Design of Dynamic Routing Scheme in Telecommunication Networks

Ahmad M. Hailan [1], Tariki Nadia[2], T.V. Vavenko [2]

1. Collage of Computer Science and Mathematics, Thi-Qar University, IRAQ, Nasiriya, E-mail: onlineahmeds@mail.ru

2. TCS Department, Kharkov National University of Radioelectronics, UKRAINE, Kharkov, Lenina ave,14. E-mail: tv_vavenko@mail.ru

Abstract – **In this paper the dynamic routing model of TCN is proposed. The novelty is that it is presented as a system of linear differential equations to describe the process of redistribution capacities of links and nonlinear algebraic equations to describe the routing of flows and congestion control. Using this model gives the opportunity to provide more efficient management of TCN resources when multiservice traffic is serviced.**

Keywords - **Dynamic routing, Quality of Service, Flow, Multiservice traffic, Prediction period.**

I. INTRODUCTION

Nowadays telecommunication networks (TCN) operate in accordance with the paradigm of NGN (Next Generation Network) and Quality of Service (QoS) [1]. The effectiveness of the TCN is determined by the quality of solving management problems. The basic requirement to modern TCN is the ability to guarantee good performance: to satisfy the QoS-requirements of client flows (speed, average delay, packet loss or jitter etc.) in accordance with the content of the Service Level Agreement (SLA). Today there are many variants of management of TCN with different degrees of effectiveness, and lot of them are used in practice. And the most popular methods are based on technology IP / MPLS.

Thus in this paper the object of research is the process of providing high performance in TCN. It can be realized only by optimizing management process of topological, link, buffer and network resources. Unfortunately these questions did not resolved still. So performance of TCN always demands to be better, especially in conditions of different characteristics and QoS-requirements of client flows [2].

The state of IP/MPLS-network can changes rapidly, so the state of the network is highly dynamic. So the mathematical models (MM) which describe the processes of management of resources in such networks also should be dynamic. Therefore MM which were proposed in [3], [4] and were represented by difference equations of state, in this article will be adapted to the new objectives of the research.

II. STRUCTURAL DESCRIPTION OF TELECOMMUNICATION NETWORK

Let a structure of TCN is described by a graph

$$G = (R, L),$$

where $R = \{R_i, i = \overline{1,m}\}$ – a set of routers of TCN, $L = \{L_{i,j}, i,j = \overline{1,m}, i \neq j\}$ – a set of links of TCN.

Then the cardinality of the set $|R| = m$ is the total number of routers, and $|L| = n$ is the total number of links. The entire set of routers (devices) can be divided into two subsets: $R^{ed} = \{R_i^{ed}, i = \overline{1,m_{ed}}\}$ – a subset of the edge devices (routers) of the network; $R^{tr} = \{R_j^{tr}, j = \overline{1,m_{tr}}\}$ – a subset of the transit devices (routers) of the network.

Each arc of graph $L_{i,j} \in L$, which simulates a corresponding link of TCN, has its bandwidth $c_{i,j}$. Let the total number of flows classes, which circulate in TCN, is equal m_c. The number of flows in a certain class is equal l. Flows is divided into classes according to the priorities of traffic, source / destination addresses or QoS-requirements.

For MM of dynamic routing we assume following points: $\Delta t = t_{k+1} - t_k$ – time of the recalculation of control variables which are related to servicing of a certain type of traffic, t_k and t_{k+1} – times of a start and end of k-th time slot; K – number of time slots during which we optimize the operation of TCN; $c_{i,j}^g(k)$ – capacity of the link which is represented by arc $L_{i,j} \in L$ and serves packets of g-th class on k-th time slot (bps); $u_{i,j}^g(k)$ – part of bandwidth $c_{i,j}$ of link, which is represented by arc $L_{i,j} \in L$, which is used with "plus" sign, if it used to increase capacity $c_{i,j}^g(k)$ of g-th class, or with "minus" sign, if it used to increase capacity of other class of traffic on k-th time slots.

Then the dynamics of the state in the distribution of resources of TCN can be described by the following system of linear differential equations:

$$c_{i,j}^g(k+1) = c_{i,j}^g(k) + u_{i,j}^g(k) c_{i,j}. \tag{1}$$

In the equations (1) values $c_{i,j}^g(k)$ are interpreted as state variables of TCN links, and variables $u_{i,j}^g(k)$ used as control values which describe the process of redistribution bandwidth of links between different classes of flows.

State variables based on their physical interpretations have the following conditions:

$$0 \le c_{i,j}^{g}(k),\ (g = \overline{1, m_c}),\qquad (2)$$

$$\sum_{g=1}^{m_c} c_{i,j}^{g}(k) \le c_{i,j}\,.\qquad (3)$$

Condition (3) guarantees that during the resource allocation process of TCN links bandwidth are not overloaded.

According to the physical interpretation of variables $u_{i,j}^{g}(k)$ in general case they have the following conditions:

$$-1 \le u_{i,j}^{g}(k) \le 1\,.\qquad (4)$$

Additional control variable which is used to solve routing problems is the value of $x_{i,j}^{(l,g)}$, which characterizes the l-th fraction of g-th class of flow in link $L_{i,j}^{g}$. According to the physical interpretation of solving routing problem values $x_{i,j}^{(l,g)}$ have the following conditions:

$$0 \le x_{i,j}^{(l,g)}(k) \le 1\,,\qquad (5)$$

the implementation of which allows to realize the multipath load balancing routing, and in terms of MPLS-network such decisions corresponds to the concept of Traffic Engineering .

To prevent congestion in links is used conditions:

$$\sum_{l} r^{(l,g)} x_{i,j}^{(l,g)}(k) \le c_{i,j}^{g}(k)\,,\ (g = \overline{1, m_c}).\qquad (6)$$

To control the level of packet loss on routers caused by overfilling queues at their interfaces it used following conditions:

$$\sum_{j:(i,j)} x_{i,j}^{(l,g)}(k) = 1\,;\qquad (7)$$

$$\sum_{j:(i,j)} x_{i,j}^{(l,g)}(k) - \sum_{j:(j,i)} x_{j,i}^{(l,g)}(k)(1 - p_{j,i}^{(l,g)}(k)) = 0\,;\qquad (8)$$

$$\sum_{j:(i,j)} x_{j,i}^{(l,g)}(k)(1 - p_{j,i}^{(l,g)}(k)) = \varepsilon^{(l,g)}(k)\,,\qquad (9)$$

where $p_{i,j}^{(l,g)}$ – the probability of packet loss of l-th flow of g-th class on j-th interface of i-th router caused by overfilling queues; $\varepsilon^{(l,g)}$ – fraction of intensity if l-th flow of g-th class which served in TCN.

Conditions (7) should be valid for the edge router which is connected to a network of packet sender, conditions (8) – for all transit routers, conditions (9) – for the edge router which is connected to a network of packet receiver.

For example the servicing of packages is simulated by queuing system $M/M/1/N$, the probability of packet loss at the interfaces of routers (indexes in the formulas omitted for convenience) can be calculated by

$$p = \frac{(1-\rho)(\rho)^N}{1-(\rho)^{N+1}}\,,\qquad (10)$$

where ρ – coefficient of link utilization; $N = \Theta_{buf} + 1$ – the maximum number of packets which can be on the interface, including buffer (Θ_{buf}) and link. Probability of packet loss we can calculate by other formulas, which are determined depending on the by queuing system.

It's necessary to calculate the routing variables $x_{i,j}^{(l,g)}$ in accordance with following condition: the probability of packet loss of l-th flow should be less than acceptable value $p_{acc}^{(l,g)}$:

$$1 - \varepsilon^{(l,g)} \le p_{acc}^{(l,g)}\,.\qquad (11)$$

The numerical values of the acceptable probability of packet loss for different flow type we can find in Recommendation ITU-T Y.1541 (as an example).

The criterion for the optimal solution of the dynamic routing problem is minimum of following function:

$$J = \sum_{k=1}^{K}\Bigg[\sum_{g=1}^{m_c}\sum_{l}\sum_{L_{i,j}\in L} f_{i,j}^{(l,g)}(k)x_{i,j}^{(l,g)}(k) + \sum_{g=1}^{m_c}\sum_{L_{i,j}\in L} v_{i,j}^{g}(k)c_{i,j}^{g}(k) + \sum_{g=1}^{m_c}\sum_{L_{i,j}\in L} \gamma_{i,j}^{g}(k)u_{i,j}^{g}(k)\Bigg],\qquad (12)$$

where $f_{i,j}^{(l,g)}(k)$ – routing metric of link which is represented by arc $L_{i,j}^{g}$ for l-th flow on k-th time slots; $v_{i,j}^{g}(k)$ – the relative cost of using the unit of link bandwidth which is represented by arc $L_{i,j}^{g}$ on k-th time slots; $\gamma_{i,j}^{g}(k)$ – the cost of the redistribution process of link bandwidth between different type of flows in TCN on k-th time.

Using the criterion (12) allows to minimize the total cost of routing problem at a prediction interval. Implementation the properties of predicting the state in the management of TCN ($K > 1$) allows do network more flexibility in redistribute of resources between flows of different classes.

III. Analysis of the Proposed Solutions of Dynamic Routing Problem

In order to study the influence of the value of the prediction interval on the efficiency of dynamic routing in TCN we used the following index:

$$P_b = \frac{P(K) - P(1)}{P(1)}100\%\,,\qquad (13)$$

which is based on using the expression

$$P = \sum_{k=1}^{K_f}\sum_{g=1}^{m_c}\sum_{l} r^{(l,g)}(k)\varepsilon^{(l,g)}(k)\qquad (14)$$

and described the gain as a percentage of the performance of service flows of different classes depending on $K > 1$ compared to the solution which was received without prediction of the state of the network ($K = 1$).

Expression (14) was used for evaluation effectiveness of the solutions, which were received through the provision of bandwidth for flows of different classes, and characterized the maximum performance of TCN, where K_f - the number of time slots $\Delta t = t_{k+1} - t_k$ during which we modulate operation of TCN.

We notice, that efficiency of dynamic routing largely depends on the quality of the prediction (accuracy) of traffic parameters (Δr), namely the rate of flow r. For the numerical calculation of prediction the rate of flow we use expression

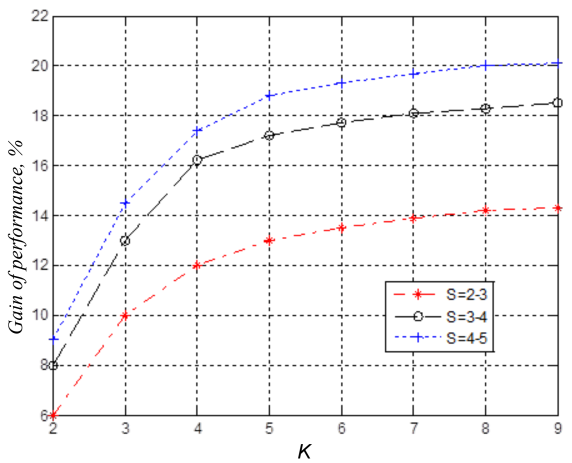
$$\Delta r(k+s) = \left[1 - \frac{\left|r^{true}(k+s) - r^{pr}(k+s)\right|}{r^{true}(k+s)}\right] 100\%, s = \overline{1, K-1}, \quad (15)$$

where $r^{true}(k+s)$ – the true value of flow rate at the time slot $k+s$; $r^{pr}(k+s)$ – the predicted value of flow rate, which will be at the time slot $k+s$, and prediction is performed at the time t_k.

During research we use following input data:

- prediction period (K) was varied from 2 to 9;
- the number of routers in the TCN ranged from 20 to 30;
- coherence (S) of nodes of TCN was varied from 2 to 5;
- accuracy of prediction the characteristics of flows (15) discretely varied from 50 to 100%.

The results of the comparative analysis the value P_b (13) have confirmed advantages of dynamic routing: performance of TCN increased by an average of 14-18 to 24-30%. The biggest gain of performance of TCN was shown with increasing network connectivity (*S*) and prediction accuracy of intensity of subscriber flows (15). The results of comparing shown in Fig. 1.



Δr =75%

Fig. 1 The results of comparing by value (13)

As can we see the results of the research (Fig. 1) it is preferable to restriction the prediction period by values $K = 4 \div 5$, because increasing the value K resulting to a proportional increasing of the dimension of the mathematical model, but at the same time increasing of productivity of TCN didn't become much more (2-3%).

IV. Conclusion

It is established that the limiting factor in increasing productivity of TCN and achieving the require QoS parameters is inefficient distribution resource of TCS (topological, link and buffer) between flows of different classes. This paper shows that the solution of this problem is related to the using of a dynamic routing models.

In this paper the dynamic routing model of TCN (1) - (12) is proposed. The novelty of this model is that it is presented as a system of linear differential equations to describe the process of redistribution capacities of links between flows of different classes and nonlinear algebraic equations to describe the routing of flows and congestion control. Using this model gives the opportunity to provide more efficient management of TCN resources when multiservice traffic is serviced. This result is achieved by taking into account dynamics of the processes of information exchange in TCN.

In this model the dynamic routing problem is formulated as an optimization. So in this paper shown why it is necessary to use criterion of optimality (12), by executing of it allows to minimize the total cost of routing of client flows with supporting guaranteed and (or) differentiated QoS at a proactive time slot, which can be interpreted as a prediction interval. Implementation of properties of predicting the state when we management TCN allows to have more flexibility to redistribute network resources between flows of different classes. It is preferable to restriction the prediction period by values $K = 4 \div 5$, because increasing the value K resulting to a proportional increasing of the dimension of the mathematical model, but at the same time increasing of productivity of TCN didn't become much more.

References

[1] S. Jelassi, G. Rubino, H. Melvin, H. Youssef, and G. Pujolle, "Quality of experience of VoIP service: A survey of assessment approaches and open issues," Communications Surveys & Tutorials, IEEE, vol. 14, no. 2, pp. 491–513, 2012.

[2] A.V. Lemeshko, O.Yu. Evseeva, S.V. Garkusha, "Research on Tensor Model of Multipath Routing in Telecommunication Network with Support of Service Quality by Greate Number of Indices," Telecommunications and RadioEngineering, vol.73, no 15, pp.1339-1360.

[3] O. Lemeshko, V. Sterin, "Design and structural-functional optimization transport telecommunication network," in *XIIth International Conference "The experience of designing and application of cad systems in microelectronics"*, Lviv Polytechnic, Ukraine, pp. 208-210, Feb. 2013.

[4] O.V. Lemeshko, V.L. Sterin, "Structural and functional optimization of transport telecommunication network," in *23rd International Crimean Conference "Microwave and Telecommunication Technology (CriMiCo)"*, Ukraine, pp. 490 – 491, Sept. 2013.