Differentiated Services Enhancements for Efficient IP QoS Implementation

H. Z. Abidin & N. M. Din,
Department of Electrical Engineering,
College of Engineering,
Universiti Tenaga Nasional,
KM 7, Jalan Kajang-Puchong,
43009 Kajang,
Selangor, Malaysia.
{husna,norashidah}@uniten.edu.my

N. Fisal,
Faculty of Electrical Engineering,
Universiti Teknologi Malaysia,
81310 Skudai,
Johor, Malaysia.
sheila@fke.utm.my

***Abstract*— To enhance the deployment of DifServ network we propose two mechanisms, i.e. Connection Admission Control (CAC) facility and hierarchical scheduling. In this paper we describe both facilities and report the results of the simulation work. Simulation work was conducted using ns-2. The CAC scheme is parameter-based, where three distinct types of DiffServ traffic were given bandwidth allocation using peak rate, effective rate and mean rate values. In the simulation work, it is found that the admission control scheme gave better service in terms of blocking probability, throughput and queue size compared to normal DiffServ network. Whereas in the hierarchical scheduling scheme, two levels of scheduling were used, i.e. using weighted round robin and priority queuing. The network performance in terms of throughput is observed. The simulation results shows that better performance were achieved with hierarchical scheduling.**

***Keywords*— DiffServ, Admission Control, Hierachical Scheduling**

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. Connection Admission Control (CAC) is one of the critical mechanisms in providing an efficient traffic control and resource management. In CAC, network attempts to deliver required QoS by allocating an appropriate amount of resources such as bandwidth, 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 prior flow characteristics. This can be analyzed by formal method. On the other hand, 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 [1].

To enhance the QoS granularity, DiffServ can be facilitated with a scheduler rather than normal First In First Out (FIFO) technique. Scheduler such as Priority Queueing, Round Robin, Weighted Round Robin, Fair Queueing and many more offer QoS by managing access to a fixed amount of bandwidth by selecting the next packet to be transmitted [2].

This paper describes work on enhancements for the DiffServ environment. The CAC scheme is discussed in Section II. Section III describes the simulation work for the CAC scheme. Section IV discusses on the hierarchical scheduling and followed by its simulation work in Section V. Section VI concludes the paper.

II. PROPOSED PARAMETER-BASED CAC IN DIFFSERV

DiffServ uses per-hop behaviours (PHBs) for different classes of traffic. These PHBs are implemented on every DiffServ router by mapping different traffic to different queues. These aggregate traffics are distinguished by the DiffServ Code Point (DSCP) in the IP header. The IETF has specified two different PHBs known as Expedited Forwarding (EF) [3] and Assured Forwarding (AF) [4]. EF traffics are normally given strict priority over the traditional best effort (BE) traffic inside the DiffServ domain. Each flow has to specify the required bandwidth in advance so that the appropriate resources can be reserved inside the network. The edge router will police each flow and the non-conformant packets will either be dropped or shaped. AF does not offer hard QoS guarantees compared to EF and IETF has specified four different AF classes. However, this paper only considers single AF class. In terms of bandwidth allocation, Peak Bandwidth (B_P) will be allocated to EF traffic, Effective Bandwidth (B_E) is allocated to AF traffic while Mean Bandwidth (B_M) is allocated to BE traffic. The calculation of these bandwidths is explained in the following subsections.

A. EF and Peak Bandwidth Allocation

A deterministic rate such as voice sources, usually hold one unit of source for the whole duration of the connection [5]. Figure 1 illustrates the state-transition-rate diagram for m-server (time-slot) loss system with Markov arrival and service process.

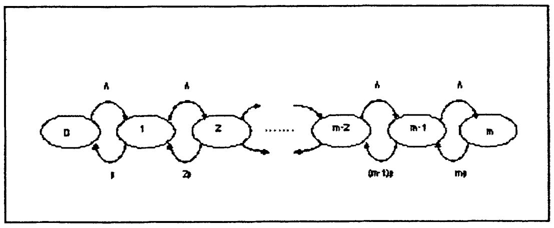

Fig 1. State-transition-rate diagram for M/M/m/m

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

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

$$p_0 = \left[\sum_{k=0}^{m}\left(\frac{\lambda}{\mu}\right)^k \frac{1}{k!}\right]^{-1},$$

where λ is the call arrival rate and μ is the call departure rate. Hence, the fraction of time that all m timeslots are busy, p_m is determined as;

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

This probability expression is known as Erlang's loss formula which is generally derived from M/M/m/m queue. Normally, Constant Bit Rate (CBR) connection is given a fixed peak bit rate such as 64kb/s for voice [6]. The Erlang's loss formula which was derived previously also indicates that Peak Bandwidth, B_p which is equal the peak rate should be allocated for EF sources.

B. AF and Effective Bandwidth Allocation

Finding the effective bandwidth 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 [7]. The fundamental of effective bandwidth calculation is formally introduced by [8]. This equation is used in this project due to its simplicity and has been used widely by other researchers. It is assumed that the source feeds a finite capacity buffer with constant service time and B_E is calculated as follows:

$$B_E = \frac{a - B + \sqrt{(a-B)^2 + 4Bar}}{2a} R \qquad (8)$$

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.

C. BE and Mean Bandwidth Allocation

Best effort IP traffic represents many of the non real-time applications such as data coming from local area network (LAN). The arrival and service time of IP packets can be approximated to Markov birth and death process in an infinite queuing system. The birth-death process of such queuing system can be illustrated as state-transition-rate diagram of Markov Chain in Figure 2.

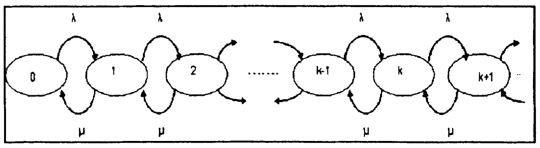

Fig 2. State-Transition-Rate Diagram for Infinite Queueing System

From the state-transition-rate diagram, the equilibrium different equation for state k can be determined as follows [5]:

$$\lambda_{k-1}p_{k-1} + \mu_{k+1}p_{k+1} = (\lambda_k + \mu_k)p_k \qquad (9)$$

where λ is the call arrival rate, μ is the call departure rate and p_k is the probability that the systems with k members. Hence, p_k can be simplified as follows:

$$p_k = p_o \prod_{i=0}^{k-1} \frac{\lambda}{\mu} \quad , k \ge 0 \qquad (10)$$

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:

$$p_0 = 1 - \frac{\lambda}{\mu} \qquad (11)$$

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

$$p_k = (1-\rho)\rho^k \quad , k = 0,1,2,.. \qquad (12)$$

By applying Little's formula, the average delay, $E[t]$ is obtained from E[t] = E[n]/λ, where $E[n]$ is the average number of customers in the system.

$$E[t] = \frac{1/\mu}{1-\rho} \qquad (13)$$

Thus, it is reasonable to allocate mean bandwidth, B_M for

BE traffic.

III. Simulation Work on Proposed DiffServ CAC Scheme

A. Simulation Model

Figure 3 shows the simulation network model and the three types of sources used are described below. In the simulation work, EF, AF and BE traffic is assigned Constant Bit Rate (CBR), Pareto and Exponential traffic respectively.

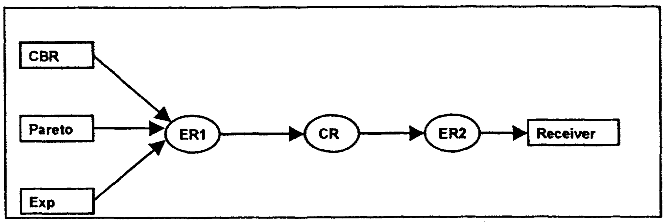

Fig 3. Simulation Model

- Source 1 (EF): CBR traffic is based on UDP transport protocol with a rate of 640kbps and packet size of 256 bytes. This traffic setup is used to represent voice application.
- Source 2 (AF): Pareto is used to represent VBR traffic based on UDP transport protocol with a mean rate of 376kbps and packet size of 1000 bytes. References [9] and [10] suggest the use of Pareto traffic agent to represent the VBR traffic model which can represent video application.
- Source 3 (BE): Exponential traffic agent is used to represent the non real-time traffic with rate of 320kbps and packet size of 1500 bytes.

All link bandwidths in the network model are 1.554Mbps. EF, AF and BE traffics are allocated with peak bandwidth, effective bandwidth and mean bandwidth respectively as shown in Table I.

TABLE 1: BANDWIDTH ALLOCATED FOR EACH TRAFFIC

Type of Traffic	Bandwidth Allocated (kbps)
EF	640
AF	269.85
BE	162.9

The following flow chart shows the simulation process that has been carried out to simulate out the proposed DiffServ CAC scheme.

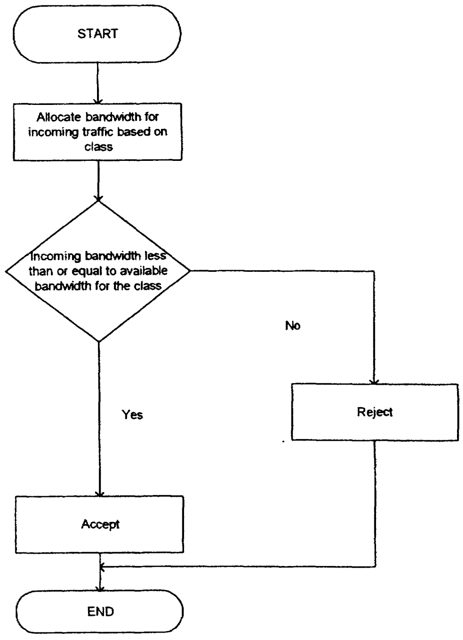

Fig 4. Proposed parameter-based CAC for DiffServ

B. Simulation Results

Network performances for the DiffServ deployed with proposed CAC scheme are compared with performance given by the normal DiffServ network. The performances are compared in terms of blocking probability, throughput and buffer queue size.

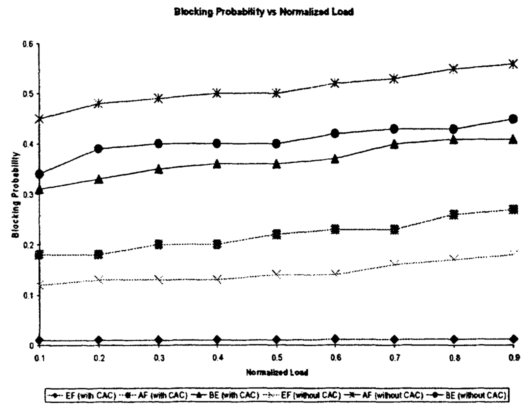

Fig 5. Blocking Probability

From Figure 5, it can be seen that more real time traffic are accepted in the network when CAC is included in the DiffServ network. Nearly zero packets are rejected for EF traffic. This is due to the sufficient bandwidth that has been allocated to the bandwidth crucial traffic such as real time video.

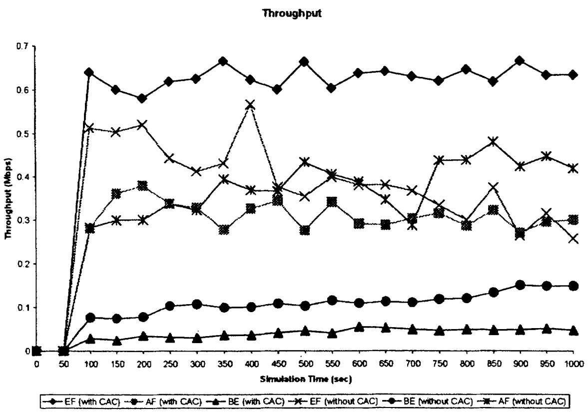

Fig 6. Throughput for each Traffic for both DiffServ with and without CAC

Figure 6 illustrates the throughput for both networks with CAC and without CAC. The throughput for real time traffic (i.e. EF and AF) is higher in DiffServ with CAC scheme. However, the throughput for BE has been reduced in the DiffServ with CAC scheme. This is due to more bandwidth allocated for real time traffic in DiffServ with CAC scheme. The throughput for EF traffic is found lower in DiffServ without CAC network.

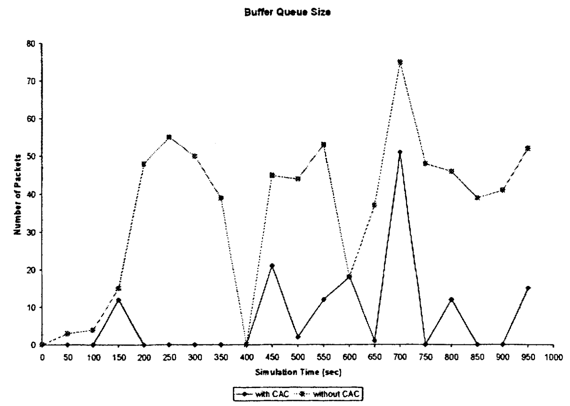

Fig 7. Buffer Queue Size

Figure 7 shows the buffer queue size for both networks with CAC and without CAC. It is seen that the buffer queue size is smaller for CAC deployed network compared to the network without CAC. Thus, it is proven that CAC offers less congested buffer and consequently, the waiting time will be reduced.

IV. PROPOSED HIERARCHICAL SCHEDULING IN DIFFSERV

Recently, hierarchical scheduling methods have been deployed in data communication area for QoS purpose in terms of rate controlling [11], Multiple Input-Queued (MIQ) switches [12], [13], scheduling latency [14] as well as in DiffServ domain [15], [16], [17]. This work suggests the used of hierarchical scheduling in DiffServ ingress edge router where the design is based on the Diffserv network model shown in [15].

A rate based scheduler and priority scheduler are proposed here. Rate based schedulers are basically schedulers with weight assigned to each service classes such as WRR while PQ is an example of a priority scheduler [2]. WRR is used in this work to schedule different classes of AF traffic before it is being scheduled using PQ with other EF and BE traffic. This technique is introduced to address the setback of both PQ and WRR scheduler.

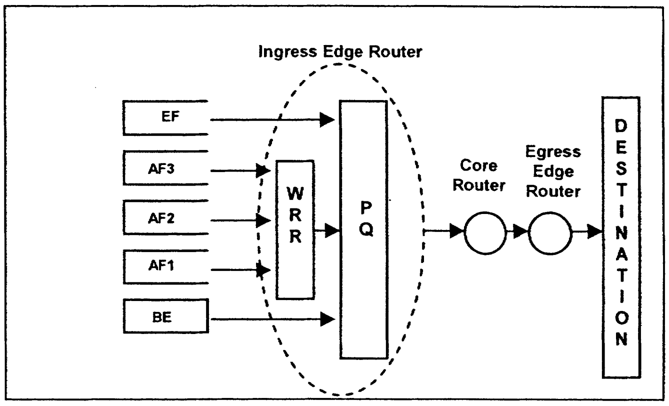

Fig 8. WRR_PQ hierarchical scheduling in simulation model

PQ is very useful for EF traffic where priorities can be set so that real time applications get priority over applications that are not time critical. However, the main disadvantage of this system is that if a higher priority queue is always full, the lower priority queues will never be served [16]. Thus, a particular kind of network traffic may dominate a PQ interface and lower priority traffic may experience excessive delay as it waits for higher priority traffic to be served. If lower priority queues are dropped due to the buffer overflow, the combination of packet dropping latency will increase and packet retransmission by host systems can lead to resource starvation for lower priority traffic.

In contrast, WRR controls the percentage of bandwidth allocated to each service class. Thus, bandwidth starvation could be avoided. WRR is also efficient in providing mechanism to support the delivery of DiffServ classes to a reasonable number of highly aggregated traffic flows. Nonetheless, the main limitation of WRR is that it gives the correct percentage of bandwidth to each service class only if all packets in all queues are in equal size or when the mean packet size is known in advance. Due to the RR nature of the algorithm, WRR tends to increase the queuing delay and jitter for EF traffic [16]. Therefore, it is envisaged that WRR_PQ technique will improve the limitations of both WRR and PQ schedulers in ingress edge router of DiffServ domain.

V. SIMULATION WORK ON PROPOSED HIERARCHICAL SCHEDULER IN DIFFSERV

A. Simulation Model

Simulation was carried out using Network Simulator (ns2) on Red Hat Linux platform based on the network model shown in Figure 8. The parameters used for the simulation are shown in Table 2.

TABLE 2: PARAMETER USED IN THE SIMULATION

Parameter	PHB				
	EF	**AF3**	**AF2**	**AF1**	**BE**
Packet size	256B	1000B	1500B	1500B	1500B
Type of Traffic	CBR	Pareto	Telnet	FTP	Exponential
Agent	UDP	UDP	TCP	TCP	TCP
TCP Congestion Window	-	-	64k	64k	64k
Burst Time	-	0.5s	-	-	0
Idle Time	-	0.5s	-	-	1
Rate	640kbps	376kbps	320kbps	320kbps	320kbps
Shape	-	1.6	-	-	-
Buffer size	50 packets	50 packets	1000 packets	1000 packets	1000 packets
All link bandwidths are 1.544Mbps					

The following flow chart shows the simulation process flow that has been carried out to simulate out the proposed DiffServ hierarchical scheduler scheme.

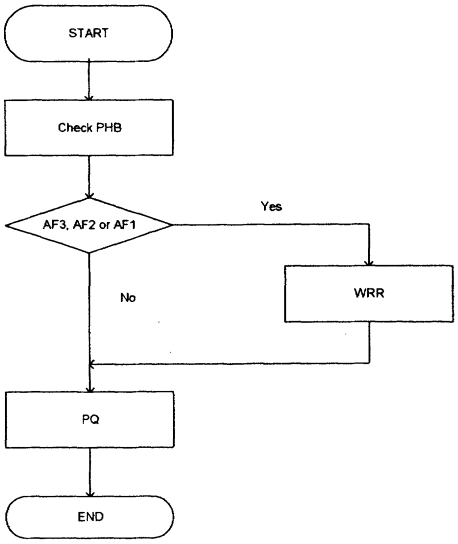

Fig 9. Proposed hierarchical scheduler technique for DiffServ

B. Simulation Results

Network performances for the proposed WRR_PQ hierarchical scheduling are compared with performance given by the normal WRR scheduler and HMCRR which was designed by [14]. The performances are compared in terms of throughput and the average end-to-end delay for each traffic type.

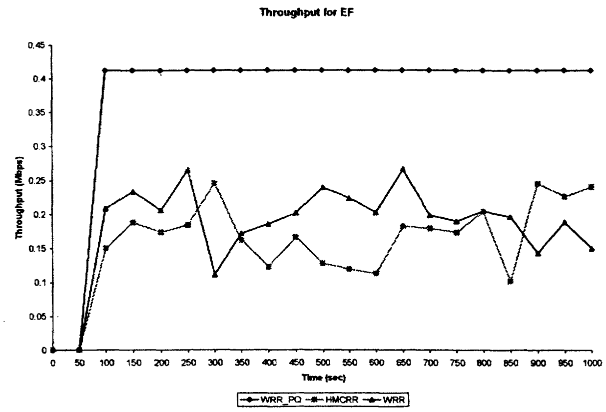

Fig 10. Throughput for EF traffic

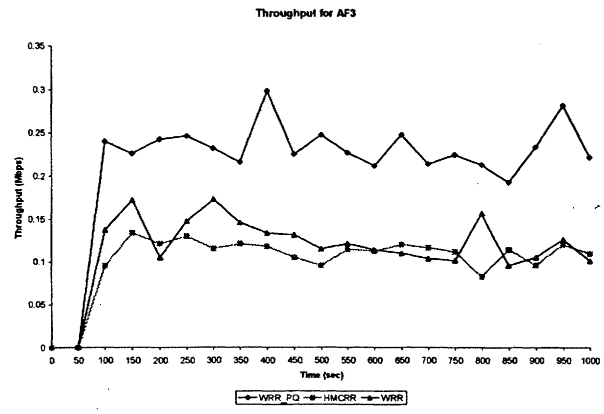

Fig 11. Throughput for AF3 traffic

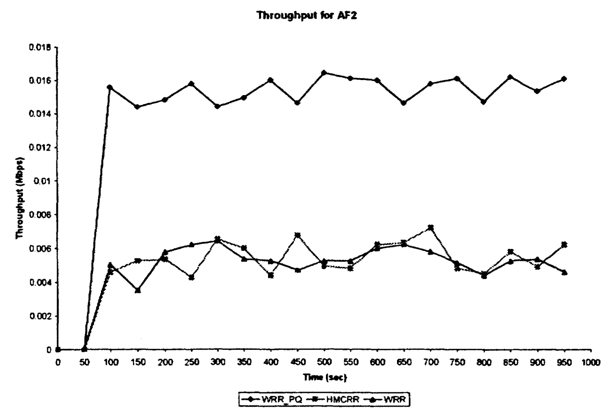

Fig 12. Throughput for AF2 traffic

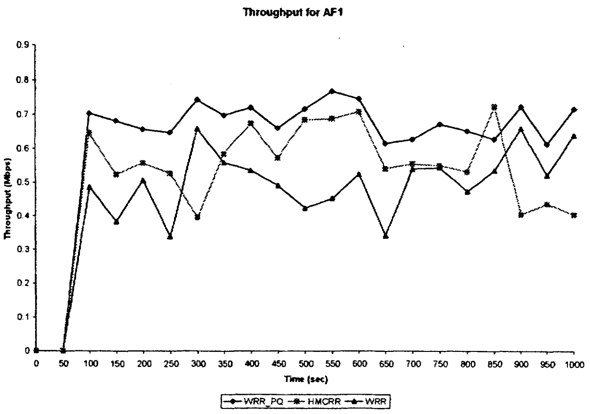

Fig 13. Throughput for AF1 traffic

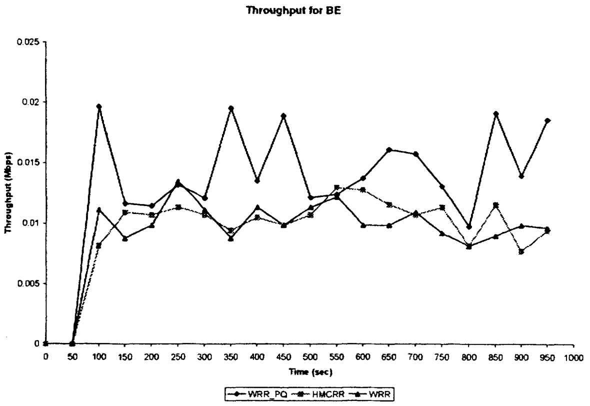

Fig 14. Throughput for BE traffic

Figures 10 to 14 illustrate throughput for each type of traffic produced by WRR_PQ, WRR and HMCRR. The figures show that WRR_PQ gives higher throughput compared to WRR and HMCRR for all types of traffic. Consequently, this will give lower packet loss ratio. Even though BE traffic might be starved, the higher throughput for BE traffic when WRR_PQ is used shows that more traffic can be served compared to the other two methods.

VI. CONCLUSIONS

CAC is an important mechanism in provisioning QoS for IP network. A simple parameter based CAC is introduced here to facilitate DiffServ network. Peak bandwidth, effective bandwidth and mean bandwidth are allocated to EF, AF and BE traffic respectively. Based on the simulation study, DiffServ network with CAC offers better services where more real time traffics are accepted in the network which consequently will increase the throughput due to sufficient bandwidths allocated to them. CAC also shows that it could reduce the buffer congestion. Hence, the end-to-end delay will be reduced particularly for real time traffic. It is envisaged that this technique could be improvised as a measurement based CAC for DiffServ network in future.

Hierarchical scheduling in DiffServ ingress edge router was introduced to provide IP QoS. Network performance in terms of throughput is observed based on our simulation results. Results show that WRR_PQ hierarchical scheduling technique gives higher throughput for all type of traffics compared to WRR and HMCRR which was introduced by [14]. Hence, this will reduce the packet loss ratio. Thus, it is clearly shown that granularity could be achieved by deploying rate based scheduler and priority scheduler in different scheduling layers in DiffServ ingress edge router.

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