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Research Article

Priority Based Balancing Model of Resource Allocation in LTE Downlink

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Abstract: Investigation of priority based balancing model of resource allocation in LTE downlink supporting RAT 1 presented. The novelty of model is that it can be used to describe the process of resource blocks allocation in LTE downlink given user equipments requests priority. Using the model allows to optimize the process of resource allocation in LTE downlink in solving the problem by mixed-integer linear programming. The advantage of the model is that the balancing of resource blocks number allocated to each of user equipments is performed based on QoS requirements: demanded bit rate, priority and resource type (with or without guarantee). Results of research confirmed the efficiency of model and adequacy of obtained on its basis solutions.
Keywords: LTE; downlink; resource block; allocation; optimization; model.

INTRODUCTION

Nowadays LTE (Long-Term Evolution) technology can be applied in network solutions providing a wide range of different info communication services [1, 2] both delay sensitive real-time services as well as data communication. It should be noted, that these services have higher requirements for network resources: bandwidth, allowable values of average packet delay and degree of their losses. That's why optimization of processes Resource Blocks Allocation is an effective facility of improving Quality of Service (QoS) in LTE network [1, 3-5]. Resource Blocks (RBs) are time-frequency resources combined in Resource Block Groups (RBG) in implementation of different Resource Allocation Types (RAT); in solving the problem of resource blocks allocation the following must be taken into account:

- available resource is determined by the frequency channel bandwidth and operation mode of network equipment;
- in accordance with the standard [1] resource allocation implemented as one of three types (RAT 0 ÷ 2);
- Decisions on resource allocation must ensure balanced RBs allocation among User Equipments (UEs) due to their QoS requirements and service priority.

In this research proposed and investigated priority based balancing model of resource allocation in LTE downlink supporting RAT 1 with development and further improvement of solutions proposed in [6-8] using UEs priorities for better ensuring QoS-requirements.

BALANCING MODEL OF RESOURCE BLOCKS ALLOCATION IN LTE DOWNLINK USING RAT 1

With the using of 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):

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

The number of RBs in subsets may vary. In [1, 2] proposed the following expression to determine the number of RBs in subsets in LTE:

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

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

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 correspond 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 coding a signal 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 bit 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 blocks allocation:

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

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:

- the term of allocating each resource block to only one user equipment:

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

- 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:

$$x_n^{m,p} M + \sum_{\substack{j=0, \\ j \ne p}}^{P-1} \sum_{\substack{t=0, \\ t \ne m}}^{M-1} x_n^{t,j} \le M \ \text{ For } m = \overline{0, M-1}; \ p = \overline{0, P-1}; \ n = \overline{1, N}; \quad (5)$$

- 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):

$$\sum_{m=0}^{M-1} \sum_{p=0}^{P-1} x_n^{m,p} r_{n,m}^{p} \ge \delta_n R_{req}^{n}, \ (n = \overline{1, N}), \quad (6)$$

where $r_{n,m}^{p} = \dfrac{N_{symb}^{RB} N_{SF}^{RB} K_S R_c^n k_b^n K}{10 T_{SF}}$ is bandwidth allocated by m-th RB on the p -th subset to n-th UE;

$$\delta_n = \begin{cases} 1, \text{ if for } n-\text{th } UE \text{ service guarantee necessary;} \\ 0, \text{ otherwise.} \end{cases}$$

For optimal balancing the number of RBs allocated to each UE, the system introduced additional conditions limitations to the control variables $x_n^{m,\,p}$:

$$(Pr_n + 1) \sum_{m=0}^{M-1} \sum_{p=0}^{P-1} r_{n,m}^{p} x_n^{m,p} \ge \beta \cdot R_{req}^{n}, \ (n = \overline{1, N}), \quad (7)$$

where β is a control variable too, characterizing lower bound of satisfaction level of QoS requirements to bit rate; Pr_n is the n-th user equipment priority (Table I).

Table 1: Standardized QoS Class Identifier (QCI) characteristics [2]

QCI	Resource Type	Priority Level	Packet Delay Budget	Packet Error Loss Rate	Example Services
1	Guaranteed Bit Rate (GBR)	2	100 ms	10^{-2}	Conversational Voice
2		4	150 ms	10^{-3}	Conversational Video (Live Streaming)
3		3	50 ms	10^{-3}	Real Time Gaming
4		5	300 ms	10^{-6}	Non-Conversational Video
65		0.7	75 ms	10^{-2}	Mission Critical user plane Push To Talk voice
66		2	100 ms	10^{-2}	Non-Mission-Critical user plane Push To Talk voice
5	Non Guaranteed Bit Rate	1	100 ms	10^{-6}	IMS Signalling
6		6	300 ms	10^{-6}	Video, (Buffered Streaming), TCP-based
7		7	100 ms	10^{-3}	Voice, Video (Live Streaming), Interactive Gaming
8		8	300 ms	10^{-6}	Video (Buffered Streaming), TCP-based
9		9			
69		0.5	60 ms	10^{-6}	Mission Critical delay sensitive signalling
70		5.5	200 ms	10^{-6}	Mission Critical Data

The following restrictions imposed to the introduced variable

$$\beta \geq 0. \tag{8}$$

To improve the quality of service in LTE network in solving the problem of balancing the number of RBs allocated to UEs it is needed to maximize the lower bound meeting QoS requirements to bit rate, i.e.

$$\max_{x,\beta} \beta. \tag{9}$$

Thus, the model of balancing the number of RBs allocated to UEs in LTE downlink based on solution of optimization problem associated with maximizing the lower level allocated bandwidth to each user equipment (9) according to its QoS requirements for bit rate (6). As the constraints stated in solving the optimization problem are conditions (3)-(8). Formulated optimization problem belongs to class of mixed-integer linear programming, because some variables of (3) are Boolean, balancing variable (8) is a positive real variable, and objective function (9) and constraints (4)-(8) are linear.

INVESTIGATION OF BALANCING MODEL OF RESOURCE BLOCKS ALLOCATION IN LTE DOWNLINK

Within the investigation were considered the following input data:

- number of UEs is 4 ($N = 4$);
- channel bandwidth 3 MHz;
- number of RBs is 16 ($N_{RB}^{DL} = 16$);
- bit rates required for each of the UEs are $R_{req}^1 = 3$ Mbps, $R_{req}^2 = 3$ Mbps, $R_{req}^3 = 3$ Mbps, $R_{req}^4 = 3$ Mbps;
- UEs priorities ($Pr_1 = 1, Pr_2 = 3,\ Pr_3 = 5,\ Pr_4 = 7$);
- all UEs with Non GBR resource type;
- number of RBs in subsets $M = \max(N_{RB}^{RBGsubset}) = 8$ (0÷7);
- matrices of RBs bandwidths for subsets 0÷1 and UEs 1÷4:

$$\left\|r_{n,k}^0\right\| = \left\|\begin{matrix} 0.1 & 0.3 & 0.2 & 0.5 & 0.4 & 0.7 & 0.1 & 0.3 \\ 0.6 & 0.7 & 0.7 & 0.1 & 0.2 & 0.3 & 0.6 & 0.7 \\ 0.8 & 0.9 & 0.7 & 0.1 & 0.6 & 0.7 & 0.8 & 0.9 \\ 0.1 & 0.3 & 0.2 & 0.5 & 0.4 & 0.7 & 0.1 & 0.3 \end{matrix}\right\|,$$

$$\left\|r_{n,k}^1\right\| = \left\|\begin{matrix} 0.1 & 0.3 & 0.2 & 0.5 & 0.4 & 0.7 & 0.1 & 0 \\ 0.6 & 0.7 & 0.7 & 0.1 & 0.2 & 0.3 & 0.6 & 0 \\ 0.8 & 0.9 & 0.7 & 0.1 & 0.6 & 0.7 & 0.8 & 0 \\ 0.1 & 0.3 & 0.2 & 0.5 & 0.4 & 0.7 & 0.1 & 0 \end{matrix}\right\|.$$

Results of using model (1)-(9) for solving problem of bandwidth allocation in LTE downlink with Resource Allocation Type 1 based on the use of optimality criterion (9) shown in Table II.

During maximization of criterion (9) obtained the following results:

- first and third UEs use zero subset, while second and fourth UEs use the first subset;
- totally used 15 resource blocks;
- Procedure of bandwidth allocation for each UE is following: 2.6 Mbps, 1.5 Mbps, 1 Mbps, and 0.8 Mbps.

There are numbers of UEs using one or other RB shown in rows “Subset 0” and “Subset 1” in Table II. Bitmap for first UE and result of resource blocks allocation to all UEs with non GBR shown on Fig. 1.

Table 2: Procedure of Resource Blocks Allocation to UEs (All UEs with Non GBR)

RB	0	1	2	3	4	5	6	7
RBG	0		1		2		3	
Subset 0	1	1			1	1		
Subset 1			4	3			2	3
RB	8	9	10	11	12	13	14	
RBG	4		5		6		7	
Subset 0	1	1			1	1		
Subset 1			2	4			2	

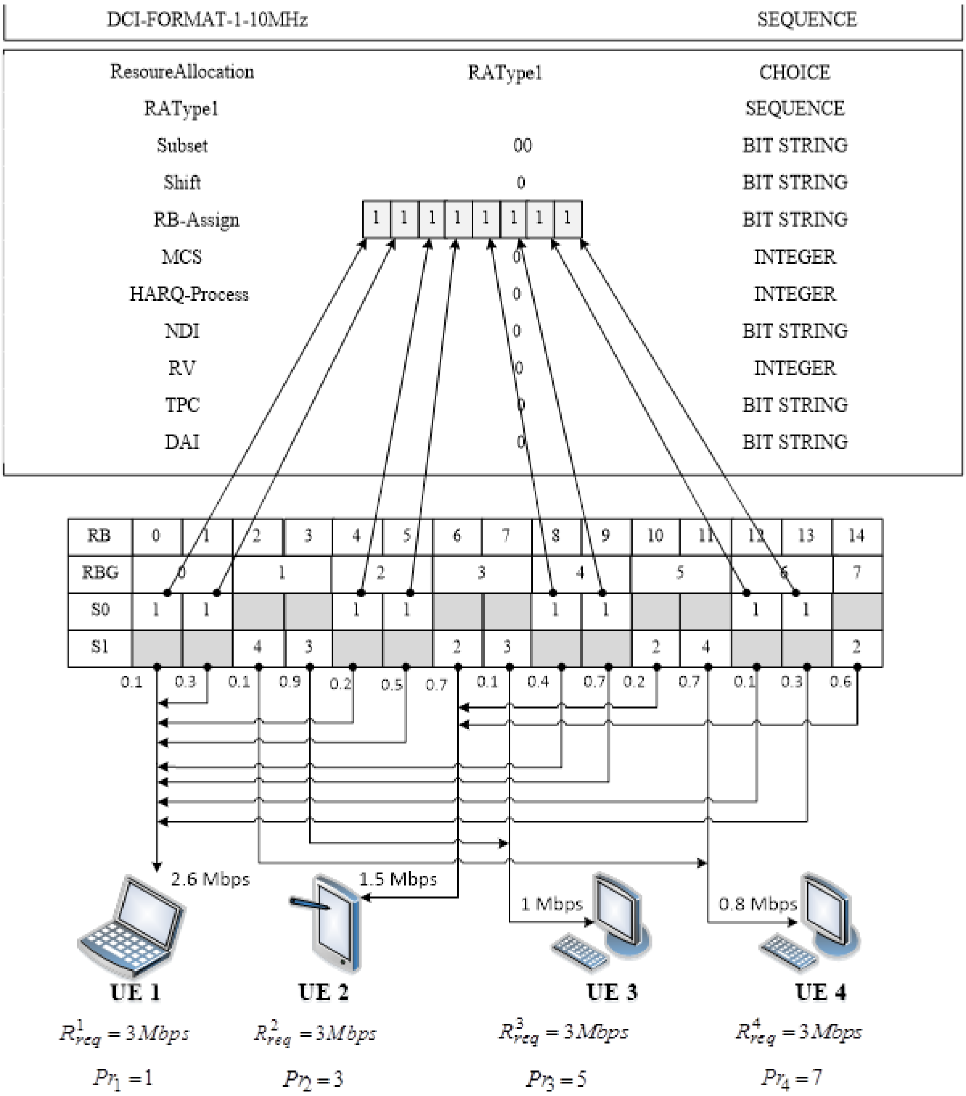

Fig-1: Bitmap for first UE and Result of Resource Blocks Allocation to all UEs with Non GBR

As shown in Table II, LTE downlink resource has been allocated among the four UEs according to their requirements for bit rate (R^n_{req}) and priority level (Pr_n). The higher priority of the UE, the more bandwidth it has been allocated to it.

In the case if second UE with Guaranteed Bit Rate and first, third, and fourth UEs with Non Guaranteed Bit Rate, then the order of RBs allocation will be changed (Table III). Procedure of bandwidth allocation for each UE is following: 2.5 Mbps, 3.1 Mbps, 0.8 Mbps, and 0.5 Mbps.

Table 3: Procedure of Resource Blocks Allocation to UEs (Only Second UE with GBR)

RB	0	1	2	3	4	5	6	7
RBG	0		1		2		3	
Subset 0	3	1			1	1		
Subset 1			2	2			2	4
RB	8	9	10	11	12	13	14	
RBG	4		5		6		7	
Subset 0	1	1			1	1		
Subset 1			2	2			2	

As shown in Table III, LTE downlink resource has been allocated among the four UEs according to their requirements for bit rate (R_{req}^{n}), resource type (GBR/Non GBR) and priority level (Pr_n). That is why to second UE for which is Guaranteed Bit Rate (GBR) and $R_{req}^{2} = 3$ Mbps allocated bandwidth is 3.1 Mbps. The rest of the stations for which are Non Guaranteed Bit Rate (Non GBR) bandwidth allocated according to their priorities, i.e. to first UE having the highest priority allocated 2.5 Mbps, and to fourth, which has the lowest priority 7, allocated just 0.5 Mbps.

CONCLUSION

In this work proposed priority based balancing model of resource allocation in LTE downlink supporting RAT 1, which is a further development of the approach proposed in [6-8]. The novelty of model is that it can be used to describe the process of RBs allocation in LTE downlink given UEs requests priority. Using the model allows to optimize the process of resource allocation in LTE downlink in solving the problem by mixed-integer linear programming, because some variables of (3) are Boolean, balancing variable (8) is a positive real variable, and objective function (9) and constraints (4)-(8) are linear. The advantage of the model is that the balancing of resource blocks number allocated to each of UEs is performed based on QoS requirements: demanded bit rate, priority and resource type (with or without guarantee).

Presented results confirmed the efficiency of model and adequacy of obtained on its basis solutions. This model can be used as the base of e-Node LTE software in solving problems resource allocation in LTE downlink with use RAT 1. Development of this approach is seen in the use of dynamic models of resource allocation represented in the state space. This will allow more fully take into account not only the current state of the LTE network, but also the dynamics of its change over time, due to variations in the signal-noise ratio, location and number of UEs, and requirements to QoS level.

REFERENCES

1. 3GPP TS 36.211 V13.0.0 (2015-12); 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical channels and modulation (Release 13). Valbonne, France, 2015.
2. 3GPP TS 23.203 V13.6.0 (2015-12); 3rd Generation Partnership Project; Technical Specification Group Services and System Aspects; Policy and charging control architecture (Release 13). Valbonne, France, 2015.
3. Ghosh A, Zhang J, Muhamed R, Andrews JCr; Fundamentals of LTE. Prentice Hall, USA, 2010: 241-250.
4. Iosif O, Banica I; On the Analysis of Packet Scheduling in Downlink 3GPP LTE System. The Fourth International Conference on Communication Theory, Reliability, and Quality of Service (CTRQ 2011), Budapest: IARIA, 2011; 99-102.
5. Kawser MT, Farid HMAB, Hasin AR, Sadik AMJ, Razu IK; Performance Comparison between Round Robin and Proportional Fair Scheduling Methods for LTE. International Journal of Information and Electronics Engineering, 2012; 2(5): 678-681.
6. Garkusha S, Al-Dulaimi AMK, Al-Janabi HDK; Result of Development of Model for Bandwidth Management in LTE Downlink with Resourse Allocation Type 1. XIIIth International conference, the experience of designing and CAD system (CADSM'2015), February 2015; 409-413.
7. Garkusha S, Al-Dulaimi AMK, Al-Janabi HD; Model of Resource Allocation Type 1 for LTE Downlink. IX International Conference on Antenna Theory and Techniques (ICATT), April 2015; 279-281.
8. Al-Dulaimi AMK; Linear Model of Bandwidth Allocation in LTE Download with RAT 1. Second International IEEE Conference Problems of Infocommunications. Science and Technology, Proceedings of PICS&T-2015, Ukraine, October 2015; 82-85.