

# AN ADAPTIVE QOS MANAGEMENT SCHEME FOR INTERWORKING CELLULAR AND WLAN NETWORKS

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**Abstract:** The design of a network architecture that efficiently integrates WLAN and cellular networks is a challenging task, particularly when the objective is to make the interoperation between the two networks as seamless and as efficient as possible. To provide end-to-end Quality of Service (QoS) support is one of the key issues towards such a goal, due to the various constraints, such as the unbalanced capacity of two systems, handoff from users' mobility and unreliable wireless media. In this paper, we propose a generic reservation-based QoS model for the integrated cellular and WLAN networks. It uses an adaptation mechanism to address the above issues and to support end-to-end QoS. The validity of the proposed scheme is demonstrated via simulation experiments. The performance results reveal that this new scheme can considerably improve the system resource utilization and reduce the call blocking probability and handoff dropping probability of the integrated networks while still maintaining acceptable QoS to the end users.

**Keywords:** *WLAN, Cellular network, Integration, QoS framework, Reservation, bandwidth adaptation.*

## 1. INTRODUCTION

In future, wireless service provision will be characterized by global mobile access at anywhere and anytime [5]. These mobile communication systems will include different access technologies such as Wireless LAN (WLAN) and cellular networks (GSM, GPRS or UMTS). WLAN systems provide very high data rate at a costly manner compared with 3G network. It has been becoming more and more popular recently. However, WLAN technology is more likely a compensator rather than a competitor to 3G networks, because it has limited coverage area and less support to high speed mobility while the later is on the contrary. So far WLAN has been setup in places like airports, hotels, and campuses. These places with the Access Point (AP) are called traffic Hot-Spots. Interconnecting WLAN radio access network with 3G or even 2G cellular networks offers an efficient way to enhance the network operator service.

The communication systems are dominated by voice transmission using the circuit switching technology [6] for a long time. However, the demand for data communication is increasing and drives the development of more bandwidth utilization efficient technology: packet switching. Currently, the mobile communication system is facing the same evolution as Internet does. The network operators are migrating from GSM system to General Packet Radio Service (GPRS) and 3G networks world wide

[14]. The ultimate vision is to provide a universal all-IP platform. Moreover, to integrate WLAN and cellular network is an important step during this process. It can provide the end users the benefits like lower cost of transmission and higher bandwidth without losing the roaming pervasive. However, the design of a network architecture that efficiently integrates WLAN and cellular networks is a challenging task, particularly when the objective is to make the interoperation between the two technologies as seamless and as efficient as possible.

To provide end-to-end Quality of Service (QoS) support is one of the key issues in the design of integrated WLAN and cellular networks. Some QoS architectures have been proposed in the Internet community. There are two major models among them. One is based on reservation and the other is based on prioritization, namely: InterServ and DiffServ [13]. They differ in the way that reservation-based approach signals through the data path and books its QoS requirements before the actual data transmission, while prioritization-based approach simply marks the traffic on the individual packet basis to indicate the QoS requirements and sends the packets to the network. It is well known that Internet has some fundamental scalability limitations when it comes to manage individual traffic flows by reservation approach. Its successor, the prioritization approach addresses the scalability problem at the cost of coarser service granularity.

Many difficulties emerged when providing the QoS solution, such as the unbalanced capacity of two systems, handoff from users' mobility and unreliable wireless media. To enable efficient use of scarce resources provided by the cellular networks while also maintaining strong service guarantees, we propose a generic reservation-based QoS model for the integrated cellular and WLAN network. Under the proposed QoS framework, we develop an adaptation mechanism to address the various challenges generated by designing an integrated WLAN and 3G networks. The validity of the proposed scheme is demonstrated via simulation experiments. The performance results indicate that this new scheme can improve the system resource utilization and considerably reduce the call blocking probability and handoff dropping probability of the integrated networks while still maintaining acceptable QoS to the end users.

This paper is organized as follows. Section 2 gives a review of the preliminary works, followed by section 3, the problems generated to provide QoS over integrated system. We introduce and analyze the proposed QoS framework in section 4. Under the proposed QoS framework, an adaptive algorithm to manage the QoS is introduced in section 5. In section 6 we describe our simulation setup and discuss the performance results based on the proposed framework. Section 7 summarizes the paper and gives concluding remarks.

## 2. PRELIMINARY WORK

Increasing data service requirements and Internet applications are driving the cellular network evolving into an IP based packet switching network [14]. Our proposed QoS framework assumes a packet switching core network based on UMTS network architecture. However, this holds the same relationship with the GPRS 2.5G networks or other packet switching cellular systems. The overall architecture is shown in Figure 6. It is well known that Internet has some fundamental scalability limitations [13] when it comes to manage individual traffic flows by reservation approach. Its successor, the prioritization approach addresses the scalability problem at the cost of coarser service granularity. To enable efficient use of scarce resources provided by the cellular networks while also maintaining strong service guarantees, we adopt the reservation based systems [1]. In WLAN the reservation is achieved by using the HCF and in UMTS is achieved by the functionality provide by BS. The other components of the framework are defined below:

- *A Policy Provisioning Module (PPM)*

The PPM is responsible for mapping actual users QoS profiles with their subscription information and decides the traffic classes for the users' traffic

flows. Then these QoS parameters can be handed to CAC module to process.

- *A Connection Admission Control Module (CAC)*

The CAC is to admit the number of flows that can be served and allocates bandwidth to them through signalling to all the network nodes along the traffic path. It also needs to maintain the QoS requirements of existing connections.

- *A QoS Mobility Management Module (MMM)*

The MMM decides whether terminals are detached, connected or idle from the network and also monitors those active nodes moving at high speed.

- *A QoS Monitoring Module (Monitor)*

The Monitor continuously measures whether its QoS merits of the QoS enabled mobile nodes have been satisfied.

## 3. THE DYNAMIC BANDWIDTH MANAGEMENT SCHEME

The bandwidth adaptation algorithm as the key factor of the proposed framework decides how to adjust the QoS connections. Ideally, each call in the system should be allocated the maximum allowable bandwidth. However, to accommodate more new arrivals and handoff calls, we have to degrade other connections. Many methods have been proposed [2-4, 7-12] for this purpose. Our method is based on based on concept of degrade profile we proposed and we effectively degrade the calls with shortest lifetime based on their state information. Use of degrade profile can guarantee the satisfied QoS level to the end user and degrade the shortest calls can reduce the degrade degree of the whole system. The pseudo code of the adaptation algorithm is described in Table 4.

New Call Arrivals	
IF (New Requested Bandwidth $B_i$ < system available bandwidth)	assign $B_i$ ;
ELSEIF (New Requested Band $D_i$ < system available bandwidth)	assign $D_i$ ;
ELSE	WHILE (undegraded call exists AND $D_i$ > system bandwidth)
	degrade shortest call;
	IF ( $D_i$ < system available bandwidth)
	assign $D_i$ ;
	ELSE
	Reject the call;

<b>Handoff Call Arrivals</b>
IF (Handoff Requested Bandwidth $B_i <$ system available bandwidth + guard band) assign $B_i$ ;
ELSEIF (Handoff Requested Band $D_i <$ system available bandwidth + guard band) assign $D_i$ ;
ELSE WHILE (undegraded call exists AND $D_i >$ system available bandwidth + guard band) degrade shortest call; IF ( $D_i <$ system available bandwidth + guard band) assign $D_i$ ; ELSE Reject the call;
<b>Departures</b>
WHILE (system available bandwidth $> 0$ ) find the longest degraded call; assign $B_i$ for this call;

**Table 4.** Pseudo code for the adaptation algorithm

To describe how much the overall system degraded, we define a new performance merit called system degrade degree. Some system parameters are described before we introduce the system degraded definition.

The traffic class of a connection is defined as  $C_i$ , where  $C_i \in \{C_1, C_2, \dots, C_i, \dots, C_K\}$ , where  $K$  is the number of service classes. The corresponding bandwidth requirement for each class is defined as  $B_i \in \{B_1, B_2, \dots, B_i, \dots, B_K\}$ , for the sake of simplicity we assume that that all the connections in the same class have the same requested bandwidth. Also let  $D_i \in \{D_1, D_2, \dots, D_i, \dots, D_K\}$  denote the minimum bandwidth request defined in the connection degrade profile.

Let  $p^i(t)$  denote the degradation probability of class  $i$  and  $n^i(t)$  the number of connections from class  $i$  at time  $t$ . Thus the degradable bandwidth at time  $t$  can be written as:

$$\sum_i (B_i - D_i) p^i(t) n^i(t) \quad (3)$$

We define bandwidth degrade degree  $BR$  as the ratio between the amount of bandwidth reduced and the requested bandwidth.

$$BR = \frac{\sum_i (B_i - D_i) p^i(t) n^i(t)}{\sum_i B_i \cdot n^i(t)} \quad (4)$$

The overall system degradation degree  $SD$  is the integration of  $BR$  over the period  $t$ :

$$SD = \int_t \frac{\sum_i (B_i - D_i) p^i(t) n^i(t)}{\sum_i B_i \cdot n^i(t)} \quad (5)$$

#### 4. PERFORMANCE ANALYSIS

This section uses simulation experiments to investigate how the proposed approach can improve the overall QoS for the integrated cellular and WLAN networks. Following the assumptions widely used in previous studies [2, 4, 9], the call arrivals in our simulation follow an independent Poisson process and the session time of each connection is exponentially distributed. It is well known that dropping an established communication is worse than rejecting a new call. Therefore cellular systems reserve a guard bandwidth for the handoff calls in order to reduce the handoff dropping probability. The reserved guard bandwidth can be either static or dynamic [3, 9, 11]. The dynamic approach often outperforms the static one at the expense of generating more control overheads [14]. However, the static approach is often attractive in practice owing to its design simplicity. In our simulation, a static guard bandwidth (i.e., 5% of the system capacity) is employed to deal with handoff calls.

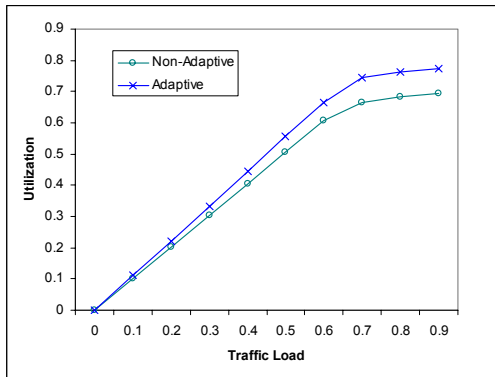
Without loss of generality, the integrated network in the simulation consists of one cellular network and one WLAN hotspot. Since WLAN has higher capacity and cheaper than UMTS, we assume the handoff probability from UMTS to WLAN is 5 times as much as that from WLAN to UMTS. The system capacity for UMTS and WLAN is 2 mb/s and 11 mb/s respectively. The bandwidth requirement for each of four QoS classes  $\{B_1, B_2, B_3, B_4\}$  defined in section 3.3 and their acceptable degrade level defined in degrade profile are assumed to be a portion of the system capacity listed in Table 5. The reservation signaling cost before the establishment of each new or handoff connection is set to a fixed value. For the sake of clarity, all the relevant simulation parameters are summarized in Table 5. The simulation is carried out under various traffic loads. We compare the

proposed approach with non adaptive multimedia services.

Parameter	Value	Parameter	Value
UMTS Capacity (U)	2 mb/s	Session time	Exp(50)
WLAN Capacity (W)	11 mb/s	Guard Band	5%
UMTS to WLAN Handoff	0.05	$\{B_1, B_2, \dots\}$	$\{5\%*W, 3\%*W, 5\%*U, 3\%*U\}$
WLAN to UMTS Handoff	0.01	$\{D_1, D_2, \dots\}$	$\{4\%*W, 2\%*W, 4\%*U, 2\%*U\}$
Reservation signaling cost	1%*W	Simulation Time	1000s

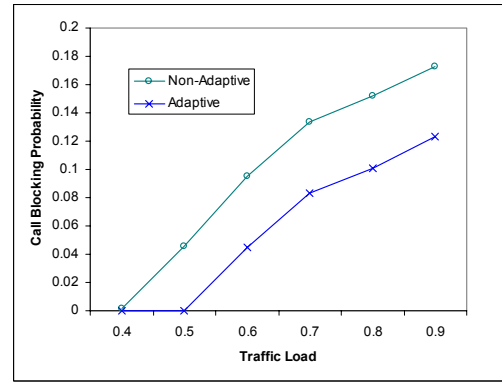
**Table 5.** Simulation parameters

In this section, we present the simulation results to show the effectiveness of the proposed scheme. We set the load to WLAN and UMTS identical in each single experiment and calculate overall system performance merits.

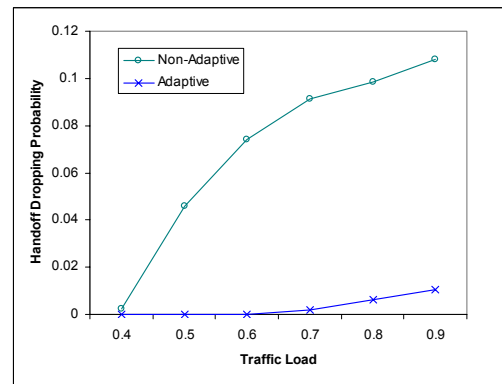


**Figure 12.** Utilization Over Traffic Load

Figure 12 compares the bandwidth utilization supported by the proposed adaptive scheme in the integrated network to that without the adaptive scheme under various traffic loads. Clearly, the utilization for adaptive multimedia connection is better than that for non-adaptive multimedia. When the traffic load becomes higher, the advantage is more evident. The reason for adaptive multimedia better utilized the system bandwidth is that the proposed scheme allows the network intelligently adjust each admitted QoS connection by its degrade profile and give sufficient amount of resources for the new or handoff calls.



**Figure 13.** Call Blocking Probability Over Traffic Load

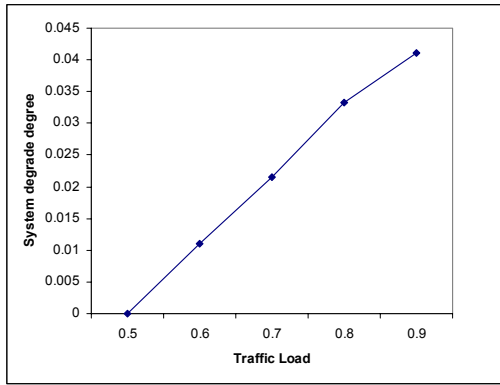


**Figure 14.** Handoff Dropping Probability Over Traffic Load

Figure 13 depicts the call blocking probability versus the traffic load for adaptive multimedia connections and non-adaptive multimedia connections. There is no call blocking probability for both methods with light traffic load. Clearly, with the increment of the traffic load the call blocking probability is increased. The adaptive approach reduced the call blocking probability compared with non-adaptive approach.

Figure 14 further evaluates the handoff dropping probability in the integrated network. The handoff dropping probability for adaptive multimedia connection is less than that for non-adaptive multimedia. When the traffic load becomes higher, the trend is more evident. It reveals that the proposed approach reduces a great number of handoff dropping calls for the integrated WLAN and cellular system.

Figure 15 shows the overall system degrade degree defined in section 5. We can observe that the system degrade degree increases with the traffic load increment. In practical system, this performance merit can be designed as threshold to control the system performance by the network operator.



**Figure 15.** System degrade degree Over Traffic Load

## 5. CONCLUSIONS

Many difficulties emerged when providing the QoS solution, such as the unbalanced capacity of two systems, handoff from users' mobility and unreliable wireless media. We proposed a generic reservation-based QoS model for the integrated cellular and WLAN networks. Our proposed model supports the delivery of adaptive real-time flows for end users taking the advantage of high data rate WLAN systems as well as the wide coverage area of cellular networks. We specifically analyze the different components of the model and their interactions. An adaptation mechanism is also developed under the proposed QoS model to address the various challenges generated by designing an integrated WLAN and 3G networks.

The performance of the system is revealed via simulation. The results show that the proposed scheme effectively use system resources. Simulation experiments also indicate that the adaptive multimedia framework outperforms the non adaptive approach in terms of lower handoff dropping probability and call blocking probability while still maintain acceptable QoS to the end users.

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