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Self-Similar Traffic in G/M/1 Queue Defined by the Weibull Distribution

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Abstract—The work considers a queuing system of the G/M/1 type that simulates service of self-similar traffic in a NodeB (e-NodeB) base station of a mobile operator. The feature of quality of service (QoS) characteristics estimation process for the self-similar traffic defined by the Weibull distribution is the solution based on the Laplace–Stieltjes transformation. The Laplace transformation for an infinite number of items under the Weibull distribution condition was found. It was shown that this series was equiconvergent to some convergence domain. The following QoS characteristics were obtained for the self-similar traffic: the average amount of time that a request spends in the system; the average number of requests waiting in the queue and the average queue length. The obtained results allowed to consider the real values of traffic serviced by a NodeB (e-NodeB) for their optimal deployment over a covered territory at the stage of frequency planning and operation of the 3G/UMTS and 4G/LTE networks.

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INTRODUCTION

The development of mobile communication networks today is connected with the implementation of the 3G/UMTS (Universal Mobile Telecommunications System) and 4G/LTE (Long Term Evolution) standards with the further transition to packet data transmission. By its nature, traffic serviced in mobile communication networks is heterogeneous. It is formed by a variety of different sources, providing voice, data and video services (YouTube, Video Surveillance, streaming video, OTT-services, M2M (Machine to machine), IoT (Internet of Things)).

The existing methods of calculation assume that the mobile communication networks use the circuit switching technology and the traffic that is serviced therein is described by the simplest Poisson flow calls. This assumption has great influence during the frequency-territorial planning, design and further operation of the hardware and software of mobile communication networks. Nevertheless, the traffic has a special structure in modern 3G/UMTS and 4G/LTE mobile networks with packet switching that is determined by burstiness and the presence of a significant number of pulsations.

In this case, during frequency-territorial planning and further optimization of the network, it is necessary to take into account the design features and structure of the network objects serving packet traffic (NodeB (e-NodeB) base stations, RNC (Radio Network Controller), MGW (Media GateWay), etc.) in their operating conditions. The rapid growth of subscriber traffic volume, the change in its nature and structure, the significant increase in bandwidth can contribute to possible overloads of network objects, their buffer devices and, accordingly, to packet delays and losses. Therefore, special attention is paid to maintaining quality of service (QoS) when servicing packet traffic.

The packet traffic serviced by the NodeB (e-NodeB) base stations of 3G/UMTS or 4G/LTE networks has a self-similar (fractal) character [1, 2]. It is mainly caused by the long-term dependence between the packet arrival times, determined by the correlation function at various time moments. The Hurst parameter H, $0.5 \le H < 1$, is used as a quantitative measure of the degree of self-similarity. The significant number of high-speed services and applications that the mobile subscriber uses affect the characteristics of packet traffic serviced by NodeB (e-NodeB). Therefore, taking into account that the arrival times of packets have distributions with "heavy tails," the Pareto, Weibull or lognormal distributions [3–5] are often used to describe the self-similar traffic.

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