Realization of Resource Blocks Allocation in LTE Downlink in the Form of Nonlinear Optimization

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Abstract - **In this paper proposed realization of resource blocks allocation in LTE downlink in the form of nonlinear optimization. In using improved model it is possible to avoid the control variables Boolean nature, which has a positive impact on the computational complexity of final technological solutions for resource allocation. Problem of RAT 1 was reduced to the problem solution of nonlinear optimization. In solving this problem minimized both the number of resource blocks used, and downlink bandwidth.**

Keywords - **Network, Channel, Resource Block, Bandwidth, Quality of Service, nonlinear optimization, LTE.**

I. Introduction

Nowadays the LTE (Long-Term Evolution) technology offered by 3GPP (3rd Generation Partnership Project) consortium is one of the most effective among solutions for high-speed multiservice access. This standard is seen as basis for the Fourth Generation of mobile telecommunications (4G) [1]. Performance of solutions in management on available network resources (frequency, time, channel, buffer, and information) determines performance of any telecommunication technology and based on mechanisms and protocols of all OSI (Open Systems Interconnection Basic Reference Model) layers. Basic layers that determine LTE technology performance are Physical and Data Link. Functions of allocation the network resource in LTE may be performed by the Radio Resource Management system (RRM), namely, the scheduler, which is responsible for allocating resources to user stations (User Equipment, UE). Such resources include symbols (time resource) and frequency subcarriers (frequency resource). As basic access technology of UE to frequency and time resources in LTE there is selected multiple access with orthogonal frequency division based on Orthogonal Frequency-Division Multiplexing (OFDM).

The smallest manageable structural radio resource unit used in self-organization is a Resource Block (RB). Each RB occupies 12 adjacent OFDM subcarriers in frequency domain and one slot (0.5 ms) in time domain, consisting of six or seven OFDM symbols (the smallest structural OFDM unit in time domain).

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The smallest structural element allocated to unique UE is Scheduling Block (SB), formed by two adjacent RBs with the same subcarriers and transmitted over a Transmission Time Interval (TTI) of 1 ms. The result of solving the problem of frequency and time resource allocation must be binding SB with UE in downlink frame transmitted over 10 ms. Thus, the task of planning time and frequency resources in LTE technology should be formulated as a problem of SB allocation among the UE network, depending on required rate and QoS parameters.

There are three Resource Allocation Types (RAT) used in LTE: RAT 0, RAT 1, RAT 2, suggesting the union of RBs in so-called Resource Block Groups (RBG). It is proposed to use RAT 1 to make bandwidth management in LTE downlink more flexible. When using RAT 1 the set of resource blocks is divided into several non-overlapping subsets, the number of which (N_{RB}^{DL}) is determined by RBG size (P parameter):

$$P = \begin{cases} 1, \text{ if } N_{RB}^{DL} \le 10; \\ 2, \text{ if } N_{RB}^{DL} = 11 \div 26; \\ 3, \text{ if } N_{RB}^{DL} = 27 \div 63; \\ 4, \text{ if } N_{RB}^{DL} = 64 \div 110. \end{cases} \quad (1)$$

The number of resource blocks in subsets may vary. To determine the number of resource blocks in subsets in LTE technology the following expression is proposed [1]:

$$N_{RB}^{RBGsubset}(p) = \begin{cases} \left\lfloor \dfrac{N_{RB}^{DL}-1}{P^2} \right\rfloor P + P, \\ \text{at } p < \left\lfloor \dfrac{N_{RB}^{DL}-1}{P} \right\rfloor \bmod P; \\ \left\lfloor \dfrac{N_{RB}^{DL}-1}{P^2} \right\rfloor P + \left(N_{RB}^{DL}-1\right) \bmod P + 1, \\ \text{at } p = \left\lfloor \dfrac{N_{RB}^{DL}-1}{P} \right\rfloor \bmod P; \\ \left\lfloor \dfrac{N_{RB}^{DL}-1}{P^2} \right\rfloor P, \\ \text{at } p > \left\lfloor \dfrac{N_{RB}^{DL}-1}{P} \right\rfloor \bmod P, \end{cases} \quad (2)$$

where $N_{RB}^{RBGsubset}(p)$ is power of the p-th subset; p is a current number of resource blocks in subset for which calculation of power is performed ($p=\overline{0,P-1}$); N_{RB}^{DL} is the number of RBs formed during the transmission of one time slot. In LTE technology the number of RBs depends on the width of frequency channel and may be equal to 6, 15, 25, 50, 75, 100.

As a result of performed analysis there was made a decision to develop a mathematical model for bandwidth management in LTE downlink using RAT 1, and it is formulated as a problem of resource blocks allocation for providing required bandwidth for each UE. In [2] proposed linear model of bandwidth allocation in LTE downlink with RAT 1 reduced to task of mixed integer linear programming (MILP). In this paper proposed an approach helps to reduce the computational complexity of the solution of initial problem, which is based on the modification of model proposed in [3].

II. Nonlinear Model of Bandwidth Allocation in LTE Downlink with RAT 1

In proposed model assumed that the following initial data are known:

N is the number of UEs;

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 corresponds to the frequency diversion between subcarriers Δf as 15 KHz and 7.5 KHz;

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 second 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);

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

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

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

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

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

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

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

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 used according to the frame configuration;

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

For solving the problem of bandwidth allocation in LTE downlink with RAT 1 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:

$$x_n^{m,p}=\begin{cases}1, \text{ if the } m-\text{th resource block on} \\ \text{the } p-\text{th subset allocated to the } n-\text{th UE;} \\ 0, \text{ otherwise,}\end{cases} \quad (3)$$

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:

$$\sum_{n=1}^{N} x_n^{m,p} \le 1, \; (m=\overline{0,M-1}; p=\overline{0,P-1}). \quad (4)$$

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

$$\sum_{m=0}^{M-1}\sum_{p=0}^{P-1} x_n^{m,p} \frac{N_{symb}^{RB} N_{SF}^{RB} K_S R_c^n k_b^n K}{10T_{SF}} \ge R_{тр6}^{n}, \quad n=\overline{1,N}. \quad (5)$$

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:

$$\sum_{s=0}^{P-2}\left[\prod_{p=s+1}^{P-1}\sum_{m=0}^{M-1} x_n^{m,p}\right]=0, \quad n=\overline{1,N}. \quad (6)$$

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

$$\sum_{n=1}^{N}\sum_{m=N_{RB}^{RBGsubset}(p)}^{M-1} x_n^{m,p}=0, \quad (7)$$

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

Use of the term (7) 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 (3) for taking into account the number of resource blocks we use a variable m, that takes values from 0 to $M-1$ ($m=\overline{0,M-1}$). Thus, fulfillment of the terms (6), (7) guarantees that resource blocks which do not belong to the p-th subset ($m=\overline{N_{RB}^{RBGsubset}(p),M-1}$), will not be allocated to UEs in conditions when the power of this subset is less than maximum value ($N_{RB}^{RBGsubset}(p) < M$).

The calculation of variables (3) according to the terms (4)-(7) is reasonable to make in solving the optimization problem using next optimality criterion [5]:

$$\min_{x} \sum_{n=1}^{N} \sum_{m=0}^{M-1} \sum_{p=0}^{P-1} \left[x_n^{m,p} r_{n,m} + x_n^{m,p} \right]. \qquad (8)$$

where $r_{n,m} = \frac{N_{symb}^{RB} N_{SF}^{RB} K_S R_c^n k_b^n K}{10 T_{SF}}$ is a bandwidth allocated by m-th RB to n-th UE.

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

III. Transformation to a Nonlinear Programming Problem

Solution of the mixed integer nonlinear programming problem with the increase of control variables (3) number caused by increase of UEs and RBs number can be much more complicated from a computational point of view. Therefore, it is proposed to formulate the problem of RBs allocation in the form of nonlinear programming problem by dropping the fact that control variables ($x_n^{m,p}$) are Boolean. For this purpose, the expression (3) is replaced by the conditions

$$0 \le x_n^{m,p} \le 1, \ (m = \overline{0, M-1};\ p = \overline{0, P-1};\ n = \overline{1, N}), \ (9)$$

i.e. introduced additional control variable $x_0^{m,p}$ that should be set to “1” in case when m-th RB is not allocated to any UE, and “0” otherwise.

In order to preserve the physical meaning of the model (4)-(7), which is in allocating the m-th RB of p-th subset to the n-th UE, it is necessary to ensure that the control variables $x_n^{m,p}$ assumed to have “0” and “1” values. For this purpose into model of RBs allocation introduced additional restrictions on the control variables:

$$\sum_{m=0}^{M-1} \sum_{p=0}^{P-1} x_n^{m,p} x_s^{m,p} = 0, \ (n, s = \overline{0, N},\ n \ne s), \qquad (10)$$

aimed to ensure that the m-th resource block is not allocated to two or more UEs at the same time. Also, to mathematical model was introduced restriction which together with (10) provides allocation of m-th RB to not more than one UE

$$\sum_{n=0}^{N} x_n^{m,p} = 1, \ (m = \overline{0, M-1};\ p = \overline{0, P-1}). \qquad (11)$$

Thus, despite the replacement of condition $x_n^{m,p} = \{0,1\}$ by (9) using (10) and (11) kept the physical meaning of control variables ensuring allocation of the m-th RB of p-th subset to the n-th UE. Application of improved model, implemented by noninteger control variable, made it easier to find an optimal solution of the problem and promoted the resource blocks allocation of downlink on practice in real time without losing its description adequacy.

Besides, as has been shown by analysis of existing solutions, in addition to solving problem of allocation of frequency and time resources can also be solved the problem of their joint allocation, which allows more accurately meet the requirements for bandwidth in the downlink of LTE technology.

IV. Conclusion

Improvement of the mathematical model of resource blocks allocation in LTE downlink with Resource Allocation Type 1 is proposed. In this model (1), (2), (5)-(11) it is possible to avoid the control variables $x_n^{m,p}$ Boolean nature, which has a positive impact on the computational complexity of final technological solutions for resource allocation. In general, the problem of RAT 1 was reduced to the problem solution of nonlinear optimization. In solving this problem minimized both the number of resource blocks used, and downlink bandwidth.

References

[1] 3GPP TS 36.211. 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical Channels and Modulation (Release 11), Valbonne, France: Sophia Antipolis, 2012.

[2] A.M.K. Al-Dulaimi, “Linear Model of Bandwidth Allocation in LTE Downlink with RAT 1,” *Second International IEEE Conference Problems of Infocommunications. Science and Technology*, pp. 82-85, October 2015 [Proceedings of PICS&T-2015, Ukraine, p. 272, 2015].

[3] M.K.H. Al-Dulaimi, A.M.K. Al-Dulaimi, O.S.Yeremenko, and H.D. Al-Janabi, “Bandwidth Management Model in LTE Downlink with Resourse Allocation Type 1,” *Systemy Obrobky Informatsiyi*, vol. 5(130), pp. 111-117, 2015.

[4] S. Garkusha, A.M.K. Al-Dulaimi, and H.D.K. Al-Janabi, “Result of Development of Model for Bandwidth Management in LTE Downlink with Resourse Allocation Type 1,” *XIIIth International conference, the exerience of designing and CAD system (CADSM’2015)*, pp. 409-413, February 2015.

[5] O.V. Lemeshko, A.M.K. Al-Dulaimi, “Development and analysis of bandwidth allocation linear model in LTE downlink with Resource Allocation Type 1,” *Telekomunikatsiyni ta informatsiyni tekhnolohiyi*, №4, pp. 5-11, 2015.