Model of Transmission Rate Allocation WiMAX with Taking Into Account the Defined Priorities

Sergiy Garkusha, Essa Mohammed Al-Azzawi

Abstract – **The results of development a mathematical model for transmission rate allocation downlink technology WiMAX are presented. The novelty of the proposed model is possibility to prevent a limit transmission rate allocated to the service flows of the user stations in the downlink by using the WiMAX technology linear or linear-quadratic objective function. Using the mathematical model is directed to allocation between subscriber stations of a time-frequency resource of the downlink, which in turn improves the conditions in the electromagnetic frequency range used. The influence of the priority request rate used in the model is the nature of the possible failures.**

Keywords – **WiMAX, Time-frequency resource, Mathematical model, Transmission rate, Priorities.**

I. Introduction

At present time while using wireless telecommunications networks (WTN) particularly networks of WiMAX there is a problem of providing electromagnetic compatibility of the networks in distinguished diapason of frequencies. Besides that under the conditions of heterogeneity and multiprotocol of modern WTN especially at overload and limitation of frequency and time resources there is a problem of increasing the level of coordination for task decision of allocation the downlink bandwidth between subscriber station (SS) and limitation traffic intensity in the network [1], [2]. There should be taken into account possibility of presenting to every service flow (SF) at MAC sublevel the data link level network with required quality of service (QoS). Considering multiservice character of modern WTN, refusals of service should refer to first of all background traffic.

The analysis showed that know methods of allocation of frequency and time recourses of downlink in WiMAX use Best Effort. The quality is not guaranteed, but between SS all the available frequency and time resources is allocated [2]. However in WiMAX besides Best Effort supported several classes of service (CoS) among which Not Real Time, Real Time, Extended Real Time, Unsolicited Grant Service, directed upon working out guaranteed bandwidth.

So, urgent scientific and practical task is developing and researching mathematic models and methods of allocating frequency and time resources of downlink WiMAX, guaranteeing their giving to SSs and their SFs required bandwidth to be the basis of promising technological decisions. Developing the model and methods must be directed upon giving only the necessary quantity of frequency and time resources that will favor the improvement of electromagnetic environment in the used frequency diapason. The result is developed mathematic model of downlink WiMAX bandwidth allocation.

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II. Initial Data

The proposed mathematical model is designed for using in the wireless bandwidth networks with IEEE 802.16a and IEEE 802.16d, applying OFDMA scheme with a fixed "window" of fast Fourier transformation (FFT) with 2048 subcarriers and the working bandwidth channel of 20 MHz.

In the proposed model, the following inputs are assumed to be known [1]: N – the number of user stations in a wireless network; K – the number of subchannels in the frequency channel specified by the submodes; L – the number of characters in the frame; R^n_{req} – the required data rate for serving the n-th SS (Mbps); S – the number of symbols that form a slot; the types of modulation and coding system (MCS), depending on geographically remote SS; the number of slots in one subchannel of the downlink to transmit useful information:

$$M = \left\lfloor \frac{UL - L_{pr}}{S} \right\rfloor , \tag{1}$$

where $\lfloor \ \rfloor$ – operation of rounding to the nearest integer in the lower side, U is a ratio of the number of characters in the downlink to the total number of characters in the frame ( ), L_{pr} – the number of symbol to transmit preamble (equal to unity).

The mathematical model records the useful information transmitted in a single frame, and consisting of a fixed and a variable part [1, 3]. In order to better recover overhead data at the receiver's side under WiMAX technology the number of repetitions of fixed and variable parts can have the following values: w=2, w=4 and w=6. As a result, the number of slots needed used for transmission of the overhead information will be calculated as follows:

$$Q_{DL-MAP} = \left\lceil \frac{88+60N}{SR_c^{\mathrm{MAP}} k_b^{\mathrm{MAP}} K_s} \right\rceil w \,; \qquad (2)$$

$$Q_{UL-MAP} = \left\lceil \frac{48+52N}{SR_c^{\mathrm{MAP}} k_b^{\mathrm{MAP}} K_s} \right\rceil w \,, \qquad (3)$$

where in the numerator there is the total number of bits of the overhead information, in the denominator there is the number bits of the overhead information transmitted in a single slot, $\lceil \ \rceil$ – operation of rounding to the nearest larger integer; R_c^{MAP} – coding rate used for encoding the signal of overhead information; k_b^{MAP} – bit loading symbol used for encoding a signal of overhead information; K_s – the number of subcarriers for data transmission in a single subchannel (for sending the overhead information DL PUSC submode is used, resulting in K_s =24).

The total number of slots for the overhead information transmission can be calculated from the expression

$$Q = Q_{DL-MAP} + Q_{UL-MAP} + Q_{FCH} \,, \qquad (4)$$

where Q_{FCH} =4 – the number of slots to transmit frame control header.

III. Model of Frequency and Time Resource Allocation in Downlink

While solving the task of data burst scheduling for SFs of all SSs transmitting in downlink within the suggested model it is necessary to provide Boolean managing variable calculation ($x_{k,m}^n$), determining the order of slots allocation:

$$x_{k,m}^n = \begin{cases} 1, & \text{if the } m\text{-th slot is used in the } k\text{-th subchannel allocated by the } n\text{-th SS;} \\ 0, & \text{otherwise.} \end{cases} \qquad (5)$$

Besides that there is magnitude α^n, modelling part of necessary bandwidth allocation refusals [3]. Then vector of the searched parameters considering (5) can be presented in the form:

$$\vec{X} = \begin{bmatrix} x_{k,m}^n \\ --- \\ \alpha^n \end{bmatrix}. \qquad (6)$$

Coordinates of vector $\vec{X}$ is multitude of variables $x_{k,m}^n$, where $n=\overline{1,N}$, $m=\overline{1,M}$, $k=\overline{1,K}$, and range of parameters α^n, where $n=\overline{1,N}$. At this multitude of variables $x_{k,m}^n$ will be determined by $N \times M \times K$, where N – common number of downlink, transmitted by all SSs, M – number of slots at one sub-channel of downlink for useful information transmitting, K – number of sub-channels in frequency channel and number of parameters α^n will be equal to N.

According to results of variables (6) calculation there is sub-channel fastening and allocating after SS to transmit primary data in downlink. Besides that at calculation the vector of searched parameters $\vec{X}$ it is necessary to fulfil a range of conditions/constraints: 1) condition of k-th sub-channel fastening during transmitting m-th slot no more than after one service flow; 2) condition of n-th service flow number of slots fastening, providing necessary bandwidth at modulation and coding scheme (MCS) used by corresponding SS; 3) condition of one burst for n-th service flow corresponded SS to minimize number of slots allocated for service information transmitting; 4) condition of “rectangular” burst forming corresponding technological particularities of IEEE 802.16 family standards, using OFDMA; 5) condition of necessary slots number for service information transmitting reserving.

According to physics of the task upon coordinates α^n of vector $\vec{X}$ there put on the next limitations [3]:

$$0 \le \alpha^n \le 1 \quad (7) \quad \text{or} \quad \alpha^n \in \{0,1\} \,, \quad (8)$$

if at the basis of agreement about Service Level Agreement (SLA) acceptable (7) or acceptable (8) partial limitation of the required transmission rate.

Calculation of the searched variables (6) according to conditions/constraints better to commit while optimization task decision, providing minimum linear (9) or linear-quadratic (10) objectives functions [3]:

$$\min_X C^t \vec{X} = \min_X \sum_{k=1}^{K} \sum_{m=1}^{M} \Big(\sum_{n=1}^{N} c_{k,m}^n x_{k,m}^n + \sum_{n=1}^{N} c^n \alpha^n \Big) \,, \qquad (9)$$

$$\min_X \left[\frac{1}{2} \vec{X}^t H \vec{X} + C^t \vec{X} \right], \qquad (10)$$

characterizing relative cost of bandwidth at the stage of burst data scheduling. Coordinates of vector $\vec{C}$ and matrix H can be presented as the following:

$$\vec{C} = \begin{bmatrix} c_{k,m}^n \\ --- \\ c^n \end{bmatrix} \; (k=\overline{1,K} \,;\; m=\overline{1,M} \,;\; n=\overline{1,N}), \qquad (11)$$

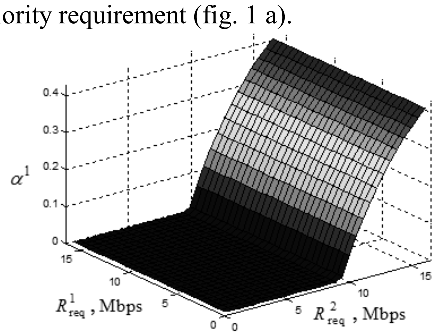
$$H = \begin{Vmatrix} \mu c_{11}^1 & 0 & 0 & 0 & 0 & 0 \\ 0 & \mu c_{12}^1 & 0 & 0 & 0 & 0 \\ 0 & 0 & \cdots & 0 & 0 & 0 \\ 0 & 0 & 0 & \mu c_{k,m}^n & 0 & 0 \\ 0 & 0 & 0 & 0 & \cdots & 0 \\ 0 & 0 & 0 & 0 & 0 & \mu c^n \end{Vmatrix}. \qquad (12)$$

Coordinates of vector $\vec{C}$ determines magnitude of specific fine for using downlink slots ($c_{k,m}^n$) and for limitation subscribers traffic (c^n), under the condition that $c^n_{k,m} << c^n$, μ – coefficient determining how many times coordinates of diagonal matrix H more (less) than vector $\vec{C}$ coordinates.

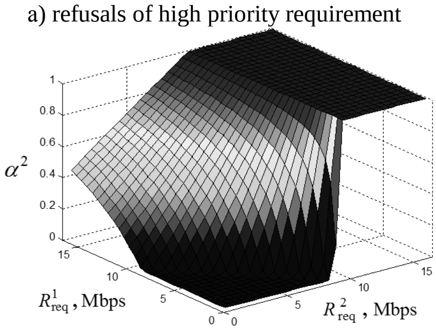
IV. CONCLUSION

There was also conducted analysis of downlink data burst scheduling process at joint maintenance of two SFs by guides of one SS with different priorities driven by changing relations meaning $\Delta C = c^n_{k,m} / c^n$. During the research was found out that the character of possible refusals at the suggested model using depends, first of all, on number of SSs and MCS use by the stations. Secondly the character of possible refusals depends of relation of costs for loading the downlink ($c^n_{k,m}$) to costs for service limitation subscribers traffic (c^n).

Below at the fig.1 and fig.2 presented dependences of refusals share at allocation necessary bandwidth of high priority (α^1) and low priority (α^2) services flows for linear and linear-quadratic objects functions. The results of the analysis showed that within suggested model service of SSs requirements is realized on the base of absolute priorities. So, using linear objective function in case when sum of requirements for demanded transmission rate exceeds bandwidth of downlink so preventive limitation gets requirement from low priority SS up to full refusal of access (fig. 1 b). Requirement for transmission rate from service flow with higher priority won't be jammed until there is possibility of refusal to low priority requirement (fig. 1 a).



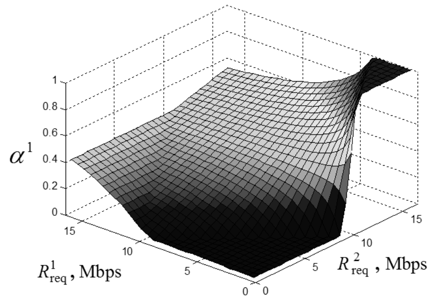
a) refusals of high priority requirement



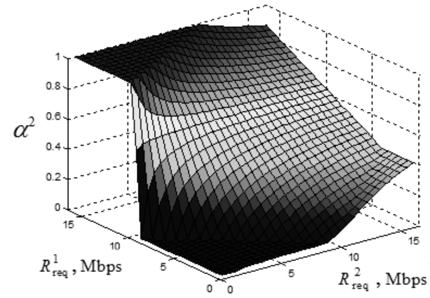
b) refusals of low priority requirement

Fig. 1. Dependence of refusals share from their requirements for demanded transmission rate at linear objective function.

Using linear-quadratic objective function there is organized more fair management at the basis of relative priorities than when using linear objective function. I.e. in case of possible overload service refusals touch upon all the services flows at this high priority has less degree (fig. 2 a) and low priority has bigger degree (fig. 2 b). Under this model has possibility to adjust preventively of traffic limitation, going into the network by changing weight coefficients also by degree of percent correlation of possible refusals magnitude when serving high priority traffic relatively to low priority by changing meaning of μ of diagonal matrix H .



a) refusals of high priority requirement



b) refusals of low priority requirement

Fig. 2. Dependence of refusals share from their requirements for demanded transmission rate at linear-quadratic objective function.

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