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Selection of an Error-Protecting Method in Packet Radio Networks*

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1. Introduction

The transmission methods ensuring error protection in packet radio networks are based on error detection and correction with the help of noise-resistant coding or the use of a feedback of different types. Having in mind that the status of the radio channel depends on many factors and alters according to the seasons and daytime, it is necessary to choose and apply such error protecting methods, that allow efficient transmission in a wide disturbances range.

In order to estimate and choose any transmission method, one of the possibilities is to compare the most important characteristics of the radio networks such as transmission rate (or messages delivery time) and reliability of the information received.

Many investigations connected with the choice of operation algorithms minimizing the average messages delivery time, have been published in [1-4]. In the present study the average delivery time depends on the transmission rate and the validity of the information received is additionally computed. Since these two characteristics are in contradiction, a variant for the selection of transmission methods is suggested with respect to a generalized characteristics which is a product of the relative transmission rate and the information validity. This result can be conditionally accepted as a quantitative estimation of the transmission efficiency. For this purpose the analytical relations for the transmission rate and the reception reliability are studied with respect to the approach used for error protection.

2. Transmission methods using noise protected coding

a) Transmission rate

The transmission rate R_k can be determined as relative speed of the information

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coded, which is the ratio between the number of the information symbols in the packet (or message) and the total number of symbols. If L is the number of bits in the message, not accounting the service information, C – the number of service bits in the packet, and X – the number of packets in which the message is defective according to a given criterion, then the length of the packet given $l(x)$ is equal to $L/x + C$.

Then

$$R_k = L/(L+CX). \tag{1}$$

It is obvious that relation (1) is valid when the continuation and intensity of the disturbances are such that the error caused by them does not exceed the correcting capacities of the code selected which is characterised above all by the number of service bits in the packet.

In case we admit that the code is selected to correct a group error, then the disturbance $\eta_\kappa \le 1/t_c$, where t_c is the time necessary to transmit the packet, η_κ – the bound value of disturbances intensity, the exceeding of which leads to incorrectable errors, i.e., such intensity, in which the information reception with errors detection and correction is impossible.

b) Transmission validity

It can be evaluated by the probability that the receiver would get corrected information. It is obvious that this event is available under the following conditions:

– if no error is discovered, the probability for error detection P^k_{dis} is determined as $P^k_{\text{dis}} = 1 - 2^{-((L+CX)-L)} = 1 - 2^{-CX}$;

– if the errors available correspond to the correcting capacities of the code applied. This probability is equal to the probability to have more than one group of errors and if it is assumed that the errors flow is Poisson [5], in which the probability for the occurrence of k events within the interval t_c (necessary for packet transmission), is:

$$V_k(t_c) = e^{-\eta t_c}(\eta t_c)^k / K!,$$

then the probability that the errors are adequate to the code correcting capacities is defined as $P_c = V_\eta(t_c) + V_1(t_c) = (1+\eta t_c)e^{-\eta t_c}$. The probability for correspondence with the correcting capacities of the code is a function of disturbances intensity and the time necessary for the transmission of one packet, denoted by t_c. The bound values of this probability are at $\eta t_c = 0$, $P_c = 1$, and at $\eta t_c = 1$, $P_c = 0{,}736$.

– if the error discovered is corrected, i.e., the probability for this event is equal to one.

Hence, the fidelity of the information received is estimated by the validity of the first two events and since these two events are independent, the probability for correct reception is $P^\kappa_\pi = P^k_{\text{dis}} . P_c$ or

$$P^\kappa_\pi = (1 - 2^{-CX})(1+\eta t_c)\, e^{-\eta t_c}). \tag{2}$$

3. Transmission methods using a determining feedback

Determining feedback of different types is applied for error protection – one with expectation, with continuous transmission, with storage, with address request for repetition, etc.

a) transmission rate

– systems with a feedback with expectation - the transmitter in them sends the next packet only after it has an acknowledge signal for correct reception V by the receiver

[6]. In this case, if an error is detected in the reception, this message is deleted, and a signal for repetition W is sent to the transmitter. The transmitter then transmits the next or repeats the preceding packet after a given time of waiting $t_w = 2\, t_p + t_n + t_q + t_{ac}$, following the preceding packet transmission, where t_p is the time for signal propagation from the transmitter to the receiver or vice versa, t_n is the time for generation and transmission of signals V or W, t_q is the time of decoding and error search in the message received and t_{ac} is the time for reception and analysis of signals V or W. In such an organisation the maximum possible number of packets transmitted for a given time t is defined as $N_{\text{transmax}} = t/(t_c + t_w)$, and the maximum transmitted symbols – $(L+CX)N_{\text{transmax}}$. The receiver gets LN_{trans} symbols, the number of the packets received being different from the number of the transmitted ones by $N_{\text{del}} + N_{\text{miss}}$, where N_{del} is the number of the packets deleted in the receiving side, due to the disturbance, and N_{miss} is the number of not transmitted packets in the interval connected with acknowledge expectation. Obviously $N_{\text{del}} = \eta\, t$; $N_{\text{miss}} = \eta\, t{*}B\, t_w/(L+CX)$, so taking into consideration these relations, the relative speed of transmission is defined as:

(3) $$R_w = LN_{\text{miss}}/\ (L+CX)\ N_{\text{transmax}} = (L/(L+CX)(\ 1-\eta/t_c(t_c + t_w)^2).$$

In this case $t_c = (L+CX)/B$ is the time necessary for transmission of one packet, and B is the transmission rate. Expression (3) shows that there exists such intensity of the disturbances at this organisation of the transmission

(4) $$\eta_w = t_c/(\ t_c + t_w)^2,$$

in which the capacity equals zero. Expression (4) determines in fact the bound values of the disturbances, while at larger values only continuous request for repetition will be realized.

If in a message transfer a repetition request for the error packet only is sent, the maximum time T_t for the transmission of one packet can be computed.

$$T_t \approx (t_t + t_w(\eta\, t_t - 1))/(1-\eta\, t_c),$$

where t_t is the time for one-fold transmission of the packet. The relative rate in this case is:

(5) $$R_{\text{rel}} = L\, t_t\,/(L+CX)\ T_t\ = L\, t_t\,/(L+CX)\ (t_t\ + t_w(\eta\ t_t\ -1\ ))/(1-\eta\, t_c\ ),$$

at that the bound value of disturbances intensity at repetition of the error packet only is defined as:

(6) $$\eta_{\text{adr}} = 1/\ t_t\ ,$$

where t_t is the time necessary for packet transmission.

The relations obtained show that if we discuss the parameter relative transmission speed only at good status of the channel the use of a determining feedback has an advantage compared to the correcting codes. But there is always a threshold value of the disturbances intensity, when the correcting codes become more efficient.

b) transmission validity

It can also be estimated by the probability the receiver to get corrected information. It is obvious that such an event is present under the following conditions:

– in case an error is detected, the probability for error detection P_{det} is determined as:

$$P_{det} = 1 - 2^{-((L+CX)-L)} = 1 - 2^{-CX};$$

– if the error correction on the account of multifold repetitions is possible using a feedback, the probability for this event P_{corf} is equal to one.

– if the error detected is corrected, the probability for such an event is equal to one.

Since the information validity is estimated by the first two events, that are independent, the probability for correct reception is:

$$P_{rec} = P_{det} {}^{\kappa} P_{corf} = 1 - 2^{-((L+CX)-L)} = 1 - 2^{-CX};$$

As already suggested, a general characteristics, equal to the product of the relative speed and the transmission accuracy, is used.

The efficiency of the transmission method with a feedback and repeating of the error packet only is determined as:

(7) $$E = L/(L+CX)\,(1 - \eta\, t_c)\,(1 - 2^{-((L+CX)-L)}) \approx L/(L+CX)\,(1 - \eta\, t_c),$$

and when using correcting codes, E_{corc} is the following:

(8) $$E_{corc} = L/(L+CX)(1 + \eta t_c)(1 - 2^{-CX})(1+\eta t_c)e^{-\eta t_c} \approx L/(L+CX)_k(1+\eta t_c)\, e^{-\eta t_c}.$$

When investigating the effectiveness of the two transmission methods it can be seen that there is a threshold value of the disturbances n, the exceeding of which makes the use of the correcting codes less efficient, the computations showing that this value is small enough and it is about $\eta_{lim} \leq 0.001/t_c$.

Using relations (7) and (8) obtained, such information redundancy (service symbols) can be defined, which gives greater efficiency of correcting codes application in comparison with the methods using repetitions, apart from the channel quality, i.e., the errors intensity. This is evidently possible, when

$$E_{corc} > E, \text{ i.e. } L/(L+CX)_k\,(1+\eta\, t_c)\, e^{-\eta t_c} > L/(L+CX)\,(1 - \eta\, t_c).$$

The inequality obtained enables the defining of the redundancy for a given status of the channel, in which the use of noise resistant coding (correcting code) is more efficient than the repeating of erroneous packets. After the respective redundancy is defined it remains only to find the correcting code with such redundancy.

Concluding, we can make the inference that since the transmission in packet radio networks is defined by the variable status of the channel, in order to ensure efficient transmission in a wide range of errors intensity, it is necessary to use correcting codes, the redundancy of which is computed with the help of the relations proposed. They take into consideration the relative transmission speed and the accuracy of the information received depending on the transmission method selected.

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Выбор метода защиты ошибок в пакетных радиосетях

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(Резюме)

Предложена возможная количественная оценка эффективности передачи в пакетных радиосетях, используя обобщенный критерий, отчитывающий среднее время доставки сообщения и достоверность принятой информации.

В статье показаны в общем виде результаты при методах передачи, использующих шумоустойчивое кодирование и методы передачи с решающей обратной связи.