

Dynamic Call Admission Control with Joint Connection-level and Packet-level QoS Support in Wireless Multimedia Networks

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Abstract

In this paper, we investigate joint provision of connection-level QoS (in terms of the new call blocking probability and the handoff dropping probability) and packet-level QoS (in terms of the delay and packet loss probability). A dynamic call admission control (CAC) scheme for realistic wireless multimedia VBR traffic is presented. The proposed CAC scheme can optimize the packet-level QoS under certain constraints on connection-level QoS. Moreover, its low complexity feature enables practical deployment. Simulation results have demonstrated that the proposed dynamic CAC scheme achieves better performance than the optimal stationary CAC scheme when applied to heterogeneous and varying traffic conditions found in wireless multimedia networks.

1. Introduction

Traditional wireless communication networks use the circuit-switching technology for voice communications, where the primary concern of quality of service (QoS) is the service connectivity and continuity at the connection-level. The connection-level QoS is usually measured by the new call blocking probability P_B and the handoff dropping probability P_D . With the explosive increase of the wireless communication demand, the next-generation wireless networks will employ the packet-switching technology to support multimedia services and achieve better utilization of limited resources. However, packets of certain services may experience varying delay, delay jitter and loss, which may have a great impact on the perceived quality of service by end users. Therefore, the packet-level QoS, in terms of delay D and the packet loss

probability P_L , has to be guaranteed as well. As a result, the QoS guarantee for multimedia services in the packet-based next-generation wireless communication networks presents a great challenge - how to allocate the varying and limited wireless resource as efficiently as possible among different connection flows, such that both the connection-level QoS and packet-level QoS can be satisfied. In this paper, we investigate the trade-off between connection-level and packet-level QoS, and propose real time resource allocation solutions to jointly provide QoS at both levels.

Call admission control schemes have been investigated extensively in traditional circuit-switching wireless networks as an important mechanism to support connection-level QoS without considering packet-level QoS [9, 6, 11, 8, 5, 4]. On the other hand, most of previous research efforts on packet-level QoS [2, 3] did not address the handoff and mobility management issues that are important for connection-level QoS provisioning.

More recently, there have been some research work addressing both connection-level and packet-level QoS for wireless networks. The resource reservation and call admission control scheme proposed in [7] considered delay by differentiating real-time and non-real-time traffic, but without quantitative packet-level QoS guarantee analysis. Meanwhile, it reserved resources for real-time traffic in all neighboring cells to provide connection-level QoS guarantee for real-time traffic, which is not efficient as the mobile user only hands off to one of these neighbors. In [12], an adaptive QoS handoff priority scheme was analyzed in both connection-level QoS (*i.e.* the new call blocking probability and the handoff dropping probability), and packet-level QoS (*i.e.* delay) performance. However, it deals with these two level QoS problems separately. Thus, there is no guarantee or optimization on the QoS performance at either level. Talukdar *et al.* [10] proposed an admission control scheme

based on a new three-class service model for integrated services packet networks with mobile hosts. It extended the InteServ architecture [1] for QoS provisioning in wired IP networks to mobile hosts. This scheme aimed at guaranteed packet scheduling delay bound at the packet-level, but had limitations in connection-level QoS provisioning since it required that each mobile host requesting a connection should provide its accurate mobility specification, which consists of the set of cells the mobile host is expected to visit during the lifetime of the flow. In addition, in all the above mentioned schemes, only delay was considered as the packet-level QoS metric, while packet loss was not addressed.

In this paper, we propose an efficient and effective CAC scheme that can jointly provide QoS at both connection and packet levels for emerging packet-switching wireless networks. The objective of our CAC scheme is to optimize the packet-level QoS under given constraints on the connection-level QoS. The proposed scheme can be adapted to varied and varying traffic conditions dynamically, and is highly computational efficient and easy to implement, thus being suitable for real time system deployment.

The rest of the paper is organized as follows. In Section 2, the dynamic CAC scheme is proposed to take the traffic dynamics of real-world networks into account. Experimental results are given in Section 3. Section 4 concludes the paper and gives future work directions.

2. The Proposed Dynamic CAC Scheme

The CAC scheme considered in this paper is of the type $\{\phi(N, T)\}$, where T is a real number, N is an integer, and $T \leq N$. The CAC policy admits a new connection request if and only if the current load is less than T , while admits a handoff request if and only if the current load is less than N . When T is a non-integer, the CAC policy admits a new connection request with the probability of a fractional part of T . $\phi(N, T)$ with fixed N and T yields stationary CAC schemes. Optimal N and T can be found under certain assumptions and constraints. However, in real-world wireless multimedia networks, the multimedia traffic is generally more complex than the assumptions. Moreover, the traffic condition in terms of new/handoff call arrival and departure rates may be changing from time to time. Considering these practical aspects, the stationary optimal CAC schemes may not be efficient. Thus, dynamic schemes that take these factors into account are highly desirable.

The objective of our dynamic CAC scheme is to optimize the packet-level QoS under the given constraints on the connection-level QoS. Generally speaking, the smaller the delay and packet loss are, the higher quality could be perceived by the end user. Therefore, the problem of dynamic CAC scheme is to adjust the two parameters N and

T adaptively such that D and/or P_L can be minimized while keeping the P_B and P_D under certain targets P_B^{tar} and P_D^{tar} .

For a fixed channel capacity C , the more channels required to accommodate the aggregated peak data rates of multiplexed connections, the higher packet loss or delay will be caused. Therefore, in order to minimize D and P_L , the dynamic CAC scheme should achieve minimum N while keeping P_B and P_D below their targets. Meanwhile, P_B and P_D is a trade-off upon the change of N or T . A higher N results in lower P_D but higher P_B under a certain T , while a higher T results in lower P_B but higher P_D under a certain N .

Based on these observations, we develop our dynamic CAC scheme described in Figure 1.

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01 INITIALIZE  $N$  and  $T$ 
02 SET TIMER
03 WAIT FOR CALL REQUEST ARRIVAL
04 If NEW CALL REQUEST ARRIVES
05   If  $(B_{occupied} + B_{req}) \leq (N - T)$ 
06     ADMIT NEW CALL WITH RATE  $B_{req}$ 
07   Else
08     REJECT NEW CALL REQUEST
09     UPDATE  $P_B$ 
10     If  $P_B \geq P_B^{tar}$ 
11        $T = T + 1$ 
12     If  $T > N$ 
13        $N = N + 1$ 
14     RESET TIMER AND GO BACK TO 03
15 If HANDOFF CALL REQUEST ARRIVES
16   If  $(B_{occupied} + B_{req}) \leq N$ 
17     ADMIT HANDOFF CALL WITH RATE  $B_{req}$ 
18   Else
19     REJECT HANDOFF REQUEST
20     UPDATE  $P_D$ 
21     If  $P_D \geq P_D^{tar}$ 
22       If  $P_B \geq P_B^{tar}$  OR  $T = 0$ 
23          $N = N + 1$ 
24       Else
25          $T = T - 1$ 
26     RESET TIMER AND GO BACK TO 03
27 If TIMER EXPIRES AND  $N \leq C$ 
28    $N = N - 1$ 
29   If  $T > N$ 
30      $T = N$ 
31   RESET TIMER AND GO BACK TO 03
32 Else GO BACK TO 03

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Figure 1. The proposed dynamic CAC scheme for optimizing packet-level QoS under connection-level QoS constraints.

The base station measures both the P_B and P_D upon new call blocking and handoff dropping events. There are three cases when the value of N should be increased. First, if the measured $P_B > P_B^{tar}$ when $T = N$, it is impossible to increase T further more without the increase of N to lower

P_B . Second, if the measured P_B and P_D both exceed the targets, then either increasing or decreasing T can not make both P_B and P_D lower than their target values. Third, if the measured $P_D > P_D^{tar}$ when $T = 0$, then it is impossible to decrease T under the current N to lower P_D . In a practical wireless communication network, where the new call traffic is generally heavier than the handoff traffic, the last case is more unlikely to happen.

The timer setting detects when N is higher than necessary to meet the targets of P_B and P_D . Upon the timer expiration, it indicates that both P_B and P_D has been below its target for a timer's period. Then, we decrease N to the minimum necessary value.

With N that satisfies both P_B and P_D constraints under the current traffic condition, the dynamic change of T between 0 and N ensures $P_B \leq P_B^{tar}$ and $P_D \leq P_D^{tar}$. If the base station detects that $P_B > P_B^{tar}$, it increases T to achieve lower P_B at the cost of higher P_D within its constraints. Otherwise, if the base station detects that $P_D > P_D^{tar}$, it decreases T to achieve lower P_D at the cost of higher P_B within its constraint.

An important design issue that affects the performance of the scheme is the timer setting. A short timer can keep up with the changing of traffic conditions and minimize the system's under-utilization period. However, if the timer is too short, the measurement of P_B and P_D may not be accurate, therefore results in unnecessary fluctuation and burden to the system. Thus, a good tradeoff of system stabilization and high utilization efficiency should be achieved by a good timer setting. The value of the timer can be chosen according to the arriving rate of call requests and the maximum time that the system could tolerate under-utilization.

3. Experimental Results

The performance of the proposed dynamic CAC algorithm was evaluated using discrete-event simulator OPNET. Multiple service types (i.e., video, audio and voice, etc) with different traffic parameters are considered. A network model of a single cell with channel capacity $C = 20$ was build in OPNET simulator. Each channel has a data rate of 9600 bits/sec. The multimedia VBR traffic models were built as an on-off model with configurable packet generation parameters listed below:

- On-state time distribution: exponential with mean 1 sec
- Off-state time distribution: exponential with mean 3 sec
- Packet inter-arrival time distribution during on-state: exponential with mean 0.1 sec
- Packet size distribution: constant with mean 120 bytes

Application type (i)	r_i (channels)	λ_{ni} (call/sec)	λ_{hi} (call/sec)	η_i (1/sec)
voice (1)	1	0.2	0.05	0.01
audio (2)	2	0.05	0.015	0.01
video (3)	4	0.025	0.005	0.01

Table 1. Traffic load parameter settings in OPNET simulation.

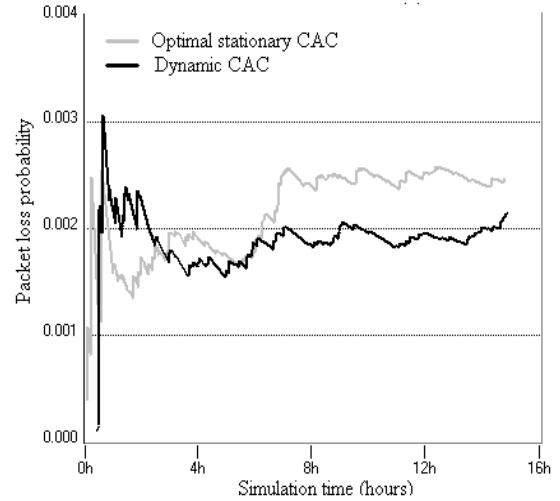


Figure 2. Comparison of the packet loss probability of the optimal stationary and the dynamic CAC schemes.

The network traffic load configurations are listed in Table 1. The r_i for each service type is the weighting factor of the peak rate during on period. It is used by the above VBR on-off model to scale the packet inter-arrival time generated. The offered traffic load is defined as

$$L = \frac{1}{C} \sum_{i=1}^3 \frac{\lambda_{ni} + \lambda_{hi}}{\eta_i} * r_i = 2.5$$

The constraints of P_B and P_D are given as $P^B \leq P_B^{tar} = 0.1$ and $P^D \leq P_D^{tar} = 0.01$. For comparison purpose, the optimal stationary CAC schemes was found as $N = 56$ and $T = 53.1$ by trial-and-error experiments, such that the P_L is minimized while P_B and P_D constraints are satisfied. Then we compare the P_L with that of the dynamic CAC scheme, as shown in Figure 2. To illustrate the dynamic CAC scheme, the variation of N and T values are shown in Fig. 3.

Simulation results for the two schemes are compared in Table 2, where N and T are the averaged values over the simulation time.

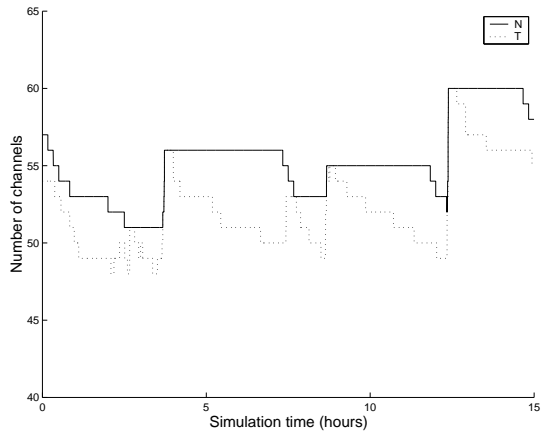


Figure 3. Illustration of varying N and T for the dynamic CAC scheme for multimedia traffic.

CAC Scheme	P_B	P_D	P_L	N	T
Stationary	0.1002	0.009	0.00245	56	53.1
Dynamic	0.0943	0.010	0.00213	55.3	52.2

Table 2. Comparison of simulation results between the optimal stationary and the dynamic CAC schemes.

It is shown that the proposed dynamic CAC scheme for VBR multimedia traffic can achieve a lower packet loss probability than the stationary ones, while satisfying both the P_B and the P_D constraints.

4. Conclusion and Future Work

In this paper, we proposed a real-time dynamic CAC scheme that jointly provide connection-level QoS and packet-level QoS for heterogeneous and varying multimedia traffic in the next generation wireless networks. The proposed dynamic CAC scheme is computation-efficient for real-time implementation. Preliminary simulation results showed that the dynamic CAC scheme achieves better performance than the optimal stationary one when being applied to the heterogeneous and varying multimedia traffic.

The packet-level QoS compared in the preliminary simulation results was the congestion-caused packet loss probability. We are evaluating the other aspects of packet-level QoS, for example, delay and packet loss caused by other factors. It is reasonable to assume that these packet-level QoS metrics have a worse performance when the number of connections in the system increases. Thus, the proposed dy-

amic CAC scheme is expected to yield good performance as well. Moreover, further research with more realistic traffic models and practical considerations based on our current work should be of great commercial as well as academic value.

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