RESEARCH NOTE

A FUZZY BASED THREE COLOR METER/MARKER FOR DIFFSERV NETWORKS

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(Received: December 9, 2002 – Accepted in Revised Form: July 7, 2004)

Abstract Differentiated Services (Diffserv) which was proposed by Internet Engineering Task Force (IETF), is a scalable and robust model for providing the end-to-end QoS. In the Diffserv networks, metering mechanisms are used to measure traffic stream. The single rate Three Color Meter (srTCM) [1],which was proposed by IETF, meters an IP packet stream and marks its packets either green, yellow, or red. Marking is based on a Committed Information Rate (CIR) and two associated burst sizes, a Committed Burst Size (CBS) and an Excess Burst Size (EBS). In this paper, a Fuzzy Logic Controller (FLC) is proposed which can be used as a metering/marking mechanism in the Diffserv's routers. Simulation results show that the proposed FLC based mechanism has better QoS performance and higher utilization than traditional srTCM mechanism.

Key Words QoS, Differentiated Services, Metering, Marking, Fuzzy Logic

چکیده سرویس‌های جدا شده (Diffserv) که توسط IETF ارائه شده است، یک مدل مقیاس‌پذیر و کارآمد برای تامین کیفیت سرویس انتها به انتها می‌باشد. در سرویس‌های جدا شده از مکانیسم‌های اندازه‌گیری ترافیک استفاده می‌شود. مکانیسم srTCM[1] که توسط IETF ارائه شده است، جریان‌های ترافیکی IP را اندازه‌گیری کرده و آنها را به رنگ سبز، زرد و یا قرمز علامت می‌زند. این علامت زنی بر اساس نرخ اطلاعات توافق شده (CIR)، طول توافق شده ناحیه انفجار (CBS) و طول اضافی ناحیه انفجار (EBS) انجام می‌شود. در این مقاله یک کنترل کننده فازی که قادر به انجام توام عملیات اندازه‌گیری و علامت‌زنی در مسیریاب های سرویس‌های جدا شده می‌باشد، ارائه گردیده است. نتایج شبیه‌سازی نشان دهنده این است که مکانیسم فازی پیشنهادی دارای کارایی کیفیت سرویس بالاتر و بهره‌وری بیشتر نسبت به مکانیسم متداول srTCM می‌باشد.

1. INTRODUCTION

The current Internet consists of different networks built from various data link layer technologies and relies on the Internet Protocol (IP). The Internet protocol makes no assumptions about the underlying protocol stacks and offers an unreliable, connectionless network-layer service that is subject to packet loss, reordering, and packet duplication. As the IP is a connectionless protocol, to provide end-to-end reliability, an additional higher layer end-to-end protocol such as the Transmission Control Protocol (TCP) is required. The current Internet protocol offers only the best-effort services. In the best-effort services, the network tries its best to forward the user traffic flows, but it can't provide any guarantees to deliver the traffic flows correctly and timely to the destination. This means that when congestion occurs in the network, the packets of best-effort services can be dropped immediately. For traditional non-real-time Internet traffic such as File Transfer Protocol (FTP) data, the best-effort delivery model of IP has not been a problem. However, many real-time applications are being developed that are delay sensitive and need the QoS guaranty. The QoS means providing consistent and predictable data delivery service to satisfy customer application requirements. Organizations delivering network-based services need powerful end-to-end solutions to effectively and predictably deliver the differing QoS requirements of voice, video, and data applications. Voice, for example, requires a small but assured amount of bandwidth, low delay, low jitter and low packet loss. A data application such as FTP needs more bandwidth, but can tolerate the delay and jitter.

The IETF has proposed Diffserv [2-4] model as an important model for supporting QoS in the Internet. In the Diffserv model, input packets are marked differently to create several packet classes. Each class has different QoS requirements. The Diffserv model provides service classification by means of the Differentiated Service (DS) field in the IP header and the Per-Hop Behavior (PHB) which defines the externally observable behavior at the node. In the differentiated service architecture, the network traffic is divided into several service classes. Within each class a number of priority levels may be envisaged. A traffic profile specifies the temporal properties of a traffic stream selected by a classifier. It provides rules for determining whether a particular packet is in-profile or out-of-profile.

A Disffserv router consists of the following components [2]:

-Classifier: packet classifier selects packets in a traffic stream based on the content of some portion of the packet header. Two types of classifiers are defined. The BA (Behavior Aggregate) classifier classifies packets based on the DS code point only. The MF (Multi-Field) classifier selects packets based on the value of a combination of one or more header fields, such as source address, destination address, DS field, protocol ID, source port and destination port numbers, and other information such as incoming interface.

-Meter: the meter is responsible to measure the temporal properties of the traffic stream selected by a classifier against a traffic profile specified in a Traffic Conditioning Agreement (TCA). A meter passes state information to other conditioning functions to trigger a particular action for each packet, which is either in- or out-of-profile.

-Marker: the packet marker sets the DS field of a packet to a particular codepoint, adding the marked packet to a particular DS behavior aggregate. The marker may be configured to mark all packets that are steered to it to a single codepoint, or may be configured to mark a packet to one of a set of codepoints used to select a Per Hop Behavior (PHB) in a PHB group, according to the state of a meter. When the marker changes the codepoint in a packet, it is said to have "re-marked" the packet.

-Shaper: The shaper delays some or all of the packets in a traffic stream in order to bring the stream into compliance with a traffic profile. A shaper usually has a finite-size buffer, and packets may be discarded if there is not sufficient buffer space to hold the delayed packets.

-Dropper: The dropper discards some or all of the packets in a traffic stream in order to bring the stream into compliance with a traffic profile. This process is known as "policing" the stream.

As mentioned before, the given treatment to the packet within the node is identified by the PHB. The marking using the DS byte identifies the treatment of packet. The DS byte contains 6 bits for the DSCP field plus 2 bits that are currently unused and reserved for the future. The defined PHB are Expedited Forwarding (EF) [5], Assured Forwarding (AF)[6] and the best-effort traffic. The Random Early Discard (RED) [7-9] is one of the most popular active queue management mechanisms, which is widely used in many routers. With RED, some packets are randomly discarded bellow the main discard threshold. In the RED mechanism, as packet are randomly discarded, when bursty traffic mixes with non-bursty traffic there is not any unfair discarding problem. Furthermore, it prevents network congestion and ensures that queues will not actually reach their full discard threshold.

Diffserv network providers may choose to offer services to customers based on a temporal profile within which the customer submits traffic for the service. In this event, a meter might be used to trigger real-time traffic conditioning actions (e.g., marking) by routing a non-conforming packet through an appropriate next-stage action element. Alternatively, by counting conforming and/or non-conforming traffic using a counter element downstream of the meter, it might also be used to help in collecting data for out-of-band management functions such as billing applications. A meter measures the rate at which packets making up a stream of traffic pass it, compares the rate to some set of thresholds and produces some number of potential results. A given packet is said to be "conformant" to a level of the meter if, at the time that the packet is being examined, the stream appears to be within the rate limit for the profile associated with that level. Some examples of possible meters are: Leaky Bucket (LB) [10], single rate Three Color Meter (srTCM)[1], two rate Three Color Meter (trTCM)[11], time sliding window approach [12] and adaptive packet marking [13].

In this paper we propose a new fuzzy based metering/marking mechanism, which can be used in Diffserv routers. The proposed mechanism uses a two-input-single-output fuzzy controller. The inputs of the fuzzy controller are: the estimated mean burst size and the average output queue size. Based on linguistic rules stored in the rule base, the fuzzy controller determines the color of the output packet. The reminder of this paper is organized as bellow. In section 2, our proposed fuzzy based metering/marking mechanism is explained. In section 3 by using computer simulation, the performance of our proposed mechanism is evaluated and compared with the srTCM mechanism. Finally, section 4 concludes the paper.

2. THE PROPOSED FLC BASED METERING/MARKING MECHANISM

In this section we present our fuzzy based metering/marking mechanism. In the proposed mechanism we use a two-input-single-output fuzzy controller. Figure 1 shows a block diagram of our proposed fuzzy mechanism. As shown in this figure, our fuzzy controller has 2 crisp inputs that are: the current average buffer size calculated by RED scheduler (avg) and the estimated burst size of the traffic source (BS). To estimate the source mean burst size, in each burst period the number of bytes are counted. After k burst/silence period, the estimated burst size (BS_k) is calculated as bellow:

$$BS_1 = N_1,$$

$$BS_2 = \frac{N_1 + N_2}{2} = \frac{BS_1}{2} + \frac{N_1}{2}$$

$$BS_3 = \frac{N_1 + N_2 + N_3}{3} = \frac{2BS_2}{3} + \frac{N_3}{3}$$

.

$$BS_k = \frac{N_1 + N_2 + ... + N_k}{k} = \frac{(k-1)BS_{k-1}}{k} + \frac{N_k}{k}$$

where N_k represents the number of bytes in the kth burst. The estimated burst size (BS) and the average buffer size (avg) are converted into two fuzzy subset {Low, Medium, High} which their membership functions are shown in Figure 2.
The rule base of the fuzzy controller is given bellow:

Rule 1: If *avg* is **Low** Then Color is **Green.**
Rule 2: If *avg* is **Medium** AND *BS* is **Low** Then Color is **Green**
Rule 3: If *avg* is **Medium** AND *BS* is **Medium** Then Color is **Yellow**.
Rule 4: If *avg* is **Medium** AND *BS* is **High** Then Color is **Red**
Rule 5: If *avg* is **High** Then Color is **Red**.

The output of fuzzy controller which represents the color of packet, is calculated by using the hight defuzzification method as bellow:

$$color = \frac{\sum_{i=1}^{9} \min\{\mu_i(BS), \mu_i(avg)\}\mu_i(color)}{\sum_{i=1}^{9} \min\{\mu_i(BS), \mu_i(avg)\}}$$

3. PERFORMANCE STUDY

In this section by using computer simulation, we evaluate the performance of our proposed fuzzy metering/marking mechanism with that of non-fuzzy mechanism. For this purpose we consider three conformance levels including: Green, Yellow and Red. The IP packets, which are marked as Red, are immediately dropped. Only the Green and Yellow packets are entered to the output buffer which is scheduled by the RED mechanism.

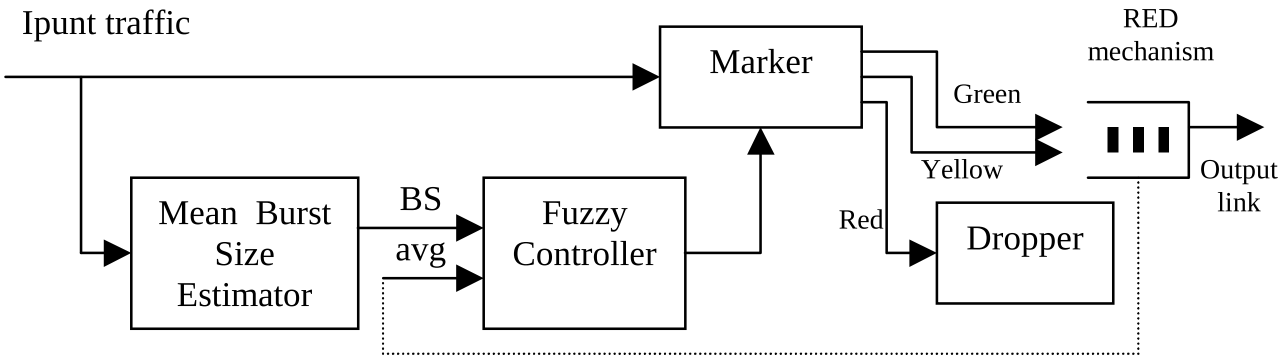


Figure 1. The structure of proposed fuzzy metering/marking mechanism.

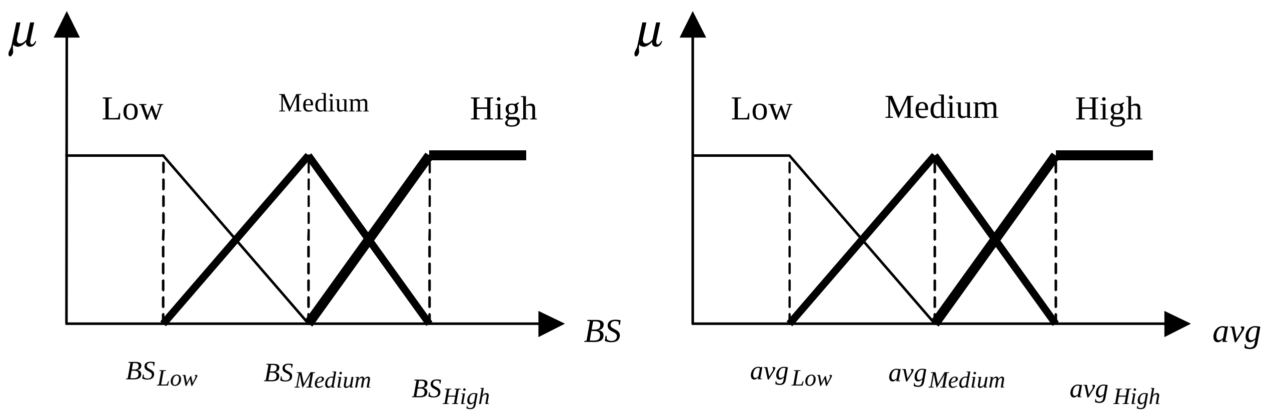


Figure 2. Membership functions of BS and avg.

TABLE 1. Simulation Parameters.

Traffic Source Parameters		**RED's Parameters**		**Fuzzy Logic Controller's Parameters**	
Parameter	***Value***	***Parameter***	***Value***	***Parameter***	***Value***
Peak Bit Rate	10 Mb/s	Min_{th} (Green)	0.1*buffer size	BS_{Low}	CBS
Mean Burst Size	0.0143 sec	Max_{th}(Green)	0.5*buffer size	BS_{Medium}	(CBS+EBS)/2
Mean Silence Size	0.12 sec	Min_{th} (Yellow)	0.05*buffer size	BS_{High}	EBS
CIR	2 Mb/s	Max_{th}(Yellow)	0.25*buffer size	avg_{Low}	0.08*buffer size
EBS	35750 Bytes	Wq	0.002	avg_{Medium}	0.12*buffer size
CBS	17875 Bytes	Maxp	0.1	avg_{High}	0.2*buffer size

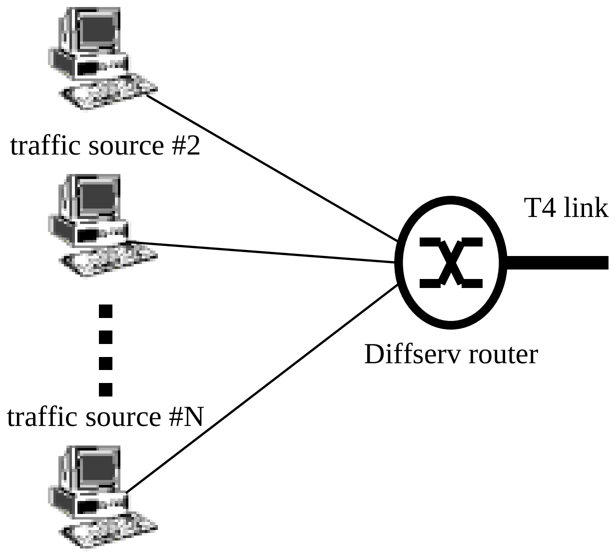


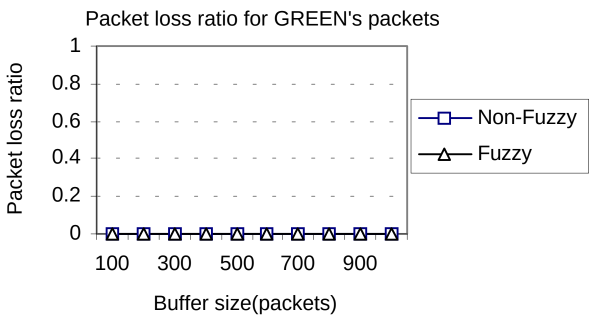
Figure 3. Network topology used in the simulation.

size is set to 256 bytes. The number of packet per burst has a geometric distribution and the silence phase has an exponential distribution. Simulation software based on discrete event simulation was developed. Table 1 shows the traffic parameters and the other simulation parameters. The network topology used in the simulation is shown in Figure 3. According to this figure, N independent traffic sources are muliplexed and sent to a edge Diffserv router. The output link capacity is 274176000 b/s (T4 link).

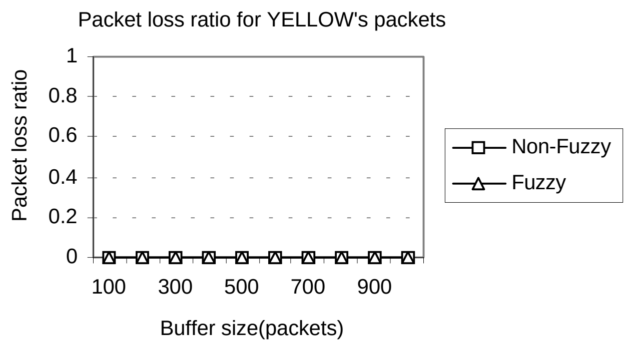
During periods of congestion, in the output buffer, Green packets are dropped with lower probability than Yellow packets. For Green and Yellow packets, we compare the loss probability, the channel utilization and the queuing delay of proposed fuzzy metering/marking mechanism with those of non-fuzzy mechanism. A bursty data traffic source is used for simulation. The packet size is set to 256 bytes. The number of packet per burst has a geometric distribution and the silence phase has an exponential distribution. Simulation software based on discrete event simulation was developed. Table 1 shows the traffic parameters and the other simulation parameters. The network topology used in the simulation is shown in Figure 3. According to this figure, N independent traffic sources are muliplexed and sent to a edge Diffserv router. The output link capacity is 274176000 b/s (T4 link).

To evaluate the performance of proposed fuzzy model, different traffic load are considered. At the first scenario, ten data traffic sources is considered, so the traffic load is equal to 0.036. In Figure 4(a,b), for two traffic classes Green and Yellow and for both non-fuzzy and the proposed fuzzy mechanisms, the packet loss probability is plotted versus the buffer size. It is clear that for low traffic load, both non-fuzzy and fuzzy mechanisms have very low packet loss probability. In Figure 5(a,b,c,d), for two traffic classes Green and Yellow and for both non-fuzzy and the proposed fuzzy mechanisms, the channel utilization and queuing delay are plotted versus the buffer size. This figure shows that the proposed fuzzy mechanism has better channel utilization and queuing delay than non-fuzzy mechanism.

In the second scenario, 250 data traffic sources are considered, so the traffic load is equal to 0. 9. In Figure 6(a,b), for two traffic classes Green and Yellow and for both non-fuzzy and the proposed

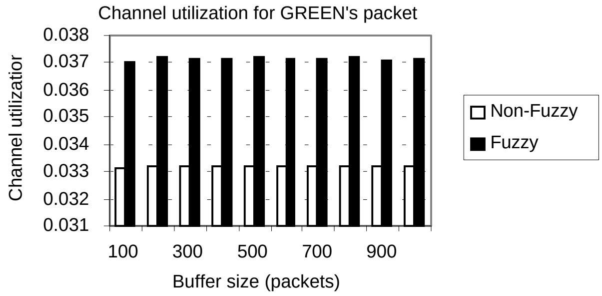


(a)

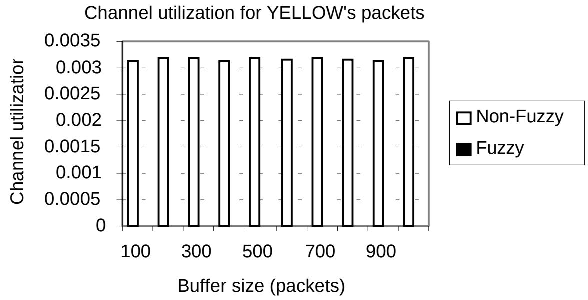


(b)

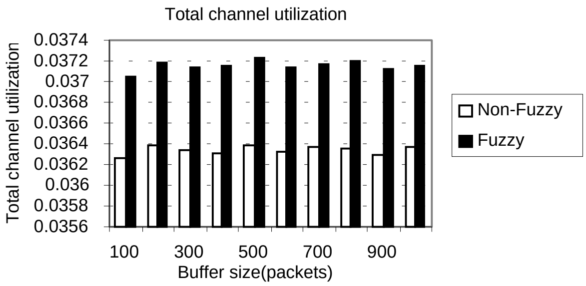
Figure 4. Packet loss versus buffer size for (a) Green packets, (b) Yellow packets.



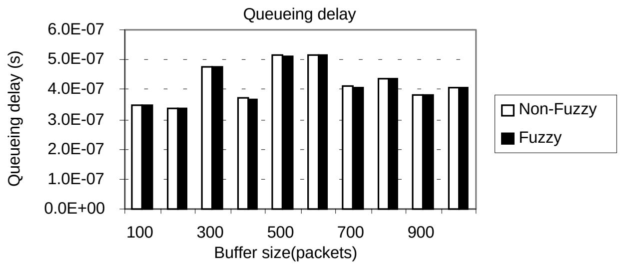
(a)



(b)

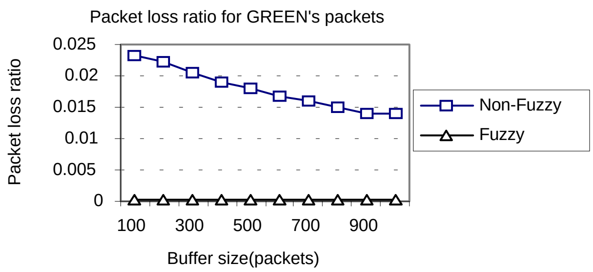


(c)

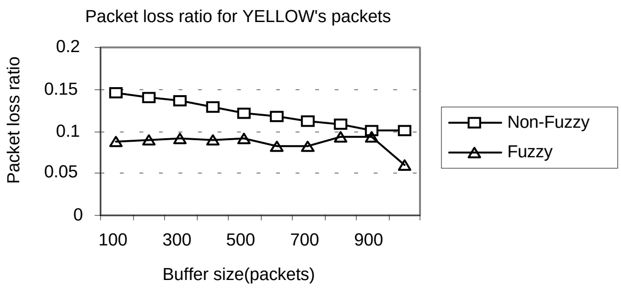


(d)

Figure 5. Performance evaluation of fuzzy and non-fuzzy mechanisms:
(a) channel utilization of Green packets, (b) channel utilization of Yellow packets,
(c) total channel utilization and (d) queuing delay.



(a)



(b)

Figure 6. Packet loss versus buffer size for (a) Green packets and (b) Yellow packets.

fuzzy mechanisms, the packet loss probability is plotted versus the buffer size. It is clear that for Green's packets, in comparison with non-fuzzy mechanism, our proposed fuzzy mechanism has better packet loss probability and also for low priority packets (Yellow's packets), its packet loss probability is close to non-fuzzy mechanism. In Figure 7(a,b,c,d), for two traffic classes Green and Yellow and for both non-fuzzy and the proposed fuzzy mechanisms, the channel utilization and

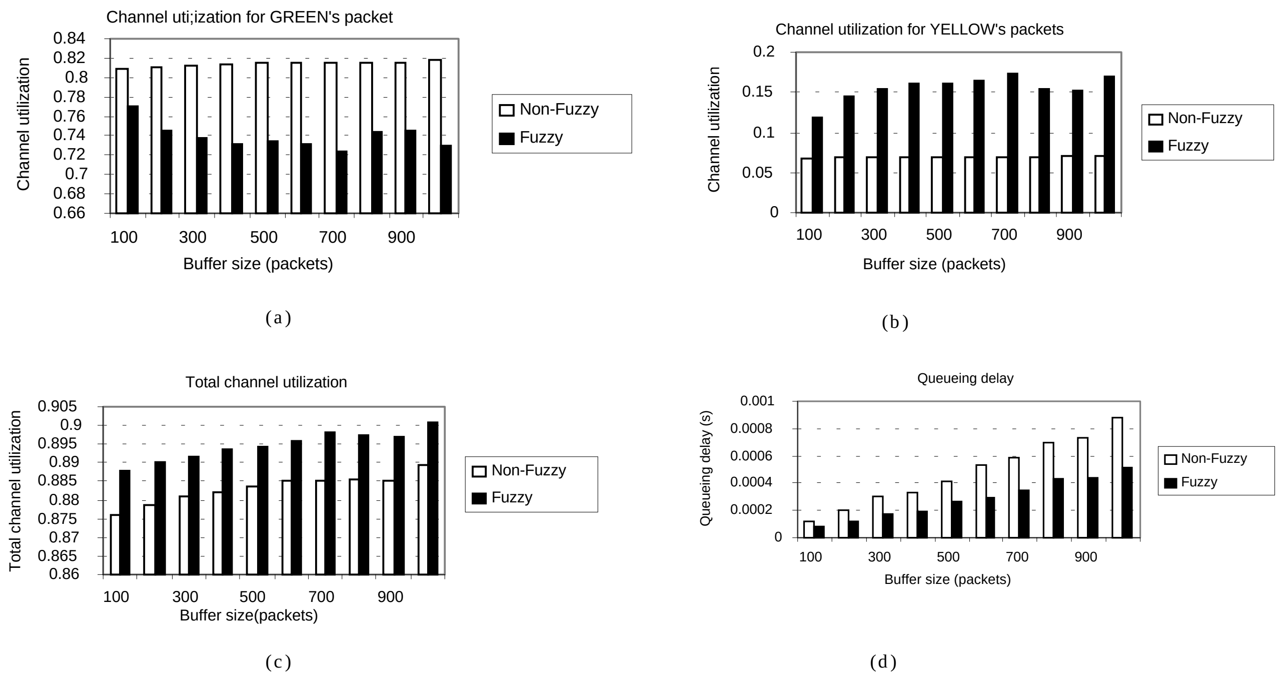


Figure 7. Performance evaluation of fuzzy and non-fuzzy mechanisms:
(a) channel utilization of Green packets, (b) channel utilization of Yellow packets, (c) total channel utilization and (d) queuing delay.

queuing delay are plotted versus the buffer size. This figure shows that the proposed fuzzy mechanism has better performance than non-fuzzy mechanism.

3. CONCLUSION

In this paper a FLC based metering/marking mechanism was proposed for Diffserv routers. In the proposed fuzzy mechanism a two-input-single-output fuzzy controller was used. The inputs of the fuzzy controller are: the estimated mean burst size and the average output queue size. Based on linguistic rules stored in the rule base, the fuzzy controller determines the color of the output packet. Using computer simulation, the performance of proposed mechanism was compared with those of non-fuzzy mechanism. It was shown that the proposed metering/marking mechanism has better packet loss (for Green packets) and total channel utilization than non-fuzzy mechanism.

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