# Adaptive Admission Control for Quality of Service Guarantee in Differentiated Services Networks

**Elaheh Alipour and Karim Mohammadi**,
University of Science and Technology, Tehran, Iran

**Summary**
For avoiding congestion, the amount of injected traffic into the network should be controlled. Differentiated services network can support the quality of service (QoS). For QoS guarantee, Admission control mechanism should be added to the edge routers of the network. The process of deciding to accept or reject a new request is called admission control. In this paper, parameter based admission control (PBAC) is compared with measurement based admission control (MBAC), as well to situation when no admission control is used. These methods are implemented in ingress nodes of differentiated services network. In proposed MBAC scheme, an adaptive method is used for estimating the required bandwidth. We use NS-2 simulator to demonstrate that the proposed admission control achieves the desired performance and possesses important attributes, e.g. high utilization with bounded loss together with low blocking.

***Key words:***
*Quality of service, differentiated services network, parameter based admission control, measurement based admission control.*

## 1. Introduction

Real time multimedia applications are increasingly becoming an important part of Internet traffic. Different architectures for quality of service (QoS) are widely used. They provide better QoS in terms of delay, loss and jitter. One main approach that has been carried out by the IETF is the differentiated service (DiffServ) model [1]. In DiffServ model, the flows are aggregated in a few classes. The packets belonging to specific classes are forwarded according to their per hop behavior (PHB) [2]. The IETF DiffServ Working Group has defined two PHBs. Expedited Forwarding (EF) PHB [3] intended to offer low loss, low delay, low jitter, assured bandwidth, and end to end service. Assured Forwarding (AF) PHB group [4] designed to ensure that packets are forwarded with a high probability of delivery, as long as the aggregate traffic in a forwarding class does not exceed the subscribed information rate.

In order to make QoS guarantee, DiffServ network has to support admission control [5]. Without admission control, narrow-bandwidth networks can become heavily congested or seriously underutilized. To be efficient, admission control must predict future traffic of all connections when it makes a decision to admit or reject a new connection. If the sum of the bandwidth usage of the current requests and a new request is greater than the network's total bandwidth, reject the request, otherwise accept it. When a new request arrives, all network bottlenecks along the end-to-end route are checked in order to be sure that sufficient capacity is available for the new connection. If this is the case, the connection will be admitted; otherwise will be rejected. A well designed admission control algorithm has an important effect on network performance. A conservative admission control will be less efficient but more likely to meet QoS requirements while a more efficient and aggressive admission control may be at the risk of not meeting QoS.

In this paper, we consider admission control for real time traffic and guarantee the packet loss rate. In regard to delay, we assume that it has been taken into account in the provisioning stage by setting small queues and by QoS routing for choosing appropriate paths. We also assume that packets are lost only at the ingress nodes. For jitter controlling, successive multiplexing queues can be used.

The rest of this paper is organized as follows: section 2 and 3 present admission control and its criteria while section 4 introduces the proposed scheme. The network performance evaluation and simulation results are presented in section 5 and 6. Finally, section 7 presents our conclusion.

## 2. Admission Control

Admission control is a set of actions to check whether a service request is to be admitted or rejected. There are three categories: parameter based admission control (PBAC), measurement based admission control (MBAC) and endpoint based admission control (EBAC) [6]. PBAC is only based on traffic descriptors and certain traffic behavior assumptions [7]. In this scheme, a set of traffic descriptors represents the statistical behavior of the traffic. PBAC may be not optimal because the new traffics are unpredictable. MBAC shifts the task of traffic specification from user to the network [8]. This approach relies on real time traffic measurements. MBAC can achieve higher network utilization since the worst case rarely happens in real networks. In EBAC scheme, the

Manuscript received June 5, 2008.
Manuscript revised June 20, 2008.

user decides to join the network based on probing by using probe packets [9]. The end to end path should be the same for both probing packets and flows.

## 3. Admission Control Criteria

Admission criteria are the rules by which an admission control scheme accepts or rejects a request [10]. Different admission control criteria have been proposed. In this paper, the equivalent capacity is used. The equivalent capacity $C(\varepsilon)$ is an estimation of the arrival rate of a class of traffic such that the stationary arrival rate of the traffic exceeds $C(\varepsilon)$ with a probability of $\varepsilon$. An admission control decision is made based on $C(\varepsilon)$, the peak rate of the new flow P and the bandwidth allocated to the class C. a new request is admitted according to the following relationship:

$$C(\varepsilon) + P \le C \tag{1}$$

There are two kinds of equivalent capacity criteria. The [11] assumes the aggregate arrival rate models by a normal distribution with mean $\mu$ and variance $\sigma^2$. $C(\varepsilon)$ is given by:

$$C(\mu, \sigma^2, \varepsilon) = \mu + \sigma\sqrt{2\ln\frac{1}{\varepsilon} + \ln(\frac{1}{2\pi})} \tag{2}$$

The mean $\mu$ and variance $\sigma^2$ of the aggregate arrival are either derived from the token bucket parameters or estimated from measurements.

In [12], Floyd proposed another criterion. Given the peak rate of N sources, the equivalent capacity estimated by:

$$C(\mu, \{P_i\}_{1\le i\le n}, \varepsilon) = \mu + \sqrt{\frac{\ln(1/\varepsilon)\sum_{i=1}^{n}(P_i)^2}{2}} \tag{3}$$

The average arrival rate $\mu$ is estimated using one of the measurement techniques. The peak rate is either provided by the source or derived from the token bucket parameters using:

$$P = r + \frac{b}{U} \tag{4}$$

Where r is the token bucket rate, b is the bucket size and U is the measurement interval. The new request is admitted when the sum of the new request and equivalent capacity is less than total bandwidth.

## 4. Proposed Algorithm

In this work, we first insert the PBAC to the ingress nodes of DiffServ network, and then use MBAC in order to improve the network performance. In proposed schemes, we assume like [13] through provisioning of the network and traffic engineering, $C_{total}$ bandwidth is available edge to edge for the real time traffic. We also assume whenever a source wants to send traffic, inform to the ingress node through a reservation protocol.

In PBAC mechanism, having a number of active sources and the peak rate of the new traffic and assuming that the new source is sending traffic with peak rate, the required bandwidth for accepting the new request is computed according to equation (5).

$$C_{est} = \sum_{i=1}^{n} \mathrm{Pr}_i + \mathrm{Pr}_{new} \tag{5}$$

Where n is the number of active sources which is available in the network and $\mathrm{Pr}_i$ is the peak rate of active sources. Having the allocated bandwidth $C_{total}$ and obtaining $C_{est}$, the admission control criterion is:

$$\begin{array}{lll} if & C_{est} \le C_{total} & admit \\ if & C_{est} > C_{total} & reject \end{array} \tag{6}$$

This scheme guarantees the QoS even if all the sources send traffic with the peak rate. However, since no traffic measurement is taken into consideration, the utilization is low and the sources' blocking rate is high.

For improving the utilization and decreasing the blocking rate, we use MBAC mechanism. In proposed MBAC scheme, the only descriptor that should be determined by the user is the peak rate of sources. In the cases that the peak rate is not available, it can be easily derived by a token bucket filter (r,b) using the equation (4). We use equivalent capacity criterion for controlling bandwidth, and multiplexed effective bandwidth is estimated according to (2). In proposed scheme, the mean $\mu$ and variance $\sigma^2$ of the aggregate arrival are estimated by measurement method. $\varepsilon$ is the upper bound on allocated loss probability.

In this paper, the time window measurement process is used. The time window scheme measures the network load over a period of time [10]. The network load is sampled every averaging period (S) and the result is stored. After a window of a number of samples (T), the estimated load is updated to reflect the maximal average load seen in the previous block. Additionally, whenever a new flow is admitted to the system, the estimate is increased and the window is restarted. The estimate will be also increased immediately if a measured sample is ever higher than the current estimate.

It should be noted that the proposed scheme is suitable for estimating the required bandwidth, accepting or rejecting the new request, of a small number of traffic.

### 4.1 Equivalent Bandwidth Estimation

In this section, we demonstrate how we estimate the required bandwidth for accepting the new request. At first, we select an appropriate interval for time window measurement process. At this time-window, we measure the mean rate $\mu$ and variance $\sigma^2$, then use a method which will be described in next section, the required bandwidth for new request is estimated which is called arrival traffic ratio (ATR). With having measured parameters and having ATR, the required bandwidth for accepting the new request is estimated according to equation (7).

$$C_{est} = \mu_{measured} + ATR + \sigma_{measured}\sqrt{-2\ln(\varepsilon) - \ln(2\pi)} \quad (7)$$

### 4.2 Arrival Traffic Ratio (ATR)

For ATR estimation, we propose the following equation:

$$ATR = (1 - TRCF) \times \Pr_{new} + TRCF \times TRatio \times \Pr_{new} \quad (8)$$

Where TRatio is traffic ratio and TRCF is traffic rate control factor (TRCF). For ATR computing, these two parameters should be determined exactly. In (8), TRCF=0 shows the source sends with the peak rate and it makes MBAC be conservative and causes decreasing utilization and increasing the blocking rate. TRCF=1 shows the traffic source sends with the mean rate and therefore, more sources can be accepted and also the utilization increases and the blocking rate decreases.

For TRatio estimation, first we should compute the number of active sources in the network and their packet rates and then using (9), the sum of sources' peak rate is calculated by:

$$\Pr_{total} = \sum_{i=1}^{N} \Pr_i \quad (9)$$

The network load is estimated through measurement. We call it Aggregate load. Now TRatio parameter is estimated by:

$$TRatio = \frac{Aggregated\ load}{\Pr_{total}} \quad (10)$$

It is clear that $0 \le TRatio \le 1$.

For TRCF computing, we use an adaptive method such that this parameter adapts itself whenever the available load of the network changes. For this purpose, a safe margin for link allocated capacity and also a safe margin for target packet loss rate are defined. These safe margins are specified according to provider's policies. According to algorithm of figure 1, TRCF is adjusted automatically with changing bandwidth estimation.

```
BW SafeMargin = %A × C_total
PLR SafeMargin = %B × TPLR
if   (PLR > PLR SafeMargin)
     TRCF = 0
Total EstimatedBW = C_est × APF
if   (Total EstimatedBW ≥ BW SafeMargin)
   TRCF = max(0, TRCF − step)
else
   TRCF = min(1, TRCF + step)
```

Fig. 1 TRCF adjusting for ABE scheme

The amounts of A and B is determined by the provider. Target packet loss rate (TPLR) depends on the service type. “Step” shows the speed of TRCF changing. “Step” should be determined according to provider's policies and the trade off between QoS violations and the network utilization. APF is calculated according to [13] and it is proportional to the quantity $\frac{\sqrt{-2\ln(PLR) - \ln(2\pi)}}{\sqrt{-2\ln(PLR_{ref}) - \ln(2\pi)}}$ so that $PLR_{ref}$ is higher than PLR. This algorithm shows when the new request arrives. If packet loss rate is more than the allocated bandwidth threshold, then by setting the minimum for TRCF, ATR will be the same as peak rate of the new request, and therefore the equivalent capacity estimation will be increased.

### 4.3 Proposed admission control criterion

When a new request arrives to the edge of the network, it should be decided whether the accepting it violates the quality of the available loads of the network or not. Having the allocated bandwidth $C_{total}$ and obtaining $C_{est}$, the admission control criterion is according to algorithm of figure 2.

```
for each new admission request :
if   (C_est × APF) ≤ C_total
{
   if   (link utilization) ≤ TLU
   {
      state = admit
      Pr_total = Pr_total + Pr_new
   }
   elseif  (packet loss rate) ≤ TPLR
   {
      state = admit
      Pr_total = Pr_total + Pr_new
   }
   else   state = reject
}
if   (C_est × APF) > C_total
   state = reject
```

Fig. 2 Admission control criterion for ABE scheme

APF is policy factor and is calculated according to [13]. Threshold link utilization (TLU) is determined by the service provider. For example, if the network utilization is more important than the QoS, TLU can set to have high amount like 90%. If the QoS is more important, the TLU can set to 60% or 70%. Target packet loss rate (TPLR) depends on service type. For voice over IP (VoIP) service it is 0.01.

In proposed scheme, for reducing the blocking rate of the sources, we use timer in the ingress nodes. If a source is rejected, it shouldn't again be requested for a certain period. The VoIP sources can tolerate delay for 5 seconds at the beginning of sending traffic. Therefore, we assume that a rejected source waits for 4 seconds before sending another request.

## 5. Network Topology

We choose to validate the proposed admission control scheme through the simulation. The simulation is performed using NS-2 simulator [14] and is implemented upon S. Andreozzi's patch model which can support some of the basic DiffServ functionalities.

For better evaluation, we use 4 scenarios. In first scenario, no admission control is used. In second one, PBAC is added to the ingress nodes of DiffServ network. In the third one, MBAC method presented in [13] is implemented and in the last scenario, our proposed MBAC scheme is simulated. We use dumbbell topology of figure 3 for all scenarios.

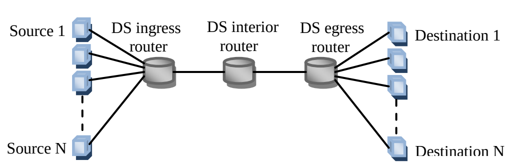


Fig. 3 Network topology

For traffic sources, we use 70 nodes consisted of two classes. There are 20 EF class source nodes and 50 best effort (BE) class source nodes. For EF class, we use VoIP model and For VoIP we use the exponentially distributed ON/OFF model with a peak rate of 64 Kbps and mean duration for the ON and OFF periods 1.004 sec and 1.587 sec respectively [15]. For comparing our scheme with [13], we choose this model for VoIP. We select the target packet loss rate 0.01. This bound represents the acceptable PLR value for the VoIP service. BE traffic is CBR with a rate of 50 Kbps and a packet size of 1000 bytes. In order to separate BE traffic and EF traffic, three queues in the DiffServ domain have been defined. One queue for BE traffic and two queues for EF traffic have been specified. The BE and EF queues have a size of 4 packets. Simulation with 10 different seed values is run in each simulated case. Simulated time for each scenario is 2000 seconds. Output link capacity is 3.2 Mbps. Different traffic use this bandwidth according to table 1.

Table 1: Allocated bandwidth for each service

| ***PHB*** | ***Allocated bandwidth*** | ***Requested bandwidth (peak rate)*** |
|---|---|---|
| EF | 23% | 64Kbps |
| BE | 77% | 50Kbps |

## 6. Simulation Results

In this section, at first we compare the first two scenarios and then compare two MBAC schemes. We are interested in the trade off between network utilization and packet loss rate together with blocking rate.

### 6.1 Results in Without-Admission Control and PBAC Scenarios

The reason for including the without-admission control scenario is to show that what happens when a DiffServ network gets overload. Figure 4 shows the PLR for the first two scenarios. Without admission control, PLR is 0.0105 that is over TPLR (0.01). With PBAC, PLR decreases to 0.001 and it can guarantee the PLR well.

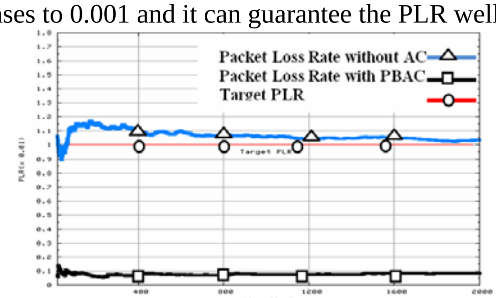


Fig. 4 PLR in without-AC and PBAC scenarios with TPLR 0.01

Figure 5 compares the utilization in two scenarios. With PBAC, the utilization decreases from 90% to 54%. This is the cost that service provider should pay for hard guarantee.

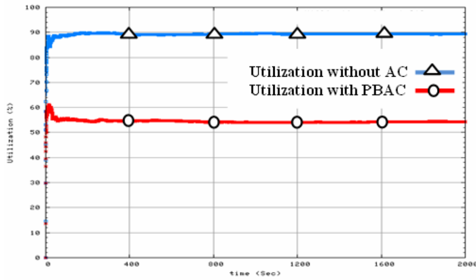


Fig. 5 Utilization in without-AC and PBAC scenarios

Figure 6 shows the average numbers of requests that arrive, are accepted and rejected. The rejected requests are so high and the blocking rate is 90%. Of course, for performance comparing of different scenarios and for creating congestion in the bottleneck, we select the number of requests so high.

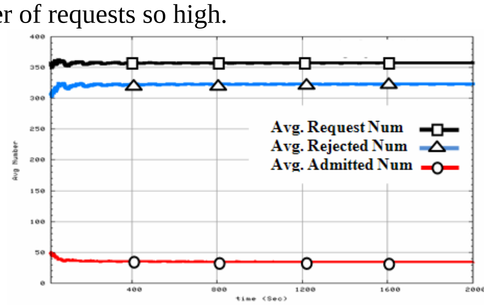


Fig. 6 The average number of requested, admitted and rejected connections in PBAC scenario

## 6.2 Results in MBAC Schemes

In order to compare the performance of our scheme, which we call it adaptive bandwidth estimation (ABE), with other existing proposals, we implement GEO scheme [13]. The reason for selecting GEO for comparison is to, like our scheme, it requires only aggregate bandwidth measurements and the sources' peak rate for accepting or rejecting the requests.

Figure 7 illustrates the PLR in two MBAC schemes. For achieving to high utilization, TLU has been set to 90%. With the same simulation parameters, in GEO the PLR is 0.006 and in proposed ABE scheme is 0.009 but is stills less than the TPLR. Note that the objective is not to achieve lower PLR, but to keep PLR below the TPLR, while maximizing utilization and simultaneously reducing blocking rate.

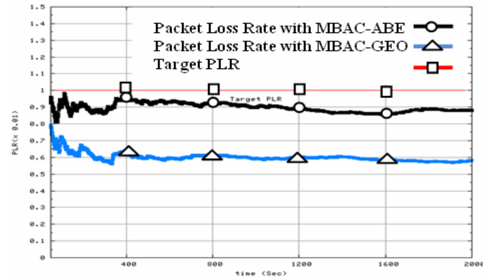


Fig. 7 PLR in GEO and ABE schemes with TPLR 0.01

Figure 8 shows link utilization in two MBAC scenarios. In ABE scheme, the utilization is 78% and it has increased 8% than GEO scheme. Because ABE is less conservative than GEO, achieving therefore higher utilization.

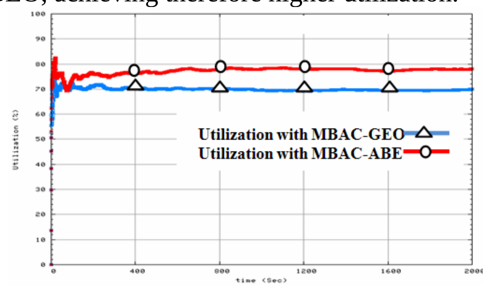


Fig. 8 Utilization in GEO and ABE schemes

Figure 9 shows the average number of rejected requests. The blocking rate decreased from 76% in GEO scheme to 12% in ABE scheme. The proposed scheme has improved the blocking rate well because the requests that once reject do not be accepted for 4 seconds.

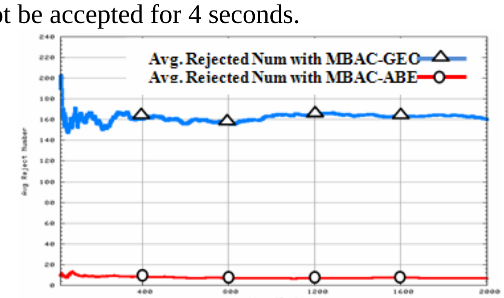


Fig. 9 The average number of rejected connections in GEO and ABE schemes

As above figures show, with the same simulation setup, both ABE and GEO achieve the target PLR but ABE address the trade-off between packet loss and utilization better than GEO. It should be noted that the key goal of an admission control algorithm is to maximize resource utilization subject to some QoS constraints. In addition, in ABE scheme the blocking rate is so smaller than GEO.

## 7. CONCLUSION

In this paper, parameter based admission control and measurement based admission control have been implemented in the ingress nodes of differentiated services network. When "hard" QoS guarantee is required, it is better to use PBAC and its cost is the low utilization. For achieving the higher utilization, MBAC mechanisms should be used. We have presented a simple MBAC algorithm for DiffServ network. We have introduced the adaptive bandwidth estimation (ABE) algorithm that takes in consideration safe margins for link capacity and packet loss rate, bandwidth estimation, and admission policy factor in order to adapt to the network load such that the estimated bandwidth adapts itself whenever the available load of the network changes. In the proposed MBAC-ABE scheme, we have achieved the high utilization and the low rejection while have satisfied the target packet loss rate.
We have validated our scheme only in a VoIP+BE scenario but we believe that it will be effective for other kinds of traffic. As future work, we will address the validation of MBAC-ABE scheme with other traffic like videoconference and video streaming, as well as testing our method in a larger scale network environment. In addition, increasing the utilization of the network will also be of a great interest.

### Acknowledgments

This research was supported by Iran Telecommunication Research Center (ITRC). We would like to express our appreciation to this company for its financial assistance.

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**Elaheh Alipour** received the B.S. and M.S. degrees in Electrical Engineering from Iran University of Science and Technology in 2004 and 2008, respectively. During 2004-2008, he stayed in Integrated Telecommunication Network Management group in communication technology part at Iran Telecommunication Research Center (ITRC).