RESOURCE ALLOCATION MODEL FOR LTE TECHNOLOGY WITH FUNCTIONALITY OF NB-IOT AND RESERVATION

DOI: 10.36724/2072-8735-2021-15-11-69-76

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Manuscript received 22 September 2021;
Accepted 27 October 2021

Keywords: *reservation strategy, resource sharing, Internet of Things, LTE, performance measures, system of state equations*

The tremendous growth in the volume of multimedia data streams to be collected by multiple video cameras and a large number of sensors or smart meters in the Internet of Things application is one of the main challenges in the transition from 4G to true 5G network systems. The necessity of conjoint servicing of heterogeneous data over the existing infrastructure has been recognized and supported by 3GPP by introducing the standardization and formalization of Narrowband Internet of Things (NB-IoT) technology. The NB-IoT is the most promising technology for big data collection in the IoT landscape thanks to its particular characteristics such as long-range coverage (10 km), high energy efficient consumption and low-cost radio design. The same spectrum is shared between LTE high-rate end equipment and NB-IoT low-rate end devices. However, the challenge is how to share efficiently the available radio resources between multiple complex devices with priorities of some type of data flow. The model of resource sharing for conjoint servicing for both traffic originated by video surveillance cameras and by sensors is constructed. Access control offering priority to one type of flows is used to create the differentiated servicing of the incoming sessions. Probability values of the constructed model's stationary states are used to determine the main performance measures. The constructed mathematical model can be used to study the reservation based resource allocation and sharing scenarios between the LTE and NB-IoT traffic flow over 3GPP LTE with NB-IoT functionality.

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Для цитирования:
Степанов С.Н., Ндайикунда Жувен, Канищева М.Г. Модель распределения ресурсов с резервированием для LTE технологии с функциональностью NB-IoT // T-Comm: Телекоммуникации и транспорт. 2021. Том 15. №11. С. 69-76.

For citation:
Stepanov S.N., Juvent Ndayikunda, Kanishcheva M.G. (2021). Resource allocation model for LTE technology with functionality of NB-IoT and reservation. *T-Comm*, vol. 15, no.11, pp. 69-76. (*in Russian*)

1. Introduction

Over the recent few years, there has been a significant increase in the deployment of subsequent generations of wireless telecommunications networks based on LTE technology [1-5], despite the emergence of a fifth-generation network that supports high data rates and allows a wide range of multimedia services. Nowadays, the internet is experiencing an unprecedented extension with the development of connected objects. It no longer just allows people to communicate at anytime, anywhere, but with the notion of connected objects, the physical world can now communicate, whether the communication between person to person, person to object, or object to object. The growth in the number of mobile devices that are also called high-data-rate ends devices (e.g. surveillance cameras, smartphones, tablets, laptops, computers, E-readers, handheld gaming consoles, …), as well as the number of smart devices such as vehicles, actuators, sensors, and others low-data-rate ends equipment increases steadily the volume of exchange information which exceeded 1 Zettabyte in 2016 [6] and will expect 175 zettabytes in 2025 [7].

The most reasonable Cisco's statistic tells about more than 29.3 billion connected devices in 2023 [8]. Following this trend, many technologies have been studied to ensure the processing and exchange of collected data. The well-known LPWAN (Low-Power Wide-Area Networks) solutions are certainly those of Sigfox [10] and Semtech [11], the latter developing the famous LoRa (Long Range) transmission technique. Historically, the focus has been on increasing throughput, for ever-lower latencies, with moderate considerations for complexity and power consumption. It is, therefore, a new type of network that must be studied: long-range wireless networks with low energy consumption, or LPWAN. Since the early 2000s, there have been communication technologies allowing low energy consumption. In particular, we can mention the IEEE 802.15.4 standard of the LPWPAN type. Nevertheless, the ranges offered by such systems are too small because, in the case of IoT, there are more particularly interested in long-range communication technologies, which allow transmissions from a few hundred meters to several tens of kilometers. Wireless connectivity solutions have recently appeared, fulfilling the criteria of long-range and low energy consumption. We can cite a company like Ingenu [12], formerly On-Ramp Wireless, founded by former members of Qualcomm, which deploys its LPWAN network in the United States and whose RPMA (Random Phase Multiple Access) technologies makes it possible to reach a very high capacity.

The French company Qowisio [13] is deploying an original dual-mode network, based on narrowband technology and LoRa technology. The Weightless Special Interest Group (SIG) and its Weightless (-P) connectivity technology, aimed at offering a quality of service similar to that of cellular networks, by offering, among other things, two-way communications, transmission power management, and adaptation of the coding scheme to the quality of the radio link. All of these low-speed solutions were specifically created for the IoT, meeting the various LPWAN criteria. However, it was only after their appearance that the 3GPP (3rd Generation Partnership Project), the standardization group for cellular networks, decided to study the evolution of 2G and 4G mobile technologies to make them compatible with the constraints specific to IoT. Because of the emergence of the IoT market, 3GPP could not afford to wait until 2020 and 5G to offer an LPWAN solution based on mobile networks. Thus, in May 2016, during Release 13 of 3GPP, the EC-GSM-IoT (2G), LTE-M (4G), and NB-IoT (4G) standards were published. They form the basis of cellular communication solutions for IoT and their operation has being planned in parallel with traditional mobile services [14]. Unlike the latter, which must physically deploy their networks (in most cases), these new standards do not involve hardware changes. Indeed, their implementation mainly consists of a simple software update of the base stations. With Release 14, these standards evolved and offered a slight additional coverage extension, as well as an increase in maximum throughput [14].

The NB-IoT technology is the most prospective candidate for big data collection in the IoT landscape thanks to its particulars characteristics, such as long-range coverage that can reach 10 km, high energy efficient consumption and low-cost radio design. Thus, to the mentioned above, together with the higher penetration of smart objects (vehicles, actuators, sensors, etc.) which have low storage capacities and the ability to produce, process, and exchange data, the emergence of the Internet of things system has caused an increase in multimedia big data [9], especially those collected by video surveillance cameras used for monitoring public or private places.

Video cameras capture images to monitor people's whereabouts, prevent thefts, assaults, and frauds, as well as to manage incidents and crowd movements. They collect a significant volume of data to be transmitted to the analytic center for processing. The smart meters and sensors are not capable of producing big volume of information as video surveillance cameras. Firstly, video surveillance was used by public services (police, transport, administrations). It was been then adopted by companies wishing to protect strategic assets, such as refineries, nuclear power stations, river dams, food factories, and pharmaceutical complexes.

Nowadays, surveillance cameras are present in various public and private places: buildings, shops, parking lots, stations, airports, roads, public transport, banks, etc. Video surveillance systems are deployed on different scales. For the monitoring of minor crimes (e.g., attacks, vandalism, theft), video surveillance is mainly used for the investigation after the fact. This level of surveillance requires simple technologies, most often analog that do not incorporate video intelligence. This the type of system that can be found in a small business or a private residence.

Large-scale video surveillance can be found in cities and neighborhoods, transportation systems, academic campuses, major events (festivals, economic summits, Olympic games, etc.), and extended security perimeters. It requires the deployment of several dozen or even hundreds of cameras. These must sometimes be accessible to hundreds of security responders from various government agencies, police forces, or emergency services. In these installations, video surveillance is added to a range of security and control systems: access control, fire control, telephony, radio communications, geomatics systems, etc.

Given the number of video cameras involved and the importance of emergency response, these applications are particularly conducive to the use of video analytics for the automated processing of video streams generating alarms during suspicious events. The impossibility of ensuring effective surveillance by operators in systems that include a large number of cameras has sparked around the world many researches to automate video surveillance through real-time analysis and interpretation of video streams.

IoT devices such as smart meters, sensors and video cameras can be deployed in both public and restricted areas where wired systems cannot be connected for economic or technical reasons. The current 4G and 4G+ infrastructures can be used to transmit the collected big data to the analytical center, but cannot fully support the scalability and reliability requirements of such massive video cameras due to insufficient capacity for this video stream's purposes. The emergence of 5G comes to resolve this issue i.e. one of the key features of 5G mobile technology is to transmit the combination of two or more heterogeneous big data streams. The 5G network increases the intelligence and reliability of decision-making and consequently answers the full potential of the Internet of Things.

A large group of sensors or smart meters may be deployed in the same area where the video cameras are installed to increase the quality of security and safety purposes. For example, in a hospital, each beacon can be equipped with a camera that will be activated when an alarm is triggered by a medical sensor for identification. The sensors and the cameras can also be used to detect traffic jams in road security or for the Smart Parking application to monitor available parking spaces. At the same time, the collection of this heterogeneous big data poses a serious problem for the management of a limited amount of radio resources. This issue has been recognized and supported by 3GPP by introducing NB-IoT technology, which allows using the same resource by LTE high-rate end devices and NB-IoT low-rate end equipment. However, 3GPP does not provide a specification of how this radio resource should be shared. This problem can be resolved by forming a mathematical model that takes into account the characteristics of all traffic streams coming or accepting for servicing.

The main goal of this study is to analyze and construct a system model, which creates the conditions for differentiated service of heterogeneous traffic. In sections 2 and 3 will be constructed the functional and mathematical model of a cell in an LTE network, in which several traffic flows generated by IoT devices are jointly served. Section 4 considered resource allocation scenarios based on access restrictions for some of the incoming requests in the framework of the constructed model. In sections 5 and 6, the Markov process, which describes the process of resource allocation is introduced.

Using Markov process, the main performance measures for servicing incoming requests are determined. In section 7, a performance measure’s algorithm is provided, and in the last section will be discussed numerical examples to illustrate the use of the constructed model that creates a differentiated service environment for heterogeneous IoT traffic.

2. System model

In this section, the introduction of a surveillance operator’s model that provides heterogeneous monitoring services in LTE bands by using LTE technology with functionality NB-IoT will be discussed. The formalization of resource sharing strategy, traffic process strategy, and the deployment scenarios will be discussed in subsequent sections.

Let us consider a surveillance operator deployed in security and safety systems with voice detection, motion detection, fire detection, and other detection types. The deployed system consists of a hybrid solution of various wide cameras to perform video monitoring and a large number of sensors and smart meters for intrusion detection (Fig. 1). We assume that sensors and other smart meters will communicate via the NB-IoT application, as one of the most prominent LPWAN IoT applications that receives global standardization support. Different radio solutions technologies can coexist within the same network.

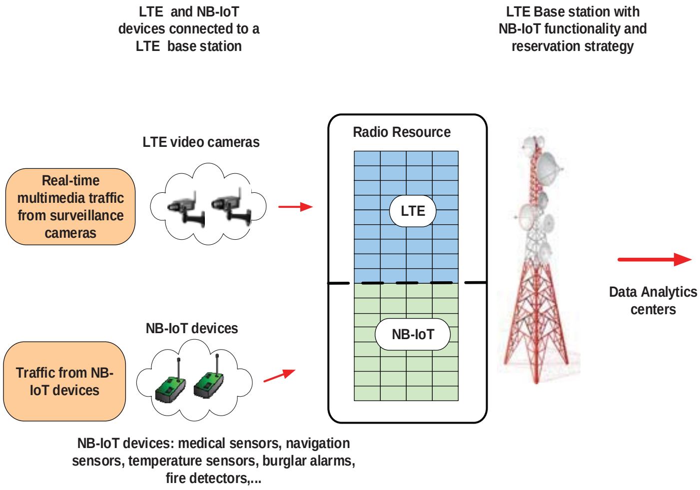

Fig. 1. Functional model of data collection and transmission in LTE networks

The amount of available radio resources of an LTE cell in the uplink direction is measured in units of the resources required for servicing the incoming request with the minimum requirement. Let us call this a channel or resource unit. The amount of resource blocks is a linear function of the total number of channels. A cell has several LTE devices and NB-IoT devices connected to a corresponding base station. LTE devices and NB-IoT devices are the sources of data transmission sessions obtained in the process of measuring the performance characteristics of the monitored technical systems. To construct a model in this paper, the methodologies given in [15-17] are used.

3. Mathematical model

We denote by v the total number of resource units (channels), and by c we denote the transmission speed in bits per second provided by one channel. The value of c usually corresponds to the minimum bit rate required for servicing one incoming request. Let us denote by $C$the maximum data rate provided by the LTE equipment in the uplink direction. $C = c \cdot v$.

In the model, we consider n streams of requests for servicing communication sessions of LTE devices and one stream of requests for servicing communication sessions of NB-IoT devices. Each flow is a combination of multiple communication sessions from a large number of independent devices of the same type. Therefore, based on the principles of probability theory, the Poissonian model can be used to describe the process of incoming requests.

Let us describe the characteristics of requests from LTE-devices incoming and servicing. The communication session properties of the cameras depend on several parameters. First and foremost, it is important to consider the characteristics of the codec (for example, using the H.264 codec), buffering data before sending (for example, using methods of traffic shaping). In the case of H.264, the average camera rate will be around 1.4 Mbps when we transmit a stream in HD resolution of 1080P and at an average level, without changing other parameters.

Let us consider the *k*-th flow originated from a large number of LTE-devices, $k=1,2,\ldots,n$. The time between successive requests arrival is exponentially distributed with parameter λ_k. Let us denote by α_k the parameter of exponentially distributed time of request servicing. The intensity of offered traffic is calculated as following $a_k=\frac{\lambda_k}{\alpha_k}$, $k=1,2,\ldots,n$. This parameter is expressed in the potential number of connections called Erlangs.

Let us describe the characteristics of requests from NB-IoT-devices incoming and servicing. Such devices use a low data rate and their number assigned to the LTE base station is very large. About 50 thousand NB-IoT devices can be connected to a single LTE macro base station according to the 3GPP partnership project, with a range of 1 km. The resources of such a base station are sufficient to service consumers in densely populated urban areas, where there are approximately 1,500 households per square kilometer each with approximately 40 sensors. NB-IoT technology allows sending only short messages of about 20-256 bytes in a message several times a day.

The volume of the transmitted file containing the results of measurements has an exponential distribution with a mean value of *F*, expressed in bits. The service time of one request from NB-IoT devices on one channel has an exponential distribution with the parameter $\mu_d=\frac{F}{c}$. Let us denote by N_d the number of NB-IoT devices and by Υ_d the intensity of the arriving request from one sensor. We assume that the arriving requests from NB-IoT devices follow the Poisson law with intensity $\lambda_d=N_d\Upsilon_d$.

4. Resource reservation scenarios

The mathematical model takes into account the heterogeneity of the arrival of requests and their intensity depends on the number of users in an LTE cell. The process of conjoint servicing of data traffic and real-time data streams in an isolated LTE cell supporting IoT functionality should take into account the resource requirements of different requests. Otherwise, the servicing of applications with lower requirements for the information resource is suspended in favor of applications with large requirements, i.e. there is a threat of uncontrolled redistribution of the information transmission resource. There are scenarios that can be used to eliminate such shortcomings:

1. Restricting access requests. In this case, the decision to accept a request in servicing can be made based on information about the number of requests under consideration during its service.
2. Restrictions on access requests based on the total number of occupied channel units. In teletraffic theory, such a method of distribution of the information transmission resources is called resource reservation.

Reservation is one of the ways to control resource allocation. There are different methods for assessing the efficiency of using the methods of allocating resources with reservation. Consider the reservation process to control the distribution of the information transmission resources. Each flow is associated with an integer θ_k, $k=1,2,\ldots,n$ called the reservation threshold for request of the *k*-th flow. When a request arrives from the *k*-th flow, we firstly determine how many resource units are occupied by transmitting requests for all types of flows. Let us denote this value by the symbol *i*. If the inequality $i>\theta_k$ is true, then the request for the *k*-th flow is considered lost and it will not be resumed. Otherwise, the request is accepted for servicing. This approach of reservation is the traditional method of resource reservation. An extension of the traditional reservation method is achieved by using the interlocking functions $\varphi_k(i)$, $k=1,2,\ldots,n$ and $\varphi_d(i)$.

The corresponding interlocking function for each incoming request sets the probability of failure for servicing, which depends on the total number of occupied resource units. Such mechanism makes possible to study various reservation schemes for a given network, including the traditional method reservation introduced above by varying the value of the probability of failure.

Let us denote by $\varphi_k(i)$ and $\varphi_d(i)$ probabilities interlocking functions defined for each possible state $(i_1,i_2,\ldots,n,d)$. The interlocking function $\varphi_k(i)$ will be used to filter the access process requests originated from video cameras and other LTE devices to the resource, depending on the total number of occupied resource units *i*. The interlocking function $\varphi_d(i)$ will be used to filter the access process requests originated from NB-IoT devices to the resource. Let us denote by Ω the set of all theoretical possible states in which the random process $r(t)$ describes the dynamic of state's changing of the constructed model. The real set S of states is a subset of Ω and is determined by the choice of the interlocking functions $\varphi_k(i)$ and $\varphi_d(i)$. In this case, the arrival request from the *k*-th flow in one of the possible states $(i_1,i_2,\ldots,n,d)\in S$ is accepted for servicing with probability $1-\varphi_k(i)$. The arrival request for servicing is lost without resuming with probability $\varphi_k(i)$. If there are no free resource units in the system, then the incoming request of the *k*-th flow is rejected with a probability equal to one $\varphi_k(i)=1$, $i=v-b_k+1, v-b_k+2, \ldots, v$. The arrival request from NB-IoT requests is accepted for servicing with probability $1-\varphi_d(i)$. The arrival request for servicing in this case is lost without resuming with probability $\varphi_d(i)$. The interlocking function, which is used to implement reservation algorithms, allows the concept of "soft reservation" to be introduced with a lower probability of blocking in contrast to hard reservation (traditional reservation) when arrival request for servicing is denied with a probability equal to one due to exceeding the reservation threshold. Therefore, the use of the soft reservation method makes possible to implement resource reservation for priority flows, as well as preserve the ability to receive non-priority requests for servicing.

5. Markov process

Let us represent the random process of changing the states of the constructed model as the transition from state to state, which is carried out under the influence of request streams incoming and outgoing. We donate by $i_k(t)$ the number of requests originated from *k*-th flow of real time devices and by $d(t)$ we denote the number of requests originated from NB-IoT low-rate end devices. The $i_k(t)$ and $d(t)$ are being on servicing at time *t*. A multidimensional Markov process with components $r(t)=(i_1(t),i_2(t),\ldots,i_n(t),d(t))$ describes the dynamic of states changing of constructed model. The components of the Markov process are defined on the finite set S of model states. The vector $(i_1,i_2,\ldots,i_n,d)$ belongs to S when $i_1,i_2,\ldots,i_n,d$ varies as follows

$$i_1=0,1,\ldots,\min\left(\infty,\left\lfloor\frac{v}{b_1}\right\rfloor\right);$$

$$i_2=0,1,\ldots,\min\left(\infty,\left\lfloor\frac{v-i_1b_1}{b_2}\right\rfloor\right);\ \ldots;$$

$$i_n=0,1,\ldots,\min\left(\infty,\left\lfloor\frac{v-i_1b_1-\ldots-i_{n-1}b_{n-1}}{b_n}\right\rfloor\right);$$

$$d=0,1,\ldots,v-i_1b_1-\ldots-i_nb_n.$$

6. Performance measures

Let us denote by $p(i_1,i_2,\ldots,i_n,d)$ the value of the stationary probability of the state $(i_1,i_2,\ldots,i_n,d)\in S$. The portion π_k of lost requests of the *k*-th flow originated by LTE-devices is equal to the portion of time when amount of free resource units is insufficient for accepting a call from the *k*-th flow or an incoming request from the *k*-th flow is denied due to resource reservation in favor of other type of requests. The value of this characteristic is determined as follows

$$\pi_k=\sum_{\{(i_1,i_2,\ldots,i_n,d)\in S\}}p(i_1,i_2,\ldots,i_n,d)\varphi_k(i)\cdot$$

For any $k=1,2,\ldots,n$, the mean number m_k of resource units occupied by servicing the requests of the *k*-th flow and the mean number y_k of requests from the *k*-th flow that are being serviced are determined as follows

$$m_k=\sum_{\{(i_1,i_2,\ldots,i_n,d)\in S\}}p(i_1,i_2,\ldots,i_n,d)i_kb_k\,;$$

$$y_k=\sum_{\{(i_1,i_2,\ldots,i_n,d)\in S\}}p(i_1,i_2,\ldots,i_n,d)i_k\,.$$

Let us introduce the performance measures for requests originated from NB-IoT devices into the model, which takes into account the algorithm for reservation resources in favor of NB-IoT. The portion π_d of lost requests originated by NB-IoT devices is equal to the portion of time when amount of free resource units is insufficient for accepting a request. The value of this characteristic is determined as follows

$$\pi_d=\sum_{\{(i_1,i_2,\ldots,i_n,d)\in S\}}p(i_1,i_2,\ldots,i_n,d)\ {}_d$$

The mean number m_d of resource units occupied by servicing the incoming requests and the mean number y_d of requests that are being serviced are determined as follows

$$m_d=\sum_{\{(i_1,i_2,\ldots,i_n,d)\in S\}}p(i_1,i_2,\ldots,i_n,d)d\,;$$

$$y_d=m_d\,.$$

The introduced characteristics of performance measures for incoming requests are easily determined by the already known values of stationary probabilities $p(i_1,i_2,\ldots,i_n,d)$ of state $(i_1,i_2,\ldots,i_n,d)$. The $p(i_1,i_2,\ldots,i_n,d)$ values are found by solving the system of equilibrium equations (1).

7. Equilibrium state probabilities

The system of state equations is constructed by equalization the intensity of transition $r(t)$ into the considered state $(i_1,i_2,\ldots,i_n,d)$ to the intensity of transition of $r(t)$ out of the arbitrary model's state $(i_1,i_2,\ldots,i_n,d)$. The state of the model under consideration can be changed by the following events: arrival of new request for servicing from LTE and NB-IoT devices, completion of servicing for requests accepted for servicing. We represent all of the equations in the system of state equations in the form of a single relation by using the indicator function $I(\ )$. This representation form of equilibrium equations is convenient for implementing iterative methods for solving the corresponding system.

$$\begin{aligned}&P(i_1,i_2,\ldots,i_n,d)\Big\{\sum_{k=1}^{n}\big(\lambda_k(1-\varphi_k(i))+i_k\alpha_kI(i_k>0)\big)+\\&+\big(\lambda_d(1-\varphi_d(i))+d\alpha_dI(d>0)\big)\Big\}=\\&=\sum_{k=1}^{n}P(i_1,i_2,\ldots,i_k-1,\ldots,i_n,d)\lambda_k(1-\varphi_k(i-b_k))I(i_k>0)+\\&+P(i_1,i_2,\ldots,i_k,\ldots,i_n,d-1)\lambda_d(1-\varphi_d(i-1))I(d>0)+\\&+\sum_{k=1}^{n}P(i_1,i_2,\ldots,i_k+1,\ldots,i_n,d)(i_k+1)\alpha_kI(i+b_k\le v)+\\&+P(i_1,i_2,\ldots,i_k,\ldots,i_n,d+1)(d+1)\alpha_dI(i+1\le v).\end{aligned}\qquad(1)$$

Values $p(i_1,i_2,\ldots,i_n,d)$ satisfy the normalizing condition

$$\sum_{\{(i_1,i_2,\ldots,i_n,d)\in S\}}p(i_1,i_2,\ldots,i_n,d)=1\cdot$$

The stationary probability of any state can be found by solving the system of equations (1) and by using some numerical methods. The matrix of the system of equilibrium equations (1) does not have any special properties, then it is recommended to use iterative methods to solve the system of equations (1). The Gauss-Seidel iterative algorithm is one of the iterative algorithms, which are used to solve the system of equations (1). The implementation of the iterative Gauss-Seidel method consists of the following.

$$P^{(x+1)}(i,i_1,i_2,\dots,i_n,d)=\frac{1}{L(i,i_1,i_2,\dots,i_n,d)}\times$$
$$\times\Big\{\sum_{k=1}^{n}P^{(x,x+1)}(i,i_1,i_2,\dots,i_k-1,\dots,i_n,d)\lambda_k\times$$
$$\times(1-\varphi_k(i-b_k))I(i_k>0)+$$
$$+P^{(x,x+1)}(i,i_1,i_2,\dots,i_k,\dots,i_n,d-1)\lambda_d(1-\varphi_d(i-1))I(d>0)+$$
$$+\sum_{k=1}^{n}P^{(x,x+1)}(i,i_1,i_2,\dots,i_k+1,\dots,i_n,d)(i_k+1)\alpha_k I(i+b_k\le v)+$$
$$+P^{(x,x+1)}(i,i_1,i_2,\dots,i_k,\dots,i_n,d+1)(d+1)\alpha_d I(i+1\le v)\Big\}.$$

Where

$$L(i,i_1,i_2,\dots,i_n,d)=\sum_{k=1}^{n}\big(\lambda_k(1-\varphi_k(i))+i_k\alpha_k I(i_k>0)\big)+$$
$$+\big(\lambda_d(1-\varphi_d(i))+d\alpha_d I(d>0)\big)$$

In accordance with the definition of the Gauss-Seidel iterative algorithm [16] the components of (x+1)-th approximation are determined from the already known components of (x+1)-th and x-th approximations.

8. Numerical assessment

Let us consider a base station BTS located in the center of the cell. The incoming requests use the resource of the base station according to service-level agreement SLA. The resource allocated to one request does not depend on the distance between the base station and the devices. We assume that the data traffic originated from LTE devices has priority in occupying the transmission capacity of BTS. Let us consider one type of LTE device, $v=50$ channel units, 5 channel units are required for servicing one request from LTE devices, i.e. $b=5$ channel units, the intensity of offered traffic $a=4$ erlangs. The offered load per one channel $\rho=0.8$. In this model one channel unit is required for servicing one request from NB-IoT devices and the intensity of offered traffic for this type of requests $a=20$ erlangs.

The figure 2 shows reservation threshold value obtained in favor of requests originated from LTE-devices. The figure 2 shows that with decreasing the value of θ the loss request of data increases and the loss of request for real time decreases.

The solution obtained with $\theta=39$ channel units provides the required quality of service for applications of the requests from LTE video cameras ($\pi\le 0.05$), but does not guarantee such quality of service for applications of the requests from NB-IoT devices, because their losses are quite large. For $\theta=39$ channel units, portion π_d of loss requests from NB-IoT devices is 0.25. The increase of θ improves the quality of service for applications of the requests originated from NB-IoT devices.

The constructed model can be used to solve such problems, but the predefined quality of serving priority traffic is achieved by increasing the losses for non-priority traffic.

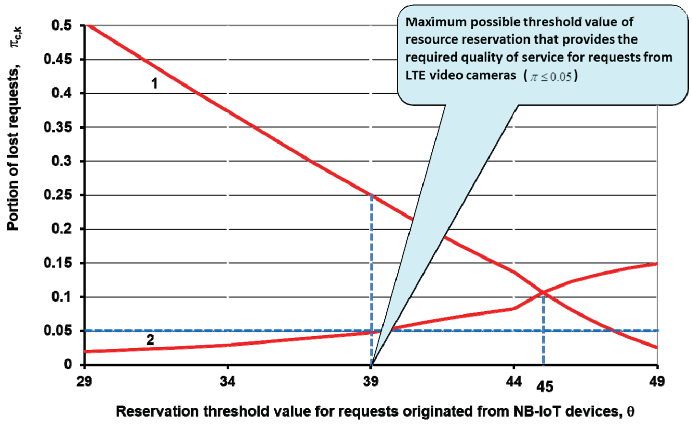

Fig. 2. The portion of lost requests depending on the threshold value of NB-IoT requests

An analysis of reservation strategy efficiency is shown in the figure 3. The following parameters are used: $n=4$; $b_k=1,5,10,20$ channel units; $a_k=200/nb_k$ erlangs; $k=1,2,3,4$; $\theta=v-b$ where $b=20$ channel units for every type of requests. The reservation stategy equalizes the loss of requests compared to the unrestricted access used in the Erlang multiservice model, but some of the requests are lost. This leads to a decrease in the resource unit utilization factor.

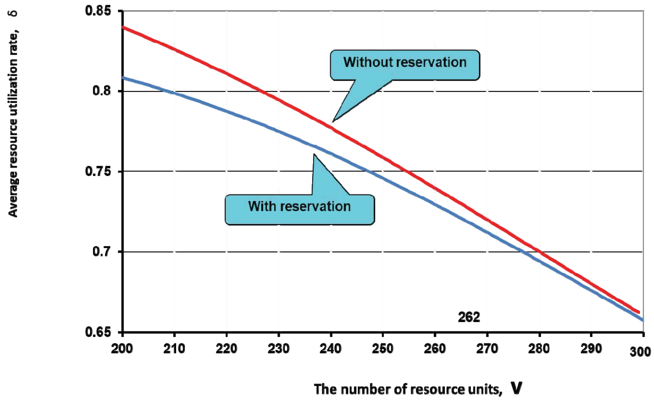

Fig. 3. Dependance of δ on the number of resource units

Conclusion

The model that takes into account the priority for one type of requests according to the SLA operator is constructed in this work. The intensity of arrival requests depends on the number of available devices. The Poisson model is used to describe the process of incoming requests from both types of devices (for real time service and for data traffic service). The duration of servicing of requests for real time and data transmission has an exponential distribution with parameter α_k and α_d respectively. The arrival request for serving originated from LTE devices is rejected only if the resource unit is insufficient. When a request from data traffic transmission arrives for servicing, there is a probability $\varphi_k(i)$ of non-servicing because some number of channels are reserved for real time traffic. The formal definitions of the main performance measures of conjoint traffic transmission are formulated in the framework of the constructed model using values of probabilities of the model's stationary states. The constructed model can be used to determine the characteristics of the model with reservation in the isolated cell of the LTE network. The constructed model can be used to solve reservation problems for specific types of requests, but the predefined quality of servicing priority traffic is achieved by increasing the losses for non-priority traffic.

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МОДЕЛЬ РАСПРЕДЕЛЕНИЯ РЕСУРСОВ С РЕЗЕРВИРОВАНИЕМ ДЛЯ LTE ТЕХНОЛОГИИ С ФУНКЦИОНАЛЬНОСТЬЮ NB-IOT

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Аннотация

Большой рост объема мультимедийных данных, создоваемые видеокамерами и большим количеством датчиков или интеллектуальных счетчиков Интернета вещей, является одной из основных задач при переходе от 4G к сетевым системам 5G. Необходимость совместного обслуживания разнородных данных в рамках существующей инфраструктуры была поддержана 3GPP путем формализации технологии узкополосного Интернета вещей (NB-IoT). NB-IoT является наиболее перспективной технологией Интернета вещей для сбора больших данных благодаря своим особым характеристикам, таким как дальность действия, высокое энергоэффективное потребление и недорогая конструкция радиосвязи. Один и тот же спектр делится между высокоскоростным оконечным оборудованием LTE и низкоскоростными оконечными устройствами NB-IoT. Однако главная задача заключается в том, как эффективно распределять доступные радиоресурсы между несколькими устройствами с приоритетами в обслуживании определенного типа потока данных. Построена модель разделения ресурсов для совместного обслуживания трафика, исходящего от камер видеонаблюдения, так и от датчиков. Управление доступом предоставляющее приоритет одному типу потоков используется для создания дифференцированного обслуживания входящих сеансов. Значения вероятностей стационарных состояний построенной модели используются для определения основных показателей эффективности. Построенная математическая модель может использоваться для изучения сценариев распределения ресурсов с резервированием в гетерогенных сетях LTE с функциональностью NB-IoT.

Ключевые слова: *Интернет Вещей, "Умный дом", ZigBee, люди с ограниченными возможностями, пожилые люди, автоматизация.*

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