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THE SERVICE REQUIRED QUALITY ENSURE MODEL OF LTE TECHNOLOGY DOWNLINK

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У статті запропонована математична модель розподілу ресурсних блоків у низхідному каналі зв’язку технології LTE. Запропонована модель спрямована на забезпечення гарантованої якості обслуговування користувачів безпроводової мережі шляхом виділення для користувацьких станцій необхідних швидкостей передачі. Проведено порівняльний аналіз отриманих рішень при використанні різних цільових функцій

Ключові слова: LTE, математична модель, необхідна швидкість передачі, цільова функція, ресурсний блок

В статье представлена математическая модель распределения ресурсных блоков в нисходящем канале связи технологии LTE. Предложенная модель направлена на обеспечение гарантированного качества обслуживания пользователей беспроводной сети путем выделения пользовательским станциям требуемых скоростей передачи. Проведен сравнительный анализ получаемых решений при использовании различных целевых функций

Ключевые слова: LTE, математическая модель, требуемая скорость передачи, целевая функция, ресурсный блок

1. Introduction

In LTE developed by 3GPP, one of the effective ways of productivity and quality of service (QoS) increasing is network protocols and mechanisms responsible for available net resources improvement. They are, first of all, time resource – OFDM-symbols and frequency resource – subcarrier. OFDM-symbol is period of time during of which amplitude and phase of modulated subcarriers is constant. The task solving about radio resources allocation is based upon requirements to QoS and can be placed on radio resources management (RRM) system, upon scheduler inside the system. In LTE as well as in HSDPA or WiMAX, mechanisms of downlink resources are not defined by the standard, leaving the choice behind the evolved NodeB (eNodeB) equipment producers [1 – 3].

The result of the task solution about allocation of frequency and time resources must be allocation resource block (RB) to user equipment (UE) in download of a single frame. Resource block is the least structure element, allocated by a single UE [4].

In the given research work we analyzed methods of frequency and time allocation, with the algorithm Round Robin Scheduler [3, 5 – 10]. Round Robin Scheduler algorithm using supposes equal allocation of frequency and time resource for every UE. In basis realization Round Robin Scheduler allocates to every UE time interval, under which this UE gets monopoly access to the channel. While this rate of data transmission UE is confined by factual meaning of signal to noise ratio (SNR). We also analyzed methods [5, 6, 8 – 10] using algorithm Max C/I Ration, providing frequency and time resource UE with the best SNR meaning, without securing fair allocation the resource between UE. Besides, we analyzed methods of frequency and time allocation, using algorithm of Proportional Fair Scheduling [5 – 10]. The conducted analysis showed that Proportional Fair Scheduling promotes UE which has high SNR meaning, simultaneously providing enough quantity of frequency and time resources UE with worse meaning of SNR.

Analysis showed that the most favorable mechanism for giving access to frequency and time resource LTE would be mechanism, including peculiarities of Round Robin Scheduler and Max C/I Ration algorithms. The choice of algorithm depends on category and load intensity. The right choice of algorithm for giving access is particularly important under high intensity.

At the result of analysis we estimated that using Proportional Fair Scheduling algorithm is directed to apply interactive “best effort” data class to avoid situation when some UE never get access to frequency and time resource. The given class of service (CoS) usage secures data delivery UE as far as possible without data transmission rate guarantee. Improvement the service quality under frequency and time resource scheduling of every UE must be directed upon guaranteed transmission rate with access availability to additional (non-guaranteed) after bandwidth line. However none of analyzed mechanisms is able to secure such CoS.

At the result of conducted analysis we made decision about necessity of frequency and time resource model in downlink LTE scheduling, formulated as allocation resource blocks task for securing guaranteed rate of UE.

2. Model of Resource Block Allocation in Downlink

The offered model is directed for application in wireless networks LTE, using frequency and time channel division. At the model development we consider the fact that the least structure unit of radio resource to be managed at the scheduling task solving RB [1].

By developing of mathematical model it takes into account the fact that as the core UE access technology to frequency and time resources in LTE technology it was chosen multiple access with orthogonal frequency division (Orthogonal Frequency Division Multiple Access, OFDMA), based on Orthogonal Frequency Division Multiplexing (Orthogonal Frequency Division Multiplexing, OFDM) [1 – 2]. In this case, the smallest structural unit of radio resource, which can be controlled by solving task of planning which is RB [1].

Each RB occupies 12 neighboring OFDM subcarriers in frequency domain, and one slot (0.5 ms) in time domain consisting of six or seven OFDM-symbols (the smallest structural unit of the OFDM time domain).

In offered model are given as known following data:

N –UE number;

1) M –the number of RB, generated during transmission of one time slot;

2) K_s – the number of subcarriers for transmission of data in one RB. This parameter depends on frequency separation between subcarriers Δf and must satisfy kHz condition $K_s \Delta f = 180$ kHz. K_s may take the values 12 and 24, which correspond to a frequency spacing subcarrier Δf in 15 kHz and 7,5 kHz;

3) N^{RB}_{symb} – the number of characters forming one resource block.

4) Parameter $N^{RB}_{symb}=7$ in the case of normal cyclic prefix usage. (cyclic prefix, CP). Duration of normal CP of first OFDM-symbol is $T^{1}_{CP}=5{,}2$ mks, and from the second till the sixth OFDM-symbol – $T^{2-6}_{CP}=4{,}7$ mks. By usage of extended CP ($T_{CP}=16{,}7$ mks) RB consists from six OFDM-symbols ($N^{RB}_{symb}=6$);

5) $T_{RB}=0{,}5$ ms – transferring time of one RB;

6) $R^{n,m}_{c}$ – code speed, used by signal coding n UE on subcarriers of m SB;

7) $k^{n,m}_{b}$ – symbol bit loading of n UE subcarriers of m SB;

8) R^{n}_{reg} – required data rate, for n UE;

While resource blocks allocation task solving within the scope of the offered model it is necessary to secure the calculation of boolean control variable ($x_{n,k}$) defining the order of allocation scheduling blocks:

$$x_{n,m} = \begin{cases} 1, & \text{if } m\text{-th scheduling block allocated } n\text{-th UE;} \\ 0, & \text{otherwise,} \end{cases} \quad (1)$$

where $m=\overline{0,M}$; $n=\overline{1,N}$.

At sought date calculation $x_{n,m}$ it is necessary to complete a number of conditions/constraints:

1) Condition of allocation m-th RB of downlink no more that to one UE:

$$\sum_{n=1}^{N} x_{n,m} \le 1 \ \ (m=\overline{0,M}). \quad (2)$$

2) Condition of allocation for n-th UE number of RB, securing necessary rate of transmission in downlink using scheme modulation and coding (MCS):

$$\frac{N^{RB}_{symb} K_s R^{n,m}_{c} k^{n,m}_{b}}{T_{RB}} \sum_{m=1}^{M} x_{n,m} \ge R_{req} \ \ (n=\overline{0,N}). \quad (3)$$

Calculation of the variables (1), in accordance with conditions-restrictions (2) and (3) is rationally to conduct in course of optimization problem solving providing minimum or maximum of pre-selected quality criteria of solving problems decision of frequency and time resources distribution in a wireless network LTE technology. To basic requirements for optimality criterion it is attributed, on the one hand, the correspondence of physical problem solving i.e. tasks of RB distribution and on the other, obtaining possibility of based on it practically workable solutions (results). Thus, the formulation of task should not be too complicated, and its solution must be known or developed an effective method. As a result of mentioned above of optimality criterion can be represented as:

$$\min f^{T} x , \quad (4)$$

where f – objective function.

Using of optimality criterion (4) it is aimed at minimizing the time-frequency resource allocated to all user stations. Selecting minimum number of time-frequency resource improves signal-noise conditions in used frequency band, and also provides availability of time-frequency resource for transmitting information required by new subscriber stations.

Quality of solution of the time-frequency resource distribution is also dependent on the type of objective function used in the optimization criteria (4).

Minimizing of used time-frequency resource can be ensured by providing the least amount of user stations of resource blocks taking into account constraint conditions (2) and (3). In this case, the objective function takes the form:

$$f_1 = \left[1,1,1,1,\ldots,1\right], \quad (5)$$

with the proviso that the number of elements in the vector f_1 corresponds to the number of elements in the vector x and all of them are equal to one.

Moreover task of minimizing of used time-frequency resource number can be solved by using objective function to minimize transmission rate allocated to all user stations. Such objective function may be represented as:

$$f_2 = \left[r_{1,1}, r_{1,2}, \ldots, r_{n,m}, , \ldots, r_{N,M} \right], \quad (6)$$

where $r_{n,m} = \dfrac{N^{RB}_{symb} K_s R^{n,m}_{c} k^{n,m}_{b}}{T_{RB}}$ – transmission rate, allocated by n on m-resource block.

In solving problem of saving time-frequency resource also can also be used objective function, which includes characteristics of target function (5) and (6), which takes the form:

$$f = f_1 + f_2 . \quad (7)$$

Using target function (7) is directed to a joint minimization of used resource blocks and transmission rate allocated to user stations in a downlink.

The problem formulated from a mathematical point of view, the use of the objective function (5) is an integer linear programming (Linear Integer Programming, LIP), and use of objective functions (6) and (7) a linear programming (Linear Programming, LP). In the model unknown variables $x_{n,m}$ (1) are Boolean, and constraints (2) and (3) to desired variables are linear.

3. Analysis of time-frequency distribution of the resource by using various kinds of the objective function solutions

In order to assess the quality of solutions in the allocation of time-frequency resource within the offered model (1-4) let us consider solutions to optimization problem using objective function of different variants.

In the offered model there were formulated three options for objective function:

- available time-frequency resource distribution with the goal of allocation to minimum number of resource blocks (objective function (5));

- available time-frequency resource distribution with the goal of minimum rate allocation to all user stations (objective function (6));

- available time-frequency resource distribution in order to minimize amount of joint use of resource blocks and transmission rate allocated to user stations in downlink (objective function (7)).

For solution results analysis of resource block allocation in a broadband wireless LTE technology using various embodiments of objective function as raw data have been used the following:

- number of user stations $N=4$;
- demultiplexing type– TDD;
- RB number, generated during transmission of one time– $M=12$;
- the number of subcarriers for transmitting data to a subchannel – $K_s=12$;
- frequency separation between subcarriers – $\Delta f \approx 15$ kHz;
- number of symbols forming one resource block – $N^{RB}_{symb}=7$;
- required transmission rate for maintenance n user's station (Mbps) – $R^1_{req}=1$; $R^2_{req}=1$; $R^3_{req}=2$; $R^4_{req}=1$.

Let us imagine result of problem solving of resource blocks allocation by using objective function (5). As we can see from results obtained (Fig. 1) to provide desired data transmission rate to user stations nine resource blocks are allocated. Thus to the first, second and third user station are allocated two resource blocks, and to the thirds of user stations three resource blocks. However, three resource blocks are unused and may be used by connecting new subscriber stations. It was also found transmission rate allocated to user stations using objective function (5) exceeds desired bit rate of each subscriber stations.

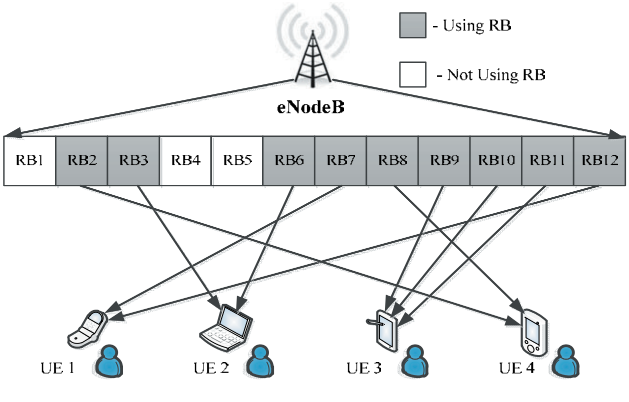

Fig. 1. An example of objective function use (5)

Results of solving using problem of objective function (6) are shown in Fig. 2. By using of objective function (6) the transfer rate of user stations was very close to required and not much higher than it. In the simulation result it was found that to the first subscriber station it has been allocated four resource blocks, to the second subscriber station two resource blocks, and to the third and fourth three resource blocks. Total number of resource blocks allocated to user stations was twelve, which corresponds to total number of downlink. Thus there is no possibility to connect new subscriber stations for data transmission used in downlink.

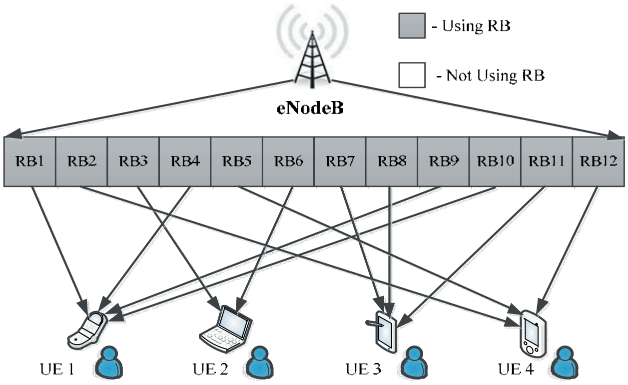

Fig. 2. Example of objective function use (6)

Fig. 3 shows results of allocation of resource blocks using objective function (7). Analysis of obtained solution results showed by using objective function (7), as in the case of using objective function (5), all user stations were given nine of the twelve available resource blocks. Thus the first, second and third user stations were given two resource blocks, and the third user station three resource blocks. In this case, three resource blocks remain available for connection for new user stations.

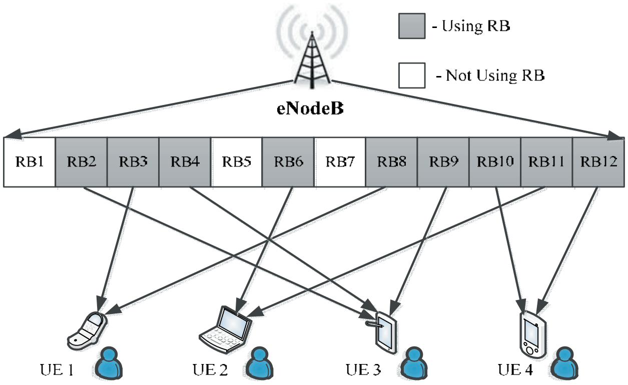

Fig. 3. Objective function use example (7)

4. Conclusions

It was found that one of the main challenges in wireless network operating along with using LTE technology is the task of required quality of service ensuring which includes need for a network user stations required transmission rate in the downlink. In this regard distribution resource blocks mechanisms were being analyzed between user stations in a downlink wireless network operates using LTE technology. Analysis of mechanisms showed all of them are focused on use of interactive «best effort» class data, by which it may be a situation where some user stations never have access to time-frequency resources. Use of this class of service (Class of Service, CoS) ensures delivery of data to user stations how it is possible without warranty data transmission rate. Improving quality of service by planning time-frequency resource of each UE should be directed to providing of guaranteed rate with access to additional (non-guaranteed) bandwidth. However, none of the analyzed arrangements can't ensure such CoS.

Based on identified drawbacks of popular decisions a mathematical model was presented by range of linear constraint equations. Novelty of model lies in formulation of resource blocks distribution problem as the task of redistribution of available bandwidth downlink LTE technology for transmission of information in direction of user stations.

In article it was conducted analysis of optimization problem solutions of distribution of sub-channels by using couple of objective functions:

- distribution available time-frequency resource allocation to minimum number of resource blocks (objective function (5));
- distribution of available time-frequency resource allocation of minimum rate to all user stations (objective function (6));
- distribution of available time-frequency resource in order to minimize amount of resource blocks joint use and the transmission rate allocated to user stations in downlink (objective function (7)).

As an example it was obtained solution formulated in work of optimization problem using system MATLAB R2012b. During analysis, it was found use of target function (5) and (7) allows making minimum number of resource allocation units, and also provides desired transmission rate to all user stations. By this part of resource blocks are available for connection of new user stations.

The usage of the offered model is directed upon securing each UE guaranteed transmission rate in downlink with access possibility to additional (non-guaranteed) bandwidth. In service classes it corresponds subclass B CoS, when the other methods don't guaranteed required transmission rate what in service classes CoS corresponds to subclass A.

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