Simple Parameter-Based CAC Scheme for DiffServ Domain

H. Zainol Abidin, *IEEE Member*, N. Md Din, *IEEE Member* and N.Fisal, *IEEE Member*

Abstract— **Future sophisticated Internet applications require strict end-to-end performance guarantees as Internet is no longer meant only for transferring data such as file transfer and email. It is changing into broadband integrated network that should be capable of carrying all sorts of traffics including real time and non real time traffics with different requirements. This is the limitation of normal Internet Protocol (IP) network which cannot guarantee enough resources in order to provide Quality of Service (QoS). This paper focuses on traffic management mechanisms in a QoS model known as Differentiated Services (DiffServ) where a parameter-based Connection Admission Control (CAC) scheme is deployed in a DiffServ network. The proposed scheme is based on the mathematical analysis of peak bandwidth, effective bandwidth and mean bandwidth.**

Index Terms— **DiffServ, QoS, effective bandwidth, admission control**

I. Introduction

Traffic control and resource management are two essential aspects in protecting the network from congestion and to achieve realistic network efficiency in compliance with the QoS. CAC can provide an efficient traffic control and resource management environment. With CAC, network attempts to deliver required QoS by allocating an appropriate amount of resources and limits the incoming calls into the network in order to protect the already connected calls from being interrupted. There are two types of CAC known as parameter-based and measurement-based. Parameter-based CAC ensures that the sum of reserved resources is bounded by capacity where amount of network resources required are given according to the flow characteristics. In contrast, measurement-based CAC relies on measurement of actual traffic load in making admission decisions and can only be analyzed through experiments on either real networks or a simulator [9].

Current DiffServ architecture lacks the mechanism for per flow admission control where such an approach weakens the service compared to IntServ [12]. It is also recommended by the Internet Engineering Task Force (IETF) in RFC 2990 [8] that an admission control function should be included in a DiffServ network. DiffServ alone does not guarantee any QoS in an end to end fashion. All it does is offering differentiated service to packets on per hop basis. Hence, the successful deployment of DiffServ requires a CAC mechanism, which needs to be scalable and relatively simple to implement. This is to ensure that the network can support additional data without degrading the QoS of data that are already admitted. CAC also could optimize the use of network resources in order to achieve realistic network efficiency [4]. This paper suggests the use of a simple parameter-based CAC in a DiffServ domain.

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II. Related Works

As mentioned in the last section, providing QoS in a DiffServ network can be further facilitated by having an admission control mechanism. Several works have been carried out by other researchers to address this problem. A measurement-based CAC algorithm is proposed by [15] by exploiting the global effective envelopes and service envelopes to accurately characterize the arriving and departing traffic aggregates.

In reference [12], two admission control schemes known as Random Early Dropping admission control and Random Early Remarking admission control are proposed. This work is basically related to work presented in [12] and [13] where these two references introduce Fair Intelligent Congestion Control over DiffServ (FICC-DS). This method involves a Resource Discovery (RD) loop, a fair estimation algorithm and a source admission control algorithm. RD which is placed between the edge routers of DiffServ estimates bandwidth fairness of DiffServ classes while Resource Management Factor (RMF) will allow an admission control to adjust its admission rate according to the availability of resources.

A new CAC and control traffic engineering framework for small networks using DiffServ is introduced in [11]. Decisions are made at the edge routers of the network and the MPLS paths are set up between each pair of edge routers. Although QoS goals are achieved, some improvements are needed such as the amount of failed EF calls should be minimized. In reference [4], it is assumed that a DiffServ network is engineered and provisioned where admission control only need to be deployed at the first points of aggregation. Besides that, no further QoS degradation is expected in the core network. The simulation results show that these approaches are relatively insensitive to differences between the sources declared and the actual behaviour. Reference [2] provides QoS guarantees in a DiffServ environment based on traffic shaping at edge routers only while in [17], the ingress routers make admission decisions according to the network status information which is obtained by sending probing packets from the ingress edge router to the egress edge router of the network. Each router will passively monitor the arriving traffic and mark the probing packets with its network status.

Different CAC schemes which carry different implementation costs in terms of resource allocation and extra signaling are compared in [5]. Two types of CAC considered here are Measurement-based CAC (M-CAC) and Resource Allocation-based CAC (RA-CAC). M-CAC guarantees end-to-end delay bounds statistically based on most recent link state information while RA-CAC guarantees the bound deterministically using Resource Reservation Protocol (RSVP) like signaling to allocate necessary resources in an aggregate and scalable way. Based on the observation, these two approaches exhibit different performance and cost in a DiffServ network. M-CAC is quite straightforward and good for the case where a light implementation is required. In contrast, RA-CAC is strict in guaranteeing the delay bound of calls at the extra cost of signaling and of additional link state information. Thus, RA-CAC is well suited when the worst-case end-to-end delay explicitly bounded even at extra cost.

Based on the above works, it is found that these CAC schemes have proven that the setbacks of normal DiffServ network can be improved. However, it is found that these techniques are not so simple to be incorporated in the DiffServ network. Thus, this paper suggests the use of a simple parameter-based CAC scheme that is applied at the ingress edge router in a DiffServ network. It is believed that the proposed CAC scheme could enhance the DiffServ network.

III. Proposed Technique

The network model used to illustrate the parameter-based CAC is shown in Figure 1. All links is 1.554Mbps with 0.5ms delay. Traffics are classified as Expedited Forwarding (EF), Assured Forwarding (AF) and Best Effort (BE). The amount of bandwidth allocated to each traffic is explained in the following subsections.

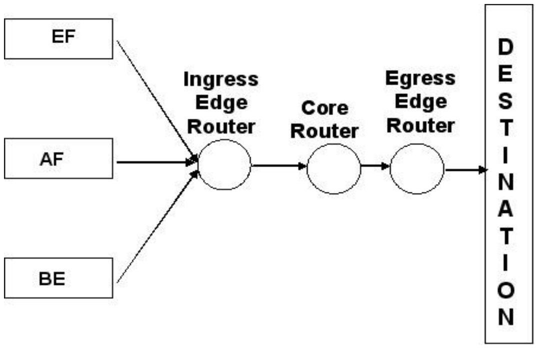

Fig. 1. DiffServ with Proposed CAC Scheme Network Model

A. EF and Peak Bandwidth Allocation

EF is assigned to Constant Bit Rate (CBR) traffic such as voice. Deterministic rate traffic such as voice sources, usually hold one unit of source for the whole duration of the connection [10] and normally it is allocated a fixed peak bit rate as reported in [1] and [18]. If the available bandwidth is occupied, the incoming EF traffic flow is rejected at the admission control. The resulting model for EF traffic is the M/M/m/m queueing system as shown in Figure 2. The figure illustrates the state-transition-rate diagram for *m*-server (time-slot) loss system with Markov arrival and service process.

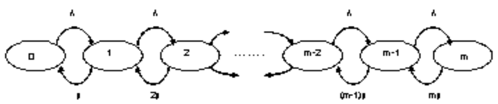

Fig. 2. State-Transition-Rate diagram for M/M/m/m

The probability that the systems having *k* calls, p_k can be obtained as follows:

$$p_k = \begin{cases} p_0 \left(\dfrac{\lambda}{\mu}\right)^k \dfrac{1}{k!} & k \le m \\ 0 & k > m \end{cases} \quad (1)$$

where $p_0 = \left[\sum_{k=0}^{m} \left(\dfrac{\lambda}{\mu}\right)^k \dfrac{1}{k!} \right]^{-1}$, λ is the call arrival rate and μ is the call departure rate.

Hence, the fraction of time that all *m* timeslots are busy, that is the call blocking probability, p_m is determined as [10]:

$$p_m = \frac{(\lambda/\mu)^m / m!}{\sum_{k=0}^{m} (\lambda/\mu)^k / k!} \quad (2)$$

B. AF and Effective Bandwidth Allocation

Effective bandwidth has been developed over recent years to provide a measure of resource usage which represents the trade-off between different type of sources that consider their statistical characteristics and QoS requirement [19]. Finding the effective bandwidth, B_E in a network is important in order to maintain the QoS of the connection and to ensure that the connections are used efficiently for Variable Bit Rate (VBR) traffic. B_E lies between B_P and mean bandwidth [3]. The effective bandwidth for VBR traffic can be calculated in many ways such as using Gaussian distribution [14], Pareto distribution [16] and Fractional Brownian Motion (FBM)[20].

AF sources such as video traffic can be represented by Gaussian distribution. The B_E for a Gaussian i.i.d random process, *x(n)* can be calculated by using the following equation [14].

$$B_E = \mu + \frac{\sigma^2}{2}\delta \quad (3)$$

where μ is mean arrival rate and σ^2 is the variance. δ is determined by using the following equation

$$\delta = \left[\frac{\ln(\alpha) - \ln(\varepsilon)}{B} \right] \quad (4)$$

where $0 < \alpha \le 1$.Typically, α is set to 1. ε is the loss probability and B is the buffer size.

Reference [16] stated that, Pareto distribution is suitable to represent modern network traffic such as VBR, Web etc. The B_E can be determined by using Pareto distribution as follows :

$$B_E \ge \mu + \left[\frac{-2a\mu \ln \varepsilon}{B^{2(1-H)} f(H)} \right]^{\frac{H}{2}} \quad (5)$$

where, μ is the mean arrival rate of the traffic stream in bps, a is the variance coefficient which is calculated as the variance to mean ratio, B is the buffer size, H is the Hurst value and finally ε is the lost probability. Function of Hurst parameter, f(H) could be determined by using the following equation.

$$f(H) = \frac{1}{(1-H)^{2(1-H)} H^{2H}} \quad (6)$$

Fractional Brownian Motion (FBM) is normally used to represent the VBR or Long Range Dependence (LRD) traffic such as video. The characters and the effects of B_E of two different bursty traffic, short-range bursty (SRB) and LRD are studied in [20]. LRD traffic can affect the loss probability predicted by B_E. In [20], it is reported that when the arrival flow exhibits LRD, B_E which is determined in conventional way fails to give bounds on Cell Loss Rate (CLR) which is considered as packet loss probability or ε in this paper. Thus, the B_E calculation for LRD traffic which is based on the FBM is modified with the modification of tail distribution of queue length to:

$$P(Q > q) \approx e^{-\delta^{LRD} q^{v}} \quad (7)$$

where $v = 2(1-H)$.

Here the asymptotic decay rate, δ^{LRD} is modified and the B_E for LRD, B_E then is rewritten as follows:

$$\delta^{LRD} = -\frac{\ln \varepsilon}{B^{v}} \quad (8)$$

$$B_E = \frac{1}{d\delta^{LRD}} \ln E[e^{\delta^{LRD} W[d]}] \quad (9)$$

where B is the buffer size, E is the expectation and $w[d]$ is the arriving workload at time interval d.

The above techniques are based on work by [6]. The effective bandwidth or equivalent capacity is computed from the combination of two different approaches known as the fluid flow model and the approximation of the stationary bit rate distribution. After looking at the different techniques, the fundamental equation [6] is used in this work due to its simplicity and has been used widely by other researchers. In [6], it is assumed that the source feeds a finite capacity buffer with constant service time and B_E is calculated as follows:

$$B_E = \frac{a - B + \sqrt{(a-B)^2 + 4Bar}}{2a} R \quad (10)$$

where $a = \ln\left(\frac{1}{\varepsilon}\right) b(1-r)R$, $r = \frac{b}{b+i}$,

R is the peak rate of the traffic, b is the burst time, i is the idle time, B is the buffer size and ε is the loss probability. For this work, B_E is calculated based on equation (10) with the project specifications. Loss probability is assumed to be limited to 1 x 10^{-9}.

C. BE and Mean Bandwidth Allocation

BE represents the non real-time applications such as data coming from the Local Area Network (LAN). Generally, non real-time traffic does not need any admission control. Thus, the mean bandwidth, $B_{M.}$ is allocated for this type of traffic. The arrival and service time of BE packets can be approximated by Markov birth and death process in an infinite queuing system or particularly M/M/1 queueing system. The birth-death process of such queuing system can be illustrated as state-transition-rate diagram of Markov Chain in Figure 3.

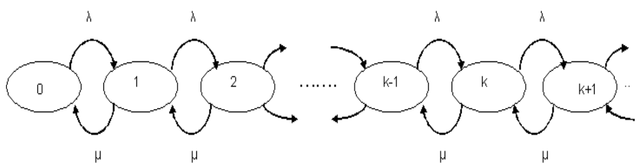

Fig. 3. State-Transition-Rate Diagram for Infinite Queueing System

The probability that the systems with k members. Hence, p_k can be simplified as follows:

$$p_k = p_o \prod_{i=0}^{k-1} \frac{\lambda}{\mu} \quad , k \geq 0 \quad (11)$$

where

$$p_0 = \frac{1}{\left[1 + \sum_{k=0}^{\infty} \left(\frac{\lambda}{\mu}\right)^k\right]}$$

Since $\lambda < \mu$, the summation will converge:

$$p_0 = 1 - \frac{\lambda}{\mu} \quad (12)$$

From the stability conditions, the utilization, ρ should be $0 \leq \rho < 1$ to ensure that $p_0 > 0$. The steady-state probability of finding k customers in the system is:

$$p_k = (1-\rho)\,\rho^k \quad , k = 0,1,2,.. \tag{13}$$

By applying Little's formula, the average delay, $E[t]$ is obtained from $E[t] = E[n]/\lambda$, where $E[n]$ is the average number of customers in the system and calculated as:

$$E[n] = \frac{\rho}{1-\rho} \tag{14}$$

$$E[t] = \frac{1/\mu}{1-\rho} \tag{15}$$

Based on the above analysis, EF, AF and BE traffics are allocated with B_P, B_E and B_M respectively. The CAC algorithm is shown in Figure 4.

```
set bandwidth allocated for EF, AF and BE
as follows:
  Bandwidth for EF = peak bandwidth, BP
  Bandwidth for AF = effective bandwidth,
BE
  Bandwidth for BE = mean bandwidth, BM

When a new packet arrives,
Classify the packet into class EF, AF and
BE;

if packet is classified as EF
  Check bandwidth availability
  if incoming bandwidth, BP <= available
bandwidth
    Accept packet
    Available bandwidth = Available
bandwidth - BP
  else
    Reject packet
if packet is classified as AF
  Check bandwidth availability
  if incoming bandwidth, BE <= available
bandwidth
    Accept packet
    Available bandwidth = Available
bandwidth - BE
  else
    Reject packet

if packet is classified as BE
  Check bandwidth availability
  if incoming bandwidth, BM <= available
bandwidth
    Accept packet
    Available bandwidth = Available
bandwidth - BM
  else
    Reject packet
```

Fig. 4. Proposed Parameter-based CAC for DiffServ

IV. RESULTS AND ANALYSIS

Network performances for the DiffServ deployed with the proposed CAC scheme are compared with performance given by the ordinary DiffServ network without any CAC mechanism. The performances of each traffic are compared based on the metrics shown in Table I.

TABLE I
METRICS USED FOR EF, AF AND BE PERFORMANCE STUDY

PHB	Metrics
EF	• Blocking Probability
AF	• Blocking Probability
BE	• Throughput • Packet loss ratio

Blocking probability is measured to study the effectiveness of a CAC technique. BE traffic which is assigned to non real time traffic is not sensitive to time delay. However, this type of traffic is sensitive to packet loss. Thus, the performance metrics used are throughput and packet loss ratio.

A. *Performance Evaluation of EF Traffic*

EF traffic is assigned for CBR traffic such as voice in this project. The QoS metric used for EF traffic is blocking probability. The simulation to evaluate the performance of EF traffic is done by increasing the EF rate while the other traffics are kept constant. The traffic specifications for EF evaluation is shown in Table II.

TABLE II
PARAMETERS USED FOR EF PERFORMANCE EVALUATION

PHB	Packet Size	Type of Traffic	Agent	Rate	Buffer Size
EF	256B	CBR	UDP	80kbps	50 packets
AF	1000B	Pareto	UDP	376kbps	50 packets
BE	1500B	Exponential	TCP	320kbps	1000 packets

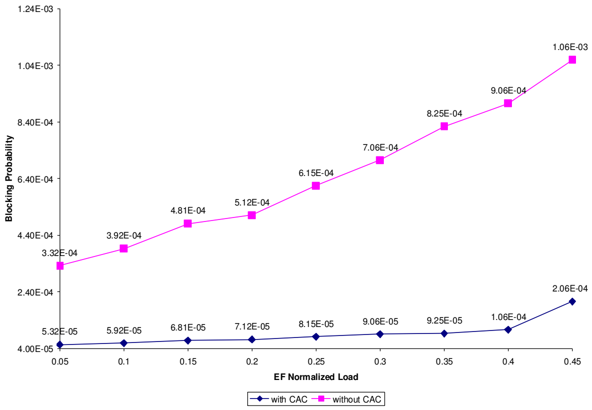

Fig. 5. Blocking Probability for EF Traffic

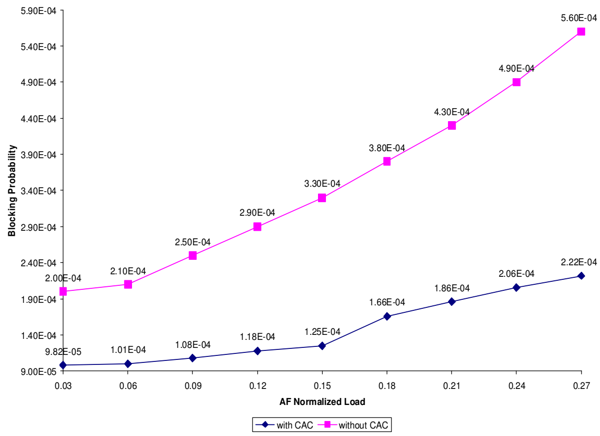

Fig. 6. Blocking Probability for AF Traffic

From Figure 5, it can be seen that more EF packets are accepted in the network when the proposed CAC scheme is included in the DiffServ network for example when the load is 0.45, the blocking probability reduced by 80.6%. This is due to the sufficient bandwidth i.e the peak bandwidth that has been allocated to the EF traffic such as voice.

B. *Performance Evaluation of AF Traffic*

The AF traffic represents VBR type of traffic such as video streaming and same as EF, blocking probability is evaluated. The simulation to evaluate the performance of AF traffic is done by increasing the AF rate while the other traffics are kept constant. Same as EF traffic, the performances are taken on load basis. The traffic specifications for AF evaluation are shown in Table III.

TABLE III
PARAMETERS USED FOR AF PERFORMANCE EVALUATION

PHB	Packet Size	Type of Traffic	Agent	Rate	Buffer Size
EF	256B	CBR	UDP	640kbps	50 packets
AF	1000B	Pareto	UDP	47kbps	50 packets
BE	1500B	Exponential	TCP	320kbps	1000 packets

Figure 6 illustrates the blocking probability for AF traffic which is assigned with pareto-based video streaming. It can be seen that more packets are accepted in the network when CAC is included in the DiffServ network. On average, the blocking probability has reduced by 57.6%. This is also due to the sufficient bandwidth that has been allocated to the AF traffic which can be classified as bandwidth crucial traffic.

C. *Performance Evaluation of BE Traffic*

BE traffic is represented by exponential traffic which is another type of non real time traffic. The simulation to evaluate the performance of BE traffic is done by increasing the BE traffic while the other traffics are kept constant. The BE performances are also observed based on their load. The traffic specifications for BE evaluation are shown in Table IV.

TABLE IV
PARAMETERS USED FOR BE PERFORMANCE EVALUATION

PHB	Packet Size	Type of Traffic	Agent	Rate	Buffer Size
EF	256B	CBR	UDP	640kbps	50 packets
AF	1000B	Pareto	UDP	376kbps	50 packets
BE	1500B	Exponential	TCP	40kbps	1000 packets

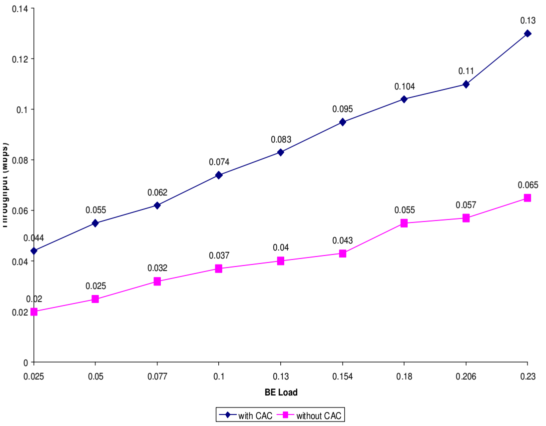

Fig. 7. Blocking Probability for BE Traffic

Figure 7 demonstrates the throughput for BE traffic in both networks with CAC and without CAC. It can be clearly seen that the proposed CAC scheme gives more BE throughput for example, when the load is 0.23, the throughput has increased by 50% when the proposed CAC scheme is deployed in the DiffServ network. Theoretically, as the throughput increase, the packet loss ratio will be decreased. Figure 8 has proven this as the packet loss ratio for BE traffic is reduced when the DiffServ network is facilitated with the proposed CAC scheme. Packets start to be dropped when the load is more that 0.05 when the DiffServ network is deployed with proposed CAC scheme. Thus, it can be concluded that, the proposed technique can improve the performance in the DiffServ network for BE traffic as this type of traffic is very sensitive to packet drops.

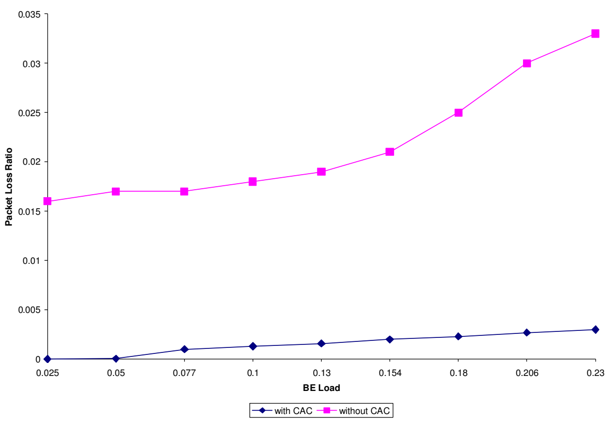

Fig. 8. Packet Loss Ratio for BE Traffic

V. Conclusions and Future Works

A simple parameter based CAC is introduced in this paper to facilitate DiffServ network. The performances given by the proposed CAC scheme for each type of traffics are discussed and compared with the normal DiffServ network.

It is proven that the proposed CAC scheme can enhance the limitation of a DiffServ network that is lacking of admission control mechanism even though the proposed CAC technique seems to be very simple compared to the previous works that have been reviewed. Due to sufficient resources, the blocking probability of real time traffic has reduced when the proposed CAC scheme is deployed in the DiffServ network. The blocking probability has reduced by 80.6% when the EF load is 0.45 and on average reduced by 57.6% for AF traffic. The throughput of non real time traffic also has increased by 50% when the BE load is 0.23. Consequently, the packet loss is also reduced as shown in the results.

It is recommended that in future, the proposed parameter based CAC scheme can be developed to be a measurement-based CAC scheme for DiffServ domain which will include signaling. Signal is sent from end to end to observe the bandwidth utilization. The allocated bandwidth is dynamic compared to the parameter-based CAC which is static. Measurement-based CAC could avoid the bandwidth wastage and increases the accepted traffics as the bandwidth allocated which is not utilized by the dedicated traffic can be used by other traffics. For example, if the bandwidth allocated to AF traffic is not used, bandwidth allocated for EF traffic can be expanded depending on the traffic requirements. Also incorporating dynamic bandwidth allocation with the parameter/measurement based CAC and extending it with a routing scheme potentially can provide a solution for QoS support in next generation IP networks.

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