MODEL RESOURCE ALLOCATION TYPE 1 IN DOWNLINK LTE

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Abstract

The results of development of the mathematical model for time-frequency resource allocation in the downlink of the LTE technology using the Resource Allocation Type 1 are given. Using the proposed model allows us to account the technological features of the LTE downlink (splitting the resource blocks into subsets, allocation of RB of only one subset to user equipment), as well as territorial remoteness of user equipment (type of modulation system and coding). During the analysis it was found that use of the proposed model is aimed at providing each user equipment with quality of service according to the bandwidth in the downlink with the possibility of access to additional (unguaranteed) bandwidth. The analysis of the proposed model for time-frequency resource allocation in the LTE technology from the viewpoint of providing the required bandwidths for user equipment in the downlink was conducted.

Keywords: LTE, time-frequency resource, resource block, scheduling block, mathematical model, required bandwidth, Resource Allocation Type 1.

1. INTRODUCTION

One of the most effective ways to improve performance and basic parameters of Quality of Service (QoS) in LTE technology (Long-Term Evolution) is to implement principles of optimal network resource allocation [1]. Such resources primarily include symbols (time resource) and frequency subcarriers (frequency resource). The smallest structural unit or a radio resource which can be allocated to any user equipment is a resource block (RB) [2]. In solving the problem of bandwidth allocation we must take into account the fact that LTE technology offers three resource allocation types (RATs). In [3, 4] models of resource blocks allocation in the LTE downlink, which uses zero recourse allocation type (RAT 0) are proposed. When using the RAT 0 each user equipment receives one or more allocated recourse block groups (RBGs) formed in accordance with the technological features of LTE. The number of RBs, belonging to one RBG (P), depends on the width of the frequency channel [5]. The main drawback of RAT 0 is that a number of RBs divisible by P parameter can be allocated for any user equipment in a downlink.

To make bandwidth control in the LTE downlink more flexible we propose to use the first resource allocation type (RAT 1). When using RAT 1 all the set of resource blocks is divided into several nonoverlapping subsets, the number of which is determined by P parameter.

The number of resource blocks in the subsets may vary [5]. As a result of the conducted analysis there was taken the decision on the need to develop a mathematical model for bandwidth management in the LTE downlink that uses the Resource Allocation Type 1 and it is formulated as a task of resource blocks allocation to provide the required bandwidth for each user equipment.

2. MODEL FOR DOWNLINK BANDWIDTH MANAGEMENT

The proposed model assumes that the following initial data are known:

1) N is the number of UEs;

2) K_S is the number of subcarriers for data transmission in a single RB. This parameter depends on the frequency diversion between subcarriers Δf and it must satisfy the term $K_S \Delta f = 180$ KHz. K_S can be equal to 12 and 24, that already correspond to the frequency diversion between subcarriers Δf as 15 KHz and 7.5 KHz;

3) N_{symb}^{RB} is the number of symbols that form a single resource block. Parameter N_{symb}^{RB}=7 in case of

using normal cyclic prefix (CP). Duration of the normal CP of the first OFDM symbol is T_{CP}^{1}=5.2 µs, from first to sixth OFDM symbol it is T_{CP}^{2-6}=4.7 µs. When using the extended CP (T_{CP} =16.7 µs) RB consists of six OFDM symbols (N_{symb}^{RB}=6);

4) T_{RB} =0.5 ms is time of one RB transmission;

5) T_{SF} =1 ms is time of one subframe transmission;

6) N_{SF}^{RB}=2 is the number of RBs that are formed on the identic subcarriers and are allocated to UE during the transmission of one subframe;

7) R_c^n is the rate of a code used in coding a signal of the *n*-th UE;

8) k_b^n is bit symbol load of the n -th UE;

9) type of channel division – FDD or TDD, and frame configuration used;

10) R_{req}^n is the required data transmission rate for *n*-th UE;

11) K is the number of subframes used to transmit information in the downlink. When using FDD the number of downlink subframes is equal to the total number of subframes per frame (K =10). When using TDD the number of downlink subframes must be in accordance with the frame configuration used (Table 1);

12) $N_{RB}^{RBG\text{subset}}(p)$ is power of the p -th subset;

13) P is the number of RBs belonging to a single RBG;

14) p is a current number of resource blocks subset for which calculation of its power is made ($p=\overline{0,P-1}$);

15) N_{RB}^{DL} is the number of RBs formed during the transmission of one time slot. In the LTE technology the number RBs depends on the width of the frequency channel and may be equal to: 6, 15, 25, 50, 75, 100;

16) $M=\max(N_{RB}^{RBG\text{subset}})$ is the largest number of resource blocks belonging to any subset.

To account for the number of subframes allocated for information transmission in the downlink [2, 6], the mathematical model uses the concept of downlink configurations matrix introduced in [3, 4]. The matrix is a rectangular with the number of lines corresponding to the number of configurations of the frame (L), and the number of columns corresponding to the number of subframes (K) in the frame, i.e.

$$H=\left\|h_{l,k}\right\|, \ (l=\overline{0,L-1};\ k=\overline{0,K-1}), \qquad (1)$$

where

$$h_{l,k}=\begin{cases}1, & \text{if the } k-\text{th subframe under the } l-\text{th configuration is used for information transmission in the downlink;}\\ 0, & \text{in the opposite case.}\end{cases}$$

When solving the task of downlink bandwidth management within the proposed model it is needed to provide the calculation of Boolean control variable ($x_n^{m,p}$), that determines the order of resource block allocation:

$$x_n^{m,p}=\begin{cases}1, & \text{if the } m-\text{th resource block on the } p-\text{th subset is allocated to the } n-\text{th UE;}\\ 0, & \text{in the opposite case,}\end{cases} \qquad (2)$$

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

When calculating the desired variables $x_n^{m,p}$ several important terms-limitations should be fulfilled:

1) The term of allocating each resource block to only one user equipment:

$$\sum_{n=1}^{N} x_n^{m,p}\le 1,\ (m=\overline{0,M-1};\ p=\overline{0,P-1}). \qquad (3)$$

2) The term of allocating a number of resource blocks to n -th user equipment that provide the required bandwidth in the downlink using modulation and coding scheme (MCS):

$$\sum_{m=0}^{M-1}\sum_{p=0}^{P-1} x_n^{m,p}\frac{N_{symb}^{RB}N_{SF}^{RB}K_S R_c^n k_b^n K}{10T_{SF}}\le R_{req}^n, \qquad (4)$$

at $n=\overline{1,N}$.

3) The term of allocating n -th user equipment a number of resource blocks of only one subset, which is introduced to satisfy the specifics of designing the LTE downlink that uses RAT 1:

$$x_n^{m,p}M+\sum_{j=p+1}^{P-1}\sum_{t=1}^{M-1}x_n^{t,j}\le M, \qquad (5)$$

at $n=\overline{1,N}$; $m=\overline{0,M-1}$; $p=\overline{0,P-2}$.

4) The term of allocating n -th user equipment a number of resource blocks that satisfy sizes of subsets determined using the expression (1):

$$\sum_{n=1}^{N}\sum_{m=N_{RB}^{RBG\text{subset}}(p)}^{M-1}x_n^{m,p}=0, \qquad (6)$$

at $p=\overline{0,P-1}$; $N_{RB}^{RBG\text{subset}}(p)<M$.

Use of the term (8) is directed to allocate a number of resource blocks, corresponding to the power of the *p*-th subset and determined with the expression (1), to UEs. Introduction of this term into the mathematical model is caused by the fact that during the calculation of control variables (4) for accounting the number of resource block we use a variable m, that takes values from 0 to $M-1$ ($m=\overline{0,M-1}$). Thus fulfillment of the term (8) guarantees that resource blocks which do not belong to the *p*-th subset ($m=\overline{N_{RB}^{RBG\text{subset}}(p),M-1}$), will not be allocated to

UEs in conditions when the power of this subset is less than maximum value ($N_{RB}^{RBG\text{subset}}(p) < M$).

The calculation of desired variables (2) according to the terms-limitations (3)-(6) is reasonable to make while solving the optimization task using optimality criterion directed at maximization of the overall downlink performance:

$$\max \sum_{n=1}^{N} \sum_{m=0}^{M-1} \sum_{p=0}^{P-1} x_n^{m,p} \frac{N_{symb}^{RB} N_{SF}^{RB} K_S R_c^n k_b^n K}{10 T_{SF}} . \qquad (7)$$

The task formulated from the mathematical point of view is the task of integer linear programming (ILP). In the model the desired variables $x_n^{m,p}$ (2) are Boolean, and restrictions for the desired variables (3)-(6) are linear.

3. Analysis of Solutions for Resource Blocks Allocation Task

As an example, the solution of the optimization task formed in the work was received using MatLab R2014a. The bintprog function of the Optimization Toolbox package was activated. Fig. 1 shows the dependence of allocation of bandwidth in the downlink between different user equipment under changing the desired value of one of them (the third UE).

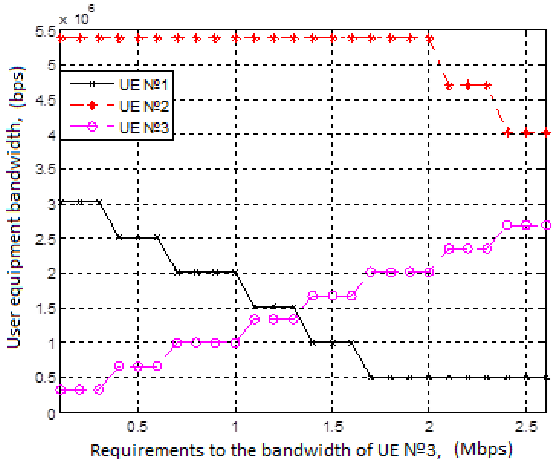

Fig. 1. Dependence of bandwidths allocated to UEs from change of the required bandwidth of the third UE

As simulation results showed at the measurement interval R_{req}^3 =0,1 ÷ 2 Mbps the second UE had the highest value of bandwidth, which was 5,376 Mbps (Fig. 1). This is explained by the fact that the second UE had the highest MCS value due to which all eight resource blocks of zero subset were allocated to it. Allocation of seven resource blocks of the first subset at the interval R_{req}^3 =0,1 ÷ 2 Mbps was made between the first and the third UEs. The bandwidth of the third UE was growing in accordance with increase of the required value from 0,336 to 2,016 Mbps. On the contrary the bandwidth of the second UE decreased from 3,024 to 0,504 Mbps due to the limitation of time-frequency resource (resource blocks), most of which were allocated to the third UE with the increase of R_{req}^3 .

At the measurement interval R_{req}^3 =2,1 ÷ 2,3 Mbps resource blocks of zero subset were allocated between the first and second user equipment. The bandwidth of the first UE was 0,504 Mbps, as only one RB was allocated to it, and the second UE was 4,704 Mbps (seven RB). All the seven resource blocks of the first subset were allocated to the third UE and its resulting bandwidth was 2,352 Mbps.

In case when R_{req}^3 took the value of 2,4 ÷ 2,6 Mbps all the eight resource blocks of zero subset were allocated to the third UE and its bandwidth was 2,688 Mbps. resource blocks of the first subset were allocated between the first and second UEs: one RB (0,504 Mbps) was allocated to the first UE and six RBs (4,032 Mbps) were allocated to the second UE. Under R_{req}^3 >2,6 Mbps the formulated task did not have a solution because it was impossible to provide all UEs with the required values of bandwidth.

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