

Low Latency Weighted Fair Queuing for Real time flows with Differential Packet Dropping

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Abstract

Mathematical models of queuing systems play an important role in the analysis of various networks. Queuing mechanisms are essential to manage congestion in heterogeneous network traffic. By applying appropriate queuing models in the current network scenario, the performance of network can be enhanced in a great way. In this context, to improve the network performance, a Low Latency Weighted Fair Queuing with Differential Packet Dropping (LLWFQD) approach is proposed in this paper. The complexity of the WFQ is solved by differential packet dropping method. In differential packet dropping approach the packets with different flows are dropped to achieve fairness. This packet dropping approach is applied to TCP flows in a queue. The results are analyzed with NS-2 for various bottleneck bandwidth and flow rates by considering the throughput, packet loss and delay as performance measures. The results of LLWFQD model are compared with WFQ and the corresponding improvements are shown in graphs. The results show the performance enhancement of LLWFQD than WFQ.

Keywords: Fair Queuing, Low Latency Queuing, Packet Dropping, QoS, Real Time Flows

1. Introduction

WFQ is a fair queuing algorithm which partitions the available bandwidth among queues of traffic based on their weights. In the past decade, several approaches based on WFQ have been implemented, but these approaches do not assure better performance when the traffic contains a mixture of both real time and non-real time data. In WFQ, each flow is associated with an independent queue with assigned weight. The WFQ scheduler assigns a start tag and a finish tag to each arriving packet and serves packets in the increasing order of their finish tags.

2. LLWFQD Queuing Model

2.1 Overview

In this paper, the Low Latency Weighted Fair Queuing with Differential Packet Dropping for real time flows approach is proposed. The complexity of the WFQ is solved by differential packet dropping method. In differential packet dropping approach the packets with different flows

are dropped to achieve fairness. This packet dropping approach is applied in the FIFO queue. This approach provides the high network resources and QoS to the real time services.

2.2 Reminder on Classification of Flow

The flow classification is done as per our previous work¹².

The average packet delay PD_{avi} for delay sample $D_i(t)$ at time 't' using an Exponential Weighted Moving Average (EWMA) is updated by egress router as per the equation 1.

$$PD_{avi}(t) = \mu * PD_{avi}(t-1) + (1-\mu) * D_i(t) \quad (1)$$

where μ is a small fraction $0 \leq \mu \leq 1$

At egress router, the difference in loss ratios can be then estimated as,

$$D = L_{act}^T - L^T \quad (2)$$

where L_{act} is the actual loss ratio and L_i is the measured loss ratio at node N_i along the path P_i at the interval T .

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If the value of packet loss ratio (as per equation (2)) is more than a threshold T_1 and if the packet delay (as per equation (1)) is more than a threshold T_2 , then the flows are marked as real time flows and high priority is marked by the egress node, otherwise they are considered as best effort traffic and these flows are marked as low priority.

2.3 Operations of Weighted Fair Queuing (WFQ) Technique

Based on the weights, the Weighted Fair Queuing (WFQ) offers fair queuing that divides the available bandwidth across queues of traffic. To assure that the important traffic gets higher priority over less important traffic, each flow is associated with an independent queue assigned with a weight. Each and every data flow in WFQ and FQ has a separate FIFO queue. The WFQ allows different sessions to have different service shares. Suppose if we regulate the weights in WFQ dynamically, then it can be used for controlling the QoS.

If 'N' data flows are currently active, with weights $W_1, W_2, W_3 \dots W_N$, data flow number i will achieve an average data rate of

$$\frac{RW_i}{(W_1 + W_2 + W_3 + \dots + W_N)} \tag{3}$$

To ensure guaranteed bandwidth service Weighted Fair Queuing (WFQ) is applied. WFQ guarantees to each flow i of weight r_i , the minimum rate R_i is given by equation (4)¹⁰.

$$R_i = C * \frac{r_i}{\sum_j r_j} \tag{4}$$

Where C is the link capacity

The WFQ scheduler will assign the start tag and the finish tag to each arriving packets. WFQ also serves the packets in the increasing order of their finish tag. The WFQ behavior is defined by the following equation.

$$S(P_i^k) = \max(V(A(P_i^k)), F(P_i^{k-1})) \tag{5}$$

The finish tag is given by the equation (6)

$$F(P_i^k) = S(P_i^k) + \frac{L_i^k}{r_i} \tag{6}$$

Where P_i^k denote the k^{th} packet of flow i , L_i^k is the size of the packet P_i^k , $F(P_i^k)$ denotes the finish tag, $S(P_i^k)$ denotes the start tag, r_i is the weight and $V(t)$ is the virtual time at time t defined by;

$$\frac{dv(t)}{dt} = \frac{C}{\sum_{i \in B(t)} r_i} \tag{7}$$

Where $B(t)$ is the set of active flows at time t .

2.4 Improved WFQ Scheduler

In the improved WFQ scheduler, the finish tag is computed by the equation (6);

$$F(P_i^k) = S(P_i^k) + \frac{(L_i^k * D_i^T)}{r_i} \tag{8}$$

where D_i^T is the delay time of packet given by the equation¹⁴

$$D_i^T = \frac{\sum_{j=p}^q d_i^j}{q-p} \tag{9}$$

Here d_i^j is the delay time of packet p in class i , $(q-p)$ is the amount of incoming packets at specified time interval.

From equation (8), it can be observed that the lesser delay for a flow i , the lower will be the value taken by the finish tag $F(P_i^k)$. Hence the flows with least delay will be scheduled first. Since delay is used in the finish tag, the flows with least delay will be selected. Hence we can say that our WFQ is Low Latency WFQ.

Figure 1 is the pictured representation of the low latency weighted fair queuing technique. The queue with the highest priority and least delay will be selected first. During congestion the traffic in each queue is protected and treated fairly, according to its weight. Each and every queue shares the transmission service proportionally to the associated weight.

To overcome this complexity of WFQ, the differential packet dropping approach is applied below. In differential

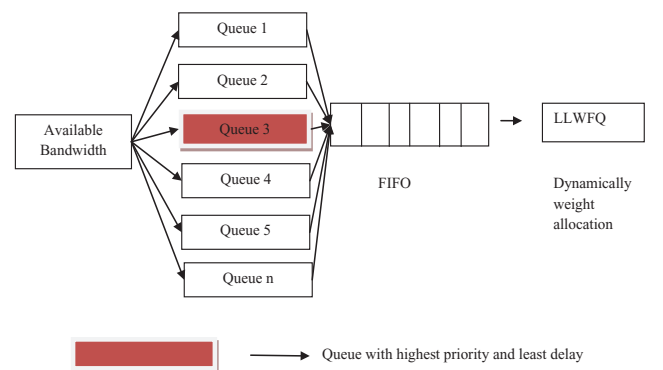


Figure 1. Packet dropping in LLWFQ.

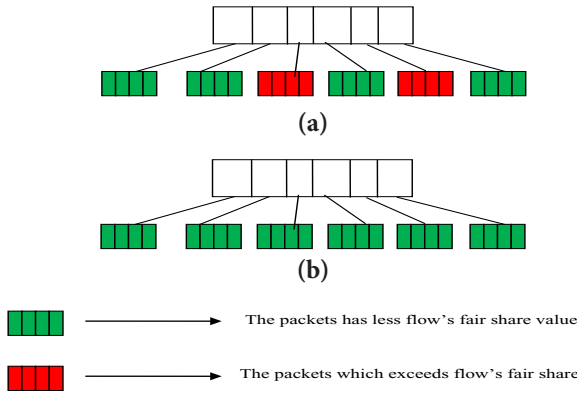


Figure 2. Packet dropping. (a) Before packet dropping and (b) After packet dropping.

packet dropping approach the packets with different flows are dropped differently to achieve fairness. This packet dropping approach is applied to the FIFO queue which is present in the Figure 1.

2.4.1 Differentiated Drop Treatment

In the above figure

- The queue (a) contains all the types of packets which have different flow’s fair share value.

Now the differential packet dropping technique is applied and the packets which exceeds the flow’s fair share value i.e. the packets with red color are dropped.

- Now the queue (b) contains only the packets with less flow’s fair share value.

Once all the flows are characterized, if the rate of the flow exceeds the fair share rate, then the corresponding packets has to be dropped. Here we are considering the ingress router with a single long-lived TCP flow⁶. The size of the incoming queue is considered as smaller, hence the average packet drop rate of this TCP flow is approximately

$$\text{given by } \frac{1}{(0.37 * P^2)}.$$

Here p is the bandwidth (R) * delay (RTT) product in packets,

When the drop rate of the packet drop is decreased to $\frac{1}{0.66P^2}$ then the TCP flow attain the complete bandwidth

R. This result matches with the result between window size and drop rate which is given by $w \sqrt{\frac{2}{3q}}$ Here w is the

window size, q is the average packet drop rate.

If the specific value of RTT is given then the packet drop rate for a fair bandwidth flow is given by;

$$\frac{1}{\left(\frac{2}{3} \left(\frac{r_{fair} * RTT}{size_p}\right)^2\right)} \tag{8}$$

where $r_{fair} * t_i$ is roughly the number of bytes transmitted by a fair bandwidth shared flow over a measurement interval t_i where r_{fair} is the per flow sharing in WFQ.

Hence the packet drop rate heuristic is proposed as shown below

$$d_i = \frac{1}{0.66 * \left(\frac{m_{fair}}{size_p} * \frac{RTT}{t_i}\right)^2}, \text{ if } m_{fair} < m_i \tag{9}$$

Where $size_p$ is the average packet size of a TCP flow, is the observed actual byte count over a measurement interval.

Here the RTT value is not known and may not be stationary over the lifetime of a TCP connection. For the flow of weight w_p , its matching bytes sent during the measurement interval t_i will be $m_{fair} * w_i$. Suppose if the observed byte is considered, the actual drop rate will be given by

$$d'_i = \frac{d_i}{(w_i)^2} \tag{10}$$

3. Simulation Results

3.1 Simulation Model and Parameters

In this section, we examine the performance of our Low Latency Weighted Fair Queuing (LL-WFQ) with Dropping (LLWFQ-D) technique with an extensive

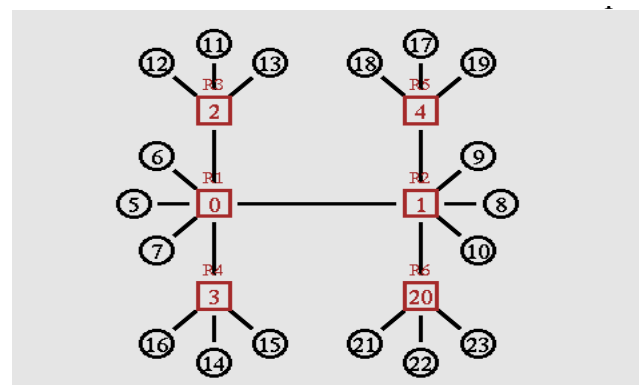


Figure 3. Simulation topology.

simulation study based on network simulator Network Simulator-2 (NS-2). We compare the results with the WFQ technique. The topology used in the simulation is shown in Figure 3.

We use a mixture of CBR and TCP traffic flows. The packet size is set to 512 bytes.

3.2 Performance Metrics

In the simulation experiments, we vary the bottleneck bandwidth and traffic rate. We measure the following metrics for video traffic.

- Throughput.
- Delay.
- Packet Loss.

The results are described in the next section.

3.3 Results

3.3.1 Effect of Varying Bottleneck Bandwidth

In our first experiment, we vary the bottleneck bandwidth as 2Mb, 4Mb... 8Mb.

Figures 4 to 6 show the delay, throughput and packet loss occurred for the real-time traffic flows, when the bottle neck bandwidth is increased from 2 to 8Mb. From the figures it can be seen that LLWFQD attains less delay

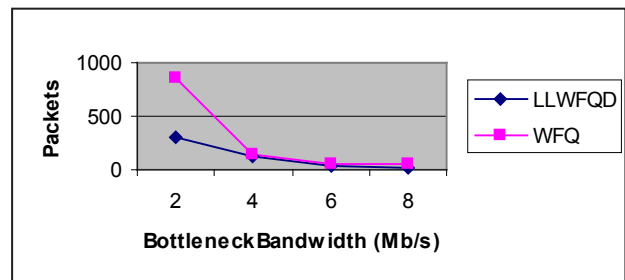


Figure 6. Bottleneck bandwidth vs packet loss.

and packet loss with increased throughput, compared to WFQ.

3.3.2 Effect of Varying Rate

In our second experiment we vary the transmission rate as 250,500,750 and 1000Kb keeping the bottle neck bandwidth as 5Mb.

Figures 7 to 9 show the delay, throughput and packet loss occurred for the real-time traffic flows, when the traffic rate is increased from 250Kb to 1000Kb. From the figures it can be seen that LLWFQD attains less delay and packet loss with increased throughput, compared to WFQ.

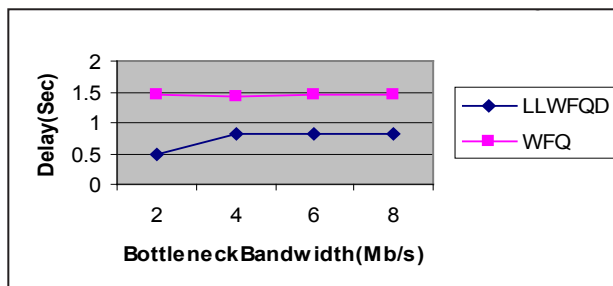


Figure 4. Bottleneck bandwidth vs video delay.

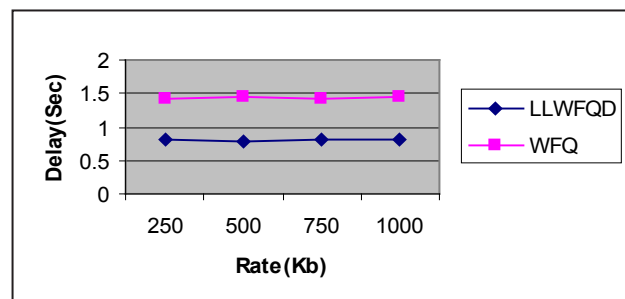


Figure 7. Rate vs video delay.

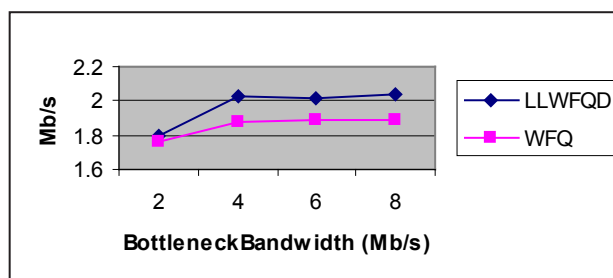


Figure 5. Bottleneck bandwidth vs video throughput.

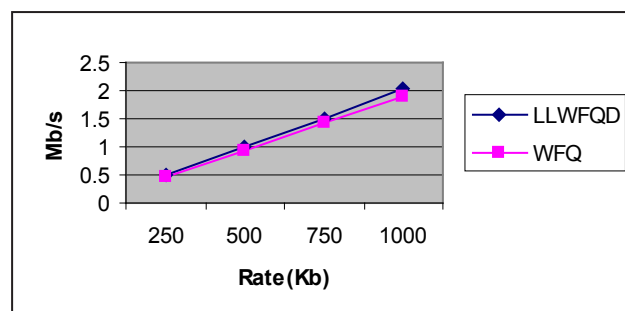


Figure 8. Rate vs video throughput.

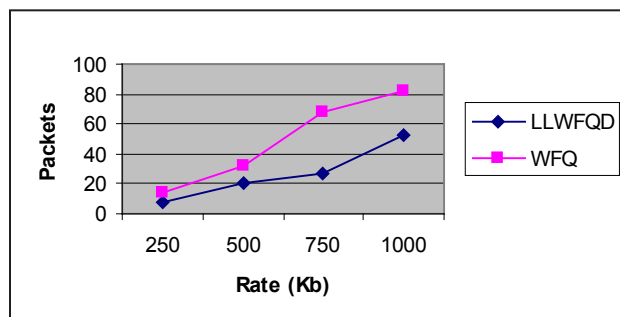


Figure 9. Rate vs video packet loss.

4. Conclusion

To overcome this complexity of WFQ, the Low Latency Weighted Fair Queuing with Differential Packet Dropping for Real time Flows approach is proposed in this paper. The complexity of the WFQ is solved by differential packet dropping method. In differential packet dropping approach the packets with different flows are dropped to achieve fairness. This packet dropping approach is applied in the FIFO queue. The packet that exceeds the flow's fair share value will be dropped. Future work may be focused on enhancing various queuing models for the network flow and comparing the performance with our model.

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