Analysis of high performance packet switch with input smoothing

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Abstract: *The paper presents high performance packet switch with input smoothing. The arriving packets are merged into frame, which enters simultaneously to input ports and reduce the latency through the switch. In this paper is shown that increasing the frame size lead to decreasing the probability of packets loss. As result the throughput of switch is increased. For research of this switch is developed simulation model in terms of packet loss probability and mean waiting time (time slots).*

Key words: *switch with input smoothing, packet loss probability, mean waiting time.*

INTRODUCTION

Due to the unscheduled nature of packets arrivals to switch, two or more packets may arrive on different inputs destined for the same output. The switch architecture may allow one of these packets to pass through to the output, but the others must be queued for later transmission [4]. This form of congestion is unavoidable in a packet switch and dealing with it often represents the greatest source of complexity in the switch architecture. The throughput of packet switch with input queuing and FIFO (First-In-First-Out) buffers is limited to 0,586 [2]. Input queuing limits each input to send at most one packet into the switch fabric per time slot, presents preventing packets from reaching idle outputs. The using of input smoothing can increase the throughput of packet switch. In this paper is presented the performance of packet switch with input smoothing. For research of this switch is developed simulation model in terms of packet loss probability and mean waiting time (time slots).

1. DESCRIPTION OF PACKET SWITCH WITH INPUT SMOOTHING

The arriving packets are merged into frame by packet switch with input smoothing. Each frame consists of *b* packets. The size of switch is *Nb x Nb* (Fig.1). The packets within a frame are stored at input buffer of each input and then enter simultaneously to input ports of switch (demultiplexed) for *b* time slots. The Nb packets can enter the fabric, of which *b* can be simultaneously received at each output where the packets are multiplexed onto the output line. If more than *b* packets destined for an output they are dropped within the switch fabric. In this paper is shown that making the frame size *b* large can make the probability of dropping the packets small.

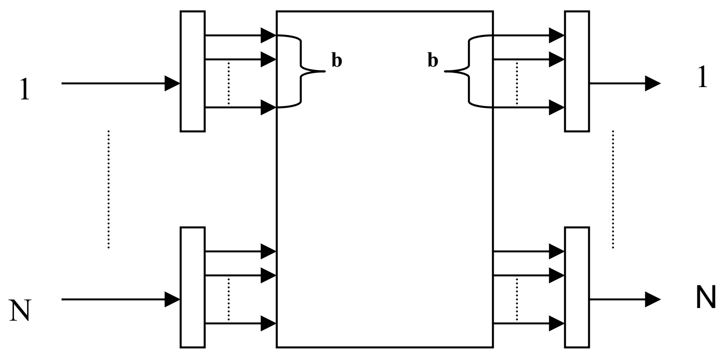

Fig. 1 Packet switch with input smoothing

2. ANALYSIS OF PACKET SWITCH WITH INPUT SMOOTHING

If the number of arrivals packets $k > b$ then k-b packets will be lost. The number of arriving packets has binomial distribution. The binominal law of the arriving packets k for a given time interval is [3]:

$$\mathbf{P}\,[A=k] = \binom{Nb}{K} (p/N)^{k} . (1-p/N)^{Nb-k}, \quad k=0,1,\ldots,Nb \tag{1}$$

Where: $P[A=k]$ - the probability k packets entering the switch fabric destined for a given output;

- A - random variable, defining the number of packets entering the switch fabric destined for a given output;
- k - number of packets enter the switch fabric destined for a given output;
- b - the maximum assumed number of packets within a frame.
- p - offered load;
- N - the number of inputs (outputs) on the switch fabric;
- Nb - the number of inputs (outputs) ports on the switch fabric.

The probability of packet loss $\mathbf{B}$ within the fabric is given by [1]:

$$\mathbf{B}\,[packet\ loss] = (1/bp) \sum_{k=b+1}^{Nb} (k-b)\, (p/N)^{k} . (1-p/N)^{Nb-k} = \tag{2}$$

$$= 1-1/p + (1/bp) \sum_{k=0}^{b-1} (b-k)\, (p/N)^{k} . (1-p/N)^{Nb-k} .$$

If taking the limit as $N \to \infty$ is obtained:

$$\mathbf{B}\,[packet\ loss] = 1-1/p + (e^{-bp}/bp) \sum_{k=0}^{b-1} (b-k)(bp)/k! . \tag{3}$$

The mean packet waiting time (measured in packet time slots) $\mathbf{W}$ is given by [1]:

$$\mathbf{W} = C + L + w \tag{4}$$

$$C = (b-1)/2$$

$$L = (b-1)$$

$$w = \frac{\sum_{k=1}^{b-1} (k-1)/2.k.P[A=k] + (b-1)/2.b.P[A \geq b]}{\sum_{k=1}^{b-1} k.P[A=k] + b.P[A \geq b]}$$

Where ***W*** - mean packet waiting time;
C - the expected waiting time of a packet while the frame is stored at the inputs;
L - the delay is resulting from the fabric running at 1/b the speed of the inputs and outputs;
w - the expected waiting time in the multiplexing operation at the outputs.

The timing diagram in Fig. 2 is used to compute the mean waiting time for input smoothing.

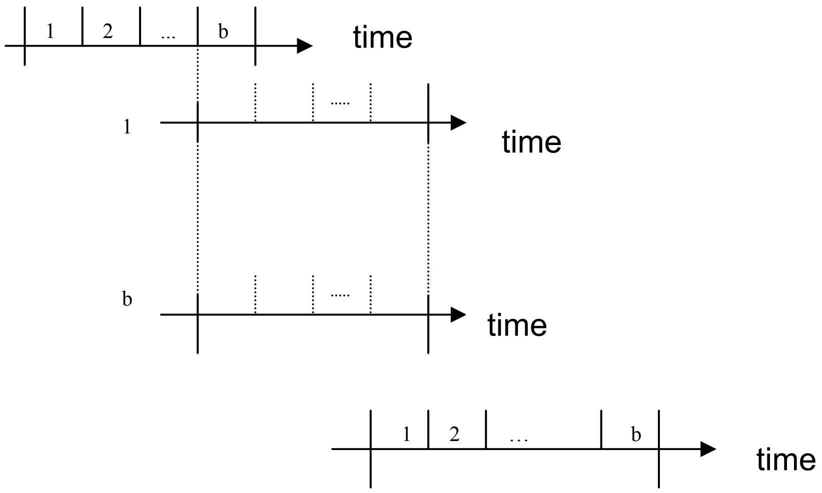

Fig. 2 The time diagram

Using equation (1), the equation (4) may be rewritten as:

$$W = 3(b-1)/2 + \frac{\sum_{k=1}^{b-1} [(k(k-1)-b(b-1))/2] \; (p/N)^k (1-p/N)^{Nb-k} + b(b-1)/2.[1-(1-p/N)^{Nb}]}{b - \sum_{k=1}^{b-1} (b-k) \; (b/N)^k.(1-p/N)^{Nb-k}} \qquad (5)$$

If taking the limit as $N \rightarrow \infty$ is obtained:

$$W = 3(b-1)/2 + \frac{\sum_{k=1}^{b-1} [(k(k-1)-b(b-1))/2] \, . \, (bp)^k/k! + b(b-1)/2.[e^{bp}-1]}{be^{bp} - \sum_{k=1}^{b-1} (b-k) \, . \, (bp)^k/k!} \qquad (6)$$

3. THE SIMULATION RESULTS

For research of high-performance packet switch with input smoothing is developed simulation model in terms of packet loss probability and mean waiting time (time slots). The conditions of modelling are following:

1. Buffer size - from 10 to 80 packets;
2. The offered load - from 0,1 to 1,0 Erlang;
3. Switch size - N=2, 4, 8, 16 and ∞.

The obtained results for packet loss probability as a function of the buffer size *b (10-80)* and switch size *N*, for offered load *p=0,8 Erlang* is shown in Table 1. Fig.3 shows the chart dependence. The results for mean waiting time as a function of the offered load, for *N=∞* and output FIFO sizes varying from *b (2, 3, 4, 5 and 6)* are shown in Table 2, and chart dependence is shown in Fig. 4.

Table1 Simulation results for packet loss probability as a function of the buffer size

Size buffer [*b* packets]	Offered load *p=0,8 Erlang*				
	B[packet loss] N=2	***B***[packet loss] N=4	***B***[packet loss] N=8	***B***[packet loss] N=16	***B***[packet loss] N=∞
b=10	0,0400	0,0700	0,0800	0,0800	0,0800
b=20	0,0100	0,0300	0,0400	0,0400	0,0400
b=30	0,0060	0,0090	0,0100	0,0150	0,0200
b=40	0,0030	0,0070	0,0080	0,0090	0,0100
b=50	0,0010	0,0050	0,0060	0,0070	0,0090
b=60	0,0008	0,0020	0,0040	0,0050	0,0070
b=70	0,0004	0,0001	0,0030	0,0040	0,0050
b=80	0,0001	0,0009	0,0010	0,0020	0,0030

Table 2 Simulation results for mean waiting time as a function of the offered load

Offered load *p*[Erlang]	Mean waiting time ***W*** [time slots] for N=∞				
	b=2	*b=3*	*b=4*	*b=5*	*b=6*
0,1	1,70	3,00	4,50	6,00	7,50
0,2	1,75	3,20	4,60	6,20	7,90
0,3	1,80	3,50	4,70	6,50	8,10
0,4	1,85	3,60	4,90	6,80	8,50
0,5	1,90	3,65	5,00	7,00	8,80
0,6	1,92	3,70	5,20	7,20	9,00
0,7	1,94	3,75	5,40	7,30	9,20
0,8	1,96	3,80	5,50	7,40	9,30
0,9	1,98	3,85	5,60	7,50	9,50
1,0	2,00	3,90	5,70	7,60	9,70

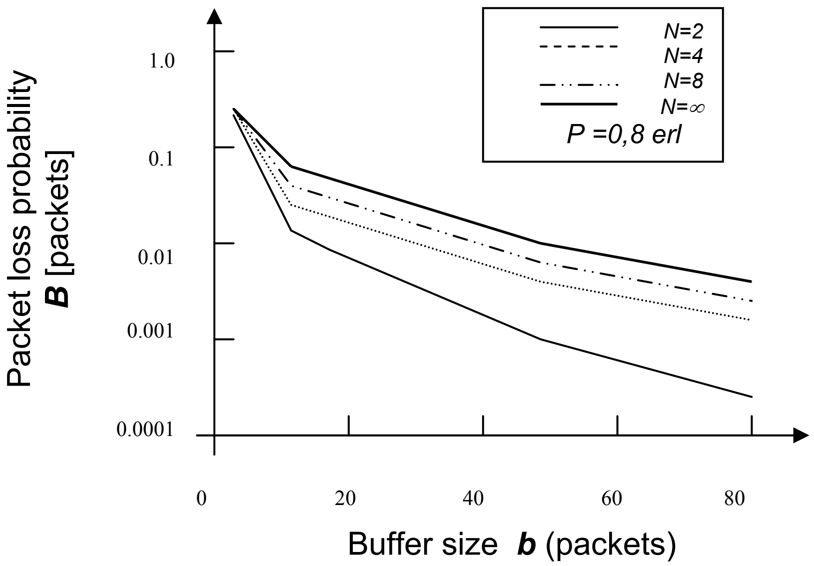

Fig. 3 The packet loss probability as a function of the buffer size and the switch size *N* for offered load *p=0,8* Erlang

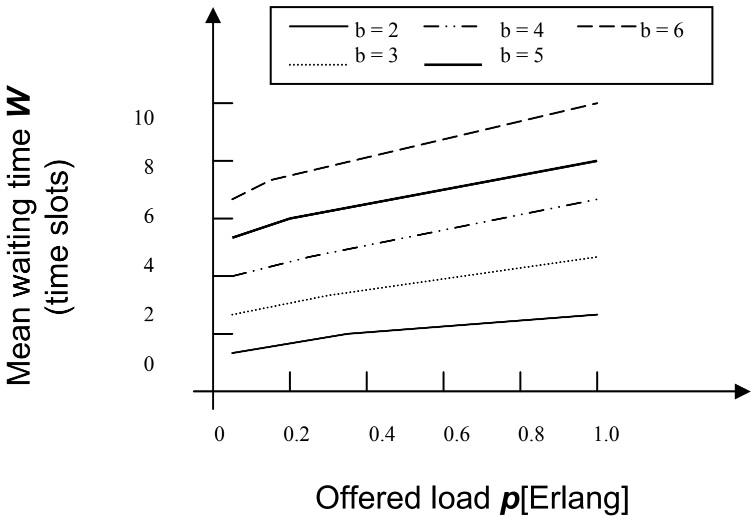

Fig. 4 The mean waiting time as a function of the offered load for *N=∞* and frame sizes from *b=2* to *b=6*

4. CONCLUSIONS

From analysis of packet switch with input smoothing can be done the following conclusions:

1. The packet loss probability increases with increasing *N*. To achieve the probability of 10^{-3} for arriving traffic of *p=0,80* is required the frame size *b > 80.*
2. The large frame size increases the size of the switch fabric and also the packet delay through the switch.
3. The mean waiting time increases proportionally with frame size *b*.

4. Input smoothing increases the throughput, but at the expense of a large size of switch fabric and latency.

In the developed by *AT&T Starlite* switch is used smoothing effect of the input flow. The fixed-length packets arrive to the switch multiplexed bit-by-bit. The multiplexed packets reduce the latency through the switch since only *b* bits (rather than an entire frame of *b* packets) have been accumulated at the input before entering the switch fabric.

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