# Fairness Evaluation of a DSCP Based Scheduling Algorithm for Real-Time Traffic in Differentiated Service Networks

Sabyasachi Mukherjee and O. S. Khanna

***Abstract*—It is a very vital factor to allocate the resources for improving the QoS (Quality of service) for any network carrying various types of traffic. Real-time applications, such as video conferences, are in the most important to get the benefit of QoS adaptation. Several scheduling disciplines are employed at the router to guarantee the QoS of the network. Each scheduling discipline has its pros and cons. DiffServ (Differentiated Services) is an IP based QoS support framework that differentiates between different classes of traffic. The function of the core router of the network is to forward packets as per the per-hop behavior associated with the DSCP (Differentiated services code point) value.**

**Weighted Fair Queuing scheduling discipline when merged with DSCP for traffic classification, maintain fairness of Qos. The common scheduling mechanisms are first-in-first-out (FIFO), priority queuing (PQ), and weighted fair queuing (WFQ). In this paper performance of various scheduling disciplines for real-time traffic like video was simulated using OPNET IT Guru, and it was concluded that, WFQ when merged with DSCP is a better method of queuing.**

***Index Terms*—FIFO, PQ, WFQ, DSCP, PHB, QoS, differentiated services, OPNET.**

## I. Introduction

The extensive universal use of Internet today demands very well resource management. Applications such as Skype, P2P, and interactive audio and video conversion, online gamming are increasing every day. In this scenario, nowadays the network routers are not simply the dump element rather they have significance participation on the resource allocation for various types of traffics [2].

When packets travel through the middle network, they experience enormous delay due to various reasons. The delay that occurs at the output buffer of a router is called queuing delay [4]. Such delay is handled effectively, fairly and efficiently by various scheduling disciplines.

Fairness and QoS are the most important aspects provided by any scheduler. First-in-first-out, priority queuing, weighted fair queuing are few most commonly used scheduling algorithms. Internet having only best-effort service does not provide any QoS mechanism and there is no classification of traffic in the network. It just represents a well-connected network where any traffic which exceeds the available bandwidth is simply dropped [7]. Real-time applications such as video conferences are the most important to get the benefit of the QoS adaptation by any network. Actually it is very crucial to provide QoS for sensitive application such as real-time applications [5]. The loss of such packets should also be effectively managed by scheduling mechanisms. On the other hand less sensitive packets should also be handled and transmitted fairly. Therefore it is the critical task for designing scheduling mechanisms to balance between all these criteria.

DiffServ (Differentiated Services) is an IP based QoS support framework that differentiates between different classes of data traffic. The differentiated services architecture function upon a simple model where traffic entering a network is first classified and then conditioned at the boundaries of the network as per the the DSCP value in the IP packet header, and assign different treatments to the packets called Per Hop Behaviour (PHB). Here, in the core router of the network, packets are forwarded as per the per-hop behaviour associated with the DSCP value [8].

In this paper a platform is implemented according to the Differentiated services network for QoS assessment of video conference service along with other less sensitive traffics and studied some QoS parameters such as throughput and latency for different queuing mechanisms. The rest of this paper is organized as follows. In section II, we described the architecture of Differentiated services network. In section III, we described various scheduling mechanisms. In section IV, we described our simulation platform. In section V, simulation results and performance comparisons are made. In section VI, conclusion is presented.

## II. Architecture of Differentiated Services Network

The different elements in the DiffServ architecture perform traffic classification and conditioning. Conditioning functions involves metering, marking, shaping and dropping. Fig. 1, cites the block diagram of a classifier and traffic conditioner. Classification is based on the some portion of packet header of each data packet. There are two types of classifiers, the behaviour aggregate (BA) classifier, which classifies packets based on the DSCP value only and the multi field (MF) Classifier which selects packets based on the value of a combination of one or more than one header fields of packets. Temporal properties are measured by Traffic meter of the stream of packets selected by a classifier as per the traffic profile. Packet marker is responsible for setting the DS field value of a packet to a code point. Shapers cause delay to some or all of the packets in the traffic stream for the

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purpose of bringing the stream into compliance with a traffic profile, while droppers discard some or all of the packets in a traffic stream for the purpose of bringing the stream into compliance with traffic profile [8]. Queue management defines which packets are to be dropped in case of congestion.

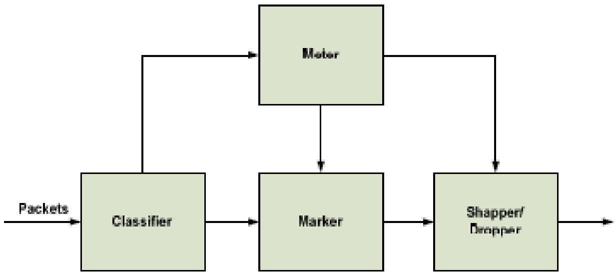


Fig. 1. Packet classifier and traffic conditioner

IETF (Internet Engineering Task Force), the DiffServ working group, has defined different PHB groups for different applications. The most commonly used PHB groups are, expedited forwarding (EF), assured forwarding (AF), and best effort (BE). Before DiffServ, the three bit precedence field in the Type of Service (ToS) of the IP header were used for priority marking of traffic by IP networks. IETF reused the ToS byte of the IP header as the DS field for DiffServ networks [8]. The EF-PHB is generally used to provide low latency, low jitter, assured bandwidth, low loss, and end-to-end services via DS domains. These characteristics are preferable for VoIP (voice over internet protocol), video conferencing and other real-time services available. EF traffic is always given superior priority above all other traffic classes, whenever congestion occurs. Assured forwarding treatment allows the operator to provide assurance of delivery of packets as long as the traffic does not cross some subscribed rate. Traffic that crosses the subscription rate has a higher probability of dropping if congestion takes place. There are four independent PHB classes in AF PHB, each with three precedence level of dropping. Default PHB has best-effort forwarding characteristics [8].

In forwarding path of a packet, differentiated services are implemented by mapping the code point contained in a field of the IP packet header for a particular forwarding treatment, or per-hop behaviour, at each network node along its path. The code points should be selected from a set of fixed values [8].

The DS field can be considered as the replacement header field of the already existing definitions of the IPv4 type of service octet and the IPv6 traffic class octet. To select the forwarding treatment a packet should experiences at each node, the six bits of the DiffServ field are used as a code point. The values of the CU bits are ignored by the differentiated services-compliant nodes while assigning the per-hop behaviour to apply to a received packet.

```
  0   1   2   3   4   5   6   7
+---+---+---+---+---+---+---+---+
|         DSCP          |  CU   |
+---+---+---+---+---+---+---+---+
```

Fig. 2. Six bits DSCP value in the DS field for selection of the PHB

In a DSCP value notation, the left-most bit is bit 0 of the DS field, and the right-most bit represents bit 5. DScompliant nodes always select forwarding treatments by matching against the entire six bit DSCP value. The value of the CU field should be ignored for PHB selection [8].

## III. Scheduling Mechanisms

The four main scheduling mechanisms are discussed in the literature: First-in-first-out, Priority Queuing, Weighted Fair Queuing and DSCP based Weighted Fair Queuing. This section illustrates these four scheduling disciplines in more details.

### *A. First-in-First-out (FIFO)*

The simplest way to schedule a packet in any network is FIFO. Here the first packet in the queue is served first in a particular time slot, regardless of any prioritization, protection or even fairness. Hence it is very simple to implement. However, it fails to achieve all other scheduling properties except complexity. FIFO suffers from head of line (HOL) issue, which means that if the first packet in the queue is blocked for any reason, the rest is blocked even though the link is idle [1].

### *B. Priority Queuing (PQ)*

Priority Queuing is developed to overcome the problem of FIFO, which does not provide any priority to any class or any data traffic. PQ generally ensures the fastest service of high priority data at every point where it is used [1]. It gives strict priority to the traffic, which is very important. The placement of each packet in one of four queues defined as-high, medium, normal, or low is performed based on the assigned priority of each packet.

The potential drawback of this scheduling mechanism is that, the lower level traffic could not be served for a long time, if the high priority is always there [6]. As a result the lower class will suffer from a starving problem, which leads to a significant discard of the packets.

### *C. Weighted Fair Queuing (WFQ)*

WFQ is a queuing algorithm based on data packet flow and the practical realization of Generalized Processor Sharing (GPS) scheme, which is a theoretical concept and maintain good fairness [3]. Two things are performed simultaneously in WFQ, first, interactive traffic is scheduled to the front of the queue for the reduction of response time, and secondly, it shares the remaining bandwidth among high-bandwidth flows in a fair way.WFQ generally looks into the matter that queues do not starve for bandwidth and all packets should get the desired services.

WFQ can detect the precedence bit marked in the IP packet header of each packet and according to that marking; it classifies the priority levels of packets. With the increment of the precedence value, WFQ allocates more bandwidth to that particular packet to avoid congestion [9].

### *D. DSCP Based Weighted Fair Queuing*

In our day to day life scheduling plays an important role for proper execution of any task. We always classify our jobs according to the priority level and then move for execution.

Similar is the fact for the routers in any network. Tasks appearing in any router to get served, first be classified according to the priority levels and then be served to maintain QoS of the network. DSCP based WFQ scheduling algorithm uses the Differentiated Services (DS) field of IP packet header for priority marking. DS field is defined in RFC2474 and RFC2475. Differentiated Services Code Point (DSCP) uses the same precedence bits as in the Type of Service (ToS) field for traffic classification but uses additional three bit which provides extra granularity.

DSCP define three distinct types of treatments, referred to as per-hop behaviors (PHB) to all traffics as, expedited forwarding (EF), assured forwarding (AF) and best-effort service. High priority traffic, like video, is assigned EF treatment [8]-[9]. EF traffic is given the highest priority. Packets being given this treatment are prioritized ahead of all other types of data. This is very much preferable for traffic that requires low delay, low jitter, and low loss. Real-time services like voice and video are in urgent requirement of this kind of treatment. The AF PHB is defined by a Committed Information Rate (CIR) and Excess Information Rate (EIR). The network should have the ability to assure the delivery of all AF traffic up to the CIR. Once the rate of AF traffic crosses the CIR, then the network will go for delivery the extra traffic up to EIR. But, if the rate of AF traffic crosses the EIR, then the traffic beyond that rate will be dropped. This is just best-effort forwarding treatment of the lowest-priority traffic. In this treatment, packets get a very limited amount of the available egress bandwidth congestion takes place.

## IV. Simulation Model Development

We considered a hypothetical network topology as illustrated in our simulations, in order to demonstrate the performance of different scheduling disciplines. DS1 link is used to connect the two routers and all other links are 10BaseT. FTP, voice, and video traffics are considered for each scheduling disciplines. Separate server is taken for each traffic type. To evaluate and compare the performance of different scheduling disciplines over video traffic we collected the video conferencing traffic received and video traffic end-to-end delay, which describes the throughput and latency respectively, for each scheduling disciplines.

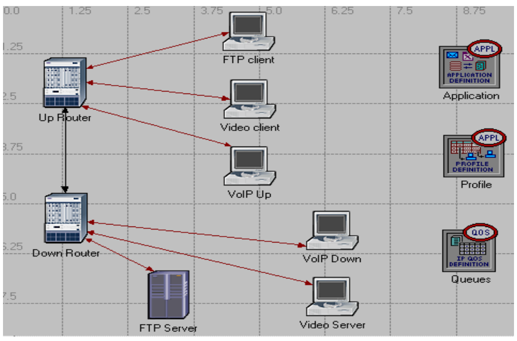


Fig. 3. The topology for which the simulation was carried out

The effect of random-early drop over drop-tail policy is also checked. While enabling random-early drop, the minimum threshold is kept 200 and maximum threshold is kept 400. Mark probability denominator, which defines, the fraction of dropped packets at the time the average queue size is at maximum threshold value, is set as 12. The value of the exponential weight factor, used for calculation of the average queue size based on the previous average and current queue size, is kept 8. For video traffic we used low resolution video starting at 10 frames per second arrival rate. The frame size is kept 128x120 pixels and keeps increasing this rate and size as load increases. The ToS is Interactive Multimedia (5) with DSCP value 101110 (EF). OPNET Application definition and IP QOS definition were employed to make all these settings.

| Attribute | Value |
|---|---|
| Frame Interarrival Time Information | 10 frames/sec |
| Frame Size Information | 128X120 pixels |
| Symbolic Destination Name | Video Destination |
| Type of Service | EF |
| RSVP Parameters | None |
| Traffic Mix (%) | All Discrete |

Fig. 4. Video traffic application definition

| Attribute | Value |
|---|---|
| Command Mix (Get/Total) | 50% |
| Inter-Request Time (seconds) | constant (10) |
| File Size (bytes) | constant (1000000) |
| Symbolic Server Name | FTP Server |
| Type of Service | Best Effort (0) |
| RSVP Parameters | None |
| Back-End Custom Application | Not Used |

Fig. 5. FTP traffic application definition

For FTP traffic the ToS is set as best-effort, the packet size is kept constant and exponential distribution for packet arrival. For voice traffic the voice encoder scheme is G.711 and ToS is set as AF43.

| Attribute | Value |
|---|---|
| Silence Length (seconds) | default |
| Talk Spurt Length (seconds) | default |
| Symbolic Destination Name | Voice Destination |
| Encoder Scheme | G.711 |
| Voice Frames per Packet | 1 |
| Type of Service | AF43 |
| RSVP Parameters | None |

Fig. 6. Voice traffic application definition

| Attribute | Value |
|---|---|
| Weight | 55 |
| Maximum Queue Size (pkts) | 500 |
| Classification Scheme | (...) |
| rows | 1 |
| row 0 | |
| ToS | EF |
| Protocol | Unassigned |
| Source Address | Video client |
| Destination Address | Video Server |
| Source Port | Unassigned |
| Destination Port | Unassigned |
| Incoming Interface | Unassigned |
| RED Parameters | (...) |
| RED Status | RED Enabled |
| Exponential Weight Factor | 8 |
| Minimum Threshold | 200 |
| Maximum Threshold | 400 |
| Mark Probability Denomi... | 12 |
| CE Marking | Disabled |
| Queue Category | None |
| Buffer Capacity | 1000 |

Fig. 7. IP QOS Definition of Video traffic

## V. Result Analysis

In this work we used OPNET IT Guru Academic version 9.1 for our network simulations. This section presents selected results from our OPNET simulations of the network shown in Fig. 1.

### A. Traffic Received for Interactive Multimedia

The transmission of interactive multimedia, that is, live streaming video requires a disturbance-less connection and a high quality link. In order to get improved performance for the video conferencing service, we simulated various protocols and studied which would best suite to produce low distortion video. Fig. 2 shows the time average video conferencing traffic received (packets/sec) for the four scheduling disciplines. It is clear from the graph that DSCPbasedWFQ outperforms all other scheduling disciplines providing higher quality of video link, hence higher throughput.

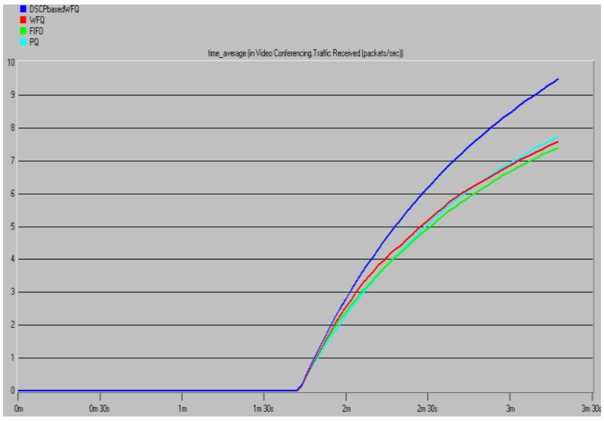


Fig. 8. Video conferencing traffic received (packets/sec)

### B. Latency for Video Traffic

Fig. 3 shows the time average video conferencing traffic end-to-end delay (sec) graph for the four scheduling mechanisms. It is also clear from the graph that DSCPbasedWFQ provide less latency and the delay is almost constant for video traffic.

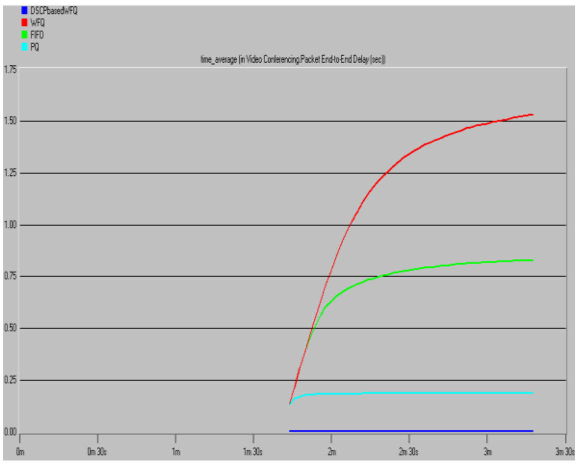


Fig. 9. Video conferencing traffic end-to-end delay (sec)

### C. Traffic received for FTP Traffic

Here also DSCP based WFQ shows larger amount of data transfer, in comparison with other scheduling techniques. It proves that DSCP based WFQ is also suitable for non real-time traffic like FTP.

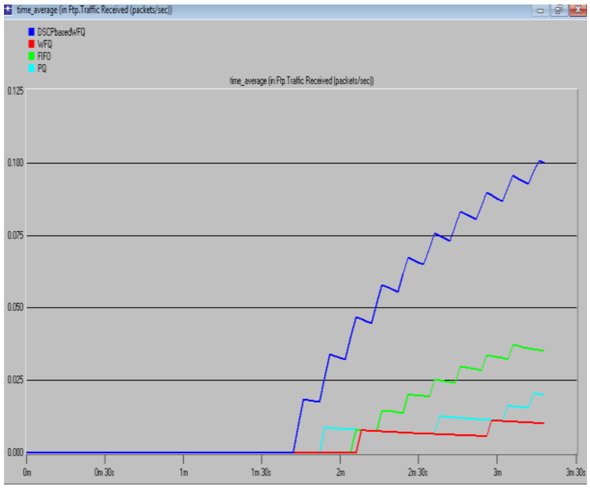


Fig. 10. FTP traffic received (packets/sec)

As it is already mentioned that we had four scenarios for the four different scheduling mechanisms. FIFO was simulated without enabling any QoS where traffic first come first served without considering any prioritization to specific traffic. So in this scenario all traffic treated equally. Though Video and voice traffic is prioritized as EF and AF43 respectively, in our simulation, this model can be applied to any kind of traffic required in collaborative systems like e-learning system.

## VI. Conclusions

In this paper, using OPNET IT Guru academic version 9.1, we summarized the performance of four main scheduling algorithms for different types of traffic. Our main focus was to improve the performance of video conferencing traffic in terms of throughput and latency. In doing so we configured the Weighted Fair Queuing mechanism with differentiated services code point, which uses the same IP precedence ToS bit for traffic classification but also include three additional bits to provide extra granularity. Hence we assigned video traffic the highest priority by giving the per-hop-behavior as expedited forwarding. Along with this we also enabled the advance queue management system as random early detection in comparison with the drop-tail policy. From the simulation results it has been shown that WFQ scheduler when designed in accordance to the DSCP performs better, providing fair amount of bandwidth for data traffic class. In general we can say that the DSCPbasedWFQ has better performance among the all compared algorithms, and it is the most suitable for providing QoS for real-time traffics as well as non real-time traffics.

As a final remark, how to set the DSCP values for different types of data traffics in practical situations is not an easy task and whether it will be equally applicable to the WLAN is also a matter of observation. This is our future scope of work.

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