit/s)**		
	1st Request	1st Renegotiation	2nd Renegotiation
Voice	24	12	8
Videostreaming	128	64	32

The following paragraphs formalize our decision algorithm. The network interface selected to serve the new call is chosen according to Eq. (1), where *tend* represents the decision tendency. The indicator function 1_y is 1 if the event y is true, else it is zero. P_{UMTS} and P_{WLAN} are the eligibility degrees given to an arriving session, respectively to be transported over the UMTS and WLAN interfaces, as show in Table II.

$$tend = P_{UMTS} * \mathbf{1}_{\eta a_{UMTS} \geq \Delta_{\eta r}} - P_{WLAN} * \mathbf{1}_{Bw_{WLAN} \geq r} \quad (1)$$

The ηa_{UMTS} and Bw_{WLAN} variables are, respectively, the available UMTS load factor and the available bandwidth in the WLAN interface. In UMTS, the load factor estimates the amount of supported traffic per base station site; in [6], the authors describe the mechanism to obtain the available UMTS load factor. The available bandwidth in the WLAN interface

TABLE II
UMTS AND WLAN ELIGIBILITY DEGREES ACCORDING TO THE USER MOBILITY CRITERION

Application		Eligibility Degree	
		P_{UMTS}	P_{WLAN}
Voice		2	1
Videostreaming		1	2
Videophone	Voice	2	1
	Video	1	2
www		1	2
FTP		1	2

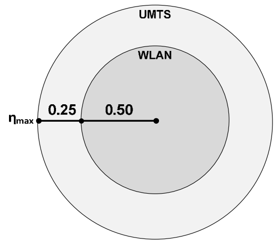


Fig. 3. η_{max} distribution according to users location - inside/outside *hotspot*

is obtained by monitoring the channel occupation ratio, as described in [7]. $\Delta_{\eta r}$ is the UMTS load factor associated to a new call and it is obtained also as described in [6]. r is the WLAN mean bit rate requested by the new call.

The network selected for an arriving call is given by Eq. (2).

$$\text{Network Allocator} = \begin{cases} \text{WLAN}, & \text{if } tend < 0 \\ \text{Reneg / Realloc}, & \text{if } tend = 0 \\ \text{UMTS}, & \text{if } tend > 0 \end{cases} \quad (2)$$

IV. SIMULATION SCENARIO

In order to demonstrate and evaluate the joint radio resource management strategy proposed in this paper, we considered a simulation scenario corresponding to an hotspot located in a shopping center. We adopted simulation scenarios where the number of users varies from 100 to 1000 and, in the busy hour, each user is involved, in average, in 6 calls, each with an average duration of 120s. We assumed that 50% of the calls are voice calls and the other 50% are videostreaming calls, i.e., only the two first applications from Table II were considered in the simulations.

The simulation system was implemented in Network Simulator 3 (NS-3) [8], being the UMTS interface developed as a statistical module, based in [6], [9]. NS-3 already implements the IEEE 802.11 multi-rate standard (i.e., 6 Mbps to 54 Mbps) [10], [7]. We assumed that the UMTS network supports applications with QoS requirements, while the WLAN network does not integrate any mechanism for QoS support.

In UMTS network, the usual value for the maximum load factor, η_{max}, is 0.75 [6]. Fig. 3 shows the η_{max} distribution in the context of an hotspot scenario. We assumed that the user density inside the hotspot is, in average, twice the density in the remain of the UMTS cell. In this case, the load factor inside the intersection area of both technologies was considered 0.50, being the remaining 0.25 applied to the outside of the intersection area.

The simulations presented in this paper used voice and videostreaming traffic parameterized according to the Table I [11], [12].

V. RESULTS ANALYSIS

In this section we present and discuss the results obtained through the simulation of three joint multi-radio resource management strategies using the scenario described in Section IV. The objective is to compare the behavior of the strategy presented in this paper, identified as Mobility Tendency (MTend), with two other strategies, namely the Load Balancing (LBal) strategy and the strategy based in the Coverage Area (CovAr).

The parameter used to compare the three strategies is the call blocking probability (CBP). This probability is given by

$$CBP(\%) = \left[1 - \frac{C_{acpt}}{C_{off}}\right] \times 100,$$

where C_{acpt} is the number of application calls accepted, and C_{off} is the total number of calls offered to the system.

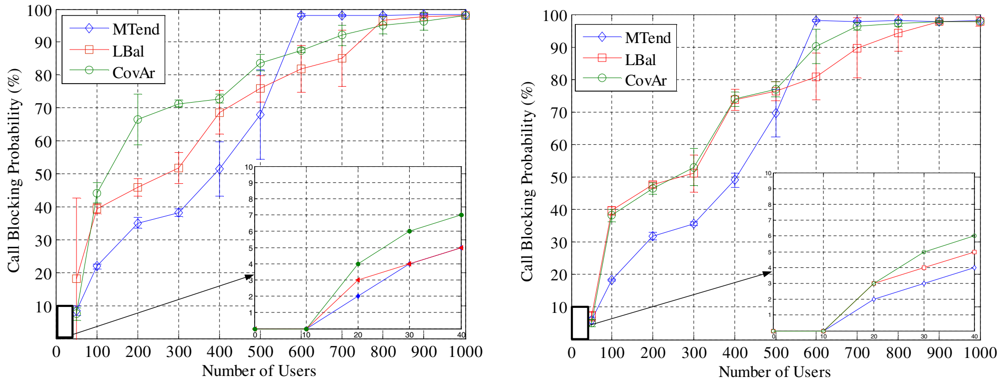
Fig. 4 (a) shows the average values and the 95% confidence intervals of the call blocking probability for all strategies. These strategies present very high probablities for a number of users above 600, reaching a call blocking probability of almost 100% between 900 and 1000 users. The MTend strategy presents a performance better than the other two, having a call blocking probability always below the other two strategies until the number of users reaches 500.

The box inside Fig. 4 (a) shows the performance of the resource management strategies for scenarios with a reduced number of users, from 10 to 40. The MTend strategy still has a better performance than the other two strategies in those scenarios, obtaining call blocking probabilities under 2% for a number of users less than 20.

The most interesting analysis should be done for low call blocking probabilities, under 20%, which are the values considered by an operator for a real service provisioning scenario. Fixing a call blocking probability, the gain obtained with the MTend strategy comparing with the concurrent strategy S is given by Eq. (3).

$$G^{CBP}_{MTend\_S} = \frac{Users_{MTend} - Users_S}{Users_{MTend}} \quad (3)$$

For example, for a call blocking probability of 2%, $Users_{MTend} = 20$ and $Users_{LBal} = 16$, i.e., 20 users have used the network with the MTend strategy, while for the strategy LBal only 16 users have used the network, what gives a gain of $G^{2\%}_{MTend\_LBal} = 20\%$. For CovAr strategy, the gain is $G^{2\%}_{MTend\_CovAr} = 25\%$. It means that the operator supports 20% to 25% more users with the MTend strategy than with the other two resource management strategies, for the given call blocking probability.



(a) (b)

Fig. 4. Call blocking probability, without (a) and with (b) call renegotiation

Fig. 4 (b) shows the average values and the same confidence intervals for call blocking probability, now assuming that the three strategies integrate the renegotiation mechanism described in Section III.

Comparing Fig. 4 (a) with 4 (b), becomes clear that the CovAr strategy increases its performance when it uses the renegotiation mechanism; this occurs because of the succeeded renegotiation of calls, mainly in scenarios where the number of users is low (between 100 and 400). Even though, the MTend strategy presents a performance better than the other two, until the number of users reaches 600. This is due mainly to the use of the reallocation mechanism implemented in the MTend strategy, which takes advantage of the resources available at both interfaces. In this case, the reallocation of calls from the congestioned network to the other network occurs. Above the 600 users, the call inter-arrive interval becomes small and the reallocation mechanism acts more frequently to maintain the networks balanced, what increases the number of blocked calls. Table III summarizes the gain obtained with the MTend strategy in comparison with the other two strategies, considering call blocking probabilities varying from 2% to 20%.

TABLE III

GAIN OF MTEND STRATEGY IN RESPECT TO LBAL AND COVAR

CBP(%)	$G^{CBP}_{MTend\_S}$ (%)			
	Without Renegotiation		**With Renegotiation**	
	S=LBal	S=CovAr	S=LBal	S=CovAr
2	20	25	20	20
5	0	38	13	35
10	22	11	19	15
20	42	28	38	36

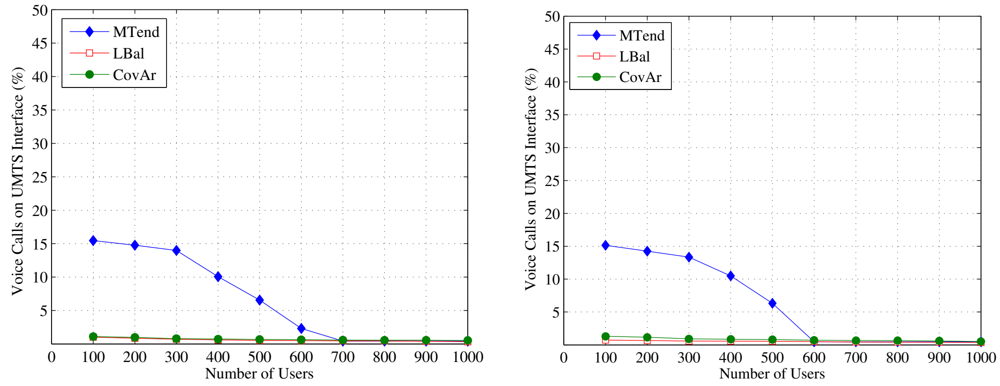
The MTend strategy algorithm directs preferentially the voice calls to UMTS. Fig. 5 (a) shows the percentage of voice calls accepted in the UMTS interface for the three strategies considered. Fig. 5 (b) shows the same percentage considering the three strategies with the call renegotiation mechanism active. Both figures show that the MTend strategy makes a better use of the UMTS network. This confirms another advantage of the MTend strategy, which is its ability to decrease the number of vertical handoffs between the two interfaces. Being the voice users tendencially more mobile than the videostreaming users, it makes sense to direct voice calls to the UMTS interface in an hotspot context, because the probability of a user exits the hotspot while he is involved in a call is high.

Fig. 6 (a) shows the percentage of videostreaming calls accepted in the WLAN interface for the three strategies considered. Fig. 6 (b) shows the same percentage considering the three strategies with the call renegotiation mechanism active. The figures show that the MTend strategy uses the WLAN interface more efficiently, mainly in scenarios with 100 to 500 users. The reason for this good performance is the priority given by the MTend strategy to the videostreaming calls in the WLAN interface. LBal and CovAr have a bigger number of videostreaming calls accepted in the WLAN interface for a number of users greater than 600, which traduces a lower guarantee of videostreaming calls for those users. The MTend strategy controls this aspect through the reallocation of calls between interfaces, maintaining the real time traffic with a delay lower than 20ms, as it is proposed in [13].

An important aspect that contributed to the better performance of MTend strategy, compared with the other two strategies, is the different packet size of the two simulated applications. Videostreaming application has its packets larger than the voice application packets, which makes the WLAN medium access more efficient in terms of throughput. In [10], [14] the WLAN throughput performance is analyzed for several packet size scenarios. These studies show that the increase of throughput is proportional to the increase of packet size, what was also confirmed with our results. The MTend strategy takes also advantage of this fact.

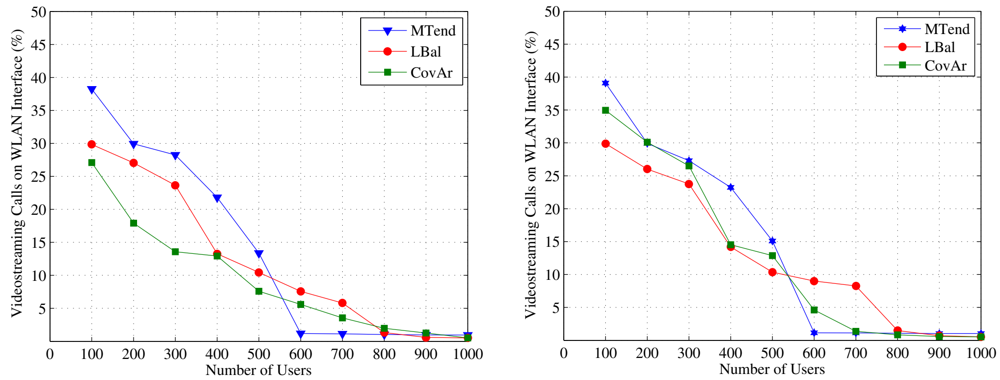
VI. CONCLUSION

This paper presents the MTend strategy for the joint management of radio resources, when the user is located in a place simultaneously covered by UMTS and WLAN networks. The algorithm presented distributes efficiently the new calls by both network interfaces, using criteria such as the mobility of users and the applications sensitivity to the QoS requirements;



(a) (b)

Fig. 5. Percentage of voice calls accepted in UMTS, without (a) and with (b) call renegotiation



(a) (b)

Fig. 6. Percentage of videostreaming calls accepted in WLAN, without (a) and with (b) call renegotiation

besides it also takes advantage of the increasing WLAN efficiency when it transports large packets, such as those generated by video applications.

The paper also introduces mechanisms for call renegotiation and call reallocation, which showed to significantly increase the global system performance. The simulation results presented in the paper show that the MTend strategy has a performance which is globally better than the two other strategies used for comparison. Besides accepting more calls, the MTend strategy guaranties a better QoS support for the applications. This strategy tends also to decrease the number of handoffs between the UMTS and the WLAN interfaces, giving priority to voice calls in the UMTS interface.

For future work, we intend to simulate the MTend strategy also with TCP applications, in order to analyze the performance of call renegotiation and/or reallocation mechanisms in face of elastic TCP traffic.

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