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MODEL GUARANTEED TRANSMISSION RATE PROVIDING IN WIMAX DOWNLINK

H.D.K. Al-Janabi, A.M.K. Al-Dulaimi, A.H. Abed
Kharkiv National University of Radioelectronics

Abstract *- Found that the provision of the required transmission rate of WiMAX can be achieved by solving the problem of frequency resource allocation in the downlink. As a result analyzed by the existing mechanisms of the frequency distribution of resources between subscriber stations in a downlink wireless network, operating using the technology of WiMAX. Based on the identified drawbacks of making a mathematical model the distribution of sub-channels in the network standard, IEEE 802.16, which provides a guaranteed rate subscriber stations in the downlink and submitted by a number of linear constraint equations. The novelty of the model lies in the formulation of the problem the frequency distribution of the resource allocation problem as a sub-channel with a firmly fixed number of subcarriers in each of them. The solution to the optimization problem sub-channel allocation proposed to carry out a multiple objective functions that the available frequency resources in order to allocate a minimum number of sub-channels, the distribution of the available frequency resources in order to allocate a minimum transfer speed of each the subscriber stations, the distribution of the available frequency resources to jointly minimize the number of used sub-channels and a transmission rate allocated to subscriber stations in a downlink. A comparative analysis of the solutions obtained by using different objective functions.*

Анотація *– У статті представлена математична модель розподілу підканалів в мережах стандарту IEEE 802.16, що забезпечує гарантовану швидкість передачі користувацьким станціям в низхідному каналі зв'язку. Використання різних видів цільових функцій в запропонованій моделі спрямовано на виділення мінімальної кількості підканалів низхідного каналу зв'язку або ж на виділення мінімальної швидкості передачі даних кожній користувальницькій станції. Проведено порівняльний аналіз отриманих рішень при використанні різних цільових функцій.*

Аннотация *– В статье представлена математическая модель распределения подканалов в сетях стандарта IEEE 802.16, обеспечивающая гарантируемую скорость передачи пользовательским станциям в нисходящем канале связи. Использование различных видов целевых функций в предложенной модели направлено на выделение минимального количества подканалов нисходящего канала связи или же на выделение минимальной скорости передачи данных каждой пользовательской станции. Проведен сравнительный анализ получаемых решений при использовании различных целевых функций.*

Introduction

In order to increase productivity and improve basic quality of service indicators (Quality of Service, QoS) for systems using WiMAX technology (Worldwide Interoperability for Microwave Access), based on standards IEEE 802. 16 [1, 2], the principles of structural and functional self-organization have to be used. The use of self-organization solutions can effectively respond to changing conditions and modalities of wireless networks that might be imposed, for example, failure of congestion or reloading of network elements, variations in incoming network traffic by the change of signal-jamming environment, etc. [3].

A high level of self-organization can be achieved through perfected-existence of network protocols and mechanisms responsible for allocation of network access resources. It should be noted standard IEEE 802.16 does not define mechanisms of planning and allocation of network resources, leaving right of choice to operators and manufacturers (vendors) equipment. To this kind of resources, first and foremost belong network traffic (information resource), capacities of communication channels (channel resource), queue (buffer resource), and frequency subcarriers (frequency re-LAS), which is especially important for wireless networks [3].

Subcarrier frequency is primary building block of OFDM, logical union of which forms an element of frequency resources, called the sub-channel. Sub-channels group in it's turn generates a frequency channel [4].

Most of famous solutions for frequency resource allocation are directed to solving subcarriers allocation problem. Number of subcarriers forming a single frequency channel may be different and is determined by scaling factor. The choice of a scaling factor used to determine width of a frequency channel and sub-channels formed by equal sets of sub-carriers. As a result task of frequency resources allocation should be reduced to the problem of sub-channels allocation between user network stations.

In this regard in the article it's offered a mathematical model of channels allocation for WiMAX technology downlink. Allocation of network frequency resource will be based on periodic (or on demand) solution of the sub-channel allocation between subscriber station (SS) taking into account characteristics of network used modes. Formulation of frequency resources allocation task as sub-channels allocation problem allowed making records of technological features of a wireless network, compared with famous solutions solve sub-carriers allocation problem.

I. Known solutions analysis

Known solutions analysis of frequency resource allocation between SS wireless network using WiMAX technology are shown that most of known approaches [5-13] of frequency resource allocation are based on solving allocating subcarriers problem between SS wireless network. The number of subcarriers allocated to one subscriber station is arbitrarily. However, in IEEE 802.16 standard [1, 2] it is indicated subcarriers are assigned to individual sub-channels, whose number is limited. Also it should be noted number of sub-channels and subcarriers are independent from channel width. Dynamic subcarriers allocation between SS network can result to change of number of pilot and guard subcarriers used in channel, account of which in mentioned decisions is not made. Therefore, the focus of future research will be concentrated on development of mathematical models for solving the sub-channel allocation between SS wireless network.

II. Mathematical model of sub-channels allocation in a wireless network of IEEE 802.16

In developing of mathematical model it must be taken into account the fact that in the case of a allocated arrangement of sub-carriers in the specification of WMAN-OFDMA, there are two sub-modes determine formation of "frequency structure" of sub-channels [4]:

- sub-mode OFDMA FUSC (Full Usage of Subcarriers);
- sub-mode OFDMA PUSC (Partial Usage of Subcarriers);

The order subcarriers allocation in downlink for sub-mode DL FUSC given in Table 1. DL PUSC mode similar data are shown in Table 2.

Table 1. The order subcarriers allocation in downlink for sub-mode DL FUSC

Channel bandwidth (MHz)	1,25	2,5	5	10	20
Number of subcarriers	128	256	512	1024	2048
Number of subcarriers to transmit data to one sub-channel	48	Not used	48	48	48
The number of sub-channels (scaling factor)	2		8	16	32
The total number of subcarriers used for data transmission	96		384	768	1536
Total number of pilot subcarriers	10		42	82	166
Number of subcarriers in lower guard interval	11		43	87	173
The number of subcarriers in the upper guard interval	10		42	86	172

Table 2. The order of sub-mode DL PUSC subcarriers allocation

Channel bandwidth (MHz)	1,25	2,5	5	10	20
Number of subcarriers	128	256	512	1024	2048
Number of subcarriers to transmit data to one sub-channel	24	Not used	24	24	24
The number of sub-channels (scaling factor)	3		15	30	60
The total number of subcarriers used for data transmission	72		360	720	1440
Total number of pilot subcarriers	12		60	120	240
Number of subcarriers in lower guard interval	11		46	92	184
The number of subcarriers in the upper guard interval	10		45	91	183

Upon mentioned above are assumed following reference data as known:

1) N – total number of SS in network;
2) K – number of sub-channels in frequency channel (is determined by used sub-modes and wide frequency channel);
3) K_s –number of subcarriers for data transmission in one sub-channel;
4) $R_c^{n,k}$ – code rate used for encoding the second signal SS on the subcarriers of k-th sub-channel ;
5) $k_b^{n,k}$ – symbol bit load of n-th SS on subcarriers of m-th sub-channel;
6) L – number of symbols in frame. It is worth to mention in WiMAX technology frame duration may vary and is given a value equal to 2; 2,5; 4; 5; 8; 10; 12,5; 20 ms. Based on the fact useful part of symbol has a fixed duration T_b=89,6 ms, then number of characters in the frame will take values of 19, 24, 39, 49, 79, 99, 124, 198, respectively to specified frame duration. Moreover between characters there exists guard interval that can take four values relatively to the useful part of symbol duration:

$T_g = T_b / 4 = 22{,}4$ ms; $T_g = T_b / 8 = 11{,}2$ ms; $T_g = T_b / 16 = 5{,}6$ ms; $T_g = T_b / 32 = 2{,}8$ ms. As a result the exact length of frame can be calculated as $(T_b + T_g)L$;

7) R_{req}^n – required data rate for n-th SS;

In course of solving problem of sub-channels allocation within offered model network it is necessary to provide account of Boolean control variable (x_n^k).The order of sub-channels allocation is determined by variable (1):

$$x_n^k = \begin{cases} 1, \; if \;\; k\text{-}th \;\; sub\text{-}channel is allocated for \; n\text{-}th \;\; SS; \\ 0, \; otherwise. \end{cases} \tag{1}$$

The total number of control variables is dependent on number of subscriber stations in network, used sub-channel, and accordingly, will be determined by the expression $N \times K$. The result of calculation variables (1) will produce a binding sub-channels for subscriber stations data of which will be transmitted in descending direction of a suitable base station (BS). In addition to calculation of required variables it is necessary to meet a number of important conditions, restrictions:

1) Condition of fixing of k-th sub-channel only for one subscriber station:

$$\sum_{n=1}^{N} x_n^l \le 1 \quad (l = \overline{1, L}); \tag{2}$$

2) Condition selection of n-th user desired rate :

$$r_k^n \sum_{k=1}^{K} x_n^k \ge R_{req}^n \;\; (n = \overline{1, N}), \tag{3}$$

where $r_k^n = \dfrac{L R_c^n k_b^n K_s}{(T_b + T_g)L + T_{\text{RTG}} + T_{\text{TRG}}}$ – bandwidth capacity of k-th sub-channel (SC), fixed at n-th SS, which depends on modulation used scheme and coding (Modulation and Coding Scheme, MCS [14]; $T_{\text{RTG}} = 105{,}7$ mks – duration of interval to switch from reception to transmission (receive/transmit transition gap, RTG); $T_{\text{TRG}} = 60$ mks – duration of the interval to switch from transmit to receive (transmit/receive transition gap, TRG) [15].

Calculation of required variables (1), in accordance with conditions, restrictions (2) and (3) should be conducted in the course of solving the optimization problem, providing minimum or maximum preselected criterion of quality solutions sub-channel allocation problem in wireless WiMAX technology. Basic requirements for optimal criterion is attributed, on the one hand, corresponding physics of problem to be solved, i.e. sub-channel allocation problem, and on the other, possibility of obtaining based on it practically workable solutions (results). Thus, the formulation of task should not be too complicated, and its solution must be known or developed an effective method. As a result of mentioned above optimality criterion can be represented in the form of:

$$\mathbf{min}\, f^T x, \tag{4}$$

where f – weight vector in objective function (4); x – vector with coordinates x_n^k (1).

Using optimality criterion (4) is aimed at minimizing the frequency resource allocated to all subscriber stations. Selecting minimum number of frequency resources improves signal-noise conditions in used frequency band, and also provides availability of frequency resources for transmission of information if it is necessary for new subscriber stations. Quality of frequency resource allocation solution is also dependent on type of f weight vector used in optimization criteria (4).

Minimizing used frequency resource can be achieved by providing the least amount of subscriber stations sub-channels, taking into account the conditions of constraints (2) and (3). In this case weight vector takes the form of

$$f_1 = [1,1,1,1,..,1], \qquad (5)$$

with the proviso that number of elements in the vector f_1 corresponds to the number of elements in the vector x all of them are equal to one.

Besides, problem of minimizing number of used frequency resource can be solved by using an objective function that enables minimization of transmission rate allocated to each of subscriber stations. Such an weight vector may be represented as

$$f_2 = \left[r_1^1, r_2^1, \ldots, r_k^n, \ldots, r_K^N\right], \qquad (6)$$

In solving problem of frequency resource-saving can be used objective function also, which includes characteristics of weight vector (5) and (6), which takes form

$$f = f_1 + f_2 . \qquad (7)$$

The use of weight vector (7) is aimed at minimizing the number of used joint sub-channel and transmission rate allocated to subscriber stations in downlink.

The problem formulated from a mathematical point of view, the use of the objective function (4) is the problem of Linear Integer Programming (LIP). In the model required variable x_n^k (1) are Boolean, and restrictions (2) и (3) on unknown variables are linear.

III. The analysis of frequency resource allocation solutions by using different types of objective function

In order to assess quality of frequency resource allocation solutions in the offered model (1)-(4), let us examine solutions optimization problems using various embodiments of objective function.

In proposed model there were formulated three options for objective function:

- frequency resources allocation in order to distinguish of minimum number of sub-channels (objective function (4), (5));
- frequency resources allocation in order to distinguish a minimum transfer rate of each of subscriber stations (the objective function (4), (6));

- frequency resources allocation in order to minimize the amount of joint used sub-channels and transmission rate distinguished to subscriber stations in downlink (objective function (4), (7)).

For results analysis solution of sub-channel allocation in the broad-band wireless Wi-MAX technology using different variants of objective function as original data were used the following data:

- number of subscribers stations N=3;
- frequency demultiplexing (Frequency Division Duplex, FDD);
- number of sub-channels– K=16;
- number of subcarriers for transmitting data to one sub-channel – K_s=48;
- required rate to service n-th subscriber stations (Mbps) – R^1_{req}=2; R^2_{req}=2; R^3_{req}=2.

Let us imagine result of solving problem of sub-channels allocation of by using objective function (4), (5). As it can be seen from the result (fig. 1) to provide required data rate subscriber stations nine sub-channels are allocated. In this case, all subscriber stations were allocated for three sub-channels. Besides seven sub-channels are not used and can be used by connecting of new subscriber stations. It was also found transmission rate allocated to subscriber stations using objective function (4), (5) exceeds required bit rate of each of subscriber stations.

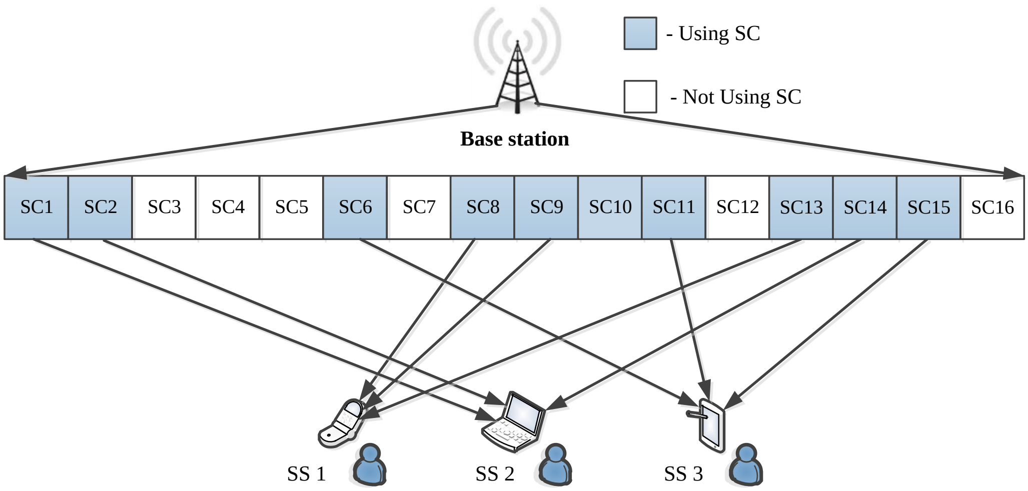

Fig. 1. Example of objective function (4), (5) using

The results of solving the problem using the objective function (4), (6) are shown in fig. 2. By using objective function (4), (6) rate of transfer to subscriber stations was very close to required and did not exceed it much higher than it. The simulation revealed the first subscriber station has been allocated four sub-channel, to the second subscriber station five sub-channels, and to the third - three sub-channels. The total number of sub-channels allocated to subscriber stations was twelve. Thus possibility to connect new subscriber stations for data transmission used in a downlink, as compared with a target function (4), (5) was decreased.

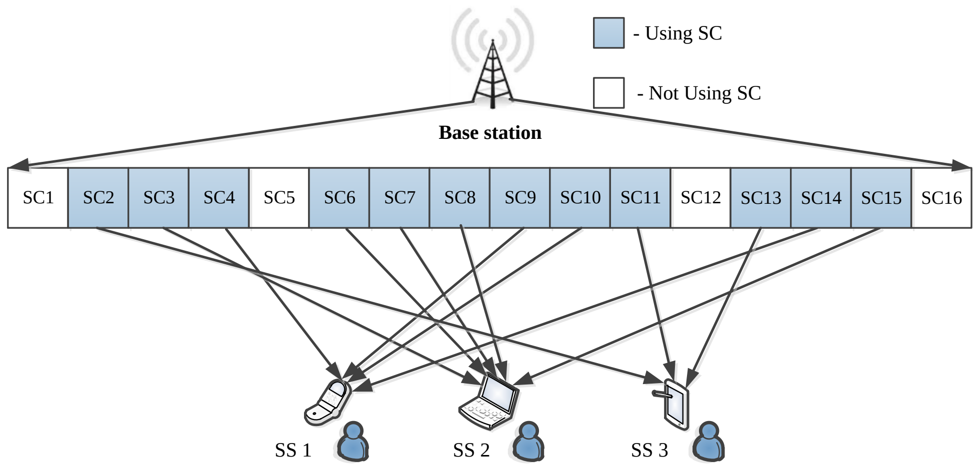

Fig. 2. Objective function using (4), (6) example

Fig. 3 shows results of sub-channels allocation objective function using (4), (7). Analysis of obtained solution showed by objective function (4), (7) using, as in the case of objective function (4), (5) using, that all subscriber stations are given nine allocated sub-channels of the sixteen available. Thus all user stations are allocated to three sub-channels. In addition seven sub-channels are available to connect new subscriber stations.

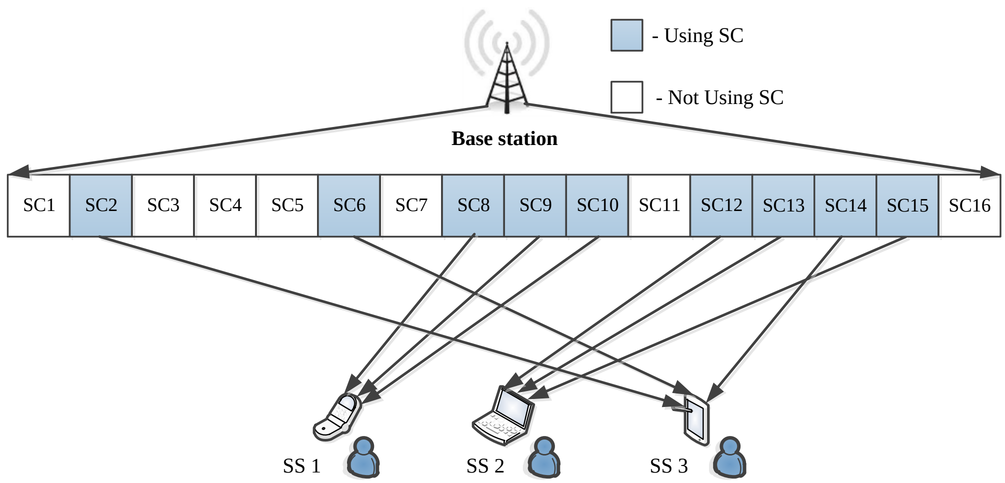

Fig. 3. Objective function using (4), (7) example

Conclusion

It was found that one of the main challenges in wireless networks operating guide-using WiMAX technologies is task of providing required quality of service, which includes to the required allocation for subscriber stations transmission rate in downlink. Also it was found that providing of required rate of WiMAX technology can be achieved by solving problem of frequency resource allocation in downlink. In this connection existing frequency resource allocation mechanisms are analyzed among subscriber stations in a downlink wireless network, operating with using of WiMAX technology.

Analysis of known solutions for the of frequency resources allocation between subscriber stations of a wireless network using WiMAX technology has shown most of the known approaches to frequency resource allocation is based on solving problem of allocating subcarriers. The number of subcarriers allocated to one subscriber station is arbitrarily. However, in IEEE 802.16 standard it is stated subcarriers are assigned to individual subchannels number of which is limited. Also it should be noted number of sub-channels and subcarriers therein depends on the width of the frequency channel. Dynamic allocation of subcarriers between subscriber stations of network can lead to a change in the number of pilot and guard subcarriers used in the channel, which are accounted for mentioned decision is not made.

Based on found shortcomings of known solutions it's offered a mathematical model present near linear constraint equations. The novelty of model lies in formulation of problem of frequency allocation of resource allocation problem as a sub-channel with a firmly fixed number of subcarriers in each of them. Furthermore, during sub-channel allocation required data rate for each of the subscriber stations is guaranteed by allocating required amount of sub-channels.

The analyzed solutions of optimization problem of sub-channels allocation in this articles by using couple of objective functions:

- frequency resources allocation in order to distinguish the minimum number of subchannels (objective function (4), (5));

- frequency resources allocation in order to distinguish the minimum transfer rate of each of subscriber stations (the objective function (4), (6));

- frequency resources allocation in order to minimize the amount of joint used subchannels and transmission rate distinguished to subscriber stations in downlink (objective function (4), (7)).

As an example, it was obtain the solution stated in optimization problems work using MATLAB R2012b system. During analysis, it was found use of target function (5) and (7) allows to make minimum number of sub-channel allocation and to provide required transmission rate to all subscriber stations. Therefore, part of sub-channels is available to connect new subscriber stations.

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