INVESTIGATION OF WIRELESS CHANNELS ACCORDING TO THE STANDARD 802.11 IN THE FREQUENCY RANGE OF 5 GHZ FOR TWO SUBSCRIBERS

Dmytro V. Mykhalevskiy*, Oksana S. Horodetska

Department of Telecommunication Systems and Television, Vinnytsia National Technical University, 95 Khmelnytsky Highway, Vinnytsia, Ukraine

*Corresponding Author Email: adotq@ukr.net

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ARTICLE DETAILS

ABSTRACT

In the given work the research of wireless channels of the family of standards of 802.11x in the frequency range of 5 GHz was taken into account taking into account the influence of architectural obstacles in the premises. As the main parameters for the research the effective transmission rate, the signal strength at the receiver input and the channel throughput are chosen. It has been established that the rate of transmission of information has a direct dependence on the signal transmission characteristic, therefore, to assess the level of signal fluctuations, it is necessary to use a confidence interval of power. On the basis of experimental research, a mathematical expression was obtained for evaluating the efficiency of wireless channels of the 802.11x family of standards for a frequency range of 5 GHz, taking into account the architectural obstacles in the room. It is established that in the presence of two subscribers in the network there are quite significant restrictions for high-performance modes.

KEYWORDS

802.11 wireless channel, effective data transfer rate, architectural barriers, signal level

1. INTRODUCTION

Widespread distribution of the 'Internet of Things' conception causes the wider introduction of the wireless technologies [1]. This conception envisages availability of substantial quantity of the devices, which require permanent connection with the relevant network. Depending on the type of a relevant device, it is possible to use both channels with low transmission capacity, and highly-productive channels. In order to ensure this possibility, it is worth to utilise the technology of family of standards 802.11x, as one of the sufficiently efficient technologies [2]. It can ensure both integration of the devices in accordance with the 'Internet of Things' and provision of access to the communication and information-communication services.

In the course of designing of networks according to the standard 802.11, the main task is to achieve better of stability of channels and increase the efficient rate of information transmission. At the same time, efficient rate of information transmission is in direct proportion to the level of the signal power at the input of receiving device and this efficient rate determines quality parameters of signals [3]. Quite widespread distribution of the wireless networks causes occurrence of a number of negative factors, which ensure appearance of delays and of mistakes in the course of sessions of traffic transmission. Therefore, search of new methods and means is essential with the purpose of minimization of influence of these factors, as well as with the purpose of improvement of the main criterion of the channel efficiency – the efficient rate of information transmission. Again, at the same time, it is impossible to create a new method without information on the nature and character of influence of the destabilising factors of the wireless channels. One of the very essential factors is connected with the architectural obstacles and barriers that occur due to the structure of those premises, within which wireless networks are created. Therefore, goal of this article is to perform investigation of the wireless channels in accordance with the 802.11x standards taking into account various architectural barriers; however, we will restrict this investigation by a single situation, where only two subscribers exist in a network.

2. LITERATURE REVIEW

As it is known, there exists a quite great quantity of the destabilising factors in the wireless transmission environment, which have influence upon the main figures of efficiency of the wireless channels of the 802.11x standards. It is possible to list the following main factors: change of parameters of a wireless channel in the course of transmission in time; obstacles, which are independent sources of emission; architectural obstacles and barriers. In order to decrease influence of these factors, it is necessary to determine dependences of connection between them and the main efficiency criteria.

In this regard, it is possible to list a number of the research articles, which can be separated in two groups: investigations of the energetic of parameter and investigations of the efficient information transmission rate. As concerns the first group of investigations, it is possible to name articles and [4]. They have proposed mathematical models and a new method on the basis of those models in order to estimate spatial distribution of a signal for any premises with angular and central position of the point of access. This method allows taking into account all existing destabilising factors, which can exist within the wireless environment.

Results of the investigations that were performed in the articles and demonstrate availability of the threshold value of the power level [5,6]. In the course of these investigations, the following characteristic properties were determined: as concerns the subscriber device, the established level

of emission was equal to 10-6 W/m^2 at the distance from one metre and
more metres. In the course of transmission of information through the
wireless channel, power improves by an order of magnitude. In addition,
a number of factors, which influence upon the estimate of the RSSI
(received signal strength indicator), were established, such as: position
of receiver in space, distance between receiver and transmitter, time of
measurement, obstructions from other devices, and availability of
architectural obstructions. It was established that there exist essential
fluctuations, as well as that they depend from of the specific of the
manufacturer equipment due to different frequencies of sampling and
discretisation. In addition, it was established that different position of
device changes level of signal by 2 dB•m, while deviation in space by 1
metre adds 6 dB•m to the level of these fluctuations. This fact can cause
certain restrictions in respect of withstandability of channels to the
external factors.

It is possible to include investigations of the factors, which influence upon
the transmission capacity of channel, to the second group. For example, it is
possible to remember articles and, where the following problem is
stated of correct operation of the CSMA/CD technology in the wireless
networks, which function according to the standard 802.11 [7,8]. Because
of this technology is the probabilistic protocol of the MAC level (Media
Access Control according to the IEEE 802), then in this case a number of
problems occurs in the course of distribution of the transmission capacity
of a channel between the existing subscribers in a network. As the result
of this, it was established that increase of quantity of subscribers causes
decrease of the signal/noise ratio, as well as decrease of efficiency of the
synchronisation algorithm of the MAC level.

Beginning from the standard 802.11n, it is envisaged to use of highly-
productive channels, which will operate in accordance with the spec trum
broadening technology. In this case, it is necessary to analyse the problem
of the estimation of operation taking into account of the channel width.
Investigation of influence of the 40 MHz channels upon the productivity
of networks was performed in article [9]. In this case, it was established that
increase of the channel bandwidth causes increase of the transmission
capacity, as well as decrease of the coverage area and increase of
sensitivity to obstructions.

As concerns comparison of the estimation of the main energetic parameter
for the ranges of 2.4GHz and 5GHz, and simultaneous analysis of
architectural barriers, it is possible to remember article [10]. This article
describes sufficiently essential quantity of results of the RSSI parameter
for six multi-storey structures in two countries of the European Union.
This analysis has demonstrated that waves of the 5GHz range are
characterized by essentially greater attenuations in the wireless channel.
Predominantly, such phenomena are observed in the vertical direction,
where materials with the higher density are utilised. Therefore, waves of
the 5GHz range have the lower transmission capacity through the
architectural obstacles and barriers. In addition, it is also possible to
underline that the higher sensitivity of device causes the higher flatness
of characteristics, as well as that, as a rule, it causes decrease of the efficient
information transmission rate.

Summarizing all above-mentioned information, it is possible to say that
sufficiently essential quantity of the destabilising factors has influence
upon the parameters of the wireless channels of the 802.11x standards. In
this case, if we want analyse the criterion of the channel efficiency, classic
models will be improper and inappropriate ones due to the availability of
random components. Therefore, goal of this article will be as follows:
search for a universal model of estimation of the channel efficiency
criterion on the basis of the experimental investigations for any premises
with architectural barriers. In addition, it will be necessary to analyse the
active CSMA/CD technology and utilisation of the 5GHz frequency range.

3. MATERIALS AND METHODS

In order to achieve the target goal, it is necessary to have relevant
condition of activation of the CSMA/CD technology. Such condition is as
follows: availability of two radio circuits – two movable subscribers in a
network. This methodology of investigations is based on the network,
which functions according to the standard 802.11 and includes the
transmitting-and-receiving equipment of the point of access (the PoA), as
well as the subscriber’s devices (SD1 and SD2).

Scheme of the wireless network is presented in Figure 1.

The network supports all existing standards 802.11 for the 5GHz range.
The PoA supports the MIMO technology (multiple-input/multiple-output)
with three transmitting-and-receiving antennas (as the most common
situation, which is present in the market. In order to perform these
investigations, a typical room was chosen, and length of the wireless
channel "l" within this section could be equal up to 15 metres. The channel
for information transmission consists of the receiving-and-transmitting
equipment, the PoA, as well as of two subscriber’s devices (SD1, SD2),
which form two wireless channels (WC1 and WC2). In order to ensure
estimation of influence of the architectural barriers, availability of two
insertion barriers was envisaged: B1 barrier at the distance of 11±3 metres
and B2 barrier at the distance of h + l = 6 metres.

Taking into account the fact that (from the point of view of the top-level
applications of the OSI model) the main criterion is to ensure transmission
of information through the channel without any changes, and then it is
possible to state that this criterion is the parameter of efficient
information transmission rate V (Mb/s). From the point of view of a
channel, the main parameter is transmission of frames without mistakes
per unit time, and such operation is determined as the parameter of the
transmission capacity of a channel Vpl (Mb/s). Because of transmission
capacity of a channel includes the parameter of the efficient information
transmission rate, as well as service information of the data link layer
and of physical layer, therefore (from the point of view of the above-listed
applications) it is possible to determine the criterion of the channel
efficiency as follows:

$$K = \frac{V}{V_{pl}}$$

(1)

Then, it is possible to choose the efficient information transmission rate V
(which is determined at the level of applications) as the main parameter
for investigations. In addition, it is also possible to choose the signal power
at the input of receiver P as the main energetic parameter, which has a
direct influence upon V. Because of the parameter of the information
transmission rate is in direct dependence on the characteristic of the
signal transmission, then (in order to estimate level of fluctuations of a
signal) it is possible to utilise the limiting values of the admissible changes
of the attenuation coefficient (of a signal), which has received the name as
follows: confidence interval of power. To this end, we will write down the

Figure 1: Structure of the network for investigation of the channel parameters

Following condition:

$$P_c - \delta < P(\Delta c, \Delta g, \Delta a, \Delta b) \leq P_c + \delta,$$  

(2)

where $\Delta c, \Delta g, \Delta a, \Delta b$ are coefficients, which determine limiting values of the admissible changes of the coefficients of attenuation of a signal; $P_c$ is the average value of the signal power; $\delta$ – coefficient of fluctuations of a signal.

The parameter of the efficient information transmission rate has fluctuations as well, and it is possible to describe these fluctuations with the help of the relevant confidence interval, which will correspond to the interval of fluctuations of power:

$$V_c - \Delta V < V \leq V_c + \Delta V,$$  

(3)

where $\Delta V$ is the confidence interval of the efficient information transmission rate, and $V_c$ is the averaged value of the efficient information transmission rate or mathematical expectation. Therefore, the main parameters for these investigations, which determine efficiency of a channel, are as follows: the efficient information transmission rate, transmission capacity, power of signal at the input of receiver, as well as their confidence intervals.

4. RESULTS AND DISCUSSION

4.1 Analysis of experimental investigations

The experimental investigations of the main determined parameters of the wireless channels according to the 802.11x standards in the 5GHz range were performed on the basis of the proposed methodology in order to estimate dependence of their characteristics from the typical architectural barriers. To this end, the following wireless channels were investigated: 802.11a, 802.11n-20 MHz, 802.11n-40 MHz, 802.11ac 20 MHz, 802.11ac-40 MHz, 802.11ac-80 MHz.

Length of the wireless channel WC1 under investigation is determined by the parameter $l$, while length of the channel WC2 is constant and it is equal to 2 metres. In order to simulate architectural barriers, we have used various structures, which were made of wooden components and bricks and which have been installed between the PoA and SUBS-R1 (subscriber 1). These investigations have been performed for the following typical situations (in the similar manner, as they were performed in article [4]): line-of-sight, availability of a single door; availability of two doors; availability of one wall or two walls.

4.1.1 Line-of-sight

It is one of the most the most widespread situations for creation of a wireless channel: it is envisaged that the PoA and subscribers are within the same room. In this case, the architectural obstacles and barriers have only influence upon the signal due to creation of the reflecting surfaces thus increasing the effect of the multipath wave propagation. Results of these investigations are presented in Figure 2.

![Figure 2](Image 284x203 to 508x348)

Figure 2: Experimental characteristics of the channel parameters for the direct visibility (line-of-sight situation): a – dependence of the efficient transmission rate on the distance between receiver and transmitter; b – dependence of the efficient transmission rate on the signal power at the input of receiver; c – dependence of the transmission rate of the physical layer on the distance between receiver and transmitter; d – dependence of the transmission rate of the physical layer on the signal power at the input of receiver.

As is evident from the graphs, characteristics of the efficient information transmission rate have a character of attenuation and they have a similar character for various standards. The same situation was observed in the case with the single wireless channel: the channel according to the standard 802.11a had the more stable characteristics. The most unstable characteristic was found for the channel according to the standard 802.11ac due to the decreased quantity of protection intervals in the course of formation of the OFDM (orthogonal frequency division multiplexing) of a signal. In addition, increase of instability is connected with utilisation of the greater channel width, because of the fact that two subscribers use one and the same frequency resource.

With the help of inequalities (2) and (3), let us determine the confidence interval of change of the main parameters of efficiency. Therefore, we will have the following:

$$\delta_{\alpha} \approx \pm 6 dBm; \Delta V_{\alpha} \approx \pm 2 Mb/s$$  

$$\delta_{a} \approx \pm 8 dBm; \Delta V_{a\alpha} \approx \pm 4 Mb/s$$  

$$\delta_{\alpha\alpha} \approx \pm 5 dBm; \Delta V_{\alpha\alpha} \approx \pm 2 Mb/s$$
\[ \Delta V_{ac} = \pm 7 \, \text{dBm}; \Delta V_{ac20} = \pm 4 \, \text{Mb/s} \]
\[ \Delta V_{ac} = \pm 8 \, \text{dBm}; \Delta V_{ac40} = \pm 6 \, \text{Mb/s} \]
\[ \Delta V_{ac} = \pm 6 \, \text{dBm}; \Delta V_{ac80} = \pm 8 \, \text{Mb/s} \]

Results of the transmission capacity of the channels demonstrate that in the case of availability of two subscribers in the network, sufficiently essential restrictions exist for the highly-productive modes according to the standard 802.11ac. These restrictions are connected with the sufficiently high value of the signal/noise ratio. Under actual usage conditions, that is in the case of availability of any destabilising factors within the transmission environment (these factors include interference obstructions) it is only possible to ensure the highly-productive mode within the immediate vicinity of subscriber to the PoA. As an exception, it is possible to create the situation, in accordance with which the subscriber device will be situated within the zone of maximum of the spatial distribution of a signal, and this fact can increase level of the signal/noise ratio, as well as increase transmission capacity of a channel (maximum at the distance of 11 metres from the PoA; see Fig. 2c).

4.1.2 A single barrier – wooden components

Such transmission environment envisages availability of doors or a wooden partition between the PoA and the subscriber device. In its turn, this fact adds an additional coefficient of attenuation of a signal. Results of these investigations are presented in Figure 3. The characteristics, which were obtained, have similar characters, but level of fluctuations is higher. The highest fluctuations are observed for the wideband channel 802.11ac 80 MHz.

In this case, it is possible to write down that the confidence interval will be as follows:
\[ \delta_a = \pm 6 \, \text{dBm}; \Delta V_a = \pm 2 \, \text{Mb/s} \]
\[ \delta_{ac20} = \pm 7 \, \text{dBm}; \Delta V_{ac20} = \pm 4 \, \text{Mb/s} \]
\[ \delta_{ac40} = \pm 6 \, \text{dBm}; \Delta V_{ac40} = \pm 5 \, \text{Mb/s} \]
\[ \delta_{ac80} = \pm 8 \, \text{dBm}; \Delta V_{ac80} = \pm 5 \, \text{Mb/s} \]
\[ \delta_{ac} = \pm 10 \, \text{dBm}; \Delta V_{ac} = \pm 10 \, \text{Mb/s} \]

The above-listed parameters of fluctuations are correct for the results at the following distances: 3 metres before and 3 metres behind the installed barrier. In other case, fluctuations are lesser by 1.5...2 times depending on the standard and they correspond to the direct visibility (line-of-sight situation). From the point of view of the physical layer, availability of one barrier causes occurrence of essential mistakes in the frames in the course of transmission. In this case, small protection intervals of the standard 802.11ac are considered as a negative factor, which increases its instability. In this case, channel 802.11n with 40 MHz bandwidth is the most efficient and stable one.

\[ \text{Figure 3: Experimental characteristics of the channel parameters in the case of availability of one barrier: a} \, \text{– dependence of the efficient transmission rate on the distance between receiver and transmitter; b} \, \text{– dependence of the efficient transmission rate on the signal power at the input of receiver; c} \, \text{– dependence of the transmission rate of the physical layer on the distance between receiver and transmitter; d} \, \text{– dependence of the transmission rate of the physical layer on the signal power at the input of receiver} \]
4.1.3 Two barriers – wooden components

In this situation, availability of two architectural barriers is envisaged, such as doors or partitions between the PoA and subscriber device. Results of investigations are presented in Figure 4.

![Figure 4](image1)

**Figure 4:** Experimental characteristics of the channel parameters in the case of availability of two barrier: a – dependence of the efficient transmission rate on the distance between receiver and transmitter; b – dependence of the efficient transmission rate on the signal power at the input of receiver; c – dependence of the transmission rate of the physical layer on the distance between receiver and transmitter; d – dependence of the transmission rate of the physical layer on the signal power at the input of receiver

Fluctuations of the main parameters are equal to:

- \( \delta a \approx \pm 10 \, \text{dBm} \); \( \Delta V_a \approx \pm 2 \, \text{Mb/s} \)
- \( \delta a_{20} \approx \pm 11 \, \text{dBm} \); \( \Delta V_{a20} \approx \pm 5 \, \text{Mb/s} \)
- \( \delta a_{40} \approx \pm 12 \, \text{dBm} \); \( \Delta V_{a40} \approx \pm 6 \, \text{Mb/s} \)
- \( \delta a_{80} \approx \pm 14 \, \text{dBm} \); \( \Delta V_{a80} \approx \pm 7 \, \text{Mb/s} \)

The above-listed fluctuations are correct at the distance of 3 metres before the first barrier and 3 metres behind the second barrier (this situation is the same as in the previous case). The sufficiently high instability of the main characteristics is observed within this short distance. As the result of this, it is possible to assume that the effect of the multipath wave propagation is increased in the case of availability of the closely adjacent reflecting surfaces due to repeated reflection from the neighbouring surface of the barrier. Then level of fluctuations is the same as in the case of the single barrier. From the point of view of the physical layer, transmission capacity of channels behind the barrier is restricted at the level of the standard 802.11n and it depends on the channel bandwidth. Quite essential attenuations make it impossible to utilise the highly-productive modes of the standard 802.11ac.

4.1.4 Barriers – walls

As a rule, availability of walls as barriers in the wireless channel causes sufficiently high attenuations of signals. Results of these investigations are presented in Figure 5.

![Figure 5](image2)
As is evident from the graphs, if the CSMA technology will be activated, it is possible to observe the sufficiently essential decrease of the efficient information transmission rate. In contrast with the single channel, in this situation we observe jumping and negative fluctuations of a signal transform into quite high fluctuations, which can achieve levels of ±13...20 dB•m. This fact allows to make an assumption that density of material has direct influence upon the coefficient of the architectural barriers.

The confidence interval has the following values:

\[
\delta = \pm 14_{\text{dB}}; \quad \Delta V = \pm 3_{\text{Mb/s}}; \\
\delta_n = \pm 16_{\text{dB}}; \quad \Delta V_n = \pm 5_{\text{Mb/s}}; \\
\delta_p = \pm 10_{\text{dB}}; \quad \Delta V_p = \pm 10_{\text{Mb/s}}; \\
\delta_{ac} = \pm 4_{\text{dB}}; \quad \Delta V_{ac} = \pm 4_{\text{Mb/s}}; \\
\delta_{ac} = \pm 12_{\text{dB}}; \quad \Delta V_{ac} = \pm 12_{\text{Mb/s}}; \\
\delta_{ac} = \pm 14_{\text{dB}}; \quad \Delta V_{ac} = \pm 14_{\text{Mb/s}};
\]

In the case of availability of the architectural barriers with high density, fluctuations of a signal transform into quite high fluctuations, which can achieve levels of ±13...20 dB•m. This fact allows to make an assumption that density of material has direct influence upon the coefficient of the multipath wave propagation as well. Availability of two architectural barriers ensures essential decrease of the signal level but working capacity of the channel can be kept with low transmission capacity due to switching of the channel to the mode with the lower transmission rate.

4.2 Estimation of the coefficient of efficiency for two wireless channels

The experimental data, which were obtained, include information on the main parameters of the wireless channel. Estimation of these parameters includes the random component, which is determined by the confidence interval. Then, method of the mathematical regression is the most expedient method in order to estimate the coefficient of efficiency of the wireless channel. Therefore, the quadratic model and logarithmic model will be the most optimum ones for the parameter of the efficient information transmission rate. Each of these models has relevant restrictions in respect of the channel length:

\[
V(l) \approx - f \cdot (\ln l) + x; \quad \text{at } l > 4 \text{ m} \\
\text{(4)}
\]

or

\[
V(l) \approx ul^2 - ls + v; \quad \text{at } l < 15 \text{ m} \\
\text{(5)}
\]

where \( f, u, s \) are coefficients of the regression reduction, which have dimension of \( \text{Mb/m} \); \( x \) and \( v \) are initial coefficients of the efficient information transmission rate. Coefficients of the regression reduction are presented in Table 1.

<table>
<thead>
<tr>
<th>Channels</th>
<th>802.11a</th>
<th>802.11n</th>
<th>802.11ac</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line-of-sight</td>
<td>5.6</td>
<td>8.47</td>
<td>7.17</td>
</tr>
<tr>
<td>f</td>
<td>0.16</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>u</td>
<td>3.36</td>
<td>2.67</td>
<td>2.5</td>
</tr>
<tr>
<td>s</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Single door</td>
<td>1.5</td>
<td>6.8</td>
<td>10.5</td>
</tr>
<tr>
<td>f</td>
<td>0.04</td>
<td>0.04</td>
<td>0.2</td>
</tr>
<tr>
<td>u</td>
<td>0.78</td>
<td>0.77</td>
<td>4.7</td>
</tr>
<tr>
<td>s</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Two doors</td>
<td>6.6</td>
<td>5.9</td>
<td>9.35</td>
</tr>
<tr>
<td>f</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>u</td>
<td>0.17</td>
<td>0.27</td>
<td>0.18</td>
</tr>
<tr>
<td>s</td>
<td>3.6</td>
<td>1.48</td>
<td>4.4</td>
</tr>
<tr>
<td>Walls</td>
<td>4.4</td>
<td>9.8</td>
<td>13</td>
</tr>
<tr>
<td>f</td>
<td>0.04</td>
<td>0.2</td>
<td>0.3</td>
</tr>
<tr>
<td>u</td>
<td>1.5</td>
<td>4.7</td>
<td>6.74</td>
</tr>
</tbody>
</table>

On the basis of the results that are presented in Table 1, it is possible to assume that there exists a possibility to determine general model of estimation of the efficient transmission rate with the help of methods of averaging. In this case, it is necessary to take into account the average values of reduction coefficients and intervals of their deviations, values of which will demonstrate availability and type of the architectural barriers in a channel. In principle, it is possible to write down the following:

\[
f = \frac{1}{n} \sum_{i=1}^{n} f_i \pm \Delta f, \quad \text{(6)}
\]

\[
u = \frac{1}{n} \sum_{i=1}^{n} \nu_i \pm \Delta u, \quad \text{(7)}
\]
\[ s = \frac{1}{n} \sum_{i=1}^{n} s_i \pm \Delta s, \]  
(8)

where \( \Delta f, \Delta u, \Delta s \) are coefficients, which determine intervals of deviation from the averaged values of the reduction coefficients. Then, on the basis of the results presented in Table 1, we will determine general values of the reduction coefficients of characteristics of the efficient information transmission rate, \( \text{Mb/m} \):

\[ f = 11 \pm 6 \]
\[ u = 0,2 \pm 0,15 \]
\[ s = 3 \pm 5 \]

In order to decrease influence of the restrictions, which are connected with the parameter "I" in the formulae (4) and (5), it is possible to apply methods of averaging in respect of these restrictions. On the basis of the mathematical simulation and the determined reduction coefficients, it was established that the most optimum method of averaging is the harmonic mean averaging. In addition, it was established that \( v \approx x + 3 \) (\( \text{Mb/s} \)). Then, it is possible to write down the formula for estimation of the efficient information transmission rate in the following manner:

\[ V(l) \approx \frac{2(x - f \ln(l))\left(u^2 - s + x + 3\right)}{u^2 - f \ln(l) - s + x + 3}. \]  
(9)

This parameter of the efficient information transmission rate must be determined on the basis of the minimum value of fluctuations in the confidence interval. Therefore, coefficient of efficiency of the wireless channel in the case of existence of two subscribers in a network (taking into account the architectural barriers within the room for the 5GHz range) will be formulated in the following manner:

\[ K = \frac{1}{V_{\text{eff}}} \left( \frac{2(x - f \ln(l))\left(u^2 - s + x + 3\right)}{u^2 - f \ln(l) - s + x + 3}\Delta V \right) \]  
(10)

Coefficient of efficiency of the wireless channel in the case of availability of two subscribers in a network depends on the reduction coefficients and on their intervals of deviations. With the help of these intervals, it is possible to perform estimation of parameters of the wireless channels of the 802.11x standards in the 5GHz range, as well as their fluctuations and type of the architectural barriers.

In order to confirm the obtained model (10), we will analyse it with the help of the mathematical simulation. For example, Figure 6 presents results for the channel according to the 802.11ac standard.

\[ \text{Figure 6: Dependence of the coefficient of efficiency of the wireless channel on: a} - \Delta f; \text{ b} - \Delta u; \text{ c} - \Delta s; \text{ d} - \Delta x \]

As it may be seen from the obtained graphs, the \( \Delta x \) interval demonstrates dependence of the coefficient of the channel efficiency on the utilised mode of operation of the standard. Determination of the variable value \( x \) in the real-time operation will make it possible to estimate the efficiency of a channel taking into account the maximum possible quantity of the destabilising factors within the transmission environment.

Influence of architectural barriers determines intervals \( \Delta f, \Delta u, \text{ and } \Delta s \). On the basis of these intervals, it is possible to determine the manner of changes of efficiency of a channel depending on the availability of the direct visibility (line-of-sight), availability and quantity of architectural barriers and density of these barriers. These intervals are changed in accordance with the confidence intervals of the efficiency parameters taking into account the fluctuations of the signal power and the efficient...
information transmission rate. This mathematical model of the efficiency coefficient is true and correct for any premises, minimum length of which does not exceed 40 metres.

In addition, it is worth to note that the above-presented model of estimation of the efficiency coefficient has a failure. This failure is connected with the correct selection of the deviation coefficient. Such correct selection can be achieved with the help of the obtained information concerning the essential quantity of experimental and statistical investigations of wireless channels.

5. CONCLUSIONS

On the basis of the performed investigations of wireless channels of the 802.11x standards in the 5GHz range in the case of existence of two subscribers in a network, the following characteristic properties were established:

- in the case of existence of architectural barriers, as well as in the case of the activated CSMA technology, level of fluctuations is higher than in the case of a single wireless channel - approximately up to 25% for the highly-productive modes. This fact makes it clear that in the case of increase of the subscriber's quantity in a network, instability of the channel parameters increases as well;

- architectural obstacles and barriers cause the same coefficient of attenuation of parameters V and Vpl for all standards under investigation (except for 802.11a standard);

- level of fluctuations of the efficiency parameters is the same in the case of utilisation of the same bandwidth of a frequency channel (for any range of channels). This fact gives the substantiation to set that increase of the channel bandwidth is in direct dependence on the level of fluctuations.

It was developed a new mathematical model of estimation of the efficiency coefficient for the wireless channels according to the 802.11x standards, and this model takes into account the fluctuations of the main parameters. This model is true and correct for the 5GHz frequency range, as well as for any premises, length of which does not exceed 40 metres, as well as for the premises where architectural barriers and obstacles exist.

REFERENCES


