

Double WFQ QoS Scheduling based on Flow Number in Diffserve Network

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Abstract — Diffserv(Differentiated Service) is a promising technique to realize scalable QoS control in the internet. Therefore, extensive efforts have been made for the practical use of this technique. Diffserv is already introduced in some networks. Control functions for Diffserv are installed in edge routers and core routers. This enables a scalable QoS control as mentioned above. This paper proposes a new active queue management scheme for AF(Assured Forwarding) services guaranteeing minimum bandwidth provided that RIO(Random Early Detection with IN and OUT) and WFQ(Weighted Fair Queuing) are used as the basic QoS control mechanisms. The proposed method controls queue threshold values of RIO each flow number and the allocated bandwidth of WFQ each flow number. Simulation results show that the proposed scheme reduces the packet discard when the packet concentrates on the specific flow.

Keywords — RIO, WFQ, QoS, Flow

1 Introduction

Various kinds of traffic, not only the WWW(World Wide Web) and mail but also video streaming and VoIP(Voice over IP) have begun to flow on the Internet. Moreover a large quantity of traffic data is increased by the appearance of the various applications [1]. Especially, the contents of multimedia services via the Internet have become popular [2]. Internet traffic includes services that require QoS specifications such as packet loss and packet delay. The required QoS specifications for each service are quite different. Therefore, it is indispensable to provide QoS control functions in the network for satisfaction of various quality specifications. Intserv (Integrated Services) and Diffserv (Differentiated Services) [3] are proposed as the techniques for the network side QoS control. Diffserv is a promising technique to realize scalable QoS control in the internet. Therefore, extensive efforts have been made for the practical use of this technique. Diffserv is already introduced in some networks. Fig.1 illustrates the structure of Diffserv Network. Diffserv network consists of edge routers and core routers. Packets are marked the priority classes in the edge router. The core routers that refer to the priority class of the packet transmit the packets. Control functions for Diffserv are installed in edge routers and core routers. This enables a scalable QoS control as mentioned above.

In the Diffserv network, since core routers do not provide QoS control functions for each flow, strict quality guarantee as resource reservation is not realized for each flow. However, since the routers in Diffserv network only install quality control functions for each QoS class, the router functions are easily extensible and a scalable quality control mechanism is

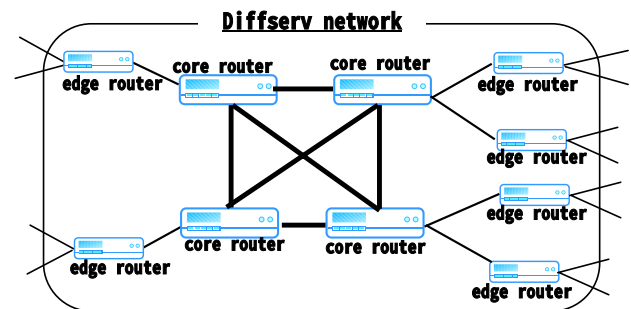


Figure 1 The structure of Diffserv Network

realized as compared with Intserv network. Therefore, Diffserv is a promising technique for practical QoS control. Service class in Diffserv includes three different specifications, i.e., EF (Expedited Forwarding), AF (Assured Forwarding) and BE (Best Effort) according to the order of priority. A wider bandwidth exceeding the specified minimum value is assigned for AF service, and the packets in this class are transmitted with the higher priority than the packets in BE class. A quality of transmission is not guaranteed for BE service. AF service includes four priority classes, i.e., AF1-AF4 according to the order of priority.

If a lot of the arrival packets go toward the same output port, the waiting packets transmitted from this router concentrate quantities of packet in the output queue. In case of going on this condition, the capacity of the output queue becomes full. And the packets in the input queue can't move the output queue under the influence of concentrating the packet to the same output queue. These packets stay for long time in the input queue. As the capacity of the input queue become gradually full, the arrival packets are discarded all. In this paper, as to the method avoiding this condition, the authors propose a new packet scheduling method for AF service that includes four priority classes (AF1-AF4). The authors propose a novel QoS control method jointly using RIO (RED with IN and OUT) and WFQ (Weighted Fair Queuing). The proposed scheme controls the threshold values of RIO based on flow number in input port. The proposed scheme intends to reduce efficiently the discard of packets when the flow in an input port increases. In this paper, the flow indicates a group of the packets to the same output port in the router. The arrival process of packet is assumed to be Poisson Process provided that we analyze the traffic performance in the core routers.

2 Base Structure

RED (Random Early Detection)[4] is a basic QoS control scheme for AF service. In RED scheme, congestion level in

the router is estimated by the detection of average queue length and input packets are discarded taking into account of average queue length. The discard probability in RED is increased as the average queue length grows. The above mentioned mechanism in RED can control queue length to be less than the prescribed value. This enables to avoid congestion. A QoS control scheme named RIO (RED with IN and OUT) was proposed in [5] as an enhanced version of RED.

On the other hand, WFQ (Weighted Fair Queuing) was proposed from a viewpoint to improve fairness among priority classes. In WFQ scheme, data rate of output link is allocated among each channel taking into account of an appropriate weight distribution

2-1 RIO structure

The arrival packets are categorized into two groups from a viewpoint of QoS control. The first group consists of the packets that do not allow discard even in the congestion. The second group consists of the packets that allow discard in the congestion. The first group corresponds to IN packets within the contracted speed. The second group corresponds to OUT packets beyond the contracted speed. Then, discard control parameters are changed based on the total of the arrival packet in the input queue. Based on the above discussion, a QoS control scheme named RIO (RED with IN and OUT) was proposed in [6] as an enhanced version of RED. In light congestion level, OUT packet discard is initiated. In heavy congestion level, some of IN packets are also discarded. The discard probability for IN packets is smaller than that of OUT packets, though. The contracted speed for each flow is guaranteed using the above control mechanism. Detection of congestion level and discard probability setting are made based on the average queue length in the input port.

The discard probability gradually increases from zero if the average queue length reaches the minimum threshold value. The discard probability immediately increases up to 1 if the queue length exceeds the maximum threshold value. The traffic control in RIO guarantees QoS in Diffserv by the packet discard described above. Threshold value of RIO set up with input queue length. As the method setting up threshold value of RIO, reference [7] proposed to change threshold value of RIO by the delay time of the packet in the router. However there are not discussions for controlling RIO based on flow. Reference [8] proposed as the control method of RIO for each flow. Reference [8] is able to discard an unsuitable packet to the condition of contract speed efficiently by controlling RIO each flow when the arrival packets concentrate in the specific flow. In this paper, we call this method FRIO as controlling RIO each flow number.

2-2 WFQ structure

Traffic control in WFQ guarantees fairness by reading out data from each queue. The bandwidth for each connection is warranted in WFQ. In [9,10] Parekh et al. analyzed end-to-end delay performance in a multistage WFQ network. For AF service, we can easily allocate bandwidths for classes AF1-AF4 using weights proportional to the minimum bandwidth for each class when applying WFQ. This obtains fairness among classes and efficient bandwidth utilization. However, it implies that packet delay times in the router may increase if the allocated bandwidth is fixed without taking

account of packet size. We can expect an efficient delay reduction effect in a dynamic bandwidth allocation scheme that takes packet size into account under the assumption that packet size distribution is not uniform and that packets with longer size are dominant.

3 Proposed scheme

In this paper, it is assumed that the router has the physical queue at each side of the input and output port. In addition, the physical queue has virtual queues at each assured class. The queue capacity of the output port full if the output destination of the arrival packets concentrates in the same output port. The packets in input queue do not enable to move the output queue because of a lot of the packets flowing into the same output port. As a result, a lot of staying packets in the output queue is increasingly influence of the staying packets in the input queue. Therefore, it is necessary to control each flow on condition the packets concentrate in the specific output port. In this paper, the flows (in other words, flow number) show the combination of input port number and output port number in the router. In short, the flow used in RIO indicates the output port number and the flow used in WFQ indicates the input port number. Based on the above discussion, this paper proposes a new control method jointed RIO and WFQ using flow. In the proposed scheme, the control functions for RIO and WFQ are enhanced under the assumption that they are used for input and output queue management. RIO control function is normal mode and flow mode. In the dynamic control method of RIO in the input queue, the threshold values of RIO are adjusted based on the total of the arrival packets at each flow. This tends to accelerate the traffic shaping effect of RIO. The RIO control function judges the input packet whether exceeding the condition of contract speed at each flow. If the total size of the packets arrived is within the condition of contract speed, the threshold values for RIO are set up as $(\min_N^{IN}, \max_N^{IN}, \min_N^{total}, \max_N^{total})$. This described in Section 2-1. On the other hand, if the total size of the arriving packets exceed the condition of contract speed, the threshold values of each flow are set up as $(\min_{flow}^{IN}, \max_{flow}^{IN}, \min_{flow}^{total}, \max_{flow}^{total})$. RIO function controls by using their threshold value.

We propose that the control method as output queue management uses WFQ at each flow. In the dynamic control method of WFQ in the output queue, the control function of WFQ check the total of transmitted packet from the output ports at each flow and the total of the waiting packet in the output queue at each flow. If both the total of transmitted packets and the transmitted the waiting packets in the output queue is over the average at each flow, the control function of WFQ is decreased the allocated bandwidth each flow. WFQ controlling at each flow calls flow mode. WFQ controlling at each Assured class calls normal mode. As a control sequence, the control process of WFQ is two steps. The first, the control function of WFQ targets Assured class. This step keeps priority of classes. The next, this function targets flow. As a result, the fairness among flow and assured class is kept without transmitted only the packets of the specific flow. We

Table 1 Simulation parameters

Router structure			The Allocated bandwidth of WFQ		
Input ports		15	AF1	4.0Mbit/s	
Output ports		3	AF2	3.0Mbit/s	
Input line bit speed		100Mbit/s	AF3	2.0Mbit/s	
Output line bit speed		10Mbit/s	AF4	1.0Mbit/s	
Input queue size		800kbit	The rate of the allocate output port		
Output queue size		800kbit			
virtual queue size	AF1	400kbit	Output port number	Type 1	Type 2
	AF2	300kbit	1	30	80
	AF3	250kbit	2	30	10
	AF4	200kbit	3	40	10
Threshold value of RIO [kbit]			The rate of the allocate Assured class		
Normal mode	$\min_{in}^N$	400kbit	Assured class	Type 3	Type 4
	$\max_{in}^N$	640kbit	AF1	25	10
	$\min_{total}^N$	100kbit	AF2	25	10
	$\max_{total}^N$	480kbit	AF3	25	40
flow mode (FRIO)	$\min_{flow}^N$	400/3 kbit	AF4	25	40
	$\max_{flow}^N$	640/3 kbit			
	$\min_{total}^N$	100/3 kbit			
	$\max_{total}^N$	480/3 kbit			

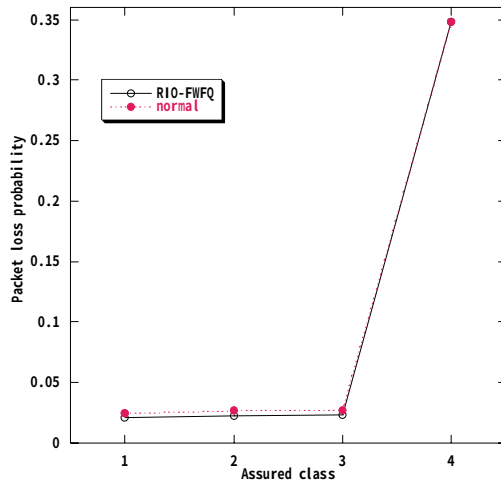


Figure 2 Packet loss probability vs. Assured class (Type 3)

call this method FWFQ as how to controlling WFQ at each flow. In this paper, we adopt FRIO in input queue management and FWFQ in output queue management.

4 Simulation Model

We assume existing priority in the order of $AF1 > AF2 > AF3 > AF4$ in Assured Forwarding class. The router has the physical queues for each input port and output port and the virtual queues for each Assured Forwarding class. As a reason that using the virtual queue, the router having the virtual queue at each Assured Forwarding class can make effectively use of the capacity of the physical queue. The capacities of the virtual queues can assign large capacity in higher priority class. The processor speed of the switch between input queues and output queues is double of input link speed.

The arrived packets are marked IN or OUT. Within the conditions of contracted speed, the arrival packets are marked IN. The arrived packets are marked OUT except IN. RIO controls each flow in input queue. Threshold value of RIO is varied when the total size of flow exceeds the condition of contract speed. The forwarding packet is decided by WFQ. In

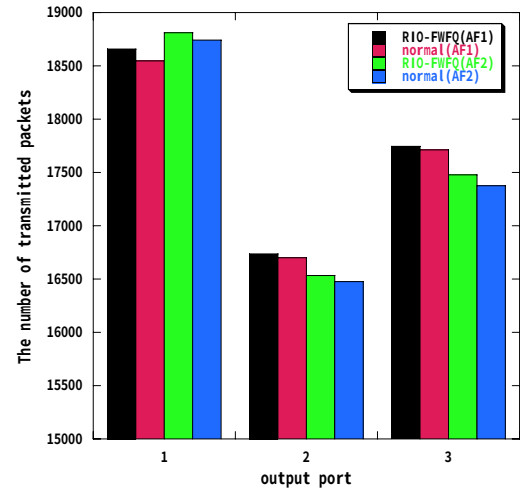


Figure 3 The number of transmitted packet vs. Output port (AF1 and AF2 ,Type3)

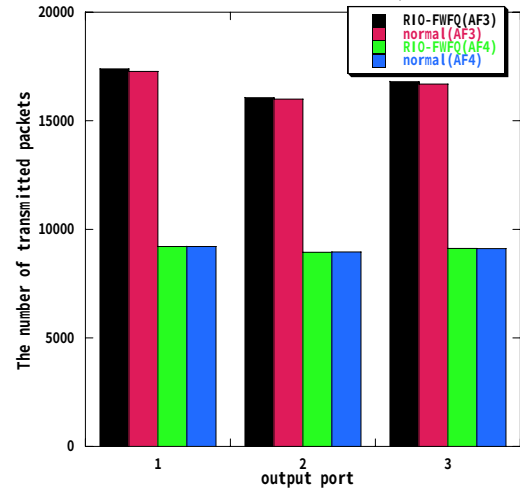


Figure 4 The number of transmitted packets vs. Output port (AF3 and AF4 ,Type3)

following descriptions, we refer to the proposed scheme for RIO as FRIO and for WFQ as FWFQ. The previous scheme using RIO and WFQ refer to normal. The input queue management uses RIO or FRIO. The output queue management uses WFQ or FWFQ.

In this simulation, the arrival process of the packet to router is supposed as Poisson arrival process. Simulation parameters are listed in Table 1. The rate of Type 1 and Type 2 shows the rate of output port transmitted the arrival packets from input port. The rate of Type 3 and Type 4 shows the rate of the allocated Assured Forwarding class. Type 1 is used the input port number 1~7, 9, 11, 13 and 15. Type 2 is used the input port number 8, 10, 12 and 14.

The main evaluation items in this simulation are packet loss probability at each flow in Assured Forwarding classes and the number of the transmitted packets at each input port and output port.

5 Simulation Results

In case of Fig.2-5 and Fig.10-13, the parameter of assured forwarding class use Type 3. In case of Fig.6-9 and Fig.14-17, the parameter of Assured class use Type 4.

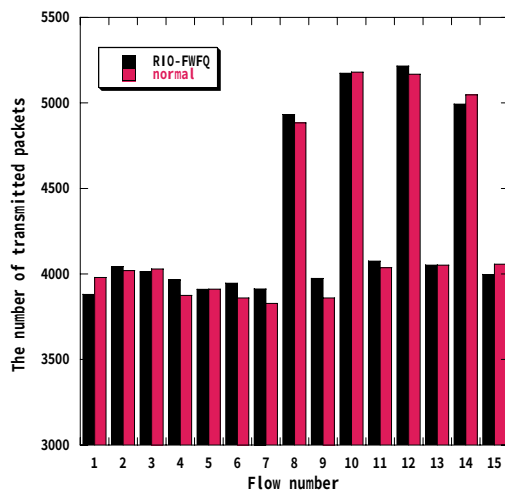


Figure 5 The number of transmitted packets vs. Flow number (Type 3)

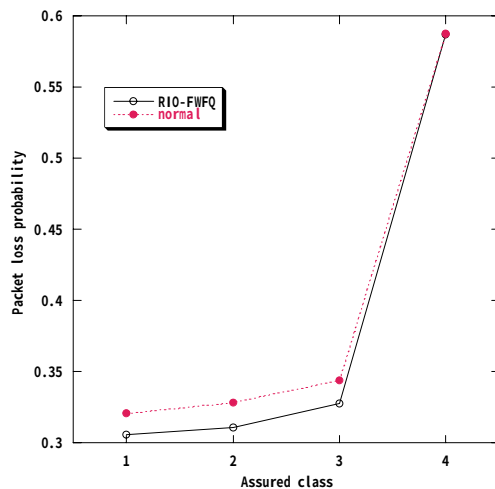


Figure 6 Packet loss probability vs. Assured class (Type 4)

Fig.2 illustrates the simulation result for the relation between the packet loss probability and assured forwarding class. In Fig.2, the packet loss probability of RIO-FWFQ is lower than the packet loss probability of normal in AF1-AF3. There is little difference the packet loss probability between RIO-FWFQ and normal. Fig.3 and Fig.4 show the simulation results of the relation between the number of transmitted packets and the output port. In Fig.3, there is most great difference the number of transmitted packets between RIO-FWFQ and normal in output port 1 which is the highest weight than the others. The number of transmitted packets between RIO-FWFQ and normal in AF4 is much the same. Fig.5 illustrates the simulation result for the relation between the number of transmitted packets and flow number in output port number 1. The number of transmitted packets of RIO-FWFQ increases almost all the flow using Type 1. Especial, RIO-FWFQ more transmitted the packet than normal in input port of low traffic weight. Fig.6 shows the simulation result of the relation between the packet loss probability and assured forwarding class. The Packet loss probability of RIO-FWFQ decreases than the packet loss probability of normal in AF1-AF3. RIO-FWFQ decreases the packet loss probability when the distribution of assured

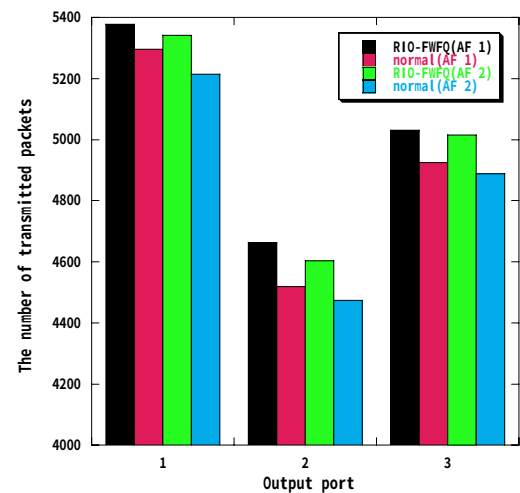


Figure 7 The number of transmitted packets vs. Output port (AF1 and AF2, Type 4)

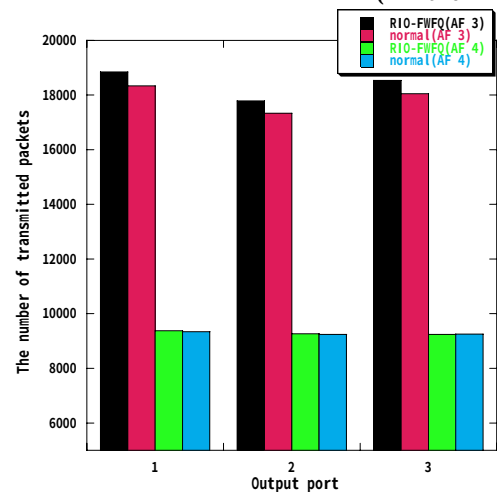


Figure 8 The number of transmitted packets vs. Output port (AF3 and AF4, Type 4)

forwarding class doesn't use Type 3 but Type 4. Fig.7 and Fig.8 illustrate the simulation result of the relation between the number of transmitted packets and Output port. The number of transmitted packets of RIO-FWFQ increase excluding AF4. Fig.9 illustrates the simulation result of the relation between the number of transmitted packets and the flow number. The number of transmitted packets increases in all flow number. Fig.10 illustrates the simulation result for the relation between the packet loss probability and assured forwarding class. In Fig.10, FRIO-FWFQ decreases the packet loss probability than FRIO-WFQ in AF1-AF3. There is little difference the packet loss probability between FRIO-FWFQ and FRIO-WFQ in AF4. Fig.11 and Fig.12 show the simulation results of the relation between the number of transmitted packets and output port. In AF 2, the number of transmitted packets most is improved by controlling RIO and WFQ at each flow. The number of transmitted packets in AF3 and AF4 is equal between FRIO-FWFQ and FRIO-WFQ. Fig.13 illustrates the simulation result for the relation between the number of transmitted packets and the flow number in output port number 1. FRIO-FWFQ most increases the number of transmitted packets of the flow number using Type2. Fig.14 shows the simulation result of the relation between the packet

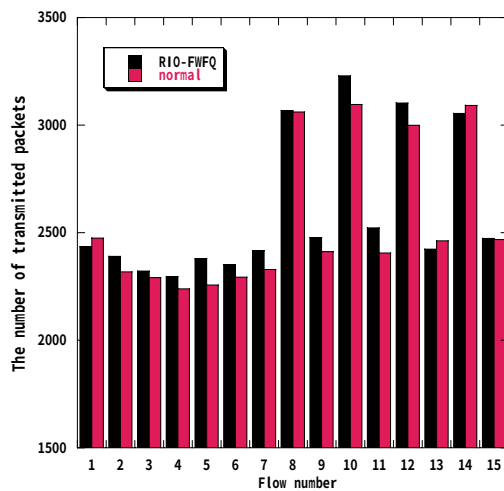


Figure 9 The number of transmitted packets vs. Flow number (Type 4)

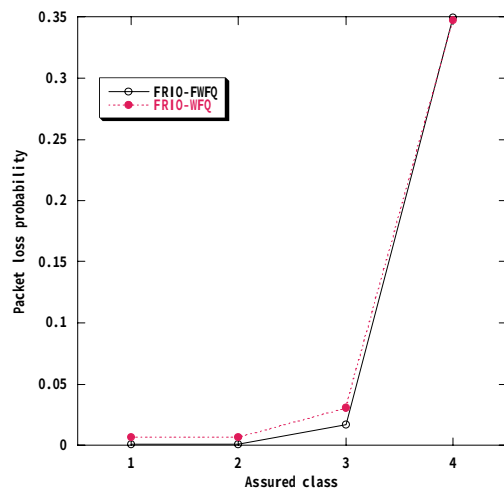


Figure 10 The number of transmitted packets vs. Assured class (Type 3)

loss probability and assured forwarding class. FRIO-FWFQ decreases the packet loss probability in AF1-AF3. FRIO-FWFQ has an effect on decreasing the packet loss probability when the distribution of assured forwarding class doesn't use Type 3 but Type 4. Fig.15 and Fig.16 illustrate the simulation result of the relation between the number of transmitted packets and output port. The number of transmitted packets of FRIO-FWFQ increase excluding AF4. Fig.17 illustrates the simulation result of the relation between the number of transmitted packets and the flow number. The number of transmitted packets increases in all flow number.

As described above, in the simulation of this paper, we compare the performance of the proposal scheme and the previous scheme. If the output destinations of the packets in the input queue concentrate to the same output port, the packet loss probability of higher priority class decreases than the packet loss probability in the previous scheme. The transmitted packets of higher priority classes increase in the proposal method than in the previous scheme. It is supposed this reason that the control function of WFQ is able to control not only among assured forwarding class but also among flow by controlling twice WFQ and the capacity of the input queue enable to make use of fairness among flow as the controlling

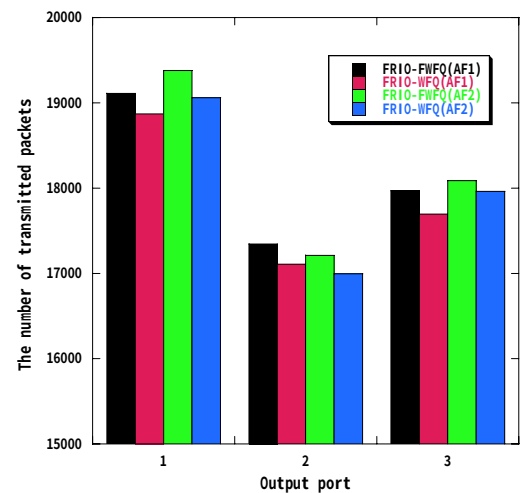


Figure 11 The number of transmitted packets vs. Output port (AF1 and AF2, Type 3)

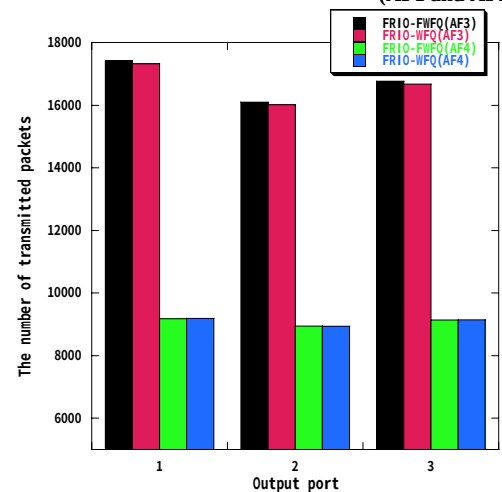


Figure 12 The number of transmitted packets vs. Output port (AF3 and AF4, Type 3)

RIO at each flow prevents many the packet of the specific flow from staying in input queue.

The proposal method has more effect when the parameter of assured forwarding class uses Type4. That is to say, this method increasingly has an effect as the rate of assured forwarding class is more unbalance.

6 Conclusion

This paper proposes a scheduling method that controls each flow in a system with QoS control jointly using RIO and WFQ for AF service in Diffserv network.

We have shown that the proposed scheme is able to manage fair by controlling RIO and WFQ each flow when the arrival packet concentrates in the specific flow. Packet loss probability is shown to be decreased by the proposal method. As comparison with only RIO or WFQ using flow control, the management in input queue and output queue is able to control by controlling both RIO and WFQ each flow.

Further studies are necessary, including the selection of proper values for various control parameters of FWFQ, FRIO and the information of the arrival packets. Areas for future work with numerical evaluations include comparison between the processing delay in the input queue and the processing delay in the output queue.

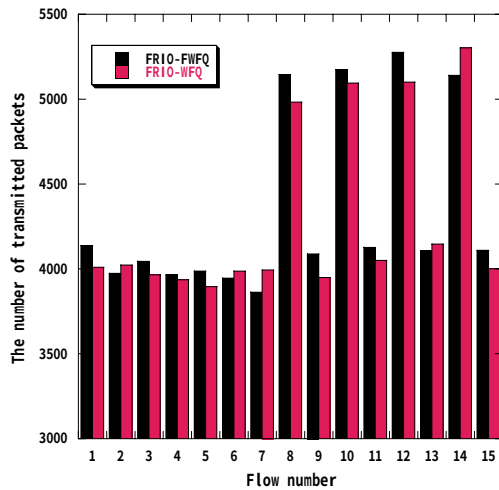


Figure 13 The number of transmitted packets vs. Flow number (Type 3)

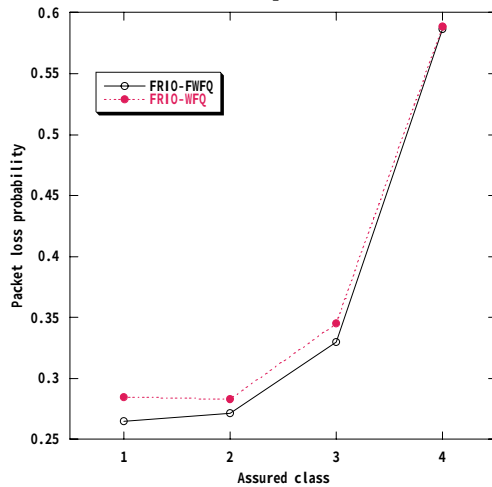


Figure 14 Packet loss probability vs. Assured class (Type 4)

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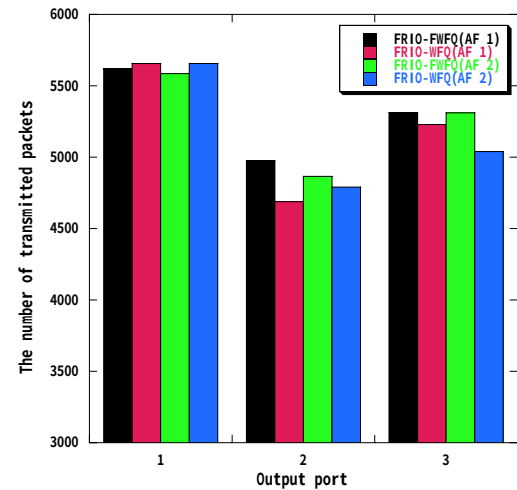


Figure 15 The number of transmitted packets vs. Output port (AF1 and AF2, Type4)

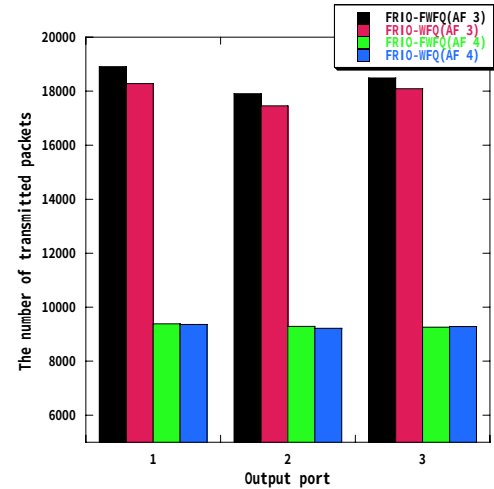


Figure 16 The number of transmitted packets vs. Output port (AF3 and AF4, Type4)

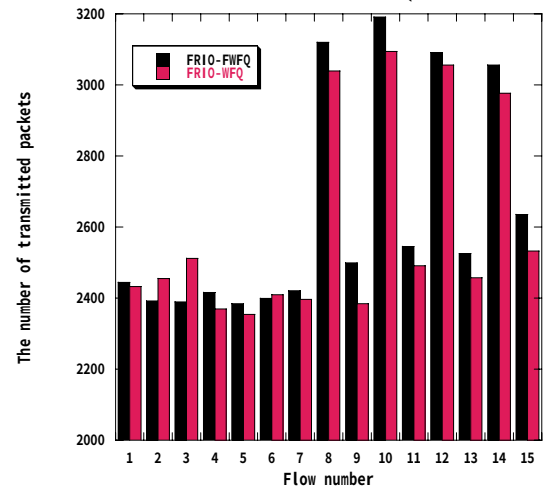


Figure 17 The number of transmitted packets vs. Flow number (Type 4)

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