Abstract of the doctoral dissertation

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Packet flow control in computer networks with use of single and bi-objective optimization for congestion avoidance in time-varying communication channel

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The main goal of this dissertation is to present and use a discrete, non-stationary, dynamic linear model with the use of optimization methods to improve the quality of packet flow control and increase the capacity of the computer network. The use of such a model, optimized with single and bi-objective optimization methods, enables the improvement of the quality of packet flow control, which directly impacts the capacity increase in the communication channel. That can increase the effective throughput on the network and avoid or mitigate network congestion effects.

The contribution delivered in specific chapters can be summarized as follows:

- **In Chapter 1** we discuss the development of congestion avoidance and mitigation methods in computer networks. The first part of the chapter discusses protocol-based methods. In the further sections, we describe methods based on the involvement of the active network nodes in the congestion mitigation process. We present the trend of shifting the congestion avoidance responsibility from network hosts towards network nodes. This approach can be justified by the fact that nodes possess the most current state of buffers and links saturation.
- **In Chapter 2** we introduce a discrete-time model of computer network, which will be taken into research in further sections. This model has embedded the delay variation in the packet path, which is a novelty. The new non-stationary, discrete, dynamical model is developed, with the concept of intermediate nodes as a source of the delay variation. This section also delivers the description of how numerical simulation of the presented novel discrete non-stationary linear model has been performed. As a check step, we also deliver the result of a simulation example of the model with the open-loop. This chapter finally presents general optimization assumptions, taken into calculations in consequent chapters together with the optimization method description.

- **In Chapter** 3 we proposed a set of 7 control systems based on the worked out novel non-stationary, discrete dynamical model. Four of these control systems have the reference value constant in time. In the three remaining cases, this reference value is adaptive and dependant on the bandwidth available in each time step. After the proposal of the single-criteria cost function, we performed the optimization for each of the proposed control systems. Three additional control systems present the idea of mitigating the delay related to the order of the model. Results of the optimization iterations have been presented in graphical forms and in the form of summarizing tables.
- **In Chapter 4** we introduced two colliding cost functions for the purpose of bi-objective optimization. We used bi-objective optimization to compare stationary and non-stationary model usage in the conditions approximated to the real network environment. The central part of this section is focused on performing bi-objective optimization with the use of introduced cost functions. This optimization is performed with two examples of the available bandwidth time flows. As a development of control systems, a module of the ordered packets memory has been added to the proposed control systems.
- **In Chapter 5** we fully focus on the process of testing the introduced and discussed control systems. We take the optimized controllers values calculated with two optimization signals in the previous chapter and deploy them in different test scenarios. We also propose an estimation method of the value of unknown available bandwidth. Consequent parts of this section are focused on the research on the disturbance impact on control quality for considered control systems. The following sections present test results applied for different variances of test scenarios. In the final subchapter, we compared all obtained results. For this purpose, we used hypervolume indicator and Wald's criterium.

The approach relying on the use of two different signals during the optimization phase and two highly different test signals allowed us to gather a significant volume of data. These data have been collated and compared, applying the Wald's criterion. This approach allowed us to designate the best of the proposed control strategies. Performed analysis and simulations justified the use of network models with time-varying delays. Such an approach presents the advantage over the models not assuming this variance.

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