THE SERVICE QUALITY MODEL OF LTE TECHNOLOGY DOWNLINK

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Abstract

Presents a mathematical model of resource blocks distribution in LTE technology downlink. Offered model aims at providing guaranteed quality of service wireless users by user stations allocating of required transmission rates. Comparative analysis of obtained solutions by using different objective functions. Using various kinds of objective functions in offered model is directed to resource blocks allocation of minimum downlink or a minimum data transmission rate of each user station. It was found the greatest savings of time frequency resource allows objective function aimed at minimizing number of used resource blocks. The model offered in classes of service CoS corresponds to Class B each providing each user station a guaranteed transmission rate, with access to additional (non-guaranteed) bandwidth. Keywords: LTE; mathematical model, required rate, objective function, resource block.

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.

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 [1].

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) [2] - [3]. In this case, the smallest structural unit of radio resource, which can be controlled by solving task of planning which is RB [2]. 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 [4]:

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

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

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

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

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

8) $R_{трб}^{n}$ – 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

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

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

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

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

$$\frac{N_{symb}^{RB} K_s R_c^{n,m} k_b^{n,m}}{T_{RB}} \sum_{m=1}^{M} x_{n,m} \ge R_{req} \ \ (n = \overline{0,N}). \tag{3}$$

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).

$$\mathbf{min} \, f^T x \,, \tag{4}$$

where f – objective function.

Using of optimality criterion (4) it is aimed at minimizing the time-frequency resource allocated to all user stations.

In this case, the objective function takes the form.

$$f_1 = [1,1,1,1,..,1]. \tag{5}$$

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.

$$f_2 = \lfloor r_{1,1}, r_{1,2}, \ldots, r_{n,m}, \ldots, r_{N,M} \rfloor, \tag{6}$$

$$f = f_1 + f_2 \,. \tag{7}$$

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

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.

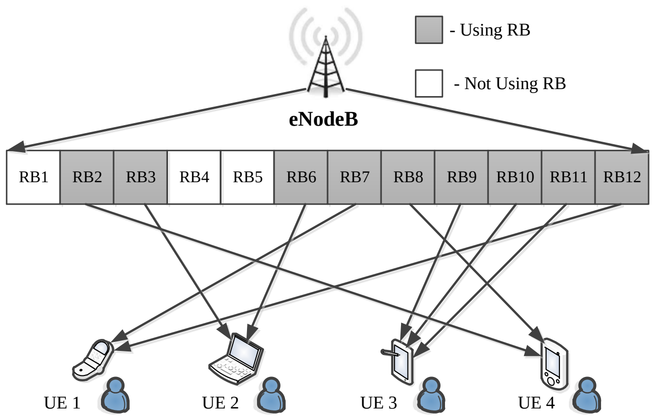

Fig. 1. An example of objective function use (5)

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.

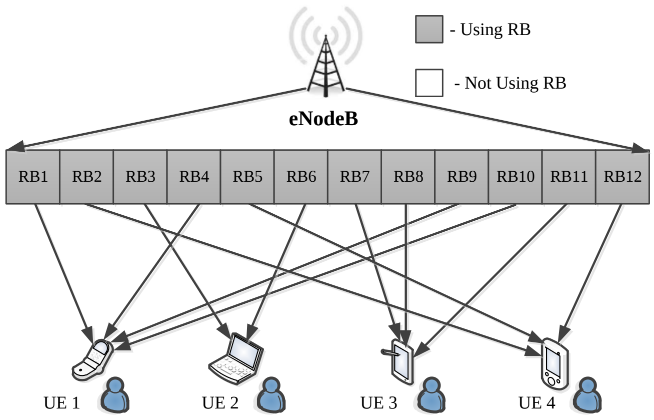

Fig. 2. Example of objective function use (6)

Fig. 3 shows results of allocation of resource blocks using objective function (7). Analysis of obtained solution results showed by using objective function (7).

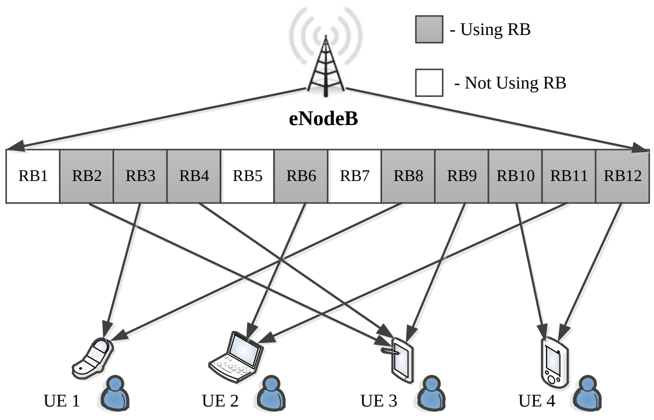

Fig. 3. Objective function use example (7)

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)).

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