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THE PROBABILITY OF AGING PACKETS IN A CHANNEL WITH ADDITIVE WHITE GAUSSIAN NOISE FOR M-QAM MODULATED SIGNALS

Based on theories of teletraffic, transmission of digital signals and the Shannon-Hartley theorem the generalized analytical model and the probability of aging packet for M-QAM modulated signals are given.

Keywords: model, channel, packet, bit, noise, probability.

Introduction. In the analytical models with packet switched communication channels using the theory of queueing systems the main output parameters are time-probability characteristics (probability of packet delivery up to aging, delays and so on) and other characteristics based on them (load, «functional good quality») [1]. In these analytical models the channel noise implicitly and indirectly affect the probability of packet delivery up to aging. Let's try to identify this connection.

Theoretical part. In the physical environment the upper limit of the data transmission speed, which is the minimum required amount of channel bandwidth is determined by the Shannon-Hartley theorem:

$$v = B\log_2\left(1+\frac{S}{N}\right) \quad , \tag{1}$$

where B is the channel bandwidth (Hz), S is the signal power (W), N is the noise power (W).

But in digital systems it will be more correct to place S/N using a normalized version of this ratio, which represents the ratio of the energy of one data bit (E_b) to noise power in 1 Hz [2]:

$$\frac{E_b}{N_0} = \frac{S}{N}\cdot\frac{B}{v_S} \quad , \tag{2}$$

where v_S is the bit rate of modulated signal. In QAM modulation case v_S can be represented as the product of symbol rate f_S, and mapping rate m (number of bits transmitted by the same symbol):

$$\frac{S}{N} = \frac{E_b}{N_0}\cdot\frac{f_S\cdot m}{B} \ . \tag{3}$$

In this way we can approve (the formulas (1) and (3)) that the minimum required amount of channel bandwidth depends on the ratio E_b/N_0:

$$v = B\log_2\left(1+\frac{S}{N}\right). \tag{4}$$

Using the results of [1] for the probability of packet delivery up to aging, we obtain:

$$P_d = \frac{1 - \dfrac{\lambda b}{B\log_2\left(1 + \dfrac{E_b}{N_0} \cdot \dfrac{f_S m}{B}\right)R}}{1 - \dfrac{\lambda b}{B\log_2\left(1 + \dfrac{E_b}{N_0} \cdot \dfrac{f_S m}{B}\right)R} + \dfrac{b}{B\log_2\left(1 + \dfrac{E_b}{N_0} \cdot \dfrac{f_S m}{B}\right)R}\left[c + \dfrac{B\log_2(1 + \dfrac{E_b}{N_0} \cdot \dfrac{f_S m}{B})R}{b}\dfrac{(1-R)}{\left(R + \dfrac{1}{c\theta}\right)}\right]}, \quad (5)$$

where λ is the intensity packet generation (1/s), b is the packet size (bits), c is the intensity of the aging packages (1/s), θ is the time recovery (s), R is the restitution coefficient of the channel.

On the other hand, in a channel with Additive White Gaussian Noise the dependece of the probability of bit error rate (losses) on the E_b/N_0 ratio with an accuracy of 0,1 *dB* is described by the following expression [3]:

$$P_{BE} \approx 2 \cdot \left(1 - \frac{1}{\sqrt{M}}\right) \cdot erfc\left[\sqrt{\frac{3\log_2(M)}{2(M-1)} \cdot \frac{E_b}{N_0}}\right], \quad (6)$$

where M is the modulation format, and erfc is the non-elementary Error function (also called the Gauss error function):

$$erfcx = 1 - erfx = \frac{2}{\sqrt{\pi}}\int_x^{\infty} e^{-t^2}\,dt\,. \quad (7)$$

Based on formulas (3), (4) and (5), we can construct a generalized analytical model of the aging packet probability in a channel with additive white Gaussian noise and M-QAM modulated signals. This model can be represented as the product of $P_c = (1 - P_d)P_{BE}$. The structure of this model is shown in Fig. 1.

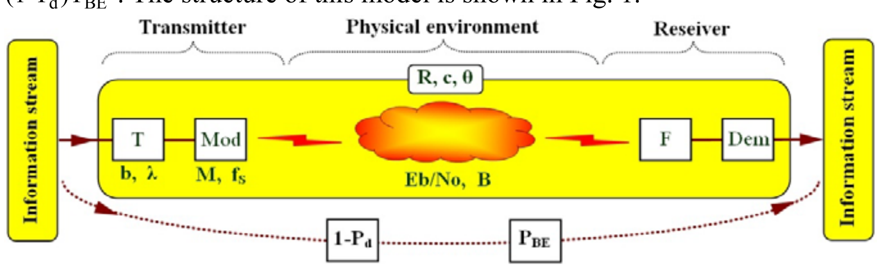

Fig. 1. T –Terminal - packet generator, Mod - QAM modulator, F - Gaussian matched filter, Dem – QAM Demodulator

In this model it is beforehand assumed that Forward Error Correction (FEC) and Reed Solomon encoding, are not performed; the loss of one bit information and delivery of the outdated packet (i.e. after the loss of packet relevance) are equivalent events.

In MathCad environment, in a channel with Additive White Gaussian Noise for M-QAM modulated signals the dependence of the aging packet probability on the E_b/N_0 ratio (Fig. 2) is built. In a channel the probability of aging packets is a more universal way to measure the channels' quality than the probability of a bit error.

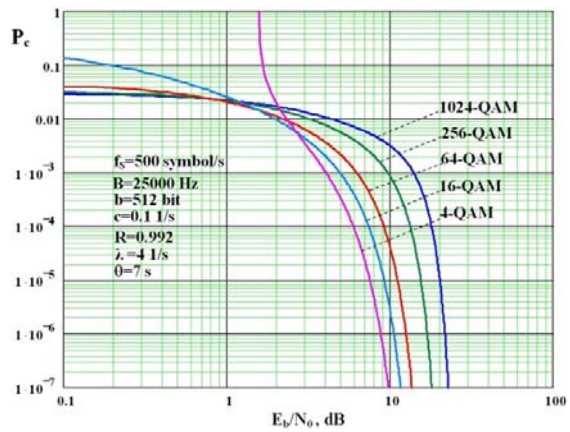

Fig. 2

Conclusion. This assertion is based on the fact that the packet could be delivered to the destination unharmed, but already outdated and with lost relevance.

REFERENCES

1. **Овсепян А.К., Арустамян В.Е., Овсепян Г.А.** Выбор критериев оптимальности интегрированных сетей с коммутацией пакетов // Вестник Государственного инженерного университета Армении. Серия "Моделирование, Оптимизация, Управление".- Ереван, 2009.-Вып.12, том 2.- С.121-126.
2. **Bernard Sklar.** Digital communication. Fundamentals and Applications, Prentice Hall PTR.- New Jersey, 2001.- 1079 p.
3. **Proakis J.G.** Digital Communication. 3rd Edition.- McGraw-Hill, New York, 1995.- 928 p.

Ա.Կ. ՀՈՎՍԵՓՅԱՆ

ՓԱԹԵԹՆԵՐԻ ԾԵՐԱՑՄԱՆ ՀԱՎԱՆԱԿԱՆՈՒԹՅՈՒՆԸ M-QAM ՄՈԴՈՒԼԱՑՄԱՄԲ ԱԶԴԱՆՇԱՆՆԵՐՈՎ ԵՎ ԳԱՈՒՍՅԱՆ ՍՊԻՏԱԿ ԱՂՄՈՒԿՈՎ ԿԱՊՈՒՂՈՒՄ

Բերված են M-QAM ազդանշաններով կապուղու փաթեթների ծերացման հավանականությունը և ընդհանրական անալիտիկ մոդելը՝ կառուցված տելետրաֆիկի, թվային ազդանշանների հաղորդման տեսությունների և Շենոն-Հարթլիի թեորեմի հիման վրա:

Առանցքային բառեր. մոդել, փաթեթ, բիթ, աղմուկ, հավանականություն:

А.К. ОВСЕПЯН

ВЕРОЯТНОСТЬ СТАРЕНИЯ ПАКЕТОВ В КАНАЛЕ С АДДИТИВНЫМ БЕЛЫМ ГАУССОВСКИМ ШУМОМ ДЛЯ M-QAM МОДУЛИРОВАННЫХ СИГНАЛОВ

Приведены обобщенная аналитическая модель и вероятность старения пакетов для M-QAM модулированных сигналов, построенная на теориях телетрафика, передачи цифровых сигналов и теореме Шеннона-Хартли.

Ключевые слова: модель, канал, пакет, бит, шум, вероятность.