Network Productivity and Quality Indicators of Broadband Connection Channels: a Review

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Abstract

This article dedicated to a review of modern methods of researching and estimation of productivity of IEE 802.11 protocol, based on Markov models and allows effectively estimate main indices of productivity of network functioning. The researches of estimation of network functioning is taking on special significance because of adaptation of IEEE 802.11 standard for network construction on a city and regional scale, that solved the problem of providing data in distant regions.

A mathematical model of information transmission processes using radio link discreet channels. This model represents the quality indicators of broadband communication channels. The model helps to generate main quality indicators of super broadband communication channel and to calculate the coverage of broadband access networks in field applications.

In article on the basis of the theory of reliable communication and mathematical modeling the comparative analysis of efficiency of communication channels in conditions of the limited by power and by a pass band without and with use of system of channel encoding is made. All calculations and results in detail analyze on the basis of model of a plane "band-efficiency"

1. Introduction

Taking place in the world process of development of network communications became objective factor in movement of world society in making of global information society. First appears the ability in overcoming of information disparity, as between different countries, so inside countries. Development of digital informal technologies and wideband wireless network data exchanging are one of the perspective ways to solve this problem.

One of the most popular protocols for wireless and mobile networks is IEEE 802.11 [1]. The fundamental mechanism of the access to the wireless environment in IEEE 802.11 is Distributed Coordination Function (DCF), realizing CSMA/CA method (Carrier Sense Multiple Access with Collision Avoidance). Frequently, IEEE 802.11 productivity evaluation is made at unicast transmission when the package is oriented only to one station-addressee. However, the protocol also regulates the mechanism of package broadcasting transmission when the package is transmitted to all the stations of the given network. The important parameter of productivity is the window of coition and delay time.

Time of b delay is measured in slots by q duration and probably taken out of set *(0, ..., W-1),* where *W=Wi* – the contention window depending on delay stage, defined by unsuccessful attempts of package transmissions of I quantity. After each unsuccessful transmission W is doubled, i.e. $W_i = 2^i W_0$, and so up to achievement of the maximal size *Wm*.

Value *W* named as a contention window does not depend on the number of made attempts (unlike address transmission), as broadcasting transmission is not confirmed, hence, repeated transmissions at MAC-level are absent.

The majority of the scientific researches of today are directed on wireless networks efficiency increase, these are the researches of productivity estimation efficiency parameters at various loading.

The process of sending messages in a discrete channel includes two basic operations: a comparison of each message with a carrier signal of finite duration signals, which comes in the radio line, and the identification (recognition) of signals coming from radio line output to the radio receiver's input.

One of key parameters of system of a digital communication is the reliability showing a level of effective transmission of digital signals, zero consisting of sequence and units transferred on communication channels. The Real channel of communication basically is characterized with functions of the noise influencing function of a useful signal. Distinction between properties of signals received of a communication channel and an original signal refers to distortions of a signal [1]. By transmission of a digital data on channels with noise always there is a probability of that the received data will contain mistakes. Modern transmission systems and reception of digital signals should have such function, that at restoration of an initial waveform from a digital signal these mistakes have been found out and corrected. The most effective way of correction of mistakes is application of methods of channel encoding. For today from the theory of encoding the set of codes and methods of their decoding action, differing correcting ability, complexity of realization and a number of other parameters is known. Below authors on the basis of the theory of reliable communication and the theory of encoding the analysis of parameters and a system effectiveness of channel encoding is made at use multiphase (MPSK - multi phase shift keying) and multifrequency (MFSK - multi frequency shift keying) manipulations from the point of view of minimization of a used band and provision of high efficiency of digital system.

2. Network productivity at high and normal loading

The following discrete and integer time scale of network work, a virtual slot of which is a unit is applied to productivity estimation and capacity in local wireless networks of IEEE 802.11 in high loading conditions.

Let's consider that virtual slots are not identical and each of them can be:

1) "empty" delay slot σ in which any of the stations does not conduct transfer;
2) "successful" slot in which only one of the stations transmits a package;
3) "collision" slot in which two or more stations transmit.

According to Bianchi model [2], it is supposed that in the beginning of every slot each station tries to send a package with the identical probability, equal to τ. In Cali model [3] it is supposed that delay time b does not depend on i and gets out of geometrical distribution with τ parameter. The behavior of separate stations considered as independent, according to Bianchi model is described by Markov chain, it is represented on Figure 1 (where p - the collision probability, considered as independent from number i of performed transmission attempts). Here, the condition of stations is described by pair (i, k), where k - value of delay counter. We can see that considerations of Bianchi and Cali models are equivalent to works of Vishnevsky and Lyakhov [4]. Besides, it was considered in these works that any station can begin transmission in the beginning of every slot. However, in real DCF scheme right after transfer termination only the transmitting station can begin transmission again, where it is also necessary to consider restrictions on transmission attempts number [5].

The above described works were done in the consideration of the ideal transmission channel, however neglecting of noises usually leads to essential overestimation of throughput estimations, as in modern city conditions electromagnetic noises are the inevitable factor worsening network throughput because of packages distortion. Therefore the further development of productivity evaluation methods of IEEE 802.11 local networks has been connected with the account of noises influence on network throughput. Vishnevsky and Lyakhov's work was the first step in this direction, [5], researches also have been carried out in efficiency evaluation direction of packages fragmentation application, recommended by IEEE 802.11 for network working in the conditions of noises.

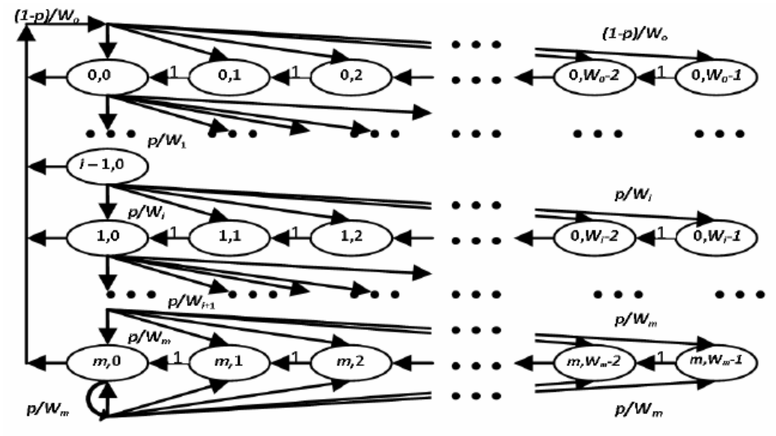

Figure 1. Markov model of station condition change.

Let's consider a wireless local network (WLAN) consisting of N statistically homogeneous stations working in high loading mode, when there are always nonempty queues in all WLAN stations. Statistically homogeneity of stations lies in the same stochastic distribution {dl, l=lmin, …, lmax}. Length of the packages chosen by each station from the queue. Distances between WLAN stations are small, therefore we will consider: 1) absence of the latent stations and 2) a simultaneity of noises occurrence in all stations. It means that all stations equally "hear" the general wireless channel.

We can see that each station conducts delay time readout only in the free channel: the counter value decreases for unit only in the event that the channel was free during the whole previous slot. At zero value achievement by the counter the station begins to transmit. Delay slots readout stops, when the channel becomes occupied, and next time delay counters decrease only when the channel will be free during σ +DIFS (Distributed Inter Frame Space) or σ +EIFS (Extended Inter Frame Space), if the last transmission on the channel was respectively successful or unsuccessful. We will consider the slot following directly after DIFS interval, finishing successful transfer from A station. The value of the delay time counter of A station is equal to b in the beginning of this slot and other stations counters remain on the same values, as prior to the transfer of A station, thus this slot is not competitive: only A station can conduct transfer in its course, if its delay time b appears equal to 0 (the given situation is called as instant transfer repetition). Accordingly, the transmission attempts which are carried out as a result of instant repetition, we will name instantly repeated attempts, distinguishing them from the other usual attempts. Thus, A station can conduct a range of broadcasting, instantly repeating them and one of these instantly repeated attempts of transmission does not have collisions in view of competition absence from other stations. Similarly, in the beginning of the slot, coming directly after EIFS interval finishing collision of several stations, only these stations can transmit, instantly repeating the attempts – The Seizing Effect lies in it.

Here we will confine ourselves by the account of instant repetitions only after successful transfer, neglecting such repetitions after unsuccessful attempts. For this purpose we will slightly change the rule of delay time b selection: after successful transfer b equiprobably gets out of set (0, …, W0-1) and after any unsuccessful attempt – out of set (1, …, w-1) where w depends on nr and is defined under the formula:

$$w = W_i = W_0 2^{nr} \text{ при } n_r < m \text{ и } w = W_m \text{ при } n_r \geq m,$$

Where Wm =W0 2m - maximal contention window.

Thus, after unsuccessful attempt (including EIFS interval) an "empty" slot always follows upon termination of which comes a competitive slot when any station can begin transmission.

2.1 Productivity at normal loading

Unfortunately, the results received in the majority of works devoted to IEEE 802.11 are inapplicable in normal loading conditions when stations queues periodically appear to be empty, in view of essential exaggerated evaluations of such productivity indicators as an average time of packages service and average time of package delay at MAC- level, i.e. average time of stay at the given station, including possible expectation and service.

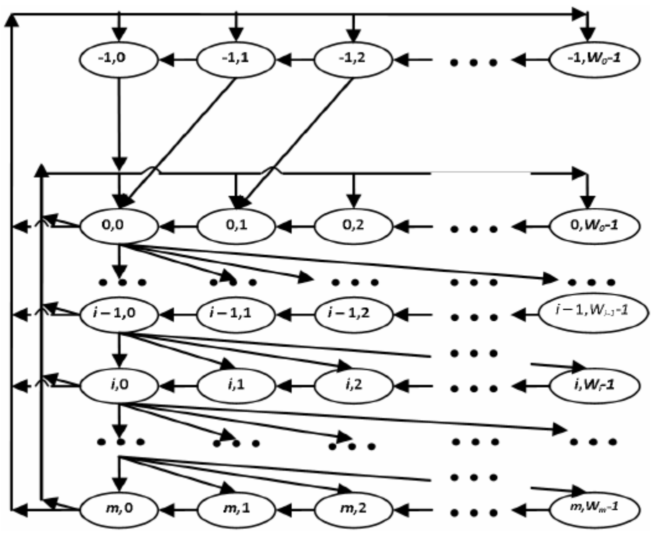

Figure 2. Markov's chain of station conditions change for a case of normal loading

The attempt to describe work of a wireless local network in the conditions of normal loading undertaken in Bianchi model is added by idle condition to which the station after the next transmission can pass. However, in the model applied in work [7], two important factors are not considered: 1) the station after package transfer passes in a delay condition even in the absence of a package in its turn and 2) possibility of immediate (asynchronous) package transmission which has come to empty queue, in the absence of other stations transmissions. For the consideration of these factors the additional (top) line of (-1, k) conditions is entered into Bianchi model, corresponding to delay conditions at empty (k> 0) queue and to (k=0) idle time condition, Figure 2.The station passes in (0, k-1) condition if it was in (-1, k> 0) or equiprobably in one of (0,0 … W0-1) conditions if it was in idle time condition at package receipt in empty queue and impossibility of asynchronous transmission. At queue underflowing the station equiprobably passes in one of (-1,0 … W0-1) conditions. The main objective of the given model is to find an average value of T time of the package service counted either from the moment of package receipt in empty queue of the given station, or from the moment of the previous package service termination from this queue and either up to the moment of ACK confirmation reception or the expiration of EIFS interval after the last unsuccessful transmission attempt (i.e. in case of package loss). The analysis of the given model allows estimating precisely enough average times of service and packages delays at MAC-level.

2.2 Analysis of efficiency evaluation methods for wireless networks

The outcomes of the abovementioned wireless local networks efficiency evaluation research have shown that the method of efficiency evaluation under normal load allows, unlike previously used approaches, to consider the interconnection of local network stations behaviors, which improves precision of the evaluation. The method is easily expanded in terms of possible review of more complex situations by means of re-using the results that were previously acquired under heavy load at all stations of the network. For instance, to model hybrid access methods, when RTS/CTS mechanism and evaluation of a probable distribution of packet sizes is being used for some of packets, it is quite enough just to calculate lengths of successful (ts) and unsuccessful (tc) transmissions. Should the channel be less than ideal, failure probability evaluation methods should take interferences into account.

3. Quality Indicators of Broadband Connection Channels

For mathematical description of major transformations (operations) of the sets that occur in the transfer of information, we will use the notion of the operator. The operator of the transmitter, turns coded messages {a□} of signals {s□} is denoted as L1, the operator of the communication line denoted as L2, the operator of the receiver converts the signal into solutions, {a□_} – L3. As a result we receive a generalized structural scheme of the discrete channel, shown in Figure 1 where n (t) - additive noise and the noise affecting the receiver's input.

Based on the structural outline Figure 1 one can write the following formula

$$\{a^*_1\} = L_1\{x_1(t)\} = - L_1\ L_2\ L_3[\{a_1\}] + [n_1(t)],$$

where $x_1(t) = L_{\text{л}}\{s_1(t)\} + n_1(t)$ - a mixture of signal and interference at the receiver input.

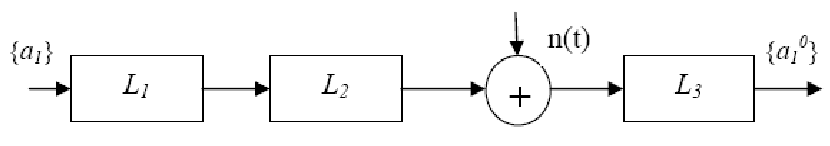

Figure 3. General Outline of the discrete channel.

The main task of the communication channel is to ensure correspondence between the elements of the sets {a□} and {a□_}. Since the channel noise and distortion apply To the of {a□} and {a□_}, will be static (random), i.e. degree of consistency necessary to characterize quantitatively probabilistic values, for example, the probability of correct transmission of a character (the correct consistency) or intelligibility with voice transmission. Obviously, only for the ideal discrete channel true identity {a□} ={a□_}, which is performed under the hypothetical conditions of {n (t)} = 0 and L2 L3 =1.

Based on the analysis of the purpose of communication system, ITU-R recommendations and reports as well as GOST requirements, it is reasonable to accept the accuracy of information transmission as the main indicator of quality. Generally, in order to evaluate the accuracy of communication in the n-channel communication system (CS), P0 mistake ration (the probability of mistake whie transmitting one piece of information) or signal to noise ratio qn (the relation of symbol (bit) energy to a noise spectral density) are used. Signal to noise ratio qn is measured in the output of correlated receiver (in the input of the comparator device)

$$q_n = P_1 / P_2 + P_3 + P_4 + P_5\,, \quad (*)$$

where P1 - power of the signal at the output (receiver), P2= kt - Interior noise power at the output of the receiver, tn - noise temperature, Ts - the duration of the signal, P3 - power of wideband external interference (noise), P4 - power of narrowband interference, P5 -- power interference. When the linear coherent processing of the external noise will have power at the output of the receiver is determined by the following expressions: $P_3 = g^2_ш / T_c,\ \partial_o$

where - the spectral power of noise; $P_4 = P_6 / Bs$, $P_{\partial_1} = \sum_{\partial=1, a=k}^{n} \rho_{ak}^2 Pa$, where *P6*-power narrowband interference at the receiver input, where - coefficient of mutual correlation

1 st and the k-th signal of the power P1 and Pk, $\rho_{0k} = \frac{1}{\sqrt{E_{c\gamma} E_{cq}}} \int_0 S_0(t) S_k(t) dt$,

$$q_n = (P_{c1} / P_{ш0}) = E_c / N_0, \quad (**)$$

where N0 - spectral power density of internal noise.

Value (*) is the maximum value and does not depend on the waveform. At the entrance to the multi-transfer (in the general band) and the presence of external interference deteriorates the quality of information as compared to (**). In some cases, you can offset this deterioration by increasing the power of the signal, but, first, a way with code division of channels may be ineffective because of the interference (they are, of course, determined by the value of Pc), and secondly, it contradicts the condition of comparative analysis (continuity signal at the input channel).

Appropriateness of the criterion (*) is explained by the fact that it determines many characteristics of communication systems (the probability of detecting a signal, the probability of error in digital systems of information, accuracy of measurement of the signal in synchronization, etc.). Consideration of a coherent receiver, useful for two main reasons: first, a receiver under the fluctuating noises is the best indicator (*), and secondly, such a receiver the most widely used in modern systems of information. It is clear that these characteristics are virtually identical, since the probability of error for this monotonic CS is linked to the unique dependence of signal-to-noise ratio. However, for tasks assessing the quality of MOP to adopt the criterion of the probability of error, and to optimize the tasks appropriate to adopt the criterion of maximum signal-to-noise ratio at the inlet at the entrance solver. This appropriateness is defined, firstly, that the recommendations of the receiver to describe the quality of a specific channel directly indicates the level of allowable error for a maximum allowable time interval, and, secondly, that in the general case, the probability of errors associated with signal noise in the analytical dependence impede the tasks of optimization in analytical form. Therefore, further to characterize the quality of the information will be used and the likelihood of errors R0 and signal-to-noise ratio.

From the expression (*) it follows that the output signal and the bandwidth (base tone) are the main resources of the NC. These resources are spent on the transfer of information. Cost-effectiveness of resources usually characterizes the SS performance and energy efficiency of frequency:

$\beta = R_1 N_o / P_c$, $\gamma = R_1 / F_c$, where No - the spectral density of the normal white noise, the existing channel in the MOP.

Using the concept of informational efficiency, which is characterized by the coefficient of bandwidth η, can be combined values (**), i.e. skalyarizovat vector is subject to η = 1. The reason for such a condition is the

Shannon's theorem that, with appropriate methods of modulation and coding value η can be very close to unity: η = R1 / C, where C - the capacity of the channel.

Known to limit the dependence of the efficiency of the channel: $\beta = \gamma / (2\gamma - 1)$. Any real radio station would have the worst characteristics of energy efficiency and frequency, ie for a real channel, the dependence of $\beta = f(\gamma)$ will be on the plane (β, γ) located below the Shannon. Note that the coefficient γ can be in communication systems vary zero to infinity (for a discrete m-ichnyh channels to log (m)), and the coefficient β from zero to For the discrete m-th channel we can obtain

$$\gamma = [\log m - P_{0\o} \log \frac{m-1}{P_{0\o}} - (1 - P_{0\o}) \log \frac{1}{1 - P_{0\o}}].$$

If the SS is using orthogonal signals (eg, W-CDMA, A-CDMA, IW-CDMA, etc.), the value of the probability of error is defined as a well-known expression:

$$P_{0\o} = 1 - \int_{-\infty}^{\infty} \frac{1}{\sqrt{\pi \partial}} e^{-(y-\sqrt{E_c})^2/\partial} \left[\int_{-\infty}^{y} \frac{1}{\sqrt{\pi \partial}} e^{-y/\partial^2} dy \right]^{m-1} dy.$$

For the binary symmetric channel without memory using conflicting signals we find from the above

$$\gamma = [1 - P_7 \log \frac{1}{P_7} - (1 - P_7) \log \frac{1}{1 - P_7}].$$

$$P_{0\o} = \hat{O}(\gamma / \beta), \hat{O}(X) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{y} e^{-y^2/2} dy$$

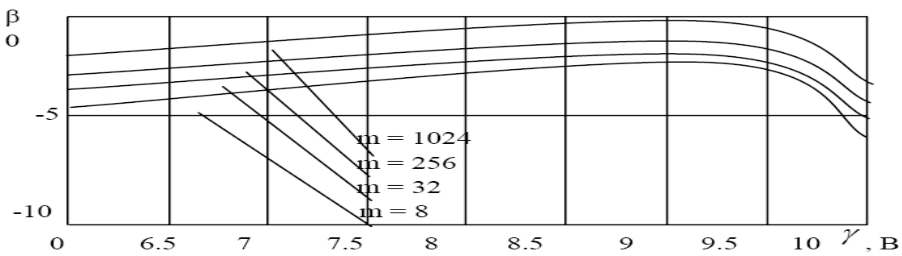

Figure 4. Dependence of energy effectiveness from frequency efficiency

The analysis of dependences (4), (5) and (6), as well as Figure 2 shows that if the information rate is specified (Ru=const), a desire to work with low signal-to-noise (system noise) can be met only by reducing the frequency and energy efficiency. In doing so, according to Shannon theorem about the benefits of coding, transmission quality of communication can be made arbitrarily good.

4. Efficiency use of system of channel encoding by transmission of digital signals on communication channels

By development of a modern digital transmission system of the information should be considered: 1) increase in transmission rate of bit *R* up to greatest possible; 2) minimization of probability of occurrence of bit mistake *PB*; 3) minimization of power consumption or minimization of the demanded attitude of energy one bit to spectral density of by power of noise *Eb*/*N*0; 4) minimization of width of pass band *W*; 5) maximization of efficiency of use of system; 6) minimization of constructive complexity of system, computing loading and costs of system [2]. To provide simultaneous performance of all these requirements it is very complex technical problem. From above stated it is visible, that requirements 1 and 2 contradict requirements 3 and 4; they provide simultaneous increase in speed and minimization *PB*, *Eb*/*N*0, *W*. There are some deterrents and theoretical restrictions which lead to the compromise in any system solutions. Some sold compromises between channel encoding and digital modulation can be shown is better through change of position of a working point on one of two planes – to the characteristic of probability of occurrence of a mistake and the characteristic of efficiency of use of a frequency band.

4.1 The minimal theoretical demanded width of a pass band

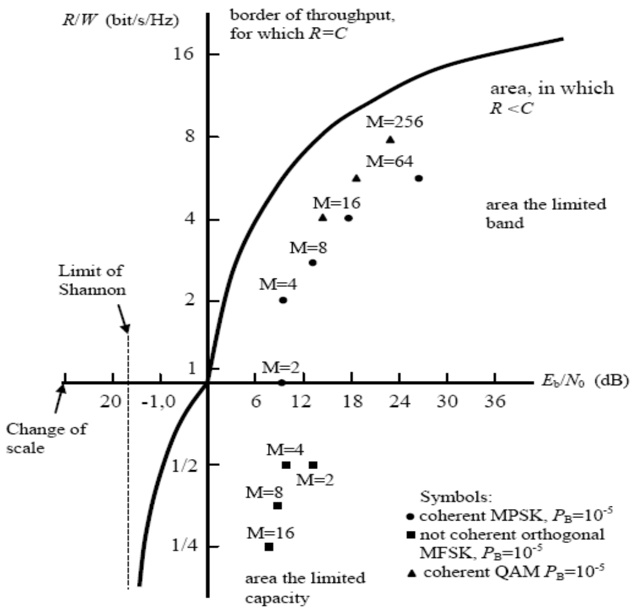

Figure 5. A plane "band-efficiency"

In any sold system which is carrying out a no ideal filtration, there will be an intersymbol interference – the part of an interval of one impulse extends on the next symbols and stirs procedure of detecting. Nyquist [3] has shown, that the theoretical minimal width of a pass band (width of a frequency band on Nyquist), demanded for not modulated transmission *Rs* of symbols for a second without an intersymbol interference, makes *Rs*/2 Hz.

In practice the minimal width of a frequency band on Nyquist increases for 10-40 % owing to restrictions of real filters. Thus, real throughput of digital communication systems decreases about ideal 2 symbol/s/Hz up to 1,8-1,4 symbol/s/Hz. From a set of *M* of symbols, the system of modulation or channel encoding appropriates to each symbol *k*-bit value, where *M*=2*k*. In this case, the number bits on a symbol can be presented as *k*=log2*M*, and, hence, transmission rate of data, or bitrate *R*, there should be in *k* times more transmission rates of symbols *Rs*, apparently from a following basic parity:

$$R = kR_s \quad \text{or} \quad R_s = \frac{R}{k} = \frac{R}{\log_2 M}$$

At use of the circuit in which for a step it is processed *k* bit, the signaling refers to as *M*-nary. Each symbol of *M*-nary of the alphabet it is unequivocally coupled to sequence from *k* bit, where *k*=log2*M* and *M* – the size of the alphabet.

If one of *M* of symbols (or signals) is transferred for interval T_s, transmission rate of data *R* can be recorded in a following kind log bit/s 2

$$R = \frac{k}{T_s} = \frac{\log_2 M}{T_s} \quad \text{bit/s}$$

From a parity effective duration *Tb* of everyone a bit can be presented through duration of symbol *Ts* or transmission rate of given *Rs*

$$T_b = \frac{1}{R} = \frac{T_s}{k} = \frac{1}{kR_s}$$

$$R_s = \frac{R}{\log_2 M}$$

It is visible, that in any digital circuit by transmission *k*=log2*M* bit for *Ts* second, to width of pass band *W* the Hz, efficiency of use of a frequency band is recorded as follows:

$$\frac{R}{W} = \frac{\log_2 M}{WT_s} = \frac{1}{WT_b} \qquad \text{bit/s/Hz}$$

For an estimation of power parameters and probabilistic characteristics of system with the limited pass band and by power without channel encoding analytical calculations are lead. Reference values of parameters of the channel are sampled is those: a radio channel with noise AWGN (additive white Gaussian noise); limited pass band *W*=4400 Hz; the attitude of by power of the received signal to spectral density of by power of noise *Pr*/*N*0=61 dBHz; demanded value of transmission rate of information *R*=17600 bit/s; the demanded probability

of occurrence of a bit mistake should not exceed *PB*=10-5. Results of calculations have shown, that under condition of limited by a pass band is necessary to use the circuit of modulation 16-level MPSK (*M*=16) and without application of channel encoding a noise stability of system will be $P_E=2{,}02\cdot10^{-6}$ and $P_B=5{,}04\cdot10^{-7}$.

Under condition of the limited by power parameters of the channel are sampled as follows: accessible pass band *W* is equal 75 kHz, and accessible P_r/N_0=51 dBHz. For such systems effectively to use modulation 16- level MFSK. Calculations have shown, that thus without use of channel encoding a noise stability of system for symbolical mistakes equally P_E=1,06·10^{-5}, and for bit – P_B=5,66·10^{-6}.

4.2. System with the limited by power and a pass band with channel encoding

For definition of efficiency and productivity of system of channel encoding in this example initial parameters are sampled same, as well as in the previous example of system with the limited pass band, namely W=4400 Hz, P_r/N_0=61 dBHz and R=17600 bit/s, but in this case it is supposed, that the probability of occurrence of bit mistake PB should be no more than 10_{-10}. As the pass band makes 4400 Hz, and of the equation

$$\frac{E_b}{N_0}(\text{dB}) = \frac{P_r}{N_0}(\text{dBHz}) - R(\text{dBbit/s}) =$$
$$= 61\,\text{dBHz} - (10 \cdot \lg 17600)\,\text{dBbit/s} = 18{,}5\,\text{dB (or 70,8)}$$

is found E_b/N_0=18,5 dB. The given system is limited both on a pass band and on accessible by power. For satisfaction requirements to a pass band can use 16-level circuit PSK; but available 18,5 dB it is completely not enough attitude $Eb/N0$ for provision of demanded probability of occurrence of a bit mistake 10-10. Therefore we shall consider what efficiency and increase of productivity can give channel encoding. Generally it is possible to use convolution or a block code. For channel encoding we shall be will apply a block code with correction of threefold mistakes (n=127, k=106, t=3). n – the general length of the block, consisting from code bits; k – quantity information bits; t – the maximal number wrong channel bits, giving in to correction, in the block in the size n bit. On Figure 2 the block diagram which is switching on the channel coder and the modem is represented.

For systems with modulation and channel encoding of transformation of speed have a following appearance

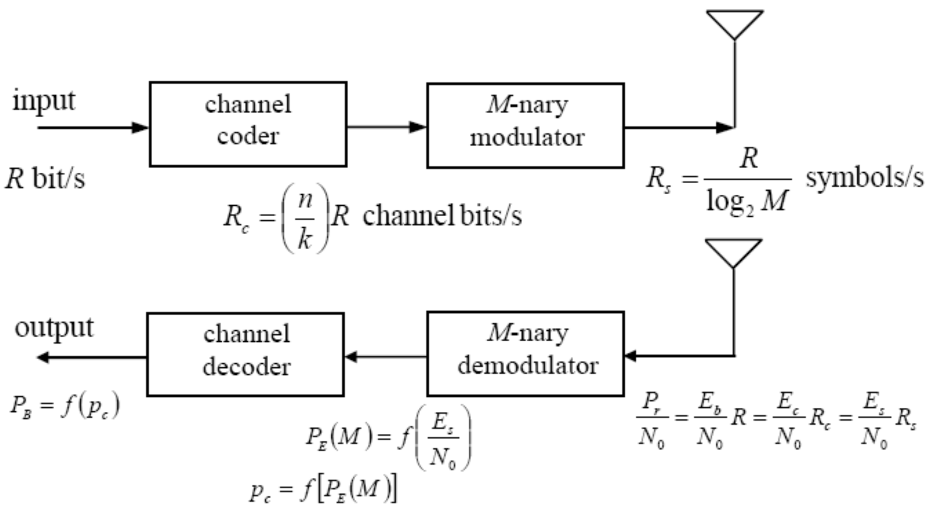

Figure 2. The circuit of the modem with channel encoding [2].

For the systems containing simultaneously both modulation, and channel encoding, transformations of attitudes of energy to spectral density of by power of noise will be the following:

$$\frac{E_c}{N_0} = \left(\frac{k}{n}\right)\frac{E_b}{N_0}$$
$$\frac{E_s}{N_0} = (\log_2 M)\frac{E_c}{N_0}$$

As values *Pr*/*N*0 and *R* are equal 61 dBHz and 17600 bits/s, from the equation (6) we find, that received *Eb*/*N*0=18,5 dB. It is necessary to note, that received *Eb*/*N*0 is fixed and does not depend on parameters of a code *n* and *k* and from parameter of modulation *M*. We define four parameters for the indication of a system effectiveness of channel encoding.

$$\frac{E_s}{N_0} = (\log_2 M)\frac{E_c}{N_0} = (\log_2 M)\left(\frac{k}{n}\right)\frac{E_b}{N_0}$$
$$P_E(M) = 2Q\left[\sqrt{\frac{2E_s}{N_0}}\sin\left(\frac{\pi}{M}\right)\right]$$
$$p_c = \frac{P_E}{\log_2 M}\ , \quad (P_E << 1)$$
$$P_B = \frac{1}{n}\sum_{j=t+1}^{n} j\binom{n}{j} p_c^j (1-p_c)^{n-j}$$

Below corresponding calculations are resulted.

$$\frac{E_s}{N_0} = 4\cdot\left(\frac{106}{127}\right)70{,}8 = 236{,}4$$

where M=16, and received E_b/N_0=18,5 dB (or 70,8)

$$P_E = 2Q\left[\sqrt{472{,}8}\cdot\sin\left(\frac{\pi}{16}\right)\right] = 2Q(4{,}35) = 1{,}44\cdot 10^{-5}; \qquad p_c = \frac{1{,}44\cdot 10^{-5}}{4} = 3{,}57\cdot 10^{-6}$$

$$P_B = \frac{4}{127}\binom{127}{4}(3{,}57\cdot 10^{-6})^4(1-3{,}57\cdot 10^{-6})^{123} +$$
$$\ldots = 5{,}28\cdot 10^{-17}$$

On the fourth step ability of a code to correction of bit mistakes is equal t=3. For reception *PB* on the fourth step for achievement of good result the first member of the sum in the equation (14) is enough to use only. It is possible to see, that with application of channel encoding occurrence of a bit mistake is almost eliminated. For a code (127, 106), we shall calculate transmission rate of data in channel bit's *Rc* and transmission rate of symbols *Rs*, by means of the equations, at M=16

$$R_c = \left(\frac{n}{k}\right)R = \left(\frac{127}{106}\right)17600 = 21087 \text{ channel bits/s;}$$
$$R_s = \frac{R_c}{\log_2 M} = \frac{21087}{4} = 5272 \text{ symbols/s}$$

From the formula, defining *PB* it is visible, that this value quite satisfies demanded probability of occurrence of bit mistakes. Thus, by means of 16-level PSK it is possible to meet the requirements of the specification of the given channel with the limited by power and throughput with use of system of channel encoding.

4.3 Definition of efficiency of channel encoding

For definition of efficiency in the beginning for the circuit 16-level PSK without channel encoding pays off, how much greater (concerning accessible 18,5 dB) value E_b/N_0 is required for reception P_B=10^{-10}. This additional E_b/N_0 is demanded efficiency of channel encoding. Using the following formula it is found *Es*/*N*0 without use of encoding which will give probability of occurrence of mistake P_B=10^{-10}.

$$P_B \approx \frac{P_E}{\log_2 M} \approx \frac{2Q\left[\sqrt{\frac{2E_s}{N_0}}\sin\left(\frac{\pi}{M}\right)\right]}{\log_2 M} = 10^{-10}$$

Calculation of the equation with a trial and error method rather E_s/N_0, will give value for system without channel encoding E_s/N_0=518,25 (27,15 dB) and as each symbol consists from log216=4 the bit's, demanded E_b/N_0 (without encoding) = 518,25/4=129,6 (21,13 dB). From the equation (11) it is known, E_s/N_0=236,4 (23,74 dB), and therefore, with channel encoding, E_b/N_0=236,4/4=59,1 (17,72 dB). Efficiency of channel encoding is defined by the following formula:

$$G\,(\text{дБ}) = \left(\frac{E_b}{N_0}\right)_{without\ encoding}(\text{dB}) - \left(\frac{E_b}{N_0}\right)_{with\ encoding}(\text{dB}) = 21{,}13\ \text{dB} - 17{,}72\ \text{dB} = 3{,}41\ \text{dB}$$

5. Conclusion

The present article reviews efficiency evaluation methods for IEEE 802.11 broadband wireless networks under heavy and normal load. The method is based on Markov models and allows a precise estimation of major efficiency parameters: competition window and delay time. This method would allow for more effective optimization of broadcasting message generation times in order to minimize the average notification time.

Thus the main indicator of quality of the ultra broadband channel is a signal-to-noise ratio at the output of the correlation receiver. To reduce the signal-to-noise ratio at the inlet to the receiver should be lowering the frequency and energy efficiency systems.

This technique allows the calculation of coverage of broadband access networks, in practice, turning out thereby experience with the introduction of broadband access technologies to ensure the quality and the introduction of competitive services.

At modernization of telecommunication systems from the point of view of development and applications of perspective technologies on the basis of effective methods algorithms of channel encoding render practical value in this direction. Application of channel encoding in systems of a digital information communication enables to lower the energy, having to everyone transferred bit's, provides a high noise stability, especially, in a digital video broadcasting where transferred symbols are the electronic form of dynamic actions, and their elements are transferred by a principle «from a point to a point».

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