Design of Multipath routing Scheme with Load Balancing in MPLS-network

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Abstract – **In the paper the mathematical model of multipath routing with load balancing in the MPLS network is proposed. This model describes the processes of routing and distribution links resource. This model takes into account the characters of links (duplex, half-duplex or simplex links) and prevents the effect of packets looping. And criterion of load balancing in proposed model is quality service parameters.**

Keywords - **MPLS, routing, load balancing, Quality of Service, NGN, average delays.**

I. Introduction

Modernization of existing telecommunication systems and networks (TCN) should be based on effective approaches that are incorporated in Next Generation Network (NGN) concept. NGN concept was created as a general standard for service network architecture to provide a wide range of services with flexible management and user personalization. The main technology of NGN transport layer is IP/MPLS [1]. Despite a lot of suggested and implied mechanisms designed for guaranteed Quality of Service (QoS) in NGN this problem is still not solved reasonably [2]. The analysis of different ways to satisfy QoS requirements shows that the main problem is to solve efficiently the tasks of network layer described in Open Systems Interconnection (OSI) model. We mention that network layer tasks are performed with different routing algorithms [3].

II. Analysis of Protocol Solutions for Load Balancing

Routing algorithms and packet forwarding technologies are in dynamic evolutionary process and the trend is to provide multipath routing considering QoS requirements and dynamic resource allocation. Implementation of multipath approach in real networks ensures network load balancing (in meaning of link load congestion and router queue overflow avoidance) provided with rationally calculated traffic path. Load balancing philosophy helps to keep network element's load rate in equal and optimal scope, increases network utility and improve QoS characteristics. The main idea of load balancing and optimal resource allocation is described in Traffic Engineering (TE) drafts. The study of different load balancing mechanisms shows that more uniform load rate results in better QoS rate.

Load balancing mechanisms are included in the most common routing protocols as RIP, RIPv2, EIGRP, OSPF, IGRP and can be implied as beforehand calculated static routes and packet forwarding rules [3]. Load balancing can be applied both for equal and unequal cost paths. It can be specified as a static distribution given by a network administrator or dynamically calculated with corresponding routing protocol. Despite a great number of different load balancing technologies its improvement still remains a significant scientific and engineering problem.

It's well known that efficiency of routing protocols depends on underlying mathematical models. Modern traffic in communication networks can be categorized as a multimedia and flow-based that justifies application of flow models as a framework for routing protocols. Furthermore those routing models have to work properly not only with simplex links but also with duplex and half-duplex channels. While solving routing problem a loop path can come in sight, thus a loop avoidance algorithm is an important part of math model that is used. After studying load balancing mechanisms we have made a conclusion that the best way is to use as a criterion QoS metric (i.e. time-based or bandwidth-based characteristic) or reliability rate.

Thus, suggested mathematical model for routing and load balancing considering all mentioned requirements is described in the next Section.

III. Flow Model of Multipath Routing with Load Balancing Based on Quality of Service Parameters

Before we consider the mathematical formulation, we need to introduce some notation. Let digraph $G=(V,E)$ represent the physical network, where V is the set of nodes and E – is the set of links. For each link $(i,j)\in E$, let c_{ij} . be the capacity of the link. Let each K be the set of traffic demands between a pair of edge nodes. For each $k\in K$, let d_k, s_k, t_k be the bandwidth demand, the source node, and the destination node respectively. For each link $(i,j)\in E$ and for each demand $k\in K$, let x_{ij}^k represent the percentage of k -th bandwidth demand provided by link $(i,j)\in E$. All the variables are non-negative real numbers, and the x_{ij}^k variables are no more than 1:

$$0\le x_{ij}^k\le 1 . \qquad (1)$$

In the process of solving the routing problem we have to consider flow conservation constraints:

$$
\begin{cases}
\sum\limits_{j:(i,j)\in E} x_{ij}^k - \sum\limits_{j:(j,i)\in E} x_{ji}^k = 0,\ k\in K, i \neq s_k, t_k, \\
\sum\limits_{j:(i,j)\in E} x_{ij}^k - \sum\limits_{j:(j,i)\in E} x_{ji}^k = 1,\ k\in K, i = s_k, \\
\sum\limits_{j:(i,j)\in E} x_{ij}^k - \sum\limits_{j:(j,i)\in E} x_{ji}^k = -1,\ k\in K, i = t_k.
\end{cases} \quad (2)
$$

This system of equation (2) says that the traffic flowing into a node has to equal the traffic flowing out of the node for any node other than source node and the destination node for each demand. Besides that this system of equation says that the net flow out of the source node is 1, which is the total required bandwidth after scaled by d_k. Also in the process of solving the routing problem we have to consider the link capacity utilization constraint:

$$\sum_{k\in K} d_k x_{ij}^k \le c_{ij},\ (i,j)\in E, \quad (3)$$

$$\sum_{k\in K} d_k x_{ij}^k + \sum_{k\in K} d_k x_{ji}^k \le c_{ij},\ (i,j)\in E, \quad (4)$$

where inequality (3) designed for network with simplex and duplex links, and inequality (4) designed for network with half-duplex links.

To prevent the effect of packets looping in duplex and half-duplex links it is necessary to follow next conditions:

$$x_{ij}^k \cdot x_{ji}^k = 0,\ (i,j)\in E,\ k\in K. \quad (5)$$

Because the most critical quality of service parameter is average delay, this parameter was chose as the criterion for solving the problem of routing. For this purpose the model (1)-(5) should take into account the additional condition:

$$\vec{\tau}_K = 0, \quad (6)$$

where $\vec{\tau}_K$ is a vector of contour delays, the coordinates of which determine the amount of delay along each independent circuit of TCN. Values of the delays can be calculated with help of any queuing theory. The number of independent circuit is determined by following equation:

$$r = n - m + 1, \quad (7)$$

where n is the number of links and m is the number of nodes of TCN. In the process of solving the routing problem we minimize the linear objective function:

$$F = \sum_{ij} f_{ij} \cdot x_{ij}, \quad (8)$$

where f_{ij} are metrics of network links.

The problem of finding the set of best paths in the considered flow model (1)-(8) is reduced to a nonlinear programming problem with minimizing function (8) with constrains (1)-(7). The advantage of the model (1)-(8) is conformity with the concept of Traffic Engineering in the realization multipath routing.

IV. Study of Multipath Routing Model with Load Balancing Based on Quality of Service Parameters

Proposed model (1)-(8) was analyzed for different input data and structures of TCN. The research of model is confirmed by its efficiency and adequacy.

For our research for an example consider TCN, which presented in Fig.1. The network consists of 5 nodes and 7 links. Source-node is node 1, destination-node is node 5. Links have numerical values, which represent their bandwidth.

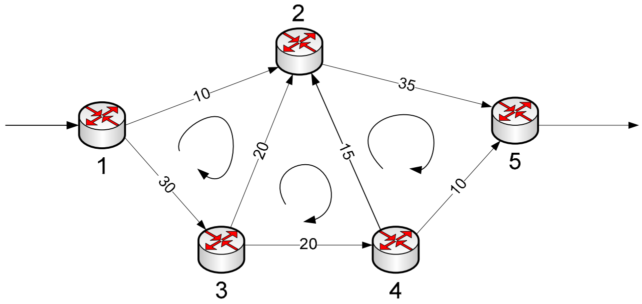

Fig. 1. An example of considered telecommunication network

Besides Fig.1 shows the independent circuit. The number of independent circuit is three.

Solutions of routing problem for considered TCN with using model (1)-(8) represent in Fig.2. Numerical values of links represent intensity in this link.

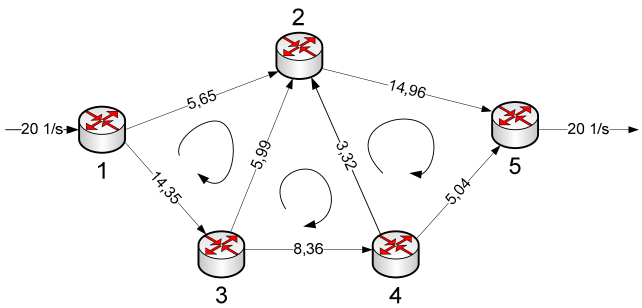

Fig. 2. Traffic ordering by solving the routing problem by the model (1)-(8)

Values of the delays we calculate with help of, for example, M/M/1 queue of queuing theory:

$$\tau_{ij} = \frac{1}{c_{ij} - x_{ij}}. \quad (9)$$

There are four paths between source-node and destination-node. We calculate delays along every paths:

1) Path 1: node1 – node 2 – node 5. $\tau^1 \approx 0{,}21$ sec;

2) Path 2: node 1 – node 3 – node 2 – node 5. $\tau^2 \approx 0{,}21$ sec;

3) Path 3: node 1 – node 3 – node 4 – node 2 – node 5. $\tau^3 \approx 0{,}21$ sec;

4) Path 4: node 1 – node 3 – node 4 – node 5. $\tau^4 \approx 0{,}21$ sec.

So delays along paths are equal to each other. Research for other values of inputting traffic to network gave the same result: delays along paths are equal to each other.

We compare proposed model (1)-(8) with flow model of multipath routing with load balancing, which was known early and suggested in [4]. This model is based in criteria of maximum link utilization. Solution of routing problem with help of proposed model (1)-(8) and well-known model, proposed in [4], are shown in Fig.3. Values of inputting traffic ranged from 1 to 25 1/sec.

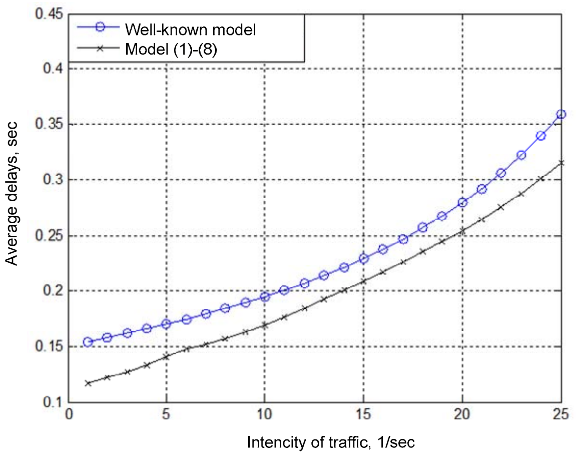

Fig. 3. Comparison of the average delays for solving of routing problem with help of proposed model (1)-(8) and well-known model

It is noticed that the values of the average delays for solving the routing problem with help of proposed model (1)-(8) were reduced to 10 % as compare with the values of the average delays for solving the routing problem with help of flow model of multipath routing with load balancing, which was known early and suggested in [4].

Quality of proposed model is that the values if the average delays of every paths are equal. And this minimize value of jitter, and thus to improve the quality of service parameters values.

The analysis of the proposed model for other topologies of TCN shows that improving of values of average delays (and thus quality of service parameters values) depend on the topology of TCN (its heterogeneity, connectivity, the number of paths between source- and destination-node). If the topology of the network is more heterogeneous, this means that there will be more improvement on average delays.

III. Conclusion

Thus in the paper the mathematical model of multipath routing with load balancing based on quality of service parameters in the MPLS network is proposed. Solution of routing problem with help of proposed model allows to provide the distribution of traffic between source- and destination-node so that delays along every path are equal between each other.

Proposed model (1)-(8) corresponds to technology Traffic Engineering. Proposed model (1)-(8) is a flow model, that corresponds to the requirement for traffic in the modern telecommunication networks.

Besides that proposed model (1)-(8) works for telecommunication networks with simplex links, duplex and half-duplex links. At the same time proposed model (1)-(8) has conditions to prevent packet looping.

Using the proposed model can improve the values of the average delays by 10% compared with the solution of routing within the previously known models.

Solving the routing problem within the proposed model should be used as etalon values for the improvement and configuration of existing routing protocols using load balancing technology.

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