A Queue Management Model On Router of Active Network

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Abstract – **The approach to simulation of queue management processes on nodes of an active network is proposed. The model is presented by a triplanar transportation problem of linear programming. The area of the model application is Next Generation Networks that function on the basis of active technologies.**

Keywords – **Queue, Management, Model, Active Network, Flow.**

I. INTRODUCTION

Realization of the concept for multiservice communication networks of next generation or Next Generation Networks (NGN) is indissolubly related to improvement of facilities of Quality of Service (QoS). Such facilities realized on a router include queue management mechanisms (queuing service) that in many ways determine the order and effectiveness of buffer and channel resource of telecommunication network (TCN) as well as its performance as a whole. Queue management is understood as agreed solution of the following tasks:

• determining amount and types of queues on a router;

• allocation (static or dynamic) of outgoing transmission path bandwidth to each queue;

• active queue managment;

• packets sheduling.

An overview of the common queue management algorithms that include first of all queue service algorithms CQ, CBQ, PQ, FQ and their various modifications (WFQ, CBWFQ, HWFQ, LLQ etc.), queue bounding algorithms RED (Random Early Detection) and WRED (Weighted RED), allowed to find a range of their disadvantages among which there are the following:

• realization of passive packet processing, resulting to their simple forwarding from the input port of a router to the output port;

• implementation of mostly non-adaptive management schemes when for each queue a strictly defined channel capacity is allocated, it is a value that does not depend on TCN state change;

• usage of packets statistic priorities that provide the order of packet service on routers.

Improvement of quality of service parameters is indissolubly related to advancing the queue management mechanisms on the basis of correction (minimization) of the above-mentioned drawbacks.

II. FEATURES OF PACKET PROCESSING ON ROUTERS OF ACTIVE NETWORK

The main disadvantages of the existing queue management facilities are conditioned by the fact that in the basis of most of existing and newly designed TCN lies the «Stupid network» paradigm that implies «shifting» most of «smart» functions of the network on its perimeter, i.e. on its label edge routers. Similar situation can be demonstrated by the technology of MultiProtocol Label Switching (MPLS), within which functions of LERs (Label Edge Routers) foremost include classification, labeling and assignment of priorities to packets of any flow, routing from a source with accounting of tables and label switch paths (LSPs) etc. Functions of label switch routers (LSRs) include only the problems of packet driving along paths preliminary calculated on label switch paths (LSPs) on the basis of analysis of label switch tables while the content of transmitted data is usually ignored.

The technology of Active Networks (AN) is called to give more flexibility and adaptivity to processes of network resource management in TCN [1], in the frame of which network «intelligence» is uniformly distributed on all routers – active routers. Functions of label switch routers in their turn extend greatly due to their ability to solve such important network problems as adaptive priority change, fragmentation (defragmentation), compression and routing of packets. The main element of a router that supports AN technology is an active processor (AP), functions of which additionally include analysis of Active Processing Control Information (APCI) in the header of each packet, containing a function identifier and descriptor.

The identifier defines a called processing function and the descriptor points out parameters of the active router state that should be used in the processing. Thus the functions of the active router include first of all determination of the output port; second of all in that case when there is control information a packet is forwarded to the active processor; third of all in accordance with the content of ACPI the processing function is called with the parameters corresponding to the current state of the network; and fourth of all a packet with updated header is transmitted to the next router. Examples of functions performed on active routers of the network are packet buffering, management of output ports bandwidth in accordance with channel loading, additional compression of traffic before its transmission across overloaded network portion, etc.

A specific feature of the active router is implementation of multiprocessor architecture due to the high requirements to packet processing rate which can reach up to dozen terabits per second. Modern high-performance routers usually are gigabit with scalability up to terabit range. Nowadays terabit rates are provided by Avici TSR-40 router – 5.6 Tbit/s. A single Pluris TeraPlex 20 router chassis gives 150 Gbit/s bandwidth with scaling to total value of 1.44 Tbit/s, and Pluris 2000 is scaled to 149 Gbit/s in case of one device and to 19.2 Tbit/s when several devices are combined. Alcatel Routing Core Platform 7770 supports rate to 640 Gbit/s per chassis and eight chassis can be united into a single logical device; as a result total performance will be 20 Tbit/s. Procket Model 8812 achieves, as developers affirm, performance of 960 Gbit/s and according to preliminary assessment, 1.2 billion packets per second. This is achieved due to implementation of Application-Specific Integrated Circuits (ASIC) as well as Very Large-Scale Integration (VLSI), which are fully programmed network processors. Due to the implementation of special ASIC circuits the router is able to process millions of new flows at each line card.

Therefore queue service mechanisms should take into account listed technological features specific to the structure and functions of the active network what means review of management models themselves in the direction of improving the degree of their adaptation to various changes in flow characteristics and requirements to quality of service.

III. QUEUE MANAGEMENT MODEL ON ROUTERS OF ACTIVE NETWORK

In order to give an adequate description of the process of packet servicing on the routers of an active network let us suppose that a multiservice network supports M flow classes distinguished by the type of assigned priority. For example in case of IP Precedence usage when assigning priorities labeling to eight classes of traffic ($M = 8$) is supported. When using Differentiated Services Code Point (DSCP), which is an extension of 3-bit IP Precedence field, we use 6 bit of Type of Service (ToS) bite from IPv4 packet header or Traffic Class bite of packet in IPv6. In the last case the amount of traffic classes is equal to 64 ($M = 64$).

A specific feature of modern queue management mechanisms is fixity of the number of serviced queues N, that in general case does not exceed the amount of classes supported by the flow network. For instance for Custom Queuing (CQ) the number of queues is equal to 16 (plus zero or system queue), and in Priority Queuing (PQ) algorithm a system administrator can allocate up to four queues for network traffic of high, medium, normal and low priority ($N = 4$).

Because of the fact that while solving tasks for QoS proving it is necessary to operate with the flow intensity; the proposed model must be flow-based. That is why we will denote with a_i ($i = \overline{1, M}$) the intensity of a flow of the i th class that goes into service of the router. Moreover, let b_j ($j = \overline{1, N}$) be a part of bandwidth of the outgoing

transmission path which is allocated to the j th queue of queues ($j = \overline{1, N}$), what is typical e.g. for CBWFQ algorithms. Besides the following term should be fulfilled

$$\sum_{j=1}^{N} b_j \leq b, \qquad (1)$$

where b is bandwidth of outgoing transmission path.

Assume that the basis of the router architecture form K parallel functional active processes, then by c_k ($k = \overline{1, K}$) we denote nominal performance of k th AP. In order to prevent overload of a router and network as a whole the following terms must be fulfilled

$$\sum_{i=1}^{M} a_i \leq \sum_{j=1}^{N} b_j \qquad (2)$$

and

$$\sum_{j=1}^{N} b_j \leq \sum_{k=1}^{K} c_k, \quad \sum_{i=1}^{M} a_i \leq \sum_{k=1}^{K} c_k. \qquad (3)$$

The fulfillment of the terms (2) is provided foremost due to the effective routing of traffic in the network, in opposite case – using active queue management (RED, WRED). Requirements of terms (3) must be satisfied at the stage of network design when choosing performance of routers.

If in known algorithms the order of packet distribution of any flow in the queue of a router is as a rule strictly fixed, then giving the dynamic nature to this process is possible due to introduction of the variable x_{ijk}, which implied a portion of the i th flow that will be directed to serve j th queue via the k th active processor. According to the physical meaning of the variable x_{ijk} the following additional terms take place [2, 3]:

$$x_{ijk} \geq 0 \quad (i = \overline{1, M}, \; j = \overline{1, N}, \; k = \overline{1, K}), \quad (4)$$

$$\sum_{j=1}^{N} \sum_{k=1}^{K} x_{ijk} = a_i \quad (i = \overline{1, M}), \qquad (5)$$

$$\sum_{i=1}^{M} \sum_{k=1}^{K} x_{ijk} \leq b_j \quad \text{and} \quad \sum_{i=1}^{M} \sum_{j=1}^{N} x_{ijk} \leq c_k. \quad (6)$$

Fulfillment of the term (5) guaranties servicing all the packets of traffic coming on the concerned router. The terms (6) are introduced to prevent overloading queues and active processes of the router during management respectively. Due to fact that in the general case selection of x_{ijk} within limitations (4)-(6) can be made by many cases, then it is reasonable to form the task connected with calculation of desired variable as an optimization task with the following (further – minimizing) target function:

$$T(x) = \sum_{i=1}^{M} \sum_{j=1}^{N} \sum_{k=1}^{K} f_{ijk} x_{ijk}, \qquad (7)$$

where weighted coefficients f_{ijk} ($i = \overline{1, M}$, $j = \overline{1, N}$, $k = \overline{1, K}$) characterize relative cost of utilizing the j th queue and the k th AP resources by packets of i th flow. Due

to suitable selection of numerical values of coefficients f_{ijk} it is possible to achieve various types of queues – custom, priority, fair, etc. – within the proposed model.

The proposed mathematical model of queue management (1)-(7) is presented as multi-index problem of linear programming, namely in the form of triplanar transportation task; to solve this problem there are known precise and approximate methods, for instance, method of potentials and method of minimal element at section.

Dimension of the formulated optimization problem which numerically aligns with the number of values x_{ijk}, in case of uniformity of computing system built on the basis of identical active processor is $S = M \cdot N \cdot K$ and for node architecture is equal to 24. In case of considerable differences of requirements to quality of service put into APCI packets of different classes, active processors can be not uniform according to the functions of packet processing. This in its turn will reflect on the structure of connections in the model (Fig.1) and as a result will lead to reduction of problem dimension ($S = 10$).
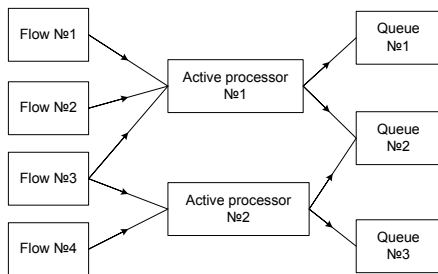

Fig. 1. Examples of queue management architecture on the active router

IV. EXAMPLE OF SOLUTION FOR QUEUE MANAGEMENT TASK ON ROUTER

For visual interpretation of the proposed model capabilities we will show the solution of queue management task with the following initial data:
- amount of traffic classes supported by network (flows) – 4;
- amount of active processors on the router– 2;
- a number of allocated queues on the router– 3.

Numerical characteristic of the model parameters (packets per second, 1/s), aligning with the terms (2)-(3), given in the Table 1.

TABLE 1

INITIAL DATA FOR CALCULATION

Model parameter	Characteristics of model parameter			
Flow rate	1	2	3	4
	$30 \cdot 10^6$ 1/s	$20 \cdot 10^6$ 1/s	$25 \cdot 10^6$ 1/s	$15 \cdot 10^6$ 1/s
Performance of active processor	1		2	
	$55 \cdot 10^6$ 1/s		$40 \cdot 10^6$ 1/s	
Bandwidth of queue	1		2	3
	$35 \ 10^6$ 1/s		$45 \ 10^6$ 1/s	$20 \ 10^6$ 1/s

The result of solution for the initial data (Table 1) is shown on the Fig. 2. During problem solving it was possible to provide fulfillment of the terms (4)-(6), and thus to prevent overload of active processors and queues and packet loss of flows.
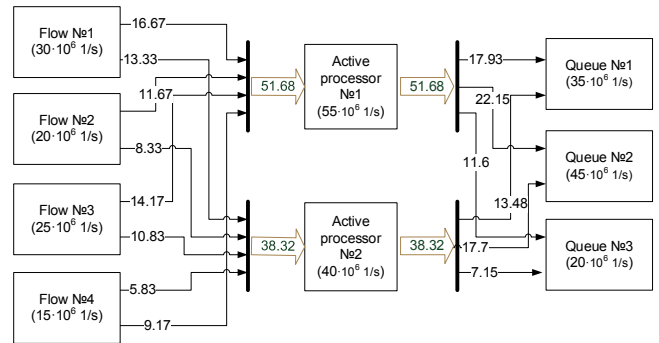

Fig. 2. Calculation results

V. CONCLUSION

Thus the given work proposes the mathematical queue management model on the basis of which the task of packet distribution into queues is presented as an optimization problem related to the class of triplanar transportation problems of linear programming. In the frame of the developed model unlike previously known solutions the account of traffic characteristics, performance of routers active processors and queue bandwidth is provided and this allows to give adaptive nature to the process of coming packets distribution into queues of the router. The main application area of the proposed queue management model is routers of multiservice new generation networks, functioning on the basis of active technologies.

Development of the proposed approach is seen in use of nonlinear management models that take into account the explicit restrictions on quality of service; in giving the dynamic nature to the process of allocation of the bandwidth for outgoing transmission path to queues as well as in providing agreed solution for queue management problems and active queue management.

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