Research of Factors Influencing the Subchannel Allocation to Subscriber Stations in WiMAX

Lemeshko Oleksandr
Telecommunication Systems Department
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine

Haider Dheyaa Kamil Al-Janabi
Telecommunication Systems Department
Odesa National Academy of Telecommunications
named after O.S. Popov
Odesa, Ukraine
e-mail: danyal_for_ever@mail.com

Hailan Ahmad
College of Computer Science and Mathematics
Thi-Qar University
Nasiriya, Iraq
e-mail: onlineahmeds@mail.ru

Hojayev Oraz
Telecommunication Systems Department
Kharkiv National University of Radio Electronics
Kharkiv, Ukraine
e-mail: oraz_muradovic@mail.ru

Abstract — **Model of subchannel allocation in WiMAX network based on solution the optimization problem associated with maximizing the lower level allocated bandwidth for each subscriber station according to its quality of service requirements for access rate was investigated. Research of proposed model confirmed the adequacy and effectiveness of solution in terms of providing different types of service level (with and without guaranties) to subscriber stations. Results showed that the number of subchannels allocated to subscriber stations with a deficit of network resource adaptive reduction of provided level of quality of service performed dependently on the type of possible guaranties and requirements regarding the access rate.**

Keywords — WiMAX; OFDMA; subchannel; allocation; subscriber station

I. INTRODUCTION

WiMAX uses technology of adaptive multiplexing with OFDMA (Orthogonal Frequency-Division Multiple Access) that allows several subscribers to work in one timeslot at different subchannels. Thus, the effectiveness of using WiMAX depends on the quality of problem solution concerned with allocation of time and frequency resources formed at physical and data link layer of OSI model. To each user (Subscriber Station, SS) in WiMAX network according to its quality of service (QoS) requirements in frame structure certain set of bursts are allocated, for which a number of frequency subchannels and timeslots are assigned. Therefore burst is a frequency-time resource in WiMAX technology. But existing methods (schedulers) of frequency-time resource allocation, such as Proportional Fair Scheduling, Round Robin Scheduler, Max C/I Ratio, Best CQI Scheduling [1] do not satisfy the requirements for differentiation or QoS guarantee. In this regard, there is an actual problem associated with improvement of frequency and time resource allocation methods in WiMAX technology.

II. MODEL OF SUBCHANNEL ALLOCATION IN WiMAX

In the model of subchannel allocation to subscriber station it is assumed that there are known the following inputs: bandwidth of used frequency channel from the range of 1.25 MHz to 20 MHz; selected mode of subchannels usage (FUSC, PUSC, OPUSC, OFUSC, and TUSC); total number of the SSs in the network N; number of subchannels K used depending on the selected channel bandwidth; required transmission rate for service of the n-th SS R_{req}^{n} (Mbps); bandwidth of k-th subchannel $R^{n,k}$ allocated to the n-th SS.

Taking into account that the useful part of the symbol has a fixed duration $T_b = 89,6$ μs, the number of symbols in frame will take values 19, 24, 39, 49, 79, 99, 124, 198 according to the indicated size of frame. Moreover, between the symbols there is a guard interval T_g, which can take four values concerning the length of the useful part of symbol. Capacity of the k-th subchannel allocated to the n-th SS ($R^{n,k}$) represents the number of transmitted bits per time unit (second) and can be calculated according to the formula [2-4]:

$$R^{n,k} = \frac{R_c^{n,k} K_b^{n,k} K_s (1 - BLER)}{T_b + T_g + T_{RTG} + T_{TRG}}, \qquad (1)$$

where $R_c^{n,k}$ is the speed of code used at signal coding of the n-th SS; $K_b^{n,k}$ is the bit load of symbol of the n-th SS; K_s is the number of subcarriers for the data transmission in one subchannel; $T_{RTG} = 105$ μs is the duration of switching interval from receiving to transmission (receive/transmit transition gap, RTG); $T_{TRG} = 60$ μs is the duration of switching interval from transmission to receiving (transmit/receive transition gap, TRG); *BLER* is the probability of block error obtained at the expense of the Hybrid Automatic Repeat Request mechanism (HARQ) [1].

While solving a problem of subchannel allocation within the represented model it is necessary to provide calculation of the control variable (x_n^k), defining the order of subchannel allocation. According to the physics of problem the following limitation should be over the control variables:

$$x_n^k \in \{0,1\}, \ (n = \overline{1,N}, \ k = \overline{1,K}), \qquad (2)$$

$$x_n^k = \begin{cases} 1, \text{ if } k-\text{th subchannel allocated to the } n-\text{th SS;} \\ 0, \text{ otherwise.} \end{cases}$$

Total number of control variables depends on amount of subscriber stations in the network and used subchannels respectively, defined by the expression $N \cdot K$. Condition of fixing one subchannel only for one subscriber station is defined according to the expression

$$\sum_{n=1}^{N} x_n^k \le 1, \ (k = \overline{1,K}). \qquad (3)$$

Condition of scheduling the transmission rate for the n-th subscriber station on the k-th subchannel not exceeding the capacity of subchannel is defined by the expression

$$\sum_{k=1}^{K} R^{n,k} x_n^k \ge R_{req}^n \delta_n, \qquad (4)$$

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

For optimal balancing the number of subchannels allocated to each SS, the system introduced additional conditions limitations to the control variables x_n^k:

$$\frac{\sum_{k=1}^{K} R^{n,k} x_n^k}{(Pr_n + 1)R_{req}^n} \ge \beta, \ (n = \overline{1,N}) \qquad (5)$$

where Pr_n is n-th subscriber station priority; β is a control variable too, characterizing lower bound of satisfaction level of QoS requirements to access rate. In general $\beta \ge 0$. To improve QoS in WiMAX network in solving the problem of balancing the number of subchannels allocated to SS it is needed to maximize the lower bound meeting QoS requirements to access rate, i.e.

$$\beta \to \max. \qquad (6)$$

Thus, the model of subchannel allocation to subscriber station in WiMAX network based on solution of optimization problem associated with maximizing the lower level allocated bandwidth to each subscriber station (6) according to its QoS requirements for access rate. As the constraints stated in solving the optimization problem are conditions (1)-(5). Formulated optimization problem belongs to class of mixed-integer linear programming.

III. RESEARCH OF SUBCHANNEL ALLOCATION WITH AND WITHOUT GUARANTEE OF ACCESS RATE

The tasks of ensuring QoS in WiMAX networks are very important with the basic QoS indicator access rate.

Depending on the type of provided service the required access rate can differentiate and in some cases even be guaranteed. It is important to note, that the same subchannel will provide a different rate for various SSs (depending on the SNR, selected modulation and coding scheme, priority), while the amount of total available resource depends on the channel bandwidth (the number of subcarriers and subchannels). There are following factors influencing the subchannel allocation indicated during the research: number of SSs; requirements of SS to quality of service (access rate); signal-noise conditions (SNR); channel bandwidth; number of used subchannels; selected mode (FUSC, PUSC, OPUSC, OFUSC, TUSC); service model (with or without access rate guarantee); priorities of SS. Besides, better balancing achieved with the higher channel bandwidth and number of subchannels, and less differentiated QoS requirements.

IV. CONCLUSION

Model for subchannel allocation in WiMAX network (1)-(6) was presented, where balancing the number of subchannels allocated to subscriber station in WiMAX network based on the solution of optimization problem associated with maximizing the lower level allocated bandwidth for each subscriber station (6) according to its QoS requirements for access rate. As the constraints stated in solving the optimization problem are conditions (1)-(5). Formulated optimization problem belongs to class of mixed-integer linear programming, because some variables of (6) are Boolean, balancing variable (6) is a positive real variable, and objective function (6) and constraints (2)-(5) are linear. Research of proposed model (1)-(5) confirmed the adequacy and effectiveness of solutions as a whole in terms of providing different types of service level (with and without guaranties) to subscriber stations.

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