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FORMING THE PROCEDURE OF ADAPTIVE SERVICE OF INFORMATIONAL TORRENTS IN THE COMMUTATING KNOTS OF TELECOMMUNICATION NETWORK

1 Introduction

One of the important tasks of improving telecommunication networks with packet commutation is the task of increasing efficiency of management of informational torrents. The task of management of informational torrents consists of such tasks: selection of the way of seeking the route for transmission the packet and forming the procedure of servicing the packet in the commutation knot. Management of informational torrents in the telecommunication network has to provide the delivery of packets from the sender knot to the addressee knot for every message source. The delivery of packets from the sender knot to the addressee knot has to be under such demands: the time of delay and the probability of loss of the packets can not exceed the permissible significance. The significance of these parameters is defined by delay and of the packets in the all commutation knots of the route, where the informational torrent is transmitted.

In this report is considered the commutation knot, in which every direction of arriving of the packets has its own buffer memory device (BMD) [1]. The servicing of the packets takes place in the commutation knot. This servicing has the aim to find the direction of their next transmitting (in the next knot according to the route of transmission or leaving the network by the packet if this is the addressee knot). The procedure of servicing of the informational torrents in the commutation knots has to provide the necessary efficiency: the delay of the packets has to be minimal and the loss of the packets has to be practically absent. The quality of servicing of all directions, in which the informational torrents arrive, must be equal in value. The equal value of quality of servicing of all informational torrents, as they have the accidental character of arriving, must be provided by the adaptive procedure of choosing BMD.

2 Procedure of choosing packets for servicing in commutating knots

The idea of adaptive procedure, which was presented in [1, 2], means that the choice of BMD, from where the packet will be taken out, depends on the state of the queue of packets in every BMD. The state of the queue of packets in BMD means the number of the packets in the queue and the time of delay of packet, which is first in the queue. The state of the queue of packets was proposed to value by the number of applications, which reflects it. We have two different types of applications for servicing:

1. every packet, which arrives in BMD, creates one or more applications for servicing; such applications we shall consider real;
2. if at least one packet is in the queue, one or some more applications forms for every lost address to the set of BMD; such applications we shall consider conditional; conditional applications reflects the time of delay of packet and form by using a special law.

It is necessary to find the law of forming the applications for servicing. The state of the queue in BMD can be valued by number of real applications, by number of conditional applications or by their sum.

If we take as a criterion the maximum of number of real applications for choosing the BMD to take out the packets, it can be expected, that adaptive procedure will provide minimal losses of the packets in the commutating knot. It is necessary to say that the adaptive procedure with such criterion of choice is effective, when the loading of BMD is less than 1 and the intensities of informational torrents are equal. If these intensities are different so the packets of informational torrents with low intensity can have a large significance of delay.

If we take as a criterion the maximum of number of conditional applications, it can be expected, the adaptive procedure will provide minimal middle significance of time of delay for the packets in the commutating knot. In addition the middle significance of time of delay for the packets in the commutating knot will be practically equal for all informational torrents, which arrive to this knot.

If for choosing BMD to take out the packet as a criterion we take the maximum of sum of real and conditional applications, it can be expected, the adaptive procedure will provide minimal losses of the packets and minimal middle significance of time of delay for the packets in the commutating knot. But it is necessary to find the corresponding lows for forming the real and conditional applications of the adaptive procedure of servicing commutating knots.

We shall consider the forming of adaptive procedure of servicing, which expects using the real and conditional applications. Forming the adaptive procedure means that it is necessary to choose the laws of forming the real and conditional applications under set significances of intensity of informational torrents and this procedure has to provide the conditions given before (minimal and equal significance of probabilities of loss and middle significance of time of delay of the packets for all informational torrents, which arrive to the knot.

3 The laws of forming of real and conditional applications for servicing

As we said before, real applications define the possibilities of the adaptive procedure of choosing the BMD to decrease the number of loss packets. The forming of real applications can be made using different laws. Let is show only two among several practical laws.

1. Every packet, which arrives to BMD, forms some number of real applications z_p. The significance of number of real conditions has to be defined. Only z_p is integer from 0 to n.
2. Forming the number of real applications depends on the stage of filling of BMD. Here can be two principle of forming: continual and threshold. In continuous principle the ordinal number of the packet defines the number of real applications. In threshold principle if packet arrives in the queue and takes place before the threshold degree, so the number of real applications increase on first fixed number. If packet takes place upper than the threshold degree, the number of real applications increases in several times than the threshold significance. This numbers are the parameters of the procedure and must be defined.

In these two variants of forming the real applications after every time the packet is taken out the BMD the number of real applications recalculates according to the length of the queue of packets.

For forming the conditional applications the task of choosing the law of their forming is actual too. The choosing of the law is defined by requirements to transmitting the packets of informational torrents. If the critical time of delay of packets exists it is possible to form the variants of the laws for forming the conditional applications, which provide different rates of their increasing.

The requirements to forming of conditional applications can be the next:

1. rate of increasing the number of conditional applications for every lost address to the set of BMD must be slow on the beginning to give the possibility for transmitting the packets from another BMD, and the rate must increases quickly, when the time of delay reaches the permissible time. Under such condition the law for forming the conditional applications must be the next:

$$z_y = N_T^p \text{ or } z_y = p^{N_T} \tag{1}$$

   where N_T - the number of lost times of taking out the packets from set of BMD, it begin to be calculated when the packet was put the first in the queue;

   p - parameter of the law of forming the number of conditional applications, which defines the rate of their increasing; $p = 1, 2, 3, ..., U$.

2. rate of increasing the number of conditional applications from the first lost address to the set of BMD is high, but when the time of delay reached the permissible time, it stops to increase. Under such condition the law for forming the conditional applications must be the next:

$$z_y = A(1 - p^{-N_T}) \tag{2}$$

   where A - parameter of the law of forming the number of conditional applications, which defines the rate of their increasing; $A = 1, 2, 3, ..., U$.

3. rate of increasing the number of conditional applications is equal. Under such condition the law for forming the conditional applications must be the next:

$$z_y = AN_T \tag{3}$$

In a summary we can say: the task of forming the adaptive procedure of servicing of the informational torrents in the commutation knots of telecommunication networks means to choose the laws of forming the real and condition applications and the parameters of these laws for servicing.

For solving this task it is necessary to have the mathematical model of the commutation knot, for its creating it is necessary to choose the modeling tool.

4 Choice the facility for modelling

The known program facilities [3] give the possibility to model the work of telecommunication network at all. For example, the program COMNET-III [4] models the ATM networks, Frame Relay, connection LAN-WAN, SNA and else. Creating the models of networks is based on entire blocks as computers, routers, switchers, multiplexers. As the result we can get: prediction of delay between last and intermediate knots of the networks, coefficients of using the segments, buffers and processors, peaks and abatements of traffic as function of time and some else.

The programs NetCracker and NetMaker XA [5] have the large libraries with the components. Also there is an option for creating the new components. But the prize of them is very high (10000-40000$) and user has to have special training for work with the programs. That's why the own program model of the adaptive procedure of choosing the BMD was made.

For solving the task of forming the adaptive procedure it is necessary to create its mathematical model. In [6],[7],[8] is presented the technology of modeling, which gives the possibility to solve it.

This technology of modeling is a set of methods and methodologies connected with each other for solving the task of elaboration of complex information systems. This technology contains of:

1. methodology formal presentation of the investigate object as structure-automat model based on base events and block diagram of algorithm of behavior;
2. method of formalize creating of the model of the investigate object as the count of the states and transitions;
3. method of equivalent intensity of torrent for transformation the part of the model in a view of count of the states and transitions for analyzing the objects of non-Markov type;
4. method of formalize transformation the part of the model in a view of count of the states for analyzing the objects of non-Markov type;
5. method of solving the system of differential equations of Kolmogorov-Chepmen;

6. methodologies of forming expressions for finding the indicators of efficacy of the investigate object.

In this technology user has to create the structure-automat model, which gives the formal presentation of the investigate object. The program model is a program facility which creates the count of the states and transitions, forms the system of differential equations of Kolmogorov-Chepmen, solves it and searches the indicators of the efficacy in the automatic mode.

5 Forming of the structure-automat model of the adaptive procedure

During forming the model all the events, which reflect the process of work of the object, are taking into consideration. All the events are examined for every BMD. As the result of analyze of the work of adaptive procedure of choosing the BMD the couples of events are set, which fix the beginning and the end of staying the examine object in some state.

6 The structure of the vector of the states of the examine object.

For the reflecting the states of the modeling object which consists of two BMD and one MUX the vector of the states includes three components Vji for every BMD, where j=1...3, i=a (for the first buffer) of i=b (for the second one). The component V1i is responsible for the length of the queue in the BMD, V2i shows the number of conditional applications, which were formed by the first packet in the queue, V3i informs about the overcrowding of the BMD (V3i=1, if the BMD is overcrowded and V3i=0 in other case). In the first moment all the components of the vector is equal 0.

7 Forming the set of the formal parameters.

The set of the formal parameters consists of the constants, which characterize the investigating object. In this report they are:

N – the maximum length of the queue in BMD;

M – the maximum number of conditional applications, which can be made by the first packet in the BMD;

R – the maximum number of the packets, which can leave the BMD at one address of the MUX;

λ_i – the intensity of arriving the packets in “i” BMD;

$\mu = \frac{1}{T_{ad}}$ – the intensity of address of MUX to the set of BMD.

The search of conditions and circumstances and their formal presenting.

Now it is needed to find conditions and circumstances for every base event. As all the base events are independent (their appearing do not connect with some conditions), that's why for every event will be only the circumstances.

For example, the event “The arriving of the packet of “i” informational torrent” can take place under such circumstances:

1. The queue of “i” BMD has the free place for the new packet, that is the number of packets in the “i” BMD is less than the maximum length of the queue. That circumstance is presented by formula:

   $$\mathbf{V1i<N} \quad (4)$$

   At that time the arrived packet is placed in the queue, that is the event “Placing the packet in the queue of “i” BMD” is taking place with the event “The arriving of the packet of “I” informational torrent”.

2. The queue of “i” BMD got it maximum significance, that is the number of packets in the “i” BMD is equal to the maximum length of the queue. That circumstance is presented by formula:

   $$\mathbf{V1i=N} \quad (5)$$

   At that time new packet is lost and the BMD becomes in the overcrowded state. So the events “Losing of the packet of “i” informational torrent” and “Becoming the “i” BMD in the overcrowded state” are taking place with the event “The arriving of the packet of “i” informational torrent”.

For the basic event “Address of the MUX to the set of BMD” the method of finding formal presenting the conditions and circumstances is the same. The formal presenting all the conditions and circumstances is in the schedule 1.

8 Forming the formulas for the calculation the intensity of transitions

The intensity of the event “The arriving of the packet of “i” informational torrent” is defined by the intensity of arriving the packets in the “i” BMD, that is λ_i. The intensity of the event “Address of the MUX to the set of BMD” is defined by the intensity of address MUX to the set of BMD, that is μ.

9 Forming the formulas for the calculation of alternative transitions

The alternative transitions are absent for the events of that object.

10 Forming the rules of modification of the components of vector of the states

During the event "The arriving of the packet of "i" informational torrent" under the circumstance number 1 the length of the queue increases on 1 in "i" BMD, so the rule of modification the vector of the states is:

$$\mathbf{V1i{:=}V1i{+}1} \tag{6}$$

Under the circumstance number 2 the packet is losing and the "i" BMD sets in the overcrowded state. So the rule of modification is:

$$\mathbf{V3i{=}1} \tag{7}$$

The rules of modification the vector of the states for the event "Address of the MUX to the set of BMD" are presented in the schedule 1.

Tabela. 1. Structure-automat model of the adaptive procedure for both BMD, *Schedule 1*

Base events	Conditions and circumstances	FCIT	RMVS
1.Arr. of the packet of "i" inform. torrent	**V1i<N**	$\lambda^{(i)}$	**V1i:=V1i+1**
	V1i=N	$\lambda^{(i)}$	**V3i:=1**
2. Address of the MUX to the set of BMD	1. **(V1a=0) AND (V2a=0) AND (V1b=0) AND (V2b=0)**	μ	**V1a:=0; V2a=0; V1b:=0; V2b:=0**
	2. **(V2a=M) AND (V2b=0) AND (V1b=0)**	μ	**V1a:=V1a-1; V2a:=0; V3a:=0**
	3. **(V2a=M) AND (V2b<M) AND (V1b>0)**	μ	**V1a:=V1a-1; V2a:=0; V3a:=0; V2b:=V2b+1**
	4. **(V2b=M) AND (V2a=0) AND (V1a=0)**	μ	**V1b:=V1b-1; V2b:=0; V3b:=0**
	5. **(V2b=M) AND (V2a<M) AND (V1a>0)**	μ	**V1b:=V1b-1; V2b:=0; V3b:=0; V2a:=V2a+1**
	6. **(V2a=M) AND (V2b=M)**	μ	**V1a:=V1a-1; V2a:=0; V3a:=0; V1b:=V1b-1; V2b:=0; V3b:=0**
	7. **(V1a+V2a)=(V1b+V2b) AND (V3a=0) AND (V1a>R) AND (V2a<M) AND (V1b>0) AND (V2b<M)**	μ	**V1a:=V1a-R; V2a:=0; V2b:=V2b+1**

	8. **(V1a+V2a)=(V1b+V2b) AND (V1a<=R) AND (V2a<M) AND (V1b>0) AND (V2b<M)**	μ	**V1a:=0; V2a:=0; V2b:=V2b+1; V3a:=0**
	9. **(V1a+V2a)=(V1b+V2b) AND (V3a=1) AND (V2a<M) AND (V1b>0) AND (V2b<M)**	μ	**V1a:=V1a-R; V2a:=0; V2b:=V2b+1; V3a:=0**
	10. **(V1a+V2a)>(V1b+V2b) AND (V1a>R) AND (V1b=0)**	μ	**V1a:=V1a-R; V2a:=0; V3a:=0**
	11. **(V1a+V2a)>(V1b+V2b) AND (V1a<=R) AND (V1b=0)**	μ	**V1a:=0; V2a:=0; V3a:=0**
	12. **(V1a+V2a)>(V1b+V2b) AND (V1a>R) AND (V1b>0) AND (V2b<M)**	μ	**V1a:=V1a-R; V2a:=0; V3a:=0; V2b:=V2b+1**
	13. **(V1a+V2a)>(V1b+V2b) AND (V1a<=R) AND (V1b>0) AND (V2b<M)**	μ	**V1a:=0; V2a:=0; V3a:=0; V2b:=V2b+1**
	14. **(V1a+V2a)>(V1b+V2b) AND (V3a=1) AND (V1b=0)**	μ	**V1a:=V1a-R; V2a:=0; V3a:=0**
	15. **(V1a+V2a)>(V1b+V2b) AND (V3a=1) AND (V1b>0) AND (V2b<M)**	μ	**V1a:=V1a-R; V2a:=0; V3a:=0; V2b:=V2b+1**
	16. **(V1a+V2a)<(V1b+V2b) AND (V1b>R) AND (V1a=0)**	μ	**V1b:=V1b-R; V2b:=0; V3b:=0**
	17. **(V1a+V2a)<(V1b+V2b) AND (V1b<=R) AND (V1a=0)**	μ	**V1b:=0; V2b:=0; V3b:=0**
	18. **(V1a+V2a)<(V1b+V2b) AND (V1b>R) AND (V1a>0) AND (V2a<M)**	μ	**V1b:=V1b-R; V2b:=0; V3b:=0; V2a:=V2a+1**
	19. **(V1a+V2a)<(V1b+V2b) AND (V1b<=R) AND (V1a>0) AND (V2a<M)**	μ	**V1b:=0; V2b:=0; V3b:=0; V2a:=V2a+1**
	20. **(V1a+V2a)<(V1b+V2b) AND (V3b=1) AND (V1a=0)**	μ	**V1b:=V1b-R; V2b:=0; V3b:=0**
	21. **(V1a+V2a)<(V1b+V2b) AND (V3b=1) AND (V1a>0) AND (V2a<M)**	μ	**V1b:=V1b-R; V2b:=0; V3b:=0; V2a:=V2a+1**

11 The indicators of efficacy of the adaptive procedure of choosing the BMD

The indicators of efficacy have to show all the problem situations for research object. During constructing the model in the view of the count of the states and transitions it is necessary to reflect in the states such problem situations.

The packets can be lost in the information network in two situations:

1. overflow of BMD, it means the packet arrives when BMD is filled out.

2. time of delay of the packets on some part of the route is more than definite significance. In such situation the packet is lost.

The first situation can be characterized by indicator “probability of loss of packets in case of overcrowded BMD”, the second - “probability of loss of packets if their time of delay is more than the permissible significance”.

According to the requirements to the adaptive procedure of choosing the BMD and the peculiarities of it technical realization the indicators of the efficacy must be: the middle significance of the delay of packets in BMD, the probability of losing of the packets in the system, the probability of appearing the conflict situation, the probability of the free motion.

12 Forming the formulas for calculating the indicators of the efficacy

The necessary information for forming these formulas is the primary parameters of the object and the probabilities of staying in the stages, which were found using the program model. The principle of creating the formulas: on one side there is the correlation of statistic definition of the indicator of efficacy. On another one – the components of the formula are expressed through the probabilities of staying in the stages, which are found from the solving of the system of differential equations.

1. The probability of loss of the packets in the system.

It can be found from the formula:

$$P_{LS} = \lim_{m_{ar}\to\infty} \frac{m_{LS}}{m_{ar}} \qquad (8)$$

m_{ar} - the number of the packets which arrived during the time of work;

m_{LS} - the number of lost packets during the time of work.

Let’s the object worked the time $\theta \cdot \mathrm{T}$, where θ - the number of addressing MUX to the set of BMD, T - the time interval between two neighbouring address MUX to the set of BMD.

The number of the packets which left the BMD during the time $\theta \cdot \mathrm{T}$:

$$m_{out} = (1 - P_0) \cdot \theta \cdot R \qquad (9)$$

P_0 - the probability of the single action;

R - maximal number of the packets, which can leave the buffer at one address of the multiplexer.

The number of the packets which arrived in two BMD during time $\theta \cdot \mathrm{T}$:

$$m_{ar} = (\lambda^{(1)} + \lambda^{(2)}) \cdot \theta \cdot \mathrm{T} \tag{10}$$

$\lambda^{(1)}$ and $\lambda^{(2)}$ - the intensity of arriving the first and the second informational torrents.

So the number of lost packets is:

$$m_{LS} = (\lambda^{(1)} + \lambda^{(2)}) \cdot \theta \cdot \mathrm{T} - (1 - P_0) \cdot \theta \cdot R \tag{11}$$

The probability of losing the packets in system:

$$P_{LS} = \frac{(\lambda^{(1)} + \lambda^{(2)}) \cdot \theta \cdot \mathrm{T} - (1 - P_0) \cdot \theta \cdot R}{(\lambda^{(1)} + \lambda^{(2)}) \cdot \theta \cdot \mathrm{T}} \tag{12}$$

2. The probability of idling

The probability is presented by formula:

$$P_0 = \lim_{n_{ad} \to \infty} \frac{n_{em}}{n_{ad}} \tag{13}$$

n_{ad} - the number of addresses MUX to the set of BMD;

n_{em} - the number of addresses MUX to the set of BMD when they are empty.

3. The probability of conflict situation

This probability will be calculated as the sum of probabilities staying the system in the states with the equal indicators of the meters L3 of both BMD:

$$P_{CS} = \sum P_i \tag{14}$$

P_i - the probability staying the system in the conflict situation. The conflict situation appears when the indicators o both BMD are equal.

4. The average value of the length of the queue of packets in "i" BMD

The middle significance of the length of packets is [9, p.234]:

$$\mathrm{L}^{(i)} = \sum_{k=1}^{N} k \cdot \mathrm{P}_k^{(i)} \tag{15}$$

k - the possible number of the packets in the BMD;

N - the maximum length of the queue in BMD;
$P_k^{(i)}$ - the probability if the queue of the "i" BMD has k packets.

5. The average value of the time of delay of one packet in the "i" BMD

The middle significance of the time of delay is [9, p.247]:

$$\overline{t^{(i)}} = \frac{L^{(i)}}{\lambda^{(i)}} \tag{16}$$

$\lambda^{(i)}$ - the intensity of arriving the packets of "i" torrent in "i" BMD;
i - the number of BMD.

Using formula (9) and (8) we shall get the formula for calculating the average value of the time of delay of one packet in the first and second BMD:

$$\overline{t^{(i)}} = \frac{\sum_{k=1}^{N} k \cdot P_k^{(i)}}{\lambda^{(i)}} \tag{17}$$

13 The example of using the program model

The program model gives the possibilities to do different investigations, for example, to find the conditions, when the average value of the time of delay for all information torrents, which arrive to the commutating knot, doesn't exceed some size.

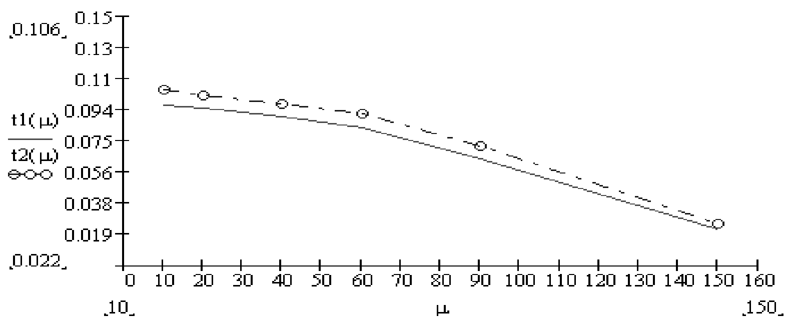

Fig. 1. The dependence between the middle significance of the time of delay of the packets in BMD and the intensity of address MUX to BMD.

t1(μ) - *the middle significance of time of delay of the packets in first BMD;*

t1(μ) – *the middle significance of time of delay of the packets in second BMD;*

μ *–the intensity of address MUX to the set of BMD*).

Let's suppose there is a necessity to find the intensity of address MUX to BMD, but the maximum time of delay of the packets in BMD must be no more than 0.07 under the condition, that the maximum length of queue is 6 packets, maximum number of the conditional applications is 6, the intensity of arriving the first information torrent is 60, the second one – 55, the number of the packets, which can leave the BMD during one address of MUX to BMD, is 1. Using program model the dependence between the intensity of address MUX to BMD was got (fig. 1).

So the minimal significance of the intensity of address MUX is 94.

14 Summary

Here is presented the procedure of adaptive service with different laws of forming of conditional and real applications, which pays attention to the state of the queue of packets in BMD.

Practical demands of delivery of packets in telecommunication networks are reflected in different laws of forming of conditional and real applications.

Program model of the procedure of adaptive service provide finding the parameters of laws of forming of conditional and real applications, which were described before.

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