JOURNAL OF INFORMATION SCIENCE AND ENGINEERING 18, 333-339 (2002)

Short Paper

An Evaluation of Deficit Round Robin Fair Queuing Applied in Router Congestion Control

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In this paper, we evaluate the performance of Deficit Round Robin Fair Queuing applied in router congestion control. Two parameters affect the performance of a DRR router: the number of flows and the buffer size. We study the influence of the two parameters on fairness. The results show that the optimal region can be achieved by means of one-dimensional optimization. Then, we investigate the impact of the packet size, bandwidth, and queuing management on a flow in a simple network by means of 2^k factorial design. Three factors are considered to analyze the performance of the delay and the packet arrival ratio for a flow: the packet size, bandwidth, and queue type. In the performance study on the packet arrival ratio, we find that the effects of the bandwidth and packet size are predominant. However, in the performance study on the delay, we find that the effect of the queue type is as great as that of the bandwidth. Active queuing management, such as DRR, which allocates bandwidth fairly, can also improve the delay performance of a flow.

Keywords: deficit round robin, fair queuing, 2^k factorial design, congestion control, queue management

1. INTRODUCTION

In this paper, we introduce the DRR [3] mechanism and evaluate the performance of a DRR router. The number of flows and total buffer size are two parameters affecting the performance of a DRR router. From the results of experiments performed using the NS-simulator [1], we find that the effect of the buffer size on fairness is small if the packet size is larger than some threshold. Then, three factors, packet size, bandwidth, and queue type, are considered to analyze the performance of the delay and packet arrival ratio for a flow on a DRR router. In the study on the packet arrival ratio performance, the effects of the bandwidth and packet size are found to be predominant but the effect of the active queuing scheme type is not great. However, in the study on delay, it is found that the effect of the active queuing scheme type is almost the same as the effect of the bandwidth. That means that achieving greater bandwidth and proper queue management [4] are equally good approaches to improving the delay performance.

Received May 24, 2000; revised September 14 & October 20, 2000; accepted December 15, 2000.
Communicated by Norio Shiratori.

2. DEFICIT ROUND ROBIN (DRR)

The Deficit Round Robin scheme (DRR) [3] can be divided into three parts: the input buffer, per-flow queue and output buffer as shown in Fig. 1. When flows arrive at the router, they are queued in the input buffer and wait for an en-queue action. The en-queue finds the right queue for each flow according to its IP source and destination address pair. Then, according to the packets of flows in the correct queues are released to the output buffer according to the DRR round robin rule, which will be described later. The routers use a hashing function, such as stochastic fair queuing [2], so the work of en-queue takes only one-step processing to put a flow to its correct position in the per-flow queues. Furthermore, DRR can adjust its buffer allocation ability for bursts in a connection by obtaining buffer space from under-loaded queues. The hashing en-queue and buffer stealing schemes efficiently improve the performance of DRR.

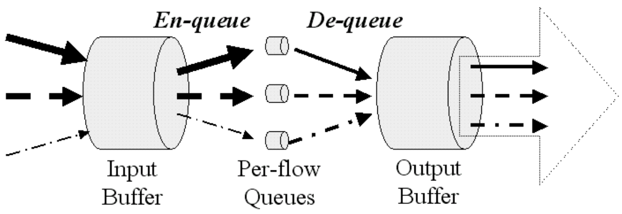

Fig. 1. Three parts of DRR.

3. PERFORMANCE ANALYSIS OF DRR

Fig. 2 shows the four design parameters of DRR. The first parameter is buckets_, which means the queue number in the en-queue stage. It decides the number of different flows for the hash function. If the number of connections is smaller than the queue number, each connection can be allocated to a certain queue where it will wait for service. If the number of connections is larger than the queue number, then collision may occur. Consequently, fairness can be affected by collisions. The second parameter is blimit_, which is the size of the memory pool. If the size of the memory pool is too small, the buffers of some queues may overflow. The third parameter is quantum_, which decides the amount of transmission for a queue in each round. The fourth parameter is mask_, which checks whether the connection is an IP source-destination pair or an IP + Port number source-destination pair.

Setting of two parameters, buckets_ and blimit_, properly is very important. In principle, the number of collisions decreases if buckets_ is large. However, a large value for buckets_ will result in difficulty in managing a large number of queues and their allocation of memory. The parameter blimit_ represents the size of the buffer pool. A large blimit_ value can improve the performance of DRR. Nevertheless, the cost will also increase if the blimit_ value is large. Setting suitable parameters is a primary concern.

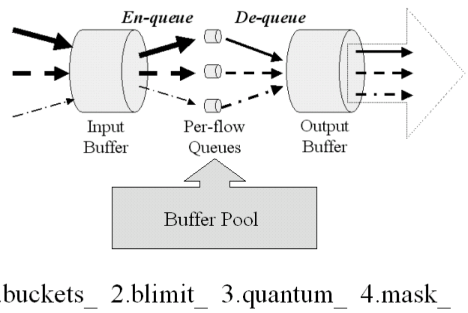

Fig. 2. DRR design parameters.

In this study, the NS-simulator [1] was used to explore the setting of parameters shown in Fig. 2. We assume that there were ten sources, which transmitted data to the same sink. The traffic pattern of each source was exponential on-off traffic: the mean on-state duration was 3 seconds, and the mean off-state duration was 0.3 second. The packet size was uniformly distributed in [1400,1600] Bytes, and the bandwdth of each link was 1 Mb.

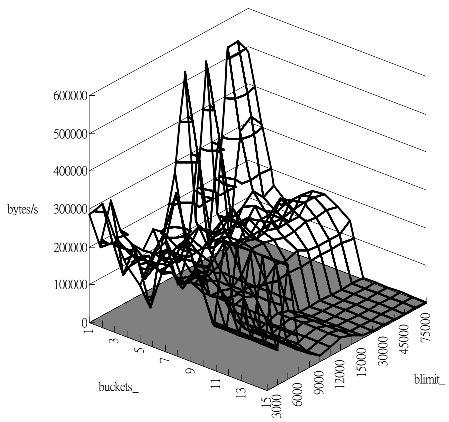

Fig. 3. Standard deviation results of throughput.

Fig. 3 shows the standard deviation graph of throughput. If the buckets_ value is smaller than the flow number, then collision may occur. If the standard deviation of throughput is large, then bandwidth allocation will not be fair. If the blimit_ value is smaller than a threshold, it is possible that there will not be enough buffer space to accommodate packets for all the flows. This means that the round robin scheme will not perform smoothly due to lack of buffer space. These two results are trivial. However, in our simulation, we also found that the standard deviation of throughput was a convex function near the optimal region, and that the optimization region could be achieved in all directions. That is, if one parameter is fixed, the problem can be reduced to a one-dimensional optimization problem. Since the buffer size (blimit_) is fixed in a router, the result is a buckets_ optimization problem.

4. EFFECTS OF PACKET SIZE, BANDWIDTH AND QUEUE TYPE ON A FLOW

In this section, we will examine real network behavior and show what affects the delay time and packet arrival ratio performance for a flow. We will consider three factors which may affect the performance of a flow: the packet size, bandwidth, and queue type. We used the NS-2 Simulator [1] to examine design issues related to a DRR router. The inter-arrival time of each traffic flow was uniformly distributed in (2.5,7.5) ms. The traffic patterns were the same in each experiment. We selected three factors to examine in our experiments: the packet size (**P**), Bandwidth (**B**), and Queue Type (**Q**), as shown in Table 1. The packet size (**P**) took two values: 500 bytes (level -1) and 1000 bytes (level 1). The bandwidth (**B**), which means the bottleneck link capacity, also took two values: 1 Mbps (level -1) and 1.5 Mbps (level 1). The last factor, Queue Type (**Q**), also took two values: level -1 for the traditional queue type, that is, first-in-first-out (FIFO) or so-called DropTail, and level 1 for active queuing management, that is, Deficit Round Robin (DRR) [3]. Here B is a HB (Higher is Better) factor and Q is a categorical factor.

Table 1. Factors and levels.

Factor	Level -1	Level 1
Packet Size, **P**	500 bytes	1000 bytes
Bandwidth, **B**	1.0 Mbps	1.5Mbps
Queue Type, **Q**	DropTail	DRR

We used the simulation environment described above and the same three factors, the Packet Size (**P**), Bandwidth (**B**), and Queue Type (**Q**), to measure the delay performance for a flow. All the experiments were conducted in the same environment, including the same source traffic patterns. The experiments differed only the combinations of various levels of the three factors. The delay performance results are recorded in Table 2.

Table 2. The performance of delay.

Bandwidth	500 bytes		1000 bytes	
(Mbps)	DropTail	DRR	DropTail	DRR
1.0	1.52971	1.56103	3.23200	1.61920
1.5	0.89872	0.91565	2.06929	1.05314

Table 3. Percentages of variation explained (Delay).

	P	***B***	***Q***	***PB***	***PQ***	***BQ***	***PBQ***
Variation Explained(%)	28.37	27.21	20.07	0.62	21.59	1.02	1.12

The regression equation related to the delay performance is

$$y = 1.61 + 0.38x_P - 0.37x_B - 0.32x_Q - 0.06x_P x_B + 0.07x_B x_Q - 0.33x_Q x_P + 0.08x_P x_B x_Q \quad (1)$$

The performance results are interpreted as follows. The mean delay was 1.61 sec; the effect of packet size was 0.38 sec; the effect of bandwidth was -0.37 sec; the effect of queuing management was -0.32 sec; the interaction between packet size and bandwidth contributed -0.06 sec; the interaction between bandwidth and queuing management contributed 0.07; the interaction between queuing management and packet size contributed -0.33 sec; finally, the three-factor interaction contributed 0.08 sec.

From the above interpretation, the packet size contributed 0.38 sec to the delay. It is reasonable that a larger packet size can potentially cause the delay time to increase. Since the effect of bandwidth was -0.37 sec, it is obvious that by increasing the bandwidth, the queuing delay can be reduced. Active queuing management, such as DRR, can also be used to improve the delay performance of an individual flow. Thus, it is clear that the active management scheme, which allocates bandwidth fairly to each flow, can also be more powerful in preventing the delay performance of an individual flow from being influenced by other background traffic compared to the simple first-in-first-out scheme (FIFO or Drop Tail). Since the effect of active queuing management (-0.32) was not very different from the effect of bandwidth, the delay performance can be improved by either increasing the bandwidth or by using a more delicate queuing management scheme. The choice of packet size is affected by the queue type since there is large interaction. Depending upon the packet size and queue type, the delay can go up or down by 0.33. The three-factor effect is small.

The importance of each factor was measured based on the proportion of the total variation in the response that was explained by the factor. The result of the allocation of variation analysis in the case of the delay performance is shown in Table 3. In order of decreasing importance, the variables are: P, B, PQ, Q, PBQ, BQ, PB. The effects of the interaction between the packet size and the bandwidth, and the interaction between the bandwidth and the queue type were not significant since their variations explained were only 0.62 % and 1.02% respectively. However, the effects of the packet size, the bandwidth, the queue type, and of the interaction of the packet size and the queue type significantly affected the delay time.

The packet arrival ratio is defined as follows:

$$\text{Packet Arrival Ratio} = \frac{number\_of\_packets\_arrived}{number\_of\_packets\_trasmitted}. \quad (2)$$

We used the same network topology and the same traffic patterns as above to investigate the impact of packet size, bandwidth and queue type on the packet arrival ratio for a flow. Table 4 shows the measured packet arrival ratios.

Table 4. The measured packet arrival ratios.

Bandwidth (Mbps)	500 bytes		1000 bytes	
	DropTail	DRR	DropTail	DRR
1.0	0.646	0.646	0.535	0.524
1.5	0.949	0.949	0.779	0.767

Table 5. Percentages of variation explained (Packet Arrival Ratio).

	P	***B***	***Q***	***PB***	***PQ***	***BQ***	***PBQ***
Variation Explained(%)	22.04923	76.9701	0.034083	0.91238	0.034083	6.4429E-05	6.4429E-05

The regression equation for the packet arrival ratio performance is

$$y = 0.72 - 0.07x_p + 0.14x_B - 0.003x_Q - 0.01x_P x_B - 0.003x_B x_Q - 0.0001x_Q x_P - 0.0001x_P x_B x_Q \quad (3)$$

The mean packet arrival ratio was 0.72; the effect of packet size was -0.07; the effect of bandwidth was 0.14; the effect of queuing management was -0.003; the interaction between packet size and bandwidth contributed -0.01; the interaction between bandwidth and queuing management contributed -0.003; the interaction between queuing management and packet size contributed -0.0001; the three-factor interaction contributed -0.0001. From the above interpretation, the dominate factor was the bandwidth. Packet size contributed -0.07 to the packet arrival ratio. The queuing management factor and the other interaction had no effect on the results. The allocation of variation analysis results for the case of the packet arrival ratio performance are shown in Table 5. Sorted the variables in order of decreasing importance, B, P, BP, Q, PQ, BQ, PBQ. The variation of bandwidth was 76.97 %, and the variation of packet size was 22.04%. In terms of their effect on packet arrival ratio performance, bandwidth was the most important factor, and the effect of packet size could not be ignored.

5. CONCLUSIONS

In this paper, we have used different simulations to systematically determine the settings of optimal parameters. We have focused on two parameters, buckets_ and blimit_. The optimal parameters could be easily determined if we fixed one parameter. Normally, the router design parameters are dependent on the network traffic. However, one dimension optimization be easily achieved. Then, we used the 2^k factorial design to investigate the delay and packet arrival ratio performance in a simple network from a flow's point of view. The three factors examined were the packet size, bandwidth, and queue type. All the other factors, including traffic, are kept the same in the different experiments. In the experiment on packet arrival ratio, the effect of bandwidth was predominant, while the effects of the active queuing scheme type and of various types of interaction were not significant. However, in the experiments on delay, active queuing management, such as Deficit Round Robin (DRR), could be used to improve the delay performance of an individual flow. Thus, it is clear that the active management scheme, which allocates bandwidth fairly to each flow, can also perform well in preventing the delay performance of individual flow from being influenced by background traffic. Moreover, we have found that the effect of the active queuing scheme type is almost the same as the effect of bandwidth on the delay performance. This means that increasing bandwidth and proper queue management are equally good strategies for improving delay performance.

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