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# PROPORTIONAL ALLOCATION METHOD OF THE REQUIRED BANDWIDTH CAPACITY FOR THE USER STATIONS USING THE LTE TECHNOLOGY

# METODA PROPORCJONALNEGO PRZYDZIAŁU WYMAGANEJ PRZEPUSTOWOŚCI STACJOM UŻYTKOWNIKÓW PRZY UŻYCIU TECHNOLOGII LTE

Abstract

The results of developing a method of distribution of the downlink frequency and time resources under the LTE technology were presented. The proposed method is aimed to ensure the quality of service of wireless for users by allocating the required user station capacity in the downlink. A comparative analysis of the proposed method was conducted with known solutions of the distribution of time-frequency resources of the LTE technology in terms of the overall performance of the downlink, the degree of balancing capacity, as well as the confidence level of allocating the required capacity to user stations.

*Keywords: LTE, QoS, QoE, Resource Block Allocation, Required data transfer, Bandwidth capacity, FDD, TDD*

Streszczenie

Przedstawiono wyniki opracowania metody podziału częstotliwościowego i czasowego zasobów łącza komunikacyjnego w dół (downlink) w technologii LTE. Proponowana metoda ukierunkowana jest na zapewnienie gwarantowanej jakości usług bezprzewodowym użytkownikom poprzez przydzielenie stacjom użytkowników wymaganej przepustowości w łączu komunikacyjnym w dół. Przeprowadzono analizę porównawczą proponowanej metody z istniejącymi rozwiązaniami podziału częstotliwościowo-czasowego zasobów w technologii LTE pod względem zapewnienia ogólnej wydajności łącza komunikacyjnego w dół, stopnia zrównoważenia przepustowości, jak również ufnego prawdopodobieństwa przydziału stacjom użytkowników wymaganej przepustowości.

*Słowa kluczowe: LTE, QoS, QoE, sieć bezprzewodowa, transmisja danych, przepustowość, FDD, TDD*

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## 1. Introduction

The LTE (Long-Term Evolution) technology, developed by the 3 GPP (3rd Generation Partnership Project), provides one of the most effective ways to increase the productivity and to improve the main quality ratings of service (Quality of Service, QoS), which is – the development of network protocols and mechanisms responsible for the planning of the available network resources. This kind of resources, in the first place, includes a temporary resource – OFDM-symbols (Orthogonal frequency-division multiplexing) and a frequency resource – the frequency subcarriers. The OFDM-symbol refers to the lapse of time, during which the amplitude and phase of the modulated subcarriers are constant. It should be noted that the solution of the problem of allocating radio resources is primarily based on the requirements for the QoS [1–4] and can be entrusted on the radio resource management system (Radio Resource Management, RRM), namely, the scheduler (scheduler). In the LTE technology, as both in HSDPA and WiMAX, the mechanisms for distribution of the downlink channel (DownLink) resources are not determined by the standard, leaving this option up to the base station equipment manufacturers (evolved NodeB, eNodeB) [5–7].

The solution of the problem of the distribution of frequency and time resources should result in scheduling blocks (Scheduling Block, SB) being attached to the user stations (User Equipment, UE) in the downlink channel of one sheet. The scheduling block is the smallest structural element allocated for one user station and formed by two resource blocks (Resource Block, RB) located next to each other on the same subcarriers (subcarrier) [8]. Therefore, the work represents the analysis of known solutions directed at the distribution of the frequency and time resources in the downlink channel based on the LTE technology.

## 2. Analysis of the Known Solutions

The methods of available resources allocation, operating under the Maximum Fairness [7, 9, 10], Max C/I Ratio [9, 10] and Proportional Fair Scheduling [9–11] algorithms, were analyzed in the research. As a result, the analysis concludes that the use of known algorithms is aimed at the operation for the interactive «best effort» data class for the purpose of ruling out a situation in which some parts of the UE will never get access to the radio resources. The use of the said service class (Class of Service, CoS) ensures the delivery of UE data, as possible, without securing a data transfer rate. The improvement of the quality of service when allocating the radio resources for each UE should be aimed at providing a guaranteed data transfer rate with a chance to access the additional (non-guaranteed) bandwidth. Although, none of the analyzed mechanisms were able to provide such CoS.

Therefore, the research presented in this paper is aimed at developing the frequency and time resources allocation method in the downlink under the LTE technology, represented as a problem of the scheduling blocks' distribution. The deployment of the proposed method should ensure the allocation of the required data transfer rate for each UE without maximization of the overall downlink performance, i.e. the solutions obtained when deploying the proposed method will be heuristic. This should in turn reduce the computational complexity when solving the problem of allocating the required bandwidth capacity for the UE.

### 3. Method of the Resource Block Allocation

The proposed method assumes the following inputs as known:

1) $N$ – total number of the UE in the network;
2) $K$ – number of SB, formed during the transfer of one sub-frame. In the LTE technology, the quantity of SB depends on the frequency channel width and can assume the values: 6, 15, 25, 50, 75, 100;
3) $R_{req}^{n}$ – the required bandwidth capacity for the servicing of $n^{\text{th}}$ UE (Mbit/c);
4) $R_{c}^{n}$ – a code rate, used during coding a $n^{\text{th}}$ UE signal;
5) $k_{b}^{n}$ – Bit load of the $n^{\text{th}}$ UE symbol;
6) $K_{s}$ – the number of subcarriers for data transfer in one RB and one SB. This parameter depends on the frequency separation $\Delta f$ between the subcarriers and must satisfy the condition $K_{s}\,\Delta f$ = 180 KHz. $K_{s}$ can take values of 12 and 24, which corresponds with a frequency separation between subcarriers $\Delta f$ equal to 15 kHz and 7.5 kHz;
7) $N_{symb}^{RB}$ – the number of characters forming one resource block. Parameter $N_{symb}^{RB}$ = 7 if using the usual cyclic prefix (cyclic prefix, CP). Duration of normal CP for the first OFDM-symbol equals to $T_{CP}^{1}$ = 5.2 microseconds, and for the second to the sixth OFDM-symbol – $T_{CP}^{2-6}$ = 4.7 microseconds. When using an extended CP ($T_{CP}$ = 16.7 microseconds) the RB is comprised of six OFDM-symbols ( $N_{symb}^{RB}$ = 6);
8) $T_{SF} = 1\ T_{SF}$ – transfer time of one sub-frame;
9) $N_{SF}^{RB}$ = 2 – the number of RB, formed on the same subcarriers and allocated on UE during the transfer of one sub-frame.

When developing the method, it is important to ensure the proper recording of the structural features of OFDMA-frame, which is formed for the time-division duplexing mode (Time-division duplexing, TDD) and frequency division duplexing mode (Frequency-division duplexing, FDD). In the TDD and FDD mode, each frame is divided into ten sub-frames. In the FDD mode, each downlink channel sub-frame must transmit the information in the downlink direction. When using the FDD mode, the number of downlink sub-frames is equal to the total number of sub-frames in the frame and is equal $N_{SF}$ = 10. In the TDD mode, the number of downlink sub-frames can be different and it is determined by the configuration of the frame used. In terms of the developed method, FDD mode is selected, using all sub-frames to transmit the data in a downlink direction.

The LTE technology proposes three types of resource allocation. The developed method is aimed at the use of the zero type of the resource allocation (Resource Allocation Type 0), which assumes the combination of RB into the so-called groups of resource blocks (resource block groups, RBG), which are allocated in the UE. The number of RB included in the one RBG ($p$) depends on the width of the frequency channel used, and it is determined in the Table 1. In a case when the division of RB quantity by the $p$ parameter does not result in the integer value, the extreme RBG value will be less than $p$ [2, 12].

In accordance with the data given in Table 1, the number of resource block groups, which can be allocated to user stations within one sub-frame, shall be determined according to the formula:

$$K_{\text{RBG}} = \left\lceil \frac{K}{p} \right\rceil \tag{1}$$

where:

$\lceil \ \rceil$ – the procedure for calculating the maximal integer.

Table 1

**Correlation between the RBG size and the total number of RB formed**

| Number of RB formed, $N_{RB}^{DL}$ | Size of RBG, $p$ |
|---|---|
| ≤10 | 1 |
| 11–26 | 2 |
| 27–63 | 3 |
| 64–110 | 4 |

As a result of all the above, the problem of downlink channel bandwidth capacity allocation under the LTE technology comes down to the problem of the resource block group distribution. Fig. 1 shows a flowchart of the sequence of operations in the framework of the proposed method of resource block group allocation, performing the allocation of the required bandwidth capacity to all user stations.

The operation of the method can be described in several stages for which the block diagram shown in fig. 1 will be used.

**Step 1.** At the start operation of the algorithm (block 1), the data is collected on the state of network and the downlink (block 2) in the form of a set of parameters. Due to the fact that the resource block groups are allocated to none of the user equipment, the data transfer rate values are equal to zero (block 3).

**Step 2.** A first sub-frame is chosen (block 4) and a first RBG out of available set of the resource block groups in a sub-frame (block 5) for allocation of its user equipment. Then the variables $W$ and $q$ are introduced into the algorithm. Variable $W$ is assigned a correlation of data transfer rate allocated to the first SS, to the rate required $\left(W = R_1 / R_{req}^1\right)$, and a variable $q$ is assigned the value of unit corresponding to examination of the first UE (block 6).

**Step 3.** At the next stage, the UE is selected, to which the RBG defined in the Step 2 will be attached. The choice is made by way of sequential enumeration of user equipment (block 7) as well as a comparison of their corresponding correlation of the bandwidth capacity allocated to UE, to the required bandwidth (block 8). In a case when the said ratio is less than the calculated value of $W$, the variables $W$ and $q$ take on values corresponding with the current user equipment (block 9). If the ratio of bandwidth capacity allocated to UE, to the required bandwidth is greater than or equal to the value of $W$, the variables $W$ and $q$ do not change their values, and the next UE is used in the algorithm (block 7).

**Step 4.** After searching through all user stations, the bandwidth capacity is calculated, which is provided for $q^{th}$ UE (block 10) by the selected RBG, after which the bandwidth capacity allocated to the $q^{\text{th}}$ UE is added to the bandwidth capacity of the selected RBG (block 11). The procedure described in steps 2–4 is repeated for all sub-frames and resource block groups.

**Step 5.** As result of the algorithm execution, a necessary set of resource block groups is attached to each UE, which corresponds to the allocation of bandwidth capacity in the downlink (block 12), followed by the execution of the algorithm stops (block 13).

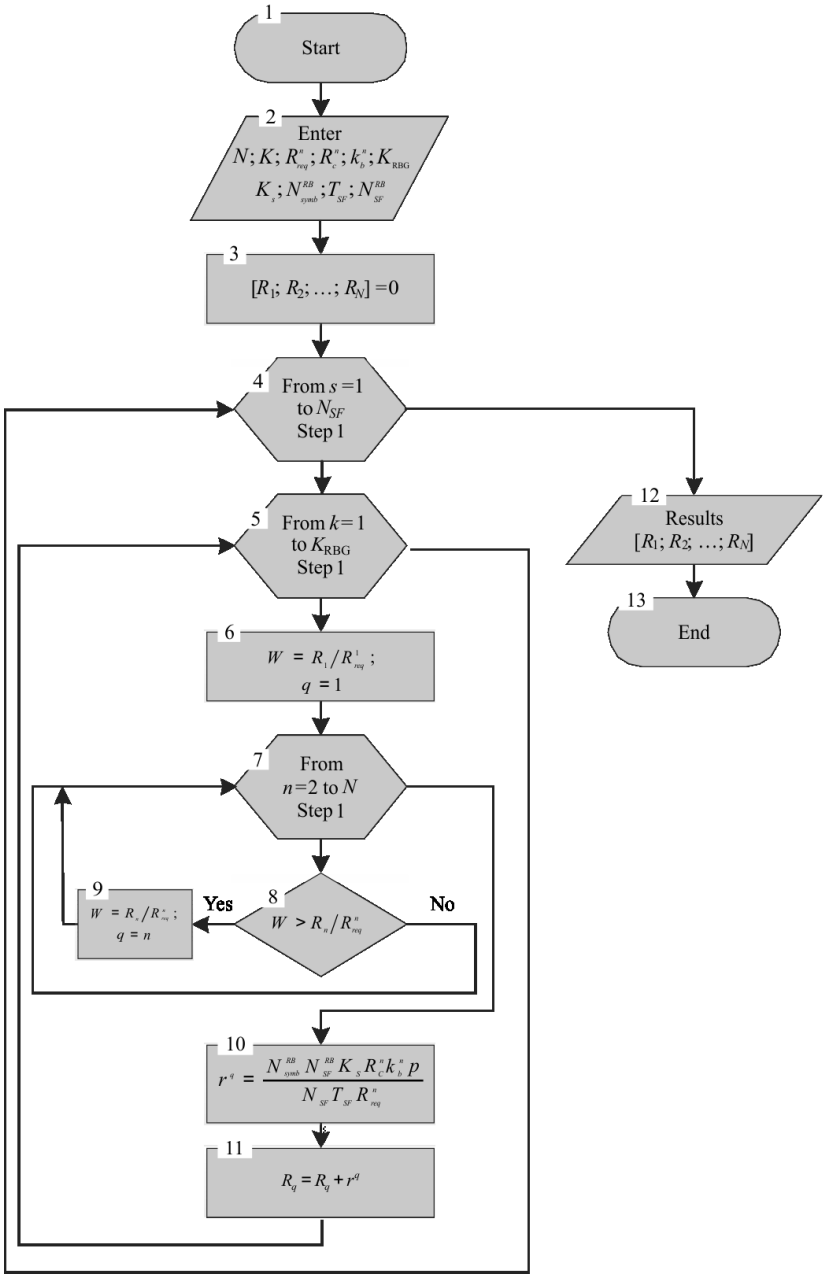



Fig. 1. Flowchart of the algorithm for the proposed method

## 4. Example of Solving the Problem of Resource Block Groups Distribution

For the purpose of the analysis of solutions for the distribution of resource block groups in the downlink obtained through the known methods, as well as the proposed method, we shall consider an example in which the following values were used as input data for the distribution of resource block groups in the downlink:

- $N = 5$ the number of user equipment;
- $K = 50$ the number of scheduling blocks formed on one sub-frame of the downlink channel;
- $K_s = 12$ the number of subcarriers for data transfer on one sub-channel;
- Rate of code, used when encoding the signal of the first UE – $R_c^1 = 2$ (QPSK), the second – $R_c^2 = 4$ (16-QAM), the third – $R_c^3 = 6$ (64-QAM), the fourth – $R_c^4 = 6$ (64-QAM), the fifth – $R_c^5 = 6$ (64-QAM);
- Bit load of the first UE symbol – $k_b^1 = 193/1024$, the second – $k_b^2 = 490/1024$, the third – $k_b^3 = 948/1024$, the fourth – $k_b^4 = 772/1024$, the fifth – $k_b^5 = 666/1024$;
- $N_{symb}^{RB} = 7$ the number of symbols forming one resource block;
- $T_{SF} = 1$ microsecond transfer time of one sub-frame ;
- $N_{SF}^{RB} = 2$ number of RB, formed on the same subcarriers and allocated UE during one sub-frame transfer;
- $R_{req}^n = 0.1 \div 2.5$ Mbit/s required transfer rate.

According to Table 1, parameter $p$ has the value equal three. Thus, based on the formula (1), the number of resource block groups formed within one sub-frame amounts to

$$K_{\mathrm{RBG}} = \left\lceil \frac{50}{3} \right\rceil = 17.$$

The results of the experiment show that the overall performance of the downlink channel using the known methods throughout the whole measurement period did not change and was equal for a Maximum Fairness method – 27.9 Mbit/s, Proportional Fairness method – 27,9 Mbit/c, and Maximum Sum Rate method – 33.4 Mbit/c. Execution of the proposed method allowed for the lowest performance of the downlink channel on the entire measurement range equal to 11.3 Mbit/s, due to the need of meeting bandwidth capacity requirements for all User equipment. Additionally, ensuring the required user equipment bandwidth capacity with a low value of modulation and coding schemes leads to the necessity for allocation of a bigger quantity of time-frequency resource, which affects the overall performance of the downlink channel.

Fig. 2 depicts the experiment results reflecting the dynamics of change in the degree of downlink channel bandwidth capacity balancing between the user equipment. The degree of bandwidth capacity balancing was determined according to the formula [2, 13]:

$$F^i = 1 - \left( \frac{\max\limits_n R_n^i - \min\limits_n R_n^i}{\sum\limits_{n=1}^{N} R_n^i} \right),$$

where:

$R_n^i$ – bandwidth capacity allocated on the $n^{th}$ UE at the $i^{th}$ measurement interval, $n = \overline{1, N}$.

As shown by the experiment results (see Fig. 2), the degree of downlink channel bandwidth capacity balancing when using the known methods throughout the measurement period was constant and amounted to: for a Maximum Fairness method – 0.6818, for Proportional Fairness method – 0.6818, and for Maximum Sum Rate method – 0. While using the proposed method, the downlink channel bandwidth capacity balancing during the entire measurement period had the highest value among all of the approaches mentioned above, equal to 0.9875.

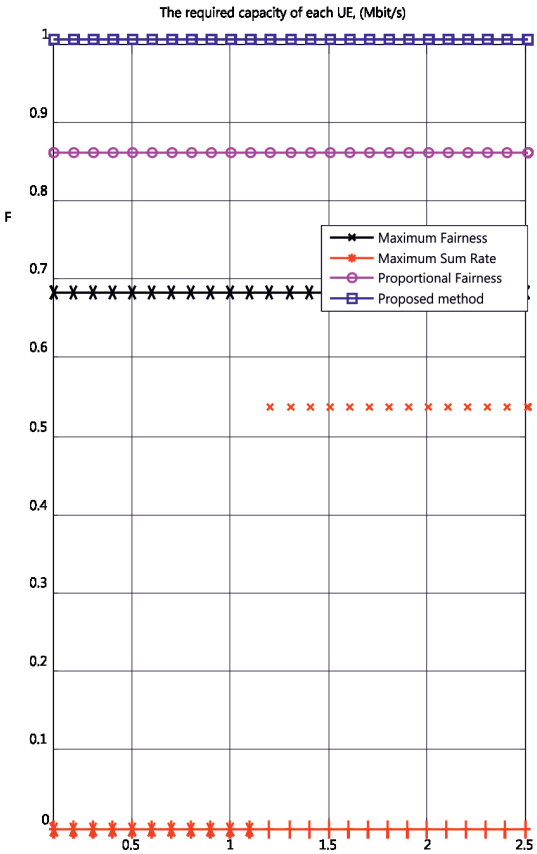



Fig. 2. Dependence of downlink channel bandwidth capacity balancing due to sub-channel allocation method used from the required bandwidth capacity

In addition, the research analyzes the bandwidth channel allocation to different user equipment in terms of the approach used for the distribution of resource block groups in the downlink, depending on the required bandwidth capacity. As shown by the results of experiment using the Proportional Fairness and Maximum Fairness methods, the required

transfer rate is not provided for the first user equipment starting at 0.6 Mbit/s. Application of the Maximum Sum Rate method enables the required data transfer rate for the entire range of measurement for only one (third) UE with the highest modulation and coding values. The proposed method allows to ensure the the required data transfer rate of UE in the range of $R_{req}^{n} = 0.1 \div 2.2$ Mbit/s, and after that, the user equipment from first through fourth having the lowest value of signal/ noise ratio.

More vividly, the results on the denial of the user equipment bandwidth capacities can be depicted in the form of the probability of meeting the requirements for bandwidth capacity allocated to all UE (Fig. 3). The probability of meeting the requirements for bandwidth capacity on $i_{th}$ measurement interval was determined according to the formula:

$$P^{i} = \frac{\sum_{n=1}^{N} Q_{n}^{i}}{N},$$

where:

$\sum_{n=1}^{N} Q_{n}^{i}$ – the number of UE, which were allocated the required bandwidth capacity on the $i_{th}$ measurement interval, i.e.

$$Q_{n}^{i} = \begin{cases} 0, & if \ R_{n}^{i} < R_{req}^{i}; \\ 1, & if \ R_{n}^{i} \geq R_{req}^{i}. \end{cases}$$

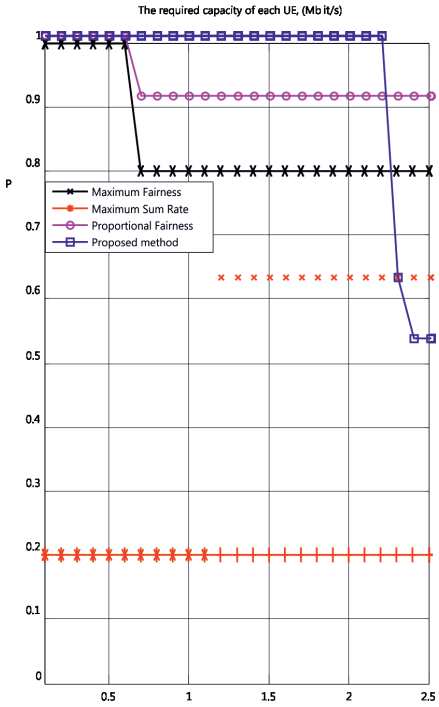



Fig. 3. Dependence of the probability of the required bandwidth capacity allocation to the UE for different methods of frequency-time resource allocation

## 5. Conclusions

It was established that one of the main tasks in a wireless network, operating with the application of the LTE technology, is the task of ensuring the required quality of service, which includes the necessity to allocate the required bandwidth capacity to the user equipment in the downlink channel. Additionally, it was found that the required bandwidth capacity in the LTE technology can be reached by solving the problem of frequency and time resource allocation in the downlink. In this regard, the analysis of the existing mechanisms of frequency and time resource allocation between user equipment in the downlink channel of the wireless network, operating with the application of the LTE technology.

Based on the identified disadvantages of the known frequency and time resource allocation mechanisms in the downlink, another method was proposed to meet the requirements for bandwidth capacity in a downlink channel. The novelty of the method lies in the fact that the problem of frequency and time resource allocation is expressed through the problem of distribution of the resource block groups of the downlink channel in the LTE technology for the transfer of data in the direction of user equipment, taking into account their territorial remoteness (type of modulation and encoding scheme), as well as the required bandwidth capacity.

The conducted analysis showed that the Maximum Sum Rate, Maximum Fairness and Proportional Fairness methods are effective only under conditions of low requirements for the bandwidth capacity. In the conditions of high demands for the bandwidth capacity of the user stations, the proposed method turns out to be effective, providing each user station with a guaranteed data transfer rate with the possibility of access to the additional (non-guaranteed) bandwidth. The application of the proposed method corresponds with the sub-class B in the classes of service CoS, while the other methods do not guarantee the required bandwidth capacity allocation, which corresponds with sub-class A in the classes of service CoS.

## References

[1] Garkusha S.V., Vasilenko Y.A., *Time-frequency resource planning model in the downlink channel for LTE technology*, Science and Technical Bulletin of Information Technologies, Mechanics and Optics, vol. 3 (85), 2013, 92–98.

[2] Garkusha S.V., *Scheduling blocks allocation model in the downlink channel for LTE technology*, Georgian Electronic Scientific Journal: Computer Science and Telecommunications, vol. 3 (39), 2013, 76–94.

[3] Garkusha S., Al-Dulaimi A.M.K., Al-Janabi H. D., *The Model of Scheduling Block Allocation in Downlink LTE*, IEEE XXXIV International Scientific Conference Electronics and Nanotechnology, Kyiv, Ukraine, 15–18 April 2014, 455–459.

[4] Garkusha S., Al-Dulaimi A., Al-Janabi H., *Result Research Model of Scheduling Block Allocation in Downlink LTE*, XII International Conference Modern Problems of Radio Engineering, Telecommunications, and Computer Science (TCSET'2014), Lviv-Slavske, Ukraine, 25 February 25 – 1 March 2014, 498–500.

[5] 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.

[6] Ghosh A., Zhang J., Muhamed R., Andrews J.Cr., *Fundamentals of LTE*, Prentice Hall, USA, 2010.

[7] 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, Hungary, 17–22 April 2011, 99–102.

[8] Dahlman E., Parkvall S., Skold J., Beming P., *3G Evolution – HSPA and LTE for Mobile Broadband*, Academic Press, Amsterdam, Netherlands, 2008.

[9] Kawser M.T., Farid H.M.A.B., Hasin A.R., Sadik A.M.J., Razu I.K., *Performance Comparison between Round Robin and Proportional Fair Scheduling Methods for LTE*, International Journal of Information and Electronics Engineering, vol. 2, no. 5, 2012, 678–681.

[10] Galaviz G., Covarrubias D.H., Andrade A.G., Villarreal S., A resource block organization strategy for scheduling in carrier aggregated systems, EURASIP Journal on Wireless Communications and Networking, 2012, 107–124.

[11] Girici T., Zhu C., Agre J.R., Ephremides A., *Proportional Fair Scheduling Algorithm in OFDMA-BasedWireless Systems with QoS Constraints*, Journal of communications and networks, vol. 12, no. 1, 2010, 30–42.

[12] 3GPP TS 36.213. 3rd Generation Partnership Project; *Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); Physical layer procedures (Release 11)*, Valbonne, France: Sophia Antipolis, 2012.

[13] Galaviz G., Covarrubias D.H., Andrade A.G., Villarreal S., *A resource block organization strategy for scheduling in carrier aggregated systems*, EURASIP Journal on Wireless Communications and Networking, 2012, 107–124.