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INVESTIGATION OF QUALITY CHARACTERISTICS OF NETWORKS MPLS-TE / FRR with additional DIRECTIONS TRAFFIC TRANSMISSION

The use nodal tensor method for solution of research quality characteristics of routing in MPLS-TE / FRR network with additional directions of traffic transmission lines . The quality parameters of the network and made direction additional transmission traffic criterion of minimum time delivery of packages to ensure balanced load and failover network.

A characteristic feature of modern telecommunication networks is the implementation of conceptually new transport network based on MultiProtocol Label Switching (MPLS), which allows for the transmission of packet traffic with support of the quality of service QoS (Quality of Service). The network uses MPLS traffic engineering TE (Traffic Engineering), which allows for efficient use of resources. Functioning network MPLS-TE is based on the use of transmission routes traffic through unidirectional tunnels TE-tunnel, bringing together the sequence of routers LSR (Label Switch Router), selected with regard to maximum utilization of network resources and performance requirements of QoS. For fault-tolerant routing in MPLS-TE network using fast peremarshrutyzatsiya packages Fast ReRoute (FRR), that is in default route can direct traffic to alternate pre zkonfihuryrovanomu TE-tunnel, chosen by the criterion of minimal packet delay [1]. Characterization QoS in MPLS-TE network focused on the choice of route of traffic load conditions, management of network resources. One of the solutions, which allows for important characteristics of QoS is to organize additional (bypass) directions of traffic routing. During the operation, of the network is often need to unloading certain routes, which too loaded. Then perhaps use additional, pre-configured route in order to maintain the required level of quality of service QoS.

The goal of this work is to solve the problem of determining the quality characteristics QoS of routing in MPLS-TE by means of additional directions of traffic routing.

Consider the solution in MPLS-TE network using nodal tensor method, provided between nodes except the main routes, there are additional routes of trafic transmission According to [2-4], a fragment of MPLS-TE network (Fig. 1) defines as multigraph G (N, V), where $N = \{N_j\}, j = \overline{1,5}$ - the set of nodes, which are nodes of the network - routers LSR, and $V = \{v_i\}, i = \overline{1,13}$ - the set of arcs provided tracts of network eight of which $(v_1 - v_8)$ are major and five $(v_9 - v_{13})$ additional. We believe that the traffic runs in direction of the router LSR-1 to router LSR-3.

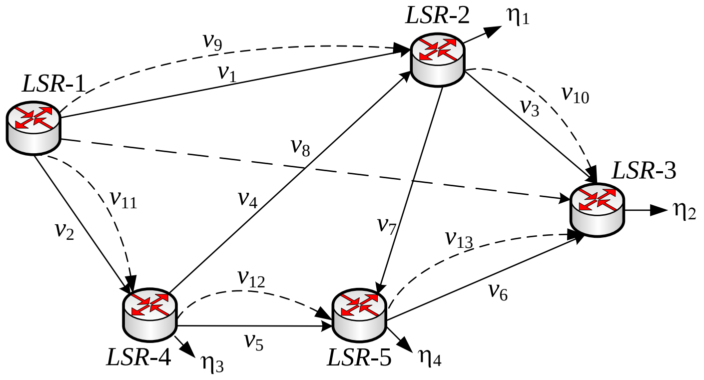

Figure 1 - Fragment of MPLS-TE network with additional traffic transmission lines

Find the time delay packets in tract T_v and on routers LSR T_η MPLS-TE network, when between network nodes (routers LSR) are as basic and additional routes of trafic transmission TE-tunnel traffic using nodal tensor method proposed in the works [2-4].

Consider known:

– basic matrix B_η structure under the considered network (Fig1).

$$B_\eta = \begin{pmatrix} 1 & 0 & -1 & 1 & 0 & 0 & -1 & 0 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & -1 & 1 & 0 & 0 & 0 & 0 & 1 & -1 \\ 0 & 1 & 0 & -1 & -1 & 0 & 0 & 0 & 0 & 0 & 1 & -1 & 0 \end{pmatrix}. \quad (1)$$

– Traffic intensity value L_v (pac / s) of tracts that are specified in the table. 1. L_v

Table 1 - Average intensity of traffic in the tracts of network

Number of tract	1	2	3	4	5	6	7	8	9	10	11	12	13
Traffic intensity L_v, (pac / s)	100	350	220	150	400	300	120	0	175	300	500	650	100

– The length of outgoing packet queues H_v^+:

$$H_v^+ = \left(0 \;\; 0 \;\; 0 \;\; 0 \;\; 0 \;\; 0 \;\; 100 \;\; 0 \;\; 0 \;\; 0 \;\; 0 \;\; 0 \right)^t. \quad (2)$$

To find the value of time delays packets in tract and routers of LSR T_η of MPLS-TE network, using the Little's Law, which according to [2-4] in the tensor representation is:

$$h_i = l^{i\alpha} \tau_{i\alpha}, \;\; i = \overline{1,n}, \quad (3)$$

Where h_i – the average length of packet queues in the i-tieth tracts , l^i – average traffic intensity i-tieth tracts, τ_i – the average latency of packets in the i- tieth tractы, n – number of paths, α – index summarizing.

Write the equation (3) according to [2-4] in the coordinate system (CS) branch and node pairs:

$$H_v = L_v \, T_v, \;\; H_\eta = L_\eta \, T_\eta, \quad (4)$$

Where H_v, H_η – covariant tensors average length of packet queues CS in branch and node pairs respectively, T_v, T_η – covariant tensors of average packet delay in CS branch and node pairs, respectively, and L_η - kontravariantnyy tensor medium-intensity traffic CS node pairs network.

Tensor delay packets on T_η routers LSR determined by the formula (4) as:

$$T_\eta = \left(L_\eta \right)^{-1} H_\eta. \quad (5)$$

The transformation projections when changing tensor CS performed according to [2-4]:

$$T_v = B_\eta^t \, T_\eta, \; H_\eta = B_\eta \, H_v^+, \; L_\eta = B_\eta \, L_v \, B_\eta^t, \quad (6)$$

Where B_η - basic matrix of nodal pairs, H_v^+ - tensor outgoing packet queues in the CS branch network.

Similarly [2-4], we define routers LSR tracts of network congestion in the transmission outgoing packet queues H_η in CS nodes pairs network. According to (6) and given by (1) the basic matrix B_η and expression (2) tensor average length of packet queues get:

$$H_\eta = \left(100 \;\; 0 \;\; 0 \right)^t. \quad (7)$$

Find the tensor intensity traffic L_η, components which determine average traffic intensity of each router LSR network (6) and the average intensity of traffic L_v in the tracts from the table. 1 and basic matrix B_η (1) we get:

$$L_\eta \approx \begin{pmatrix} 1065 & -520 & -120 & -150 \\ -520 & 920 & -400 & 0 \\ -120 & -400 & 1570 & -1050 \\ -150 & 0 & -1050 & 2050 \end{pmatrix}. \qquad (8)$$

Using the expression (5), (7) and (8), we find the value of the average delay time of packets at each router LSR doing the calculation in CS node pairs:

$$T_\eta \approx 10^{-3} \begin{pmatrix} 1{,}812 & 1{,}412 & 0{,}893 & 0{,}590 \\ 1{,}412 & 2{,}408 & 1{,}202 & 0{,}719 \\ 0{,}893 & 1{,}203 & 1{,}605 & 0{,}887 \\ 0{,}590 & 0{,}719 & 0{,}887 & 0{,}985 \end{pmatrix} \begin{pmatrix} 0 \\ 100 \\ 0 \\ 0 \end{pmatrix} \approx \begin{pmatrix} 0{,}141 \\ 0{,}241 \\ 0{,}120 \\ 0{,}072 \end{pmatrix}. \qquad (9)$$

Find the time delay for each packet of tract network by expression (1), (6) and (9) by completing the calculation of projections tensor T_v in CS branch network. The calculation results are summarized in Table. 2.

Table 2 - Average length of the delay packet in network tracts

Number of tract	1	2	3	4	5	6	7	8	9	10	11	12	13
The delay packets T_v, s	0,141	0,072	0,099	0,069	0,048	0,121	-0,021	0,240	0,141	0,099	0,072	0,048	0,121

Considering that the value of delay package is additive along appropriate route [2-4], we find the delay packet in MPLS-TE network, in tunnels TE-thunnel given to all routes of transmission traffic, both core and additional. Then in the tunnel TE-thunnel in the direction of router LSR-1 to router LSR-3, which has zero congestion, delay packet is τ_{v8} 0,240s with. According to the main route of transmission of traffic on MPLS-TE network tunnels TE-thunnel delay is: LSR-1→LSR-2→LSR-3 $\tau_{v1-v3}\approx$ 0,240 c; LSR-1→ LSR-4→ LSR-5→ LSR-3 $\tau_{v2-v5-v6}\approx$ 0,240 s; LSR-1→LSR-4→LSR-2→LSR-5→LSR-3 $\tau_{v2-v4-v7-v6}\approx$ 0,240 s; LSR-1→LSR-4→LSR-5→LSR-2→LSR-3 $\tau_{v2-v5-v7-v3}\approx$ 0,240 s; LSR-1→LSR-2→LSR-4→LSR-5→LSR-3 $\tau_{v1-v4-v5-v6}\approx$ 0,240 s; LSR-1→LSR-2→LSR-5→LSR-3 $\tau_{v1-v7-v6}\approx$ 0,240 s. For given additional routes of transmission traffic network MPLS-TE in tunnels TE-thunnel delay packet is: LSR-1→LSR-2→LSR-3 $\tau_{v9-v10}\approx$ 0,240 s, LSR-1→LSR-4→LSR-5→LSR-3 $\tau_{v11-v12-v13}\approx$ 0,198, $N_1 \to N_2 \to N_5 \to N_6$ $\tau_{v11-v12-v14}\approx$ 0,240 s. So, the value of time delay packets in tract MPLS-TE network in tunnels TE-thunnel for different traffic routes of transmission are the same and equal to 0.240 s. Note that the same value received packet delay package for certain tracks that are more directions transferring. For Example, $\tau_{v1} \approx \tau_{v9} \approx 0{,}141$ s, $\tau_{v3} \approx \tau_{v10} \approx 0{,}099$ s, $\tau_{v2} \approx \tau_{v11} \approx 0{,}072$ s, $\tau_{v5} \approx \tau_{v12} \approx 0{,}048$ s, $\tau_{v6} \approx \tau_{v13} \approx 0{,}121$ s. This makes it possible to assert that the use of additional transmission lines for selected traffic transmission lines with different traffic congestion, can get the same value of delay package the primary and secondary transmission direction.

Conclusions

1. Consider the decision problem of determining quality characteristics of MPLS-TE network with additional transmission routes traffic through the node tensor method, which allowed us to obtain reduce delay packets along specified routes TE-thunnel transfer traffic:

– for network with additional routes of transmission received traffic delays equal value packages for different delivery routes traffic between given pairs of nodes, which is $\tau \approx$ 0,240 s.

2. When using nodal tensor method in solving the problem of routing to network with additional traffic transmission lines with different workload received the same values as packet delay for the main, and for additional transmission direction.

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