Joint Call Admission Control for Integrated UMTS-WLAN Network

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Abstract— **Integrated UMTS-WLAN networks are expected to seamlessly support different applications and services, such as multimedia services, with varying quality of service (QoS) requirements. Real-time multimedia like audio and video require strict bounds on throughput, jitter and delay. These three parameters of packet radio channels vary considerably with changes in traffic volume. To prevent over-subscription of network radio resource which usually leads to deterioration in the QoS of existing calls, there is need for an efficient call admission control (CAC). We propose a joint call admission control (JCAC) algorithm for QoS provisioning and effective radio resource utilization in integrated UMTS-WLAN networks. The detailed procedure of the joint CAC is presented.**

***Index Terms*— Call admission control, QoS, UMTS, WLAN, Interworking.**

I. INTRODUCTION

SUCCESSFUL deployment of 3G networks based on UMTS [1] in many countries coupled with the springing up of WLAN in many hotspots such as campuses, hotels, airports, restaurants and business enterprises necessitates the interworking of the two networks that are complementary. 3G wireless networks provide wide area coverage at high mobility with a data rate of up to 2 Mbps but at a higher cost compared to WLAN. WLAN on the other hand supports higher speed data of 11 Mbps-54 Mbps, but covers only small areas and allows limited mobility.

The aim of interworking is to combine these complementary features in order to provide enhanced services to customers. This will provide WLAN users with always-on and ubiquitous connectivity with below 2 Mbps data rates whenever the users are outside the WLAN coverage area. Conversely, interworking will provide 3G wireless users with lower-cost services and higher data rate whenever the users are within the range of the WLAN networks with which the home service provider has an interworking agreement. The performance and flexibility of wireless data services would be dramatically improved if users could seamlessly roam across the two networks [2]. Benefits of interworking UMTS and WLAN include unified billing, greater coverage, higher data rate, lower overall service cost, and higher revenue to service providers.

Integrated UMTS-WLAN networks are expected to simultaneously support different services such as voice, video, interactive multimedia and data. These services have varying QoS requirements. To support these services in integrated UMTS-WLAN networks, efficient radio resource management is a major concern. CAC is a provisioning strategy that is used to limit the number of calls allowed into the networks in order to reduce the network congestion and provide the desired QoS to users in service [3]. The objective of CAC is to maximize utilization of the system radio resource while still meeting the QoS requirements of all users as guaranteed. A good CAC has to balance the tradeoff between new-call blocking and handoff- call dropping in order to provide the desired QoS requirements [4], [5].

The rest of this paper is organized as follows. Section 2 reviews the two general solutions proposed for UMTS-WLAN inteworking. Radio resource usage and QoS provisioning in wireless IP networks are described in session 3. Section 4 discusses QoS and CAC in UMTS and WLAN networks. The proposed joint CAC for integrated UMTS-WLAN networks is presented in section 5.

II. INTERWORKING SOLUTIONS

The standards developing bodies have attempted to define standards for the interoperation of UMTS and WLAN [6]. Generally, two solutions have been considered, namely, loosely coupled and tightly coupled interworking. These solutions differ in the level of integration required between the two networks and are briefly reviewed in as follows.

A. Loosely-coupled Interworking

In loose coupling, WLAN is utilized as a packet based access network complementary to UMTS networks. This architecture allows the WLAN to bypass the 3G core network and interface directly to the core IP network via the WLAN gateway. The data paths in the WLAN and UMTS networks are completely separated so that WLAN data traffic is never

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Manuscript received May 4, 2005. This work was supported in part by Deutscher Akademischer Austausch Dienst (DAAD), Telkom/ Ericsson, and National Research Council, South Africa under the Broadband Communication Centre of Excellence Program.

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injected into the UMTS core network. The required modifications to UMTS network are minimal whereas WLAN security, mobility and QoS issues are addressed using the Internet Engineering Task Force (IETF) schemes. This solution allows for independent deployment of WLAN and UMTS networks. Roaming agreement can then be established between the operators of the two networks.

B. *Tightly-coupled Interworking*

In tight coupling, the WLAN is directly connected to the UMTS core network. Consequently, all the WLAN traffic is injected into the UMTS core data network. Therefore, the Serving GPRS Support Node (3G-SGSN) and Gateway GPRS Support Node (3G-GGSN) in UMTS network need to be modified in order to handle the higher bit rates supported in the WLAN network.

The major advantage of the tight coupling architecture is that it enhances mobility across the two networks such that IP addresses at the mobile stations can be maintained. An additional advantage is that UMTS operators can reuse UMTS existing mechanism such as authentication, security, and billing functions in WLAN. Because of the level of integration required, tight coupling is only feasible when both WLAN and UMTS networks belong to the same operator.

III. RADIO RESOURCE USAGE AND QOS PROVISIONING IN WIRELESS IP NETWORKS

Efficient radio resource usage has always been a primary concern in wireless communication systems [7]. A key challenge is to make sure that adequate resource is allocated in order to maintain the negotiated QoS. The question is how much resource should be considered adequate?

Wireless IP networks consist of two major parts: a wireless access network and an IP backbone network. Existing cellular networks such as GPRS, UMTS and WLAN are examples of wireless access networks while an IP network is any network that uses the standard IP protocol for transmission of packets. Generally, in wireless IP networks, the access network in the bottleneck regarding the network capacity and in the access network, the air interface is the main bottleneck. Therefore it is necessary to efficiently manage the limited radio resource in the air interface.

In the IP backbone network, the IETF QoS architectures [8]: integrated services (intserv) and differentiated services (diffserv) architectures are the two main architectures for QoS provisioning. Intserv approach uses Radio Reservation Protocol (RSVP) to explicitly signal and dynamically allocate resource at each intermediate node along the path for each traffic flow. In this architecture, every change in an MS attachment point requires new RSVP signaling to reserve the resource along the new path. The major limitations of intserv architecture are excessive signaling overhead, latency and lack of scalability.

Diffserv approach on the other hand is a priority-based architecture which classifies packets into a small group of services. The packets of each class are marked and traffic conditioned by the router at the network edge. Each class receives a particular QoS in the network. Scalability is the major advantage of the diffserv architecture. The joint CAC proposed in this paper is based on diffserv IP network architecture. The following section discusses QoS and CAC in the access networks (UMTS and WLAN).

IV. QOS AND CALL ADMISSION CONTROL IN WLAN AND UMTS NETWORKS

A CAC guarantees that the admittance of a new call into a resource constrained network does not violate service commitments made by the network to already admitted calls, while still making the best use of the network resource. CAC algorithms facilitate more efficient use of the radio resource in the access networks.

In wired networks, CAC has been extensively studied as an essential tool for congestion control and QoS provisioning. Similarly, a lot of research effort has concentrated on CAC in different cellular networks but very little work has been done in the area of joint CAC in heterogeneous networks. In wireless networks, the design of CAC is more complicated due to users' mobility [9]. An accepted call that has not been completed in the current cell may not get a channel in the adjacent cell to continue its service due to limited radio resource in wireless networks. This will eventually lead to the call being dropped. Since users are more intolerant to dropping a handoff call that blocking a new call, handoff calls are usually given a higher priority.

In general, CAC can be grouped into two categories: parameter-based (proactive) and measurement-based (reactive) [10]. Parameter-based admission control schemes use a priori traffic specification to determine the parameters of deterministic or stochastic models. On the other hand, measurement-based admission control offers QoS to users without requiring priori traffic specifications or online policing [11]. It depends on the measurement of actual traffic load in the network in making admission decisions. As a result, it shifts the task of traffic specification from the user to the network and relieves the network from the burden of traffic policing [10].

The main criterion used in evaluating any CAC algorithm must be how well it fulfills its primary role of ensuring that services commitments are not violated. The second evaluation criterion is how well a level of network utilization a CAC can achieve while still meeting its service commitments. The third evaluation criterion is how high the implementation and operation cost of an algorithm is. [12]. Thus the implementation cost of a CAC should not be prohibitive. Other criteria are optimality, stability and scalability.

A. *QoS and Call Admission Control in WLAN*

The IEEE 802.11 family of WLAN: 802.11, 802.11a, 802.11b, and 802.11g, are largely based on contention approach and do not allow prioritization of traffic or stations. Two protocols are defined for the MAC layer in the original IEEE specification: a centralized control scheme called the point coordination function (PCF), and a contention-based scheme called the centralized coordination function. Most manufacturers of WLAN have chosen not to implement PCF [13]. DCF is a carrier sense multiple access with collision avoidance (CSMA/CA) mechanism in which all packets transmitted are required to be acknowledge. If a packet is sent and not acknowledge, the transmitting station knows that its attempted transmission has failed due to collision. A station wishing to transmit a packet has to sense the channel as idle for a minimum duration called DCF inter-frame space (DIFS) before it can begin to transmit. The station can begin transmission of packets if the channel is sensed idled for DIFS. Otherwise, it will generate a random backoff time which varies between (0, CW). CW is called the contention window It has a minimum value, CW_{min}, which is called the minimum contention window. While waiting, the intending transmitter continues to sense the channel. If it hears another station transmitting, it aborts its own attempt until the channel becomes free again. It then generates a random wait period using a greater CW. CW kept increasing for each unsuccessful attempt to transmit until a maximum value of $CW_{max} = 2^m CW_{min}$, where m is the maximum backoff stage. The DCF provides a severe limitation on the usable throughput of WLAN, and does not allow for any differentiation of service [13].

The problem of lack of adequate QoS support in WLAN has led to the development of 802.11e [14] which will soon become a formal standard. It uses a distributed access approach, called the enhanced distribution function [EDCF]. It supports relatively priority services through the introduction of Access Categories (ACs). Instead of using a single queue and one channel access function in the DCF, each station implements multiple ACs. Each AC consists of independent transmit queue and a channel access function with its own parameter, that include minimum and maximum contention windows [15]. EDCF ensures that the packets sent by each QoS-enhanced mobile station can be differentiated by assigning different access parameters. However, supporting service differentiation in the MAC protocol does not guarantee that the QoS requirements of each traffic class will be fully satisfied. A CAC algorithm is necessary to guarantee the required QoS. In [14], a CAC strategy was developed for IEEE 802.11e to guarantee the QoS requirement of each traffic class. Mobile stations in the WLAN make use of some MAC management messages specified in the IEEE 802.11e draft to transmit load conditions to the corresponding AP. The AP executes the CAC algorithm to estimates the performance of resource usage and decides if a new traffic stream is permitted into the system. Performance evaluation of IEEE 802.11e is presented in [16], [17] and [18].

B QoS and Call Admission Control in UMTS Networks

In the design of UMTS network, QoS was taking into account from the very beginning. Therefore UMTS networks can support different services, such as voice and video, over its packet switching domain. The QoS architecture in UMTS is based on the concept of Bearer Service (BS) which follows a layered based approach. Each layer consist of one or more BSs that are concatenated together to provide the desired QoS support on an end-end basis. The 3GPP defines four classes for the UMTS bearer service, taking into account the nature of the traffic produced by the various applications that are used over the network. The four classes are summarized in table 1 [19].

CAC techniques are of great importance in UMTS networks in order to satisfy the QoS requirements of different classes and to utilize the network resource in an efficient manner. CAC determines whether a requested bearer access can be established or not. In the literature, different CAC schemes have been proposed. Some of these schemes are presented in [21], [22], and [23].

V JOINT CALL ADMISSION CONTROL FOR INTEGRATED UMTS-WLAN NETWORKS

CAC has been studied separately in UMTS and WLAN. A joint CAC mechanism is necessary for efficient resource management, QoS provisioning, and vertical handover support between the two networks. The proposed joint CAC for integrated UMTS-WLAN networks will ensure the following:

- Support multiple service rates
- Guarantee the QoS requirements of accepted calls
- Provide a priority mechanism for handoff calls
- Optimally control whether or not to accept a new call or handoff call and which network (UMTS to WLAN) to accept it
- Maximize radio resource utilization in the integrated Network

Table 1. QoS classes in UMTS network

QoS Class	Transfer Delay	Jitter	Low Bit Error rate	Guarantee Bit Rate	Example
Conversational	Stringent	Stringent	No	Yes	Video-conferencing, Audio-conferencing
Streaming	Constrained	Constrained	No	Yes	Video streaming, Audio streaming
Interactive	Looser	No	Yes	No	Web browsing, Interactive chats, Games
Background	No	No	Yes	No	E-mail, SMS

A Joint CAC Assumptions

The following assumptions are made in the proposed joint CAC.

- WLAN hotspots are double coverage zone i.e. they have both UMTS and WLAN coverage.
- Every traffic class has a minimum and a maximum bandwidth

B New Calls

In UMTS-only zones, new calls can only be accepted into the UMTS network. In WLAN coverage area, double coverage zone, the joint CAC attempts to admit new calls first into the WLAN. If there is enough radio resource to meet the required QoS, the call is admitted into WLAN. If the call cannot be admitted into the WLAN, the joint CAC admits it into the UMTS network provided that there is enough radio resource. Otherwise the call is blocked.

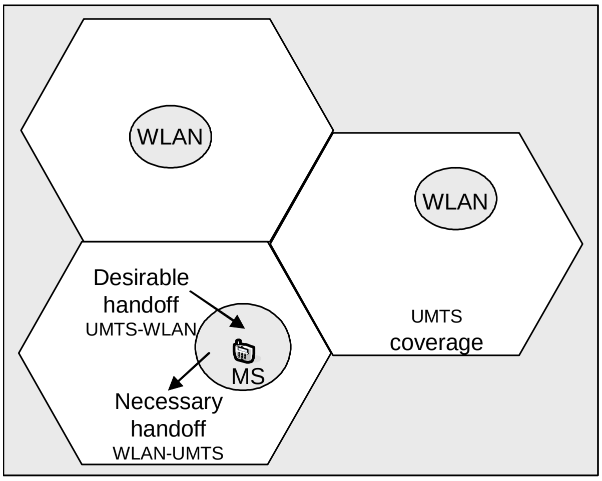

Fig. 1. Handoff call arrival in an integrated UMTS-WLAN network

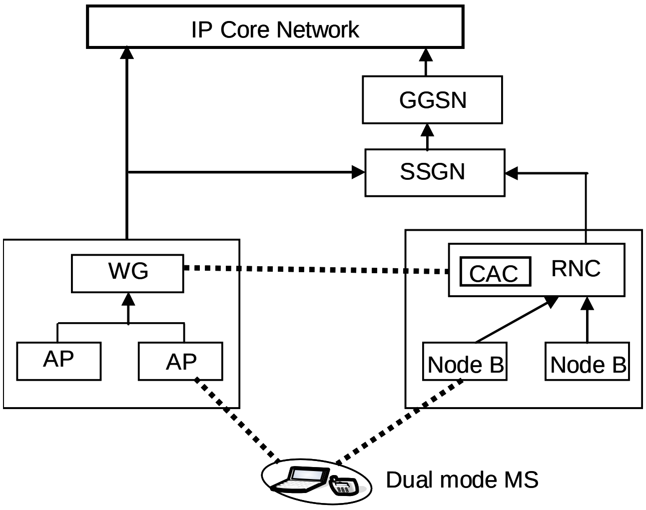

Fig. 2. Joint call admission control for integrated UMTS-WLAN networks

C Handoff Calls

A distinction is made between two types of handoff calls in the proposed joint CAC: necessary handoff and desirable handoff. As shown in figure 1, when a mobile station moves from the WLAN coverage area to the UMTS network, it is necessary to handover the ongoing call to the UMTS network. This handoff is called a necessary handoff. If there is enough resources in the UMTS network the call will be admitted. Otherwise it will be dropped. On the other hand, when a mobile station moves from the UMTS network to the WLAN, a handover is desirable. This handoff is called a desirable handoff because if the call is not handed over to the WLAN, it remains in the UMTS network.

D Bandwidth Reservation

It is essential to keep the probability of dropping a handoff call (necessary handoff call) within acceptable limits. This is because subscribers are more intolerant to dropping an ongoing call than blocking anew call. The proposed joint CAC makes bandwidth reservation in the UMTS network for necessary handoff calls. No resource reservation is made for new calls in UMTS network. In the WLAN on the other hand, no reservation is made for any call (new calls or desirable handoff calls).

E Call Admission Thresholds

One major problem with WLAN is how to estimate the value of the achievable throughput or bandwidth. This value depends on several time-varying factors including the number of active stations, the offered traffic, volume and each AC's parameters [9]. The method proposed in [21] can be used to measure the relative bandwidth of a WLAN. The relative occupied bandwidth indicates the percentage of the wireless medium that is being used. Let B_{tw} denote the upper threshold for WLAN bandwidth, let B_r equals the required bandwidth of an arriving call and let B_{cw} be the WLAN bandwidth that is currently being used by ongoing calls. The call is accepted into WLAN if the following condition is satisfied.

$$B_{cw} + B_r <= B_{tw} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

In UMTS network, the following are defined.
Let the upper (maximum) cell bandwidth of UMTS = C_t
Let the summation of the UMTS cell bandwidth that is currently being used = C_u
Let the required minimum bandwidth of a new call = C_{new}
Let the required minimum bandwidth of an handoff call = C_h
Let the reserved bandwidth for necessary handoff call = Cr

A new call is admitted if

$$C_{new} + C_r + C_u <= C_t \ldots\ldots\ldots\ldots\ldots..(2)$$

A handoff call is admitted if

$$C_h + C_u <= C_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

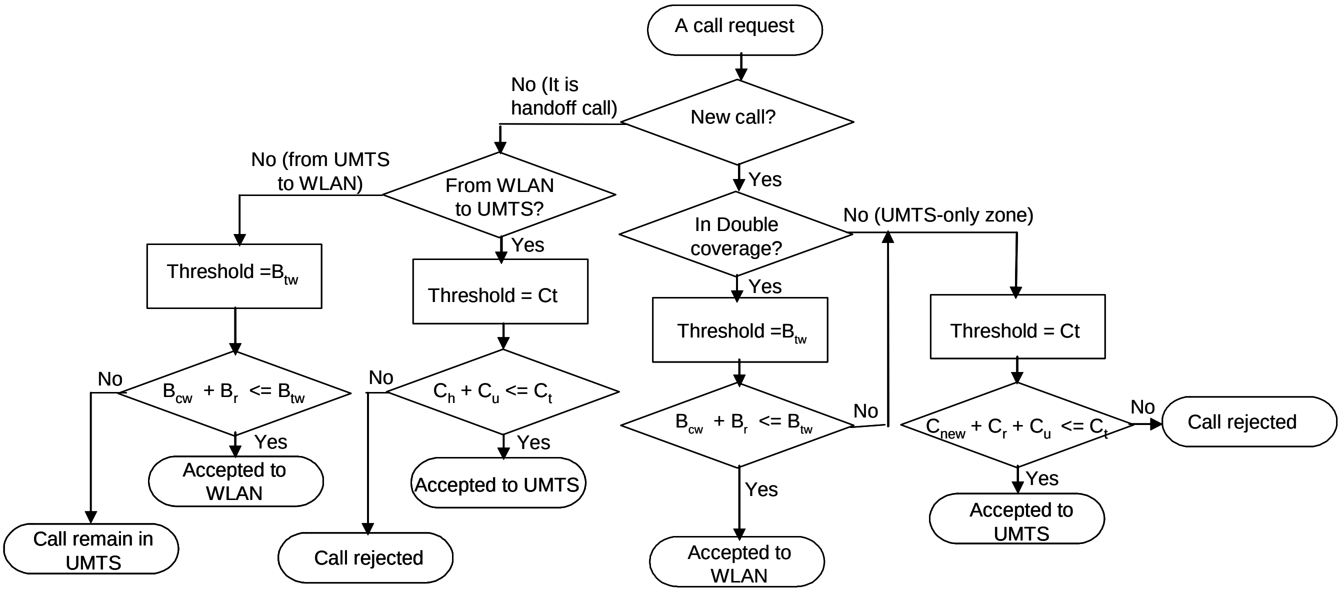

Fig. 3. Joint Call Admission Procedure in an integrated UMTS-WLAN Network.

Figure 2 shows the proposed joint CAC for integrated UMTS-WLAN network. It is applicable to both tight coupling and loose coupling. The mobile station operates in dual mode and it is capable of initiating services either in UMTS domain or WLAN domain of the integrated network. The joint CAC can be implemented in the radio network controller (RNC). Load information from access points in WLAN and base stations in UMTS can be conveyed to the RNC. The detailed call admission procedure of the proposed joint CAC is shown in Figure 3. Due to the cost of procuring spectrum license and equipment, UMTS services are more expensive than WLAN services. The proposed joint CAC will reduce overall service cost by admitting news call into WLAN as much as possible. Performance evaluation of the joint CAC scheme will be based on new call-blocking probability, hand off call-blocking probability and radio resource utilization.

VI CONCLUSIONS

A joint call admission control algorithm will facilitate more efficient utilization of radio resource in integrated UMTS-WLAN networks. The proposed joint CAC will guarantee the QoS of accepted calls. Dropping of necessary handoff calls will be kept within acceptable limits by making channel reservations in UMTS network. It will reduce overall service cost by admitting every new call into WLAN whenever the customer is within the WLAN coverage and there is enough radio resource to accommodate the call. Future work includes simulations of the proposed joint call admission control scheme.

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