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QoS Routing Model over Disjoint Paths with Guaranteed Bandwidth in Software-Defined Networks

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Abstract. *A mathematical model for calculating disjoint paths that provide guaranteed bandwidth in the data plane of software-defined telecommunication networks is proposed. The advantage of the solution is the formulation of the routing problem in the optimization form using bilinear conditions to ensure guaranteed bandwidth over the set of calculated paths (multipath). At the same time, the choice of the optimality criterion is determined by the requirements for the level of network security and/or Quality of Service.*

Keywords: *Quality of Service; bandwidth; routing; disjoint paths; load balancing; Software-Defined Networks.*

I. Introduction and Problem statement

The widespread introduction of Software-Defined Networks (SDNs) is due to their many advantages over traditional telecommunication networks. This is, first of all, the flexibility of traffic management to optimize the network and the processes that take place in it [1, 2]. For their part, routing tools are effectively used to ensure a given level of Quality of Service, network security, and fault tolerance. At the same time, one of the directions of development of routing solutions is to support disjoint path routing [3-6]. This requires the development of new or improvement of existing mathematical models, which can further serve as a basis for QoS routing protocols on the SDN data plane.

II. Mathematical Model of Disjoint Paths Calculation that Provide Guaranteed Bandwidth in the Resulting Multipath

The basic mathematical model of routing, which is presented in [5, 6], is proposed for further improvement. It can be used to calculate the set of non-intersecting routes (disjoint paths) in terms of Quality of Service. Within the basic model [6], the network structure is described by a graph in which the sets of vertices representing network routers and arcs representing communication links are given. As a result of solving the routing problem, a set of disjoint paths is selected by calculating a set of Boolean variables. Each of them determines the affiliation of a link to the set of calculated paths in the network. The model includes the conditions of connectivity of the calculated paths and the absence of their intersection. The novelty of the model is the conditions for ensuring a given level of Quality of Service, presented in the bilinear form. Fulfilling these conditions ensures that the total bandwidth of the set of calculated paths that do not intersect will not be lower than the specified level. As a result, within the proposed mathematical model, the technological problem of QoS-routing in the SDN data plane is formulated in an optimization form with the criterion of optimality, the form of which is determined by the requirements for network security and/or Quality of Service. In addition, taking into account the type of constraints imposed on routing variables, the formulated optimization problem belongs to the class of problems of mixed-integer nonlinear programming (MINLP).

III. Conclusions

A study of QoS-routing processes using the proposed model of disjoint paths calculation on a set of numerical examples confirmed its adequacy and effectiveness in ensuring a given level of bandwidth along the used paths that did not intersect. The prospect of further development of advanced performance-based disjoint path QoS-routing models is seen in the implementation of fault-tolerant routing and corresponding protection schemes under the support of different QoS indicators such as bandwidth, average delay, and packet loss probability, as well as network security, which is crucial when transmitting critical traffic.

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