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Development of an Algorithm for Experimental Evaluation of Increasing the Capacity of Mobile Telecommunication Networks

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Abstract: The article considers the average daily throughput of mobile telecommunication networks, one of the characteristics of which is the degree of workload of the system equipment during the day, which is estimated by the load concentration factor in the NNN. Also, an analysis was made of the features of managing user information flows in mobile networks, on a fragment of the LTE network

Keywords: Throughput, LTE networks, resource allocation, performance, quality index, frequency assignment, range.

Introduction: An analysis of existing methods of increasing the throughput of information networks was carried out in order to use the most effective methods of user data transmission in a fragment of the LTE network. The average daily throughput is considered, one of its characteristics is the workload level of the system equipment during the day, which is evaluated by the load concentration coefficient in NNN, the value of which mainly depends on the structural composition of the network. subscribers and lies in the range of 0.09-0.15. The value of this coefficient should be minimal for uniform loading of the network. Also, the features of managing information flows of users in mobile networks were analyzed. It has been shown that equally available radio resources during congestion can be captured by more intense flows of certain categories of users and can lead to a significant decrease in throughput due to complete blocking of other users.

Main part:
The statement of the problem of servicing two streams of heterogeneous traffic is carried out. It is shown that with an increase in the admissible queue length, as well as the bandwidth, the number of possible system states increases sharply, and with a constant waiting time, the process will no longer be Markov. A model has been developed for choosing the numerical values of the minimum and maximum allowable transmission rates, which considers the process of receiving one stream of requests for servicing real-time traffic, with intensity and one stream of requests for data transmission of elastic traffic, with intensity , which are distributed according to the Poisson law. To serve one application for the transmission of elastic traffic, the maximum possible resource is allocated from the cell bandwidth, in the amount satisfying the inequality, where and set the minimum and maximum file download speeds, respectively, . It is assumed that the volume of the transferred file has an exponential distribution, with the average value F. It is assumed that the time of file transfer using only the minimum speed and only the maximum speed has an exponential distribution c1, respectively, with c2 the parameters $\mu_{d,1} = \frac{c_1}{F}$ and $\mu_{d,2} = \frac{c_2}{F}$. Relative priority is taken into account when using the information transmission resource. It is shown that if the cell has enough free resources, i.e. inequality $i_r c_r + i_d c_2 \le C$ then the request is accepted for service, and a resource in the amount of bit / s is allocated for it. If the resource does not have the specified value, but the inequality is fulfilled
In the absence of the specified resource value, but the fulfillment of the inequality , $i_r c_r + i_d c_1 + c_r \le C$ the transfer rate of all files decreases. $\frac{C-(i_r+1)c_r}{i_d}$ to a value that satisfies the condition $\frac{C-(i_r+1)c_r}{i_d} \ge c_1$. If the inequality is satisfied, the received application to transfer data files is rejected.

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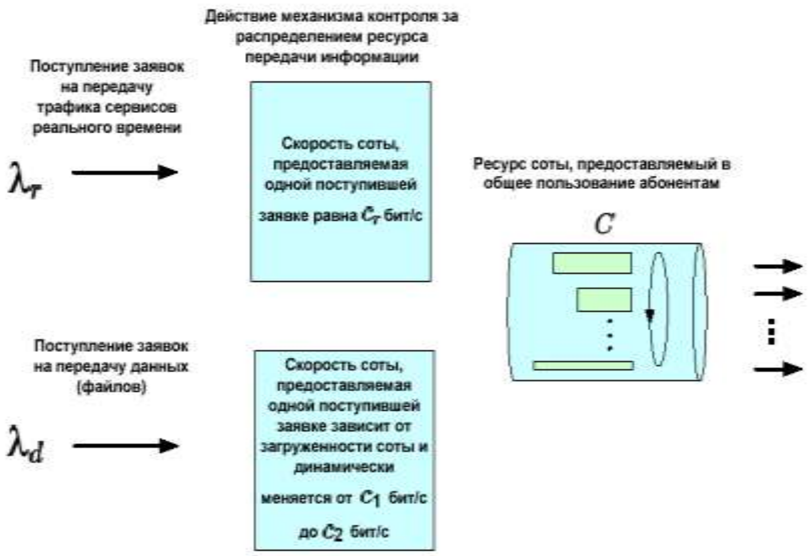
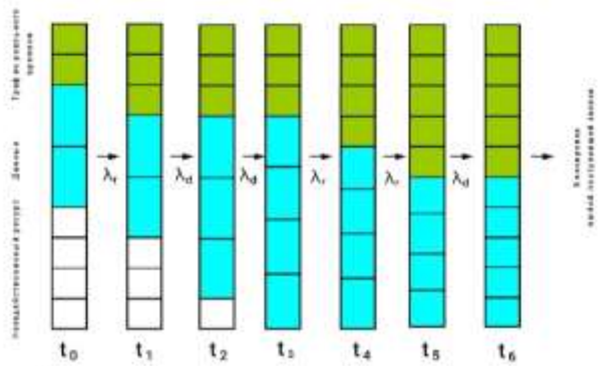
If the inequality is satisfied, the received application to transfer data files is rejected. The process of resource allocation $i_r c_r + i_d c_1 > C$ for a part of the LTE network is analyzed. The working diagram of the built model is shown in Picture 1.



Picture 1. Operation scheme of a single cell model in an LTE network. In the model under consideration, the data transfer rate changes dynamically according to the load. In this case, the used resource and, therefore, the traffic transfer rate of real-time services will not change. An example of the resource allocation procedure is considered, the results of which are shown in Picture2.



Picture 2. An example of resource allocation for the studied network cell model
 LTE standard.

A mathematical representation of the resource allocation model is implemented. The simulation results are evaluated by the percentage of lost requests and the average value of the used cell resource.

The percentage of applications for real-time service traffic transmission that satisfy the condition is $i_r c_r + i_d c_1 + c_r > C$ determined as follows:

$$\pi_r = \sum_{(i_r,i_d)\in S:\, i_r c_r + i_d c_1 + c_r > C} p(i_r, i_d)$$

The average number of real-time traffic requests in service is defined as:

$$m_r = \Sigma_{(i_r,i_d)\in S}\, p(i_r, i_d)\, i_r.$$

The average value of the cell information transmission resource occupied by the application service for real-time traffic transmission is found by the following ratio:

$$s_r = \Sigma_{(i_r,i_d)\in S}\, p(i_r, i_d)\, i_r c_r = m_r c_r.$$

Similarly, definitions of quality of service indicators for requests for file transfer are formulated: loss of requests for elastic traffic transfer

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$$\pi_d = \sum_{\{(i_r,i_d)\in S \mid i_r c_r + i_d c_1 + c_1 > C\}} p(i_r,i_d).$$

The average number of requests for the transfer of elastic traffic in service is defined as:

$$m_d = \sum_{(i_r,i_d)\in S} p(i_r,i_d) i_d.$$

The average value of the cell information transmission resource occupied by servicing applications for the transmission of elastic traffic is found from the relation

$$s_d = \sum_{(i_r,i_d)\in S} p(i_r,i_d) i_d \min\left\{c_2, \frac{C - i_r c_r}{i_d}\right\}.$$

The average value of the cell information transmission resource used to serve one file is found from the relation

$$c_d = \frac{s_d}{m_d}.$$

The average file transfer time is found by Little's formula:

$$T_d = \frac{m_d}{\lambda_d(1-\pi_d)}.$$

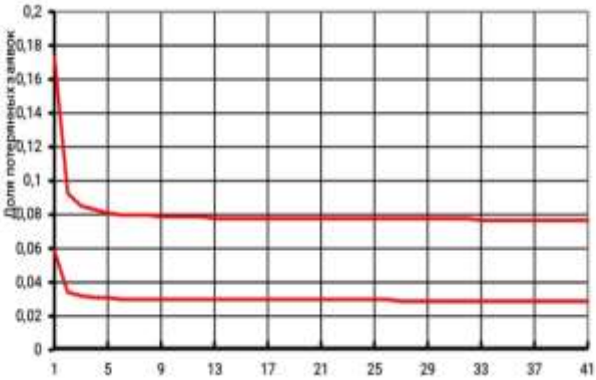
It is shown that the obtained relations are in the nature of laws of conservation of the intensities of service application flows adopted in the communication system under consideration. Another indicator of the efficiency of data transmission in the cell was introduced - the percentage of time that the entire cell resource is involved in the transmission of user traffic:

$$\pi_f = \sum_{\{(i_r,i_d)\in S \mid i_r c_r + i_d c_2 > C\}} p(i_r,i_d).$$

system of equilibrium equations:

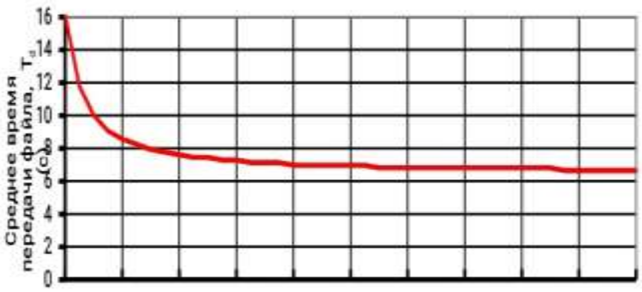
$$\begin{aligned} &p(i_r,i_d)[\lambda_r I(i_r c_r + i_d c_1 + c_r \le C) + \lambda_d I(i_r c_r + i_d c_1 + c_1 \le C) \\ &+ \lambda_r \mu_r I(i_r > 0) + \min\left\{\frac{i_d c_2}{F}, \frac{C - i_r c_r}{F}\right\} I(i_d > 0) = \\ &= P(i_r - 1, i_d)\lambda_r I(i > 0) + + p(i_r, i_d - 1)\lambda_d I(i_d > 0) + \\ &+ p(i_r + 1, i_d)(i_r + 1)\mu_r I(i_r c_r + i_d c_1 + c_r) \le C + \\ &+ p(i_r, i_d + 1)\min\left\{\frac{(i_d + 1)c_2}{F}, \frac{C - i_r c_r}{F}\right\} I(i_r c_r + i_d c_1 + c_1 \le C). \end{aligned}$$

Assuming normalization: $\sum_{(i_r,i_d)\in S} P(i_r,i_d) = 1.$
This system is solved using the Gauss-Seidel integration method.
Using the built model, definitions of the main indicators of the quality of service to incoming requests are formed: the percentage of denied requests, the average use of the data transmission resource for each type of traffic, the average file delivery to give time, average usage of transmission resource for serving one file, etc.
In the form. Picture 3 shows the loss of traffic requests for real-time services and the calculation of the loss of elastic traffic requests with increasing the value of the maximum data transfer rate from 1 Mbit / s to 40 Mbit / s . The analysis showed that with an increase in speed, not only requests for file transfer, but also requests for the transfer of real-time service traffic disappear, which is caused by the accelerated release of cell resources.



Upper limit on data transfer rate (Mbp/s)

Picture 3. Dependence of claim losses on increasing the maximum availability of the resource for transferring data traffic 4 shows the results of changing the average data file transfer time as the speed increases. Studies have shown that with increasing speed, the average time of data file transfer decreases when one cell resource is used for file transfer, and then tends to a constant value according to the cell load.



Picture 4. Using average cell resources for file transfer with maximum resource availability in data traffic

If we talk about the experimental evaluation of increasing the throughput of mobile telecommunication networks, then it is necessary to talk about the optimization with assignment of frequencies to radio communications.

Frequency Optimization For Radiologists

If it is not possible to cooperate with the radar, the system allows the user to optimize the radio communication networks, including the optimization of the assignment of operating frequencies to radio communications. It is known that if the noise is taken into account only in the main channels of emission and reception, then the problem of optimizing the determination of the operating frequencies of the radar can be reduced to the problem of coloring the graph, and if the noise is taken into account. only in the main and out-of-band channels of emission and reception, then to the traveling salesman problem [1] .

Although both of these problems are NP-hard, efficient algorithms have been developed to solve them. However, in the real tasks of optimizing the setting of the operating frequencies of the radar, it is necessary to take into account the noise in the emission and reception side channels, including the combined and intermodulation channels. The author built a mathematical model of the task of optimizing the assignment of operating frequencies to the radar according to the criterion of minimizing the noise level between radio devices (RS), which differs from known mathematical models, taking into account all possible factors. out-of-band and spurious emissions and RS reception channels. We call a relay station included in a radio network simple, if at any time this relay station can work on only one frequency out of a certain number of mi (1 of the specified frequencies), regardless of the frequencies on which other radio network radars operate. It is shown in [2] that any radio communication network includes simple radars, single-channel and multi-channel duplex

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radars, single-channel and multi-channel radars with pseudo-random switching of frequencies. a radio communication network consisting only of ordinary radars. A radar can only create electromagnetic interference to the RS of other radars, and the levels of this interference depend only on the RS characteristics and spatial location of the two radars and the frequencies at which the radars are located. The RS of any two conventional radars can create intermodulation electromagnetic interference only for the RS of the third conventional radar, moreover, the levels of this interference depend only on the characteristics and spatial arrangement and frequencies of the RS of the three radars. radars work. As an objective function in the mathematical model of the RL frequency assignment optimization task, we obtain the minimization of the sum of penalties for the use of 184 RL frequencies for the presence and magnitude of electromagnetic interference levels between RS. For the presence and magnitude of intermodulation electromagnetic noise levels between RL and RS RL. We enter the matrix X ((xij),i (1,n, j (1,m)) in which the element ij x is equal to 1 if the frequency j f is given to the simple RL RLi, otherwise it is equal to 0. Then the objective function can be written as ((((((((((((((m j i j i j i j i j n i m j n i m j ij ij n i a x c x x 1 (2) 1 1 1 2 1 1 1 2 1 1 2 2 1 1 2 2 1 1 2 min. 1 (3)
1 1 1 1 1 6 1 3 1 1 2 2 3 3 1 1 2 2 3 3 1 1 2 2 3 ((((((((((((((m j i j i j i j i j i j i j n i m j n i m j n i c x x x

Constraints in the model requirements to assign to each simple RL RL , i 1, n, i (exact mi frequencies: i m j (xij (m (1 for all i (1, n)). Next group) parameters and range of variables:
0, 0, 0, 1, {0,1} (2) (3) 1 1 2 2 1 1 2 2 3 3 aij (ci j i j (ci j i j i j (mi (xij (all i (1,n, j) for) (1,m,i 1 (1,n, j 1 (1,m,i2 (1,n, j2 (1,m,i3 (1,n, j3) (1,m . The proposed mathematical model) is a multidimensional multiple assignment problem because it differs from the classical assignment problem in that a single applicant can be assigned to multiple positions and any subset of two or three positions is filled by conflicting applicants. can occupy. This problem is NP-hard, so its solution Approximate algorithms have been developed: greedy algorithm and local search algorithms in a certain neighborhood [3]. These algorithms determine the electromagnetic compatibility of any two and three RSs operating at given frequencies The work of calculating these calculations and finding the optimal operating frequencies for two and three RS is reviewed [4, 5].

Conclusion: This means that equally available radio resources during traffic jams may be captured by more intense flows of certain categories of users and may lead to a significant decrease in throughput due to complete blocking of other users. To avoid such situations, the throughput of mobile telecommunication networks is increased by using existing resources or by upgrading them using additional frequency bands.
Computational experiments have shown that the greedy algorithm rarely leads to the optimal solution in real problems of optimizing the assignment of RL frequencies with a sufficiently high density of RSs of different RLs and a limited frequency resource. On the other hand, in neighborhood 1 and neighborhood 2, the deterministic local search algorithm, starting from the solution obtained by the greedy algorithm, finds an optimal solution in a reasonable time almost 80% of the time. In other cases, the solution found is close enough to the optimal solution.

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