LOAD BALANCING MATHEMATICAL MODEL IN SDN-BASED WIRELESS TECHNOLOGIES

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Abstract

In this study, we propose to update the formerly known flow-based load balancing model in the presence of heterogeneous topologies in communication networks (CN). It was further emphasized that the proposed approach could be used in SDN-based wireless technologies. To reduce network and data traffic load, the model changes the optimality criteria of route alternatives. Optimization focuses on re-evaluating the optimality criteria of a routing solution. As an alternative, a linear-quadratic criterion was proposed to minimize the maximum utilization of network links. As a result, the CN load balancing process has been improved to optimize the end-to-end average packet delay as much as possible, which is a critical Quality of Service (QoS) parameter in networks.

With the aim of performing multipath routing tasks efficiently in communication networks with a heterogeneous architecture, an approach based on minimizing the high level of network traffic is required. Both the physical characteristics of the network's construction [1-4] and the functional asymmetry, which is seen, for instance, in the allocation of bandwidth of communication links that, in the long run, may lead to the formation of "bottlenecks" in the communication networks and thus determine the maximum values of the load on the network elements, can contribute to architectural heterogeneity. This has a negative impact on the efficiency of load balancing in terms of providing extreme values of QoS indicators [5, 6], for example, the average end-to-end packet delay. Therefore, this study is committed to improving the load-balancing process for solving the multipath routing problem in CNs with heterogeneous architectures [3] and adapting these solutions to be implemented in SDN-based wireless networks.

In this context, the work suggests enhancing the mathematical model of load balancing in the CN [1-2], which fully satisfies the requirements of the traffic engineering concept. This enhancement involved re-evaluating the optimality criterion for the existing routing solutions. As a next step, the linear quadratic criterion is proposed, which aims to minimize the maximum traffic load on network communication links while also considering other factors affecting link utilization efficiency. As a result, the CN's load-balancing process was better organized, and the network's critical QoS indicator, the average end-to-end packet delay, was decreased. A comparison of the obtained results with calculations based on other optimality criteria, a linear function of the number of network communication links utilized, was performed as part of the quantitative analysis of the improvement benefits.

At the same time, analyses were performed for network topologies that varied in size and degree of heterogeneity. The average end-to-end packet delay was measured in milliseconds at three different Hurst parameter settings. Each setting was for a different type of network traffic. It was determined through this study that the average end-to-end packet delay could be decreased by employing the proposed criterion for organizing load balancing in a CN with a heterogeneous architecture. This is because the proposed model is primarily linear, which means it will not add much complexity to modern routers' algorithmic support and software [1-4].

Implementation of the recommendations on the practical application of the models obtained and the method of load balancing in solving the tasks of routing and reserving network resources in the CN is primarily aimed at creating favorable conditions and determining the appropriate scope of their application. It is related to the need for a system of important organizational and technical measures that affect the principles of structural-topological and algorithmic-software realization. First, as shown by the results of the analysis conducted, the proposed solution provides the highest effectiveness in the case of using network structures with high connectivity of CN routers[1-4]. This is conditioned by the fact that it is possible to calculate the set of paths and effectively distribute a load of users among them. Otherwise, multipath routing implementation will not improve service quality [7-9].

Second, the load balancing model proposed will improve the QoS when used in CN with heterogeneous architecture, i.e., when there are cuts in the network that have much smaller bandwidth than in other cuts. Therefore, when collecting information about the network state, it is necessary to update data on the number and connections of CN routers and monitor the state of more complex network fragments, namely, its cuts. It will lead to some expansion of the set problems that are solved on the routers in determining the set of optimal routes and the order of load balancing among them.

Third, the organization of load balancing and reserving resources in the CN under the proposed model is more appropriate for medium and high network loads. In this case, there is a necessary supply of network resources that can be reallocated and used in a balanced manner. Under low load, even non-optimal solutions, such as single path routing, will be able to provide the required QoS level, although this will lead to inefficient use of the network resource. At critical loading of the network, i.e., at the state of CN close to the overload, there will be no free resource, so the use of the proposed solutions is also not appropriate in this case[1-4, 9].

Fourth, the practical implementation of the proposed models and method determines the need to increase the level of centralization of solutions. In addition, the obtained solutions can be adapted to the architecture of software-defined networks. Here the proposed models and load balancing method can be implemented on SDN controllers as the basis of the corresponding routing and traffic management mechanisms complementing the latest solutions in this field. In practice, functions of the central SDN controller, which collects information about the network state and routes calculation, can be assigned. The potential of SDN to address challenges in wireless technologies, such as SDN-based Wireless Sensor Networks (WSN), is significant.

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