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About the service model of two classes of multicast traffic

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The increase of users and high network requirements have led to the introduction of millimeter wave technology in order to increase data transfer speeds and minimize delays. The transition to the millimeter wave band in 5G imposes new features in the implementation of services. In this work the mathematical model has been developed to describe the process of servicing multicast traffic using the methods of queuing theory. Signal propagation features are taken into account by dividing the coverage area into two areas: circle and ring. The constructed mathematical model makes it possible to find analytical expressions for calculating the loss probability of multicast connections and the amount of occupied resource in various areas.

Key words and phrases: muticast, service area, queuing theory.

1. Introduction

To ensure low latency and high-speed data transmission in 5G networks, it became necessary to expand the frequency band, since the frequency band used below 6 GHz is fully loaded [1]. Millimeter waves (from 24 to 100 GHz) began to be used [2], which provides a large bandwidth, and therefore a high data transfer rate. At the same time, the use of such high frequencies imposes some features. Directional patterns with the widest possible angle of inclination are optimal for multicast connections in order to reach a larger number of users, which is achieved by reducing the number of elements in the antenna array. However, this leads to a decrease in the gain of the transmitting antenna, which reduces the coverage area of one access point, which means that deployment costs also increase. In this study the mathematical model is constructed to study the characteristics of the system through stationary probabilities obtained through the system of equilibrium equations. At the same time, the model takes into account both the signal propagation characteristics by dividing the coverage area into two areas, also in relation to the distance of users to the AP. The article investigates the following metrics of interest: loss probability and average number of occupied network resources.

2. System model

To study the performance quality metrics of the mobile communication network, an access point (AP) in millimeter wave range is considered to study the performance quality of the operation of the mobile communication network. Figure 1 shows the coverage area of the AP delimited by circle, the radius of which is determined by the signal propagation model. In the coverage area there are randomly distributed stationary users. Users generate requests for the provision of services over two classes of multicast connections, for which the AP allocates the required amount of radio resources. The amount of radio resources required corresponds to the simplest model of signal propagation. Therefore, in the model under consideration, the coverage area is divided into two areas: circle and ring. The circle is the area closest to the AP, in the center of which the AP is located, shown in Fig. 1, the circle is indicated in yellow. The ring is the rest up to the limits of the covering area shown in Fig. 1, which is indicated in red. If multicast connection has already been initiated in the circle, then in order to accept a multicast connection of the same type in the ring, the already allocated resources

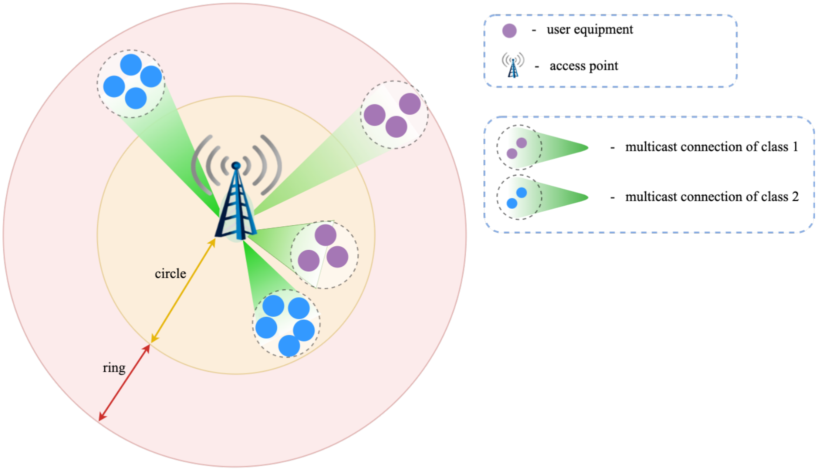

Figure 1. System model

for multicast connection is increased. Thus, multicast connection requests in the entire AP coverage area are served on the same resource. The resource quantity requirements for processing multicast connection requests from users in the circle are less than the corresponding requirements from users in the ring.

3. Mathematical model

To describe the process of servicing user requests by AP, consider a resource queuing system with an unlimited number of devices and a limited number of resource units equal to R servicing requests (Fig. 2) for multicast connections [3].

We use the following symbols to describe the model: m is the class of multicast traffic, $m = 1, 2$, l is the area, $l = 1, 2$, where 1 is a circle and 2 is a ring. Let λ_{ml} are arrivals intensities and μ_{ml} are parameters of the exponential distribution of the servicing duration of multicast requests of class $m, m = 1, 2$ in circle and ring $l = 1, 2$, then $\_ml$ are resource requirements for multicast requests in different areas. We consider the system with resource $R > b_{m,2}, m = 1, 2$.

The functioning of the system can be described using a four-dimensional random process

$$\mathbf{X}(t) = ((I_{11}(t), I_{12}(t), I_{21}(t), I_{22}(t)), t \geq 0)$$

where $I_{ml}(t) \in \{0, 1\}$ is the indicator of the multicast connection of class $m, m = 1, 2$, in the area $l, l = 1, 2$, at time t. The state space is represented in the following form:

$$\mathcal{X} = \{(i_{11}, i_{12}, i_{21}, i_{22}) :$$

$$i_{ml} \in \{0, 1\}, m, l = 1, 2, i_{11}b_{11} + i_{12}(b_{12} - b_{11}) + i_{21}b_{21} + i_{22}(b_{22} - b_{21}) \leq R\}.$$

Let $\mathbf{x} = (i_{11}, i_{12}, i_{21}, i_{22})$. Then $P(\mathbf{x}), \mathbf{x} \in \mathcal{X}$, is the stationary probability distribution of random process $\mathbf{X}(t)$. To calculate the stationary probabilities of states of the system, we use system of equilibrium equations. Having found the constant probabilities, we can get the metrics of interest like loss probabilities and coefficient of resources using for individual types of traffic and the whole system as a whole.

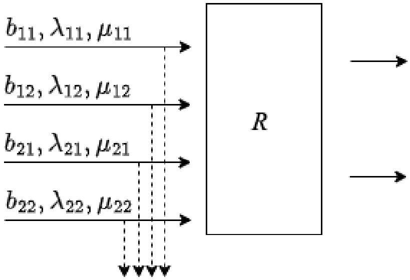

Figure 2. Scheme of the resource queueing system

4. Conclusions

In this paper, the model for the service by access point of multicast traffic at the request of users located in its coverage area is constructed, taking into account the particularities of signal propagation through the division of the coverage area into two areas. This mathematical model makes it possible to find analytical expressions for calculating the loss probabilities for multicast connections, as well as the amount of occupied resource both by individual classes of traffic in different areas of the coverage area and in the entire system as a whole.

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О модели обслуживания двух классов услуг мультивещания

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Увеличение числа пользователей и высокие требования к сети привели к внедрению технологии миллиметровых волн для увеличения скорости передачи данных и минимизации задержек. Переход на миллиметровый диапазон волн в 5G накладывает новые

функции при реализации услуг. В данной работе разработана математическая модель для описания процесса обслуживания многоадресного трафика с использованием методов теории массового обслуживания. Особенности распространения сигнала учитываются путем разделения зоны покрытия на две области: круг и кольцо. Построенная математическая модель позволяет найти аналитические выражения для расчета вероятности потери многоадресных соединений и объема занимаемого ресурса в различных областях.

Ключевые слова: мультивещение, зоны покрытия, теория массового обслуживания.