Novel Admission Control Scheme in Multi-priority Multimedia Network Based on Bandwidth Throughput Evaluation Algorithm

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Abstract

A novel connection admission control (CAC) scheme based on bandwidth throughput evaluation algorithm is studied in multi-priority multimedia network. In the new scheme, bandwidth throughput evaluation algorithm is introduced to obtain the delay threshold of different priority traffic. Through bandwidth throughput evaluation algorithm, the delay threshold result of different traffic class is derived. The admission of different priority traffic was controlled by the delay threshold so as to guarantee network quality of service. Numerical results show that not only the service of high priority traffic or the service of low priority traffic is guaranteed in the new scheme, but also the network utilization is promoted.

Keywords: *multiple priority, bandwidth throughput evaluation, delay reservation; connection admission control*

1. Introduction

In order to guarantee the QoS of multi-priority multimedia network, various call admission control (CAC) algorithms are proposed [1-4]. These algorithms only pay their attention to the QoS guarantee and the utilization of network on the network part; they neglect the research of the admission control on the user part. Norden [5] proposes a multi-traffic delay reservation scheme under the user part to decrease entire network blocking probability, but its delay bound is not discussed and is simply set to be a constant. Ikenaga [6] proposes an analytical model of delay reservation scheme. By applying it to a server-based QoS management network, it could get the related blocking probability and the waiting time distribution of requests. Wang [8] proposes a static-priority schedule scheme. When a new connection request happens, the scheme controls its admission through calculating its delay violation probability. But Ikenaga's and Wang's network model is not completely accord with real network, because it supposes all traffic classes have same bandwidth. In real network, different traffic class always has different bandwidth.

Patil G. [9] studied the CAC scheme in wireless cellular networks. The CAC scheme gives preferential treatment to higher priority calls by reserving some bandwidth to reduce handoff failures. Sha S. [10] developed a two-dimensional Markova chain processes (MCP) analytical model to evaluate the performance of CAC for heterogeneous wireless network. The designed threshold-based CAC algorithm is proposed base on the user's classification and channel allocation policy.

Xing Xu [11] study the admission control scheme of multi-priority admission control scheme through analyzing network state space. The statistic delay threshold result of different traffic class is derived; it is used to control the admission of every traffic class. But the statistical algorithm has large computation complexity, especially when the network has various kinds of traffic and bandwidth resource.

In this paper, under a more appropriate network model, that is, different traffic classes has different bandwidth and priority, a novel admission control scheme based on bandwidth throughput evaluation algorithm was proposed. It is known that the network traffic needs to occupy network bandwidth resource, so if we know the information of network bandwidth throughput, we could analyze network traffic load in order that CAC scheme manages the admission of network traffic.

Through bandwidth throughput evaluation algorithm, the delay threshold result of different traffic class is derived. The admission of different priority traffic was controlled by the delay threshold so as to guarantee network quality of service. Numerical results show that the new scheme promotes the network utilization and network admission probability of multi-priority multimedia traffic.

2. Network Model Description

In this paper, we considered a more appropriate model of network of multi-class and multi-priority traffic. Suppose that there are K kinds of traffic classes in the network. Connection requests of class-i $(i = 1,2,\cdots,K)$ are assumed to form a Poisson process with mean arrival rate λ_i:

$$P_i(t, n_i = N) = \frac{(\lambda_i t)^N e^{-\lambda_i t}}{N!} \tag{1}$$

The call finishing time of a class-i call is assumed to follow an exponential distribution with mean $1/\mu_i$:

$$P_i(t) = \mu_i e^{-\mu_i t} \tag{2}$$

The bandwidth requested by a class-i connection is denoted by b_i, and the total bandwidth of network is denoted by C. Class-i call has priority p_i

3. The Novel Connection Admission Control Scheme

In this section, a novel CAC scheme with delay reservation based on bandwidth throughput evaluation algorithm is presented.

Suppose K kinds of traffic classes exist in multimedia network. When a connection of class-i $(i = 1,2,\cdots,K)$ arrives and if network has enough resource, the class-i connection is admitted immediately. If the network has not enough resource and there is no higher priority and equal priority connection waiting, the new arrival class-i connection is set as hold state and starts waiting. The class-i connection in the hold state keeps waiting until the network has enough resource to admit it or its waiting time exceeds th_i (calculated by bandwidth throughput evaluation algorithm, represents the delay threshold of traffic class i). When the waiting time exceeds delay threshold th_i, the waiting connection will be rejected at once.

Whenever there is a higher priority and equal priority connection waiting in the multimedia network, the new arriving connection will be rejected directly.

4. Delay Threshold of Novel Admission Control

In multi-priority scheme admission control scheme, if there is a class-i connection in the reservation state, its waiting time was controlled by delay threshold th_i. So we should get the delay threshold for every traffic classes. The delay threshold of multi-priority delay comes from the bandwidth throughput evaluation.

The bandwidth throughput per unit time of class-k could be obtained:

$$(1-cbp_k)\lambda_k b_k \tag{3}$$

Where cbp_i represents the call blocking probability of class-i, then $(1-cbp_k)$ is the success rate of admission of class-i.

So, the bandwidth throughput per time unit of all traffic has:

$$\sum_{i=1}^{K}(1-cbp_i)\lambda_i b_i \tag{4}$$

The load of the network link with bandwidth C in multi-priority multimedia network is:

$$\frac{\sum_{k=1}^{K}(1-cbp_k)a_k b_k}{C} \tag{5}$$

The bandwidth throughput of the network under full load has:

$$\begin{aligned} C' &= \frac{1}{\frac{\sum_{k=1}^{K}(1-cbp_k)a_k b_k}{C}} \times \sum_{k=1}^{K}(1-cbp_k)\lambda_k b_k \\ &= \frac{\sum_{k=1}^{K}(1-cbp_k)\lambda_k b_k}{\sum_{k=1}^{K}(1-cbp_k)a_k b_k} C \end{aligned} \tag{6}$$

When class-I traffic enters delay reservation state, it needs those bandwidth resources listed below under the multi-priority multimedia network:

Enough bandwidth resource to admitted new arrival traffic that has higher priority;

Bandwidth resource bi to admitted class-I traffic under delay reservation state;

Suppose the bandwidth resource used to admitted class-I traffic under delay reservation state is b_1', and the priority has $p_1 > p_2 > \cdots > p_k$. For highest priority class-1 traffic, b_1' is equal to b_1:

$$b_1' = b_1 \tag{7}$$

Then, for the lower priority class-2 traffic, the bandwidth resource throughput b_2' which used to admit class-2 traffic under delay reservation state has the following formula with b_2:

$$b_2' = \frac{b_2}{(1 - \frac{(1-cbp_1)\lambda_1 b_1}{C'})} \tag{8}$$

Where $\lambda_1 b_1$ is the occupied bandwidth resource of class-1 traffic per time unit, $(1-cbp_1)\lambda_1 b_1 / C'$ is the probability of occupied network bandwidth throughput of class-1 traffic. So, if class-2 traffic with bandwidth b_2 was admitted, the unoccupied network bandwidth throughput b_2' was equal to $b_2 / (1-(1-cbp_1)\lambda_1 b_1 / C')$.

If there is class-3 traffic that has lower priority than class-1 and class-2, the bandwidth resource throughput b_3' which used to admit class-3 traffic under delay reservation state could be calculated through:

$$b_3' = \frac{b_3}{(1-\frac{(1-cbp_1)\lambda_1 b_1}{C'} - (1-\frac{(1-cbp_1)\lambda_1 b_1}{C'}) \times \frac{(1-cbp_2)\lambda_2 b_2}{C'})} \tag{9}$$

Where $\lambda_2 b_2$ is the occupied bandwidth resource of class-1 traffic per time unit, $(1-(1-cbp_1)\lambda_1 b_1 / C') \times ((1-cbp_2)\lambda_2 b_2 / C')$ is the probability of occupied network bandwidth throughput of class-2 traffic.

It could be found that the solving process of b' is an iterative process, and has the following iterative formula:

$$\begin{aligned} b_i' &= \frac{b_i}{1-\sum_{k=1}^{K} \frac{d_k b_k}{b_k'} \frac{(1-cbp_k)\lambda_k b_k}{C'}} \\ &= \frac{b_i}{1-\sum_{k=1}^{K} \frac{(1-cbp_k) d_k \lambda_k b_k^2}{b_k' C'}} \\ d_k &= \begin{cases} 1 & p_k > p_i \\ 0 & p_k \le p_i \end{cases} \end{aligned} \tag{10}$$

Where d_k is used to determine whether class-k traffic has higher priority than class-I traffic.

When bandwidth throughput b' was derived, the average delay $\overline{t_i}$ which represents the average elapsing time for admitting class-I traffic under delay reservation state is:

$$\overline{t_i} = \frac{b_i'}{C'} \tag{11}$$

It is known that the service time of network traffic is exponential distribution. When there are multiple multimedia traffics in service, it can be derived that the service time distribution of the fastest finished traffic is exponential distribution [12].

Obviously, the class-I traffic could not be completely admitted in average delay $\overline{t_i}$, so the delay threshold th_i should be multiplied weighting coefficient $coeff_i$, so as to promote the admission success rate:

$$th_i = coeff_i \times \overline{t_i} = coeff_i \times \frac{b_i}{C'} \tag{12}$$

Where, $coeff_i$ is the quintiles of exponential distribution, th_i is the confidential interval of delay threshold for admitting traffic, higher priority traffic has higher confidential level than lower priority traffic. It could be calculated that the confidential level is 0.95, 0.75 and 0.5, when $coeff_i$ is 2.9957, 1.3863 and 0.6931.

During the derivation of time threshold, the call blocking probability of multi-priority traffic could not get directly. Currently, the CBP of non-preemptive queue of the network model proposed in this paper still has not analytical expression and other approximate method has high computation complexity [13]. Because our scheme is not simply the non-preemptive queuing question, so the CBP of our scheme is more difficult to be derived. In this paper, we only hope to get the approximately results of time threshold of different traffic class. So, the CBP in (3) are simply displaced with the CBP of best effort scheme calculated by the Kaufman-Robert recursion method [14-15]; it could be seen from Figure 2, the curves of the two schemes have close trend.

It could be found that the computation complexity of bandwidth throughput algorithm is $O(KN)$; it is much smaller than the computation complexity $O(KN^2)$ of statistical algorithm proposed in [9]. Where K represents the kinds of traffic, N is the bandwidth resource of multi-priority multimedia network.

5. Simulation Results

In this paper, we compared three different CAC schemes: our multi-priority CAC scheme (MP-CAC scheme), non-preemptive delay reservation CAC scheme (NP-CAC scheme) and best effort CAC scheme. Non-preemptive delay reservation resource CAC scheme reserves a waiting position for all traffics, if the network is busy and there is no connections waiting or lower priority connection waiting, the new arriving connection enters into waiting position or occupies the position of lower priority connection. Best effort CAC scheme is the simplest CAC scheme, if a connection arrives and the network has enough resource, the connection is admitted, otherwise the connection is rejected by network.

In our simulation, the network has three kinds of traffic classes as [16], table 1 shows its characteristics.

Table 1. Traffic Characteristics

Traffic class	Arrival rate	Mean of served time	Occupied resource	Priority	Type
Class-1	20	1	2	High	Voice
Class-2	10	1	4	Medium	Voice/Moving
Class-3	2	1	10	Low	Data

In our multi-priority CAC scheme, because three traffic classes have different priority, the admitting probability in (12) is different. Higher priority traffic class has higher confidential interval. In simulation, class-1, class-2 and class-3 have the confidence factor of 0.95, 0.75 and 0.5 respectively. So the numerator in (12) is 2.9957, 1.3863 and 0.6931 respectively.

In this section, we discuss the comparison of the performance of three CAC schemes when the network capacity changes.

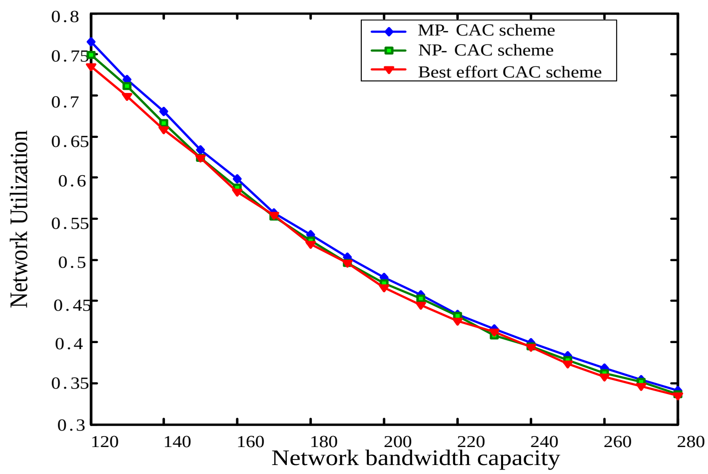

Figure 1. Network Utilization versus Network Capacity

Figure 1 shows that our multi-priority CAC scheme has the best utilization; non-preemptive delay reservation scheme performs worse than the multi-priority scheme. Meanwhile, the utilization with the best effort scheme is the worst than the other schemes.

The delay reservation scheme has the better utilization than best effort scheme, because the scheme can use the bandwidth as soon as sufficient bandwidth becomes available. Our multi-priority delay reservation scheme achieves better utilization than the non-preemptive delay reservation, because it has reserves the waiting position for each traffic class, while the latter scheme reserves only a waiting position for all traffic.

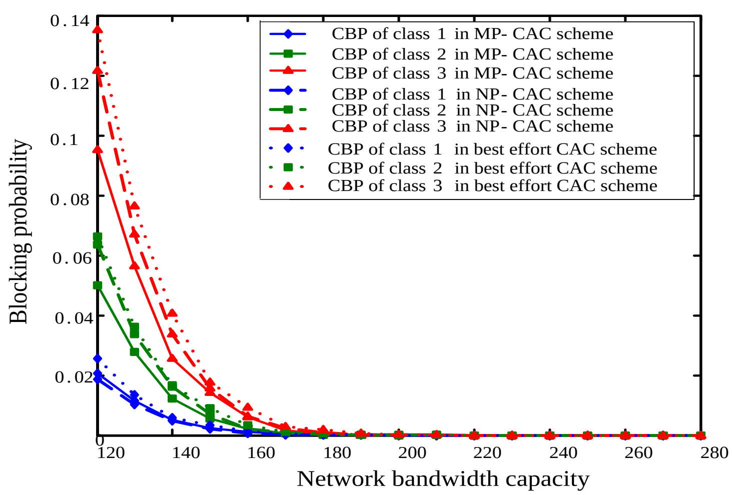

Figure 2. CBP versus Network Capacity

Figure 2 displays the results of CBP versus network capacity. Figure 2 show that the non-preemptive has the lowest CBP of class-1, our multi-priority CAC scheme is slightly higher than it, and the best effort scheme has the highest CBP of class-1. The multi-priority scheme has the lowest CBP of class-2 and class-3 than the other two schemes. Because the multi-priority scheme reserves the waiting position for lower priority calls, so it could decrease the CBP of lower priority. In non-preemptive delay reservation scheme, the highest priority calls has the best admission probability, but it decrease other lower priority calls admission probability. Figure 2 show that either the service of high priority traffic or the service of low priority traffic is guaranteed in our multi-priority CAC scheme.

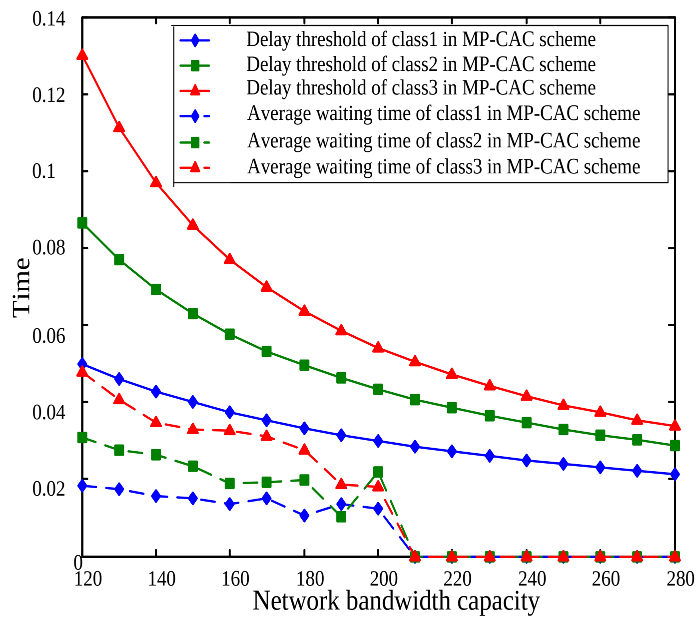

Figure 3. Time Threshold and Average Waiting Time versus Network Capacity

Figure 3 shows the delay threshold and average waiting time of each traffic class, it could be found that higher priority traffic need less waiting time to be admitted than lower priority traffic. For lower priority traffic, their success rate of connection admitted could be promoted, when they are willing to keep waiting for service in their delay threshold. There is a little fluctuate of average waiting time when the capacity is 180, 190 and 200, this is because the chance of waiting for service decreases greatly when the network link capacity is enough, so the simulation results is not very stable.

6. Discussion and Conclusion

A great deal of CAC schemes pay their attention to the control under network part, they ignore the control under user part in the network. Based on delay reservation control, a multi-priority delay reservation CAC scheme is proposed in this paper. Numerical results show either the service of high priority traffic or the service of low priority traffic is guaranteed in the novel CAC scheme with multi-priority delay reservation, and the utilization of the network is also promoted especially when the network load is heavy.

Simulation results also show that the average waiting time of users is much less than their waiting time threshold, that is, only if users keep waiting for a while, they may be admitted by the multimedia network at once, and when the network capacity increases, user's waiting time will reduce too. So the strategy introducing delay reservation control into CAC is significant.

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