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# ON THE ISSUE OF DETERMINING THE BANDWIDTH OF IP NETWORKS

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In reality, there is a situation in telecommunications networks when routers process a large number of IP packets of various sizes. The service or processing time of these packets depends on the switching matrix used. The switching matrix is the basis of any router, since packets are transmitted from the input data port to the output port using it. Switching can be performed in several ways: through memory, through the bus, through the connecting[1;2].

In more complex interconnecting networks, switching occurs in several stages, which ensures simultaneous transmission of packets from different input ports to the same output port through a switching matrix. It should be noted that routers that switch via memory and via the bus cannot simultaneously transmit several packets from input ports to output ports, since this depends on the specifics of packet processing in the switching matrix – packet processing is carried out using the FIFO method (First In – First Out). Switching through a connecting network allows the router to process multiple packets simultaneously [2].

The router can process 2 million or more packets per second [3].

For example, 5 thousand IP packets with a size of 64 bytes or 10 thousand with a size of 32 bytes can be processed at the same time. It is logical to assume that, all other things being equal, if only IP packets of 32 bytes in size are used on routers, performance will increase by 2 times, since the number of packet service locations in RAM will increase by 2 times.

Thus, taking into account the percentage of different sizes of information packets is very important for a more accurate calculation of the parameters of the IP network switching node.

Let's consider the simplest mathematical model of the performance of an IP network switching node.

Suppose there are IP packets of two sizes on the router service: 1024 and 32 bytes each. The standard amount of RAM of the router selected for research (in this case, for the Cisco 2811 router) is 256 MB. Then the router for a certain time can process either 250 thousand packets of 1024 bytes, or 8 million packets of 32 bytes, or 200 thousand packets of 1024 bytes and 1.6 million packets of 32 bytes, etc. Let's assume that the router's RAM is used as efficiently as possible. And we will also make an assumption about the equal delay time (maintenance) for all IP packet sizes (it is equal to 10-20 ms) [4].

Now, let's take a situation where the number of places in RAM is not a constant (constant), but is a discrete random variable. In this case, it is impossible to accurately calculate the performance of the switching node according to standard methods.

In the case of transmitting IP packets of the same size, the performance can be calculated as:

$$C_{IP}=M_R(1000/t_{serv})\ [\text{Pack/s}], \qquad (1)$$

where $M_R$is the number of packet service locations in RAM or the number of packets serviced, taking into account the size (250 thousand – 1024 bytes each, 8 million – 32 bytes each);$t_{serv}$is the packet processing time (delay introduced by the router).

When using 1024-byte IP packets, the performance will be equal to:

$$C_{IP}=M_R(1000/ts_{erv})=250000\times(1000/20)=12{,}5\times10^6\ [\text{Pack/s}],$$

and in the case of using IP packets of 32 bytes:

$$C_{IP}=M_R(1000/ts_{erv})=8000000\times(1000/20)=400\times10^6\ [\text{Pack/s}].$$

As you can see, the performance of the switching node when using packets of a smaller information size has increased 32 times, since the packet service space in the router's RAM has increased 32 times.

Let's determine what the performance will be if packets of different sizes come to the router at the same time. For brevity, let's denote them “*A*” and “*B*”.

Let's assume that the information flow of IP packets arriving at the router looks like this (from right to left): *AAVVVAV*..., where “*A*” is a packet of 1024 bytes, “*B*” is a packet of 32 bytes.

We will consider the appearance of the current IP packet as an independent event from the appearance of the previous packet, and the information flow itself is infinite.

The probability that a randomly selected package turns out to be “*A*” will be $P_A$, and that “*B*” will be $P_B$.

Consider two hypotheses: $H_1$ and $H_2$. To simplify calculations, we assume that $H_1$ – 5 consecutive packages are “*B*” type packages and $H_2$ – 1 out of 5 packages is a “*A*” type package. Then the probability of hypotheses $P(H_1) = R_B^5$, and $P(H_2)=1–R_B^5$. Since the total probability of hypotheses is equal to one, it means that they form a complete group of events. In this article, the tserv service time for an IP packet of any size is the same value, so it is sufficient to consider the above two hypotheses. In fact, on routers with unequal delays of IP packets of different sizes, it will be necessary to investigate other combinations of information packets.

Since the number of packet service locations in RAM in the accepted case is a random variable, we will find its mathematical expectation:

$$M = \sum_i X_i P_i = 4\left(1 - P_B^5\right) + 5P_B^5 = 4 + P_B^5,$$

where $X_i$ is the $i$-th value of a random variable; $P_i$ is the probability of occurrence of the $i$–th value of a random variable.

Substituting its mathematical expectation into expression (1) instead of the number of packet service locations in RAM, we get:

$$C_{IP}=1000/t_{serv}[4+P_B^5].$$

At 10% packet processing “*B*” performance $C_{IP}$=200,0005 [Pack/s].

## Listofusedliterature

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