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Predicting traffic anomalies in container virtualization

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Abstract. *Container solutions have a number of advantages over traditional ones. However, as the number of containers grows, the management complexity factor grows exponentially. In this case, the occurrence of traffic anomalies leads to deviations from the required QoS parameters. A method for predicting traffic anomalies in container virtualization has been developed. The method takes into account the peculiarities of traffic generated by a pool of containers under the control of a special system that ensures its routing and balancing in the environment of a computer system. Therefore, to predict traffic anomalies during container virtualization, it is necessary to analyze changes in the Hurst parameter.*

Keywords: *container virtualization, virtual machine, fractal traffic, Hurst parameter.*

I. Introduction and Problem Statement

Nowadays, there are two the most popular choices for running applications: virtual machine technology and, relatively new, container virtualization technology. Each of the technologies has its own advantages and disadvantages. Container virtualization technology has a number of advantages over traditional ones: containers are created much faster, overhead is reduced, and problems with synchronization and inter-network dependencies are eliminated. However, this raises a number of problems. In particular, as the number of containers grows, the complexity of their management grows exponentially. In this case, the occurrence of traffic anomalies leads to significant deviation from the required QoS parameters. One of the approaches to solving this problem involves predicting traffic anomalies. The approach is based on the statement that the degree of traffic fractality increases with its abnormal deviations.

Many modern papers were devoted to discover the issues of meeting the requirements of QoS [1-5]. They considered different approaches. So, in [1], the authors are focused on the optimal allocation of resources. In [2], the authors emphasize the redistribution of information flows. Paper [3] proposes clustering, and in paper [4] the authors propose options for increasing the values of QoS parameters in mobile components of computer systems. A number of studies are focused on using the results of short-term traffic prediction [5-8]. However, all the considered researches do not take into account the peculiarities of traffic generated by a pool of containers.

The goal of this paper is to develop a method for predicting traffic anomalies in container virtualization based on determining the behavior of indicators of its fractality degree. The method takes into account the peculiarities of traffic generated by a pool of containers under the control of a special system that ensures its routing and balancing in the environment of a computer system.

II. Problem Solution and Results

An inherent feature of fractal processes is scale invariance with respect to the attractor. Let us consider the possibilities of studying the properties of scale invariance of network processes using stochastic models of generalized Brownian motion. For this, the paper formalized this property, taking into account the use of container virtualization technology. On the basis of this formalization, a mathematical model of traffic generated by a pool of containers has been developed. The model is based on a statistical approach to describe Brownian motion (Wiener process). It is shown that for a pool of containers the Wiener process can be defined as a nonstationary Gaussian process with zero mathematical expectation and a special correlation function.

To analyze this process, we use the formalized increment of the Wiener process for discrete instants of time. It is shown that the increments are correlated, and due to the Gaussian nature of the distribution density, they are also independent. Calculated distribution density has the property of scale invariance. It is shown that a random displacement function can be specified using a normally distributed random process with independent values.

A natural generalization of Brownian motion is to replace the Hurst parameter with any real number from the interval $0 < H < 1$ to obtain fractal Brownian motion. This generalization allows calculating statistical characteristics for fractal traffic.

To characterize the properties of scale invariance, the increment correlation coefficient is calculated and an expression for the correlation function of the traffic generated by the container pool is determined. In this case, the operation of fractional integration is used. On its basis, the Hurst coefficient is calculated. It is shown that the greater the value of the Hurst coefficient, the more extended the dependence characterizes the properties of the considered random process. Consequently, the rate of change of this coefficient characterizes the degree of traffic abnormality and can serve as a numerical characteristic for predicting the occurrence of anomalies.

III. Conclusions

A method has been developed for predicting traffic anomalies in container virtualization based on determining the behavior of indicators of its fractality degree. The method takes into account the peculiarities of traffic generated by a pool of containers under the control of a special system that ensures its

routing and balancing in the environment of a computer system.

The analysis of traffic deviations from the stationary mode is based on the analysis of the fractal properties of network processes. For this, a generalized Brownian motion model is used. The model uses the operation of fractional integration of Brownian motion with the kernel, which has the form of a power function with a fractional exponent.

The dependence of the power-law tail of the distribution on the Hurst parameter is shown. Therefore, to predict traffic anomalies in container virtualization, it is necessary to analyze changes in the values of the Hurst parameter.

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