One Simple Way of Comparing the Bandwidth of a Signaling CCS No7 Channel under the Influence of Bursty and Random Errors

Dragan Mitić, Aleksandar Lebl, Žarko Markov

Institute for Telecommunications and Electronics, Iritel A.D. Belgrade
Batajnički put 23, 11080 Belgrade, Serbia
E-mail: mita@iritel.com; lebl@iritel.com; zarko.markov@iritel.com

Abstract: The bandwidth of signaling channel with bursty errors can be larger or smaller than the bandwidth of channels with random errors. In this paper, we give the answer to the question: Is it possible in an easy way to determine the relationship between the bandwidths of these two models? First, we define the method that determines the bandwidth of the signaling CCS No7 channel under the influence of random errors, and then the method that determines the bandwidth of the signaling CCS No7 channel under the influence of bursty errors. The paper also gives the procedure, which easily compares the channel bandwidth for these two types of errors.

Keywords: bandwidth of signaling CCS No7 channel; random errors; bursty errors; Jensen's inequality

1 Introduction

The bandwidth of the signaling CCS No7 (*Common Channel Signaling Number 7*) channel is inversely proportional to the time of service (processing time and waiting time, i.e. delay). This is why we can say that the bandwidth of the signaling CCS No7 channel is indirectly determined by the recommendation Q.706, [1], which determines the time delay in CCS No7 systems. Parameters: bit rate and signal propagation time on the digital channel are processed in this recommendation, and these are important parameters that characterize the digital transmission.

Parameter bit rate penetrates almost all areas of CCS No7. Its influence on the signaling characteristics of protocol MTP (*Media Transfer Protocol*) cannot be neglected. Bit rate is an unavoidable factor in the standardization of certain parts of this protocol. In this paper we will always mean a bit rate of 64 kb/s and the MTP standards related to this bit rate.

Signal propagation time through the data channel, T_p, is the time period that begins when the last bit of signaling unit leaves the data channel on the transmitting side and ends when the last bit of signaling unit leaves the data channel on the receiving side. This time depends on the distance between the points that interchange signaling information and on the digital media (Table 1/Q.706, [1]).

The importance of this parameter is primarily in the fact that it forms a new parameter called the double propagation time, T_L. In the literature [1, 2, 3] it is widely used as a constant parameter. The assigned value is T_L = 30 ms and corresponds to the longest terrestrial connections, which are about 2000 km. In this paper, it is considered that this parameter is 30 ms.

A simple method to compare the influence of *BER* (*Bit Error Rate*) on the bandwidth of the signaling CCS No7 channel under the influence of random and bursty errors is presented at the end of this paper.

2 Bandwidth of Signaling CCS No7 Channel under the Influence of Random Errors

The signaling unit's Message Signal Unit (MSU) and Link Status Signal Unit (LSSU), as well as all other signaling messages, must not be lost. Processing of the signaling channel is arranged as a waiting queuing system. The place where the messages for one channel are waiting to be sent is called the transmission and/or retransmission buffer. The signaling units are in it as long as the sending party does not receive confirmation of successful receipt of the signaling unit from the receiving side.

The main indicator of the traffic signal channel bandwidth as a waiting queuing system is the mean waiting time, which is calculated from the moment of the unit content readiness for sending until the start of sending it to the channel. This statement will be used in this paper.

The problem of bandwidth will be connected with the problem of dimensioning the signaling channel in the sense of its utilization. The signaling channel is dimensioned so that the offered traffic, a, in the normal operation of the channel do not exceed a specified maximum, a_{max}. The criterion for determining the values of a_{max} are the conditions for the operation of the signaling channel. According to the current recommendations, the value a_{max} varies between 0.2 Erl and 0.4 Erl. From Q.706 [1], we use the expression which presents the average waiting time to send the signaling message by signaling CCS No7 channel, Q_t, in the presence of uniformly (or randomly) distributed errors. In the case of error appearance, the basic error correction method and message retransmission are applied. The mentioned expression from [1] is given in the form:

$$Q_t = \frac{T_f}{2} + \frac{a}{T_m} \cdot \frac{\left(m_2 + P_{SU} \cdot T_L \cdot \left(T_L + 2 \cdot T_m\right)\right)}{2 \cdot \left(1 - a \cdot \left(1 - \frac{P_{SU} \cdot T_L}{T_m}\right)\right)} + P_{SU} \cdot T_L \quad (1)$$

where the variables are:

- Q_t – mean waiting time;
- T_f – Fill In Signal Unit (FISU) message duration;
- a – traffic of MSU units;
- T_m – mean duration of MSU message (or serialization time);
- P_{SU} – probability of incorrectly transmitting signaling unit;
- T_L – double propagation time from the sending to the receiving side;
- m_2 – the second moment of the MSU duration, ($m_2 = T_m^2 + \sigma_m^2$, where σ_m^2 is the variance of the MSU duration).

Distribution of the MSU duration and other parameters are as in the examples listed in (Model A, Table 3/Q.706, [1]).

In order to consider the error impact on the waiting time to send a signaling message by the signaling CCS No7 channel, it is necessary to calculate a function which gives the mean waiting time for sending signaling messages by the signaling channel, depending on the bit error intensity (*BER*), $Q_t = Q_t(BER)$. The connection between the probability of incorrectly transmitted signaling unit, P_{SU}, and the *BER* is given by the following expressions [3]:

$$P_{SU} = 1 - (1 - BER)^n \quad (2)$$

$$BER = 1 - (1 - P_{SU})^{1/n} \quad (3)$$

where n is the number of bits in the signaling unit. From [3] it follows that $n = 8 \cdot l_{SU}$, where l_{SU} expresses the number of octets in the signaling units.

In Eq. (1), the offered traffic of signaling units will be expressed using the effective traffic of signaling units, which is calculated according to the following expression [4, 5]:

$$a_{eff} = a \cdot \frac{1 + P_{SU} \cdot \frac{T_L}{T_m}}{1 - P_{SU}} \quad (4)$$

The effective traffic, a_{eff}, in real conditions of error existence is always greater than the offered traffic, a, because the messages are retransmitted due to the errors, and the repeated messages cause an increase in traffic on the CCS No7 channel. Ideally, when there are no transmission errors ($P_{MSU} = 0$, i.e. $BER = 0$), the effective traffic, a_{eff}, would be equal to the offered traffic, a.

The curves shown in Fig. 1 are obtained when P_{SU} is expressed by *BER*, Eq. (2) is substituted in Eqs. (1) and (4); and when the offered traffic, a, is replaced by the effective traffic a_{eff}, Eq. (4) is introduced in Eq. (1).

Parameters: a=0.2 Erl, lenght MSU 15,60 and 150 octets

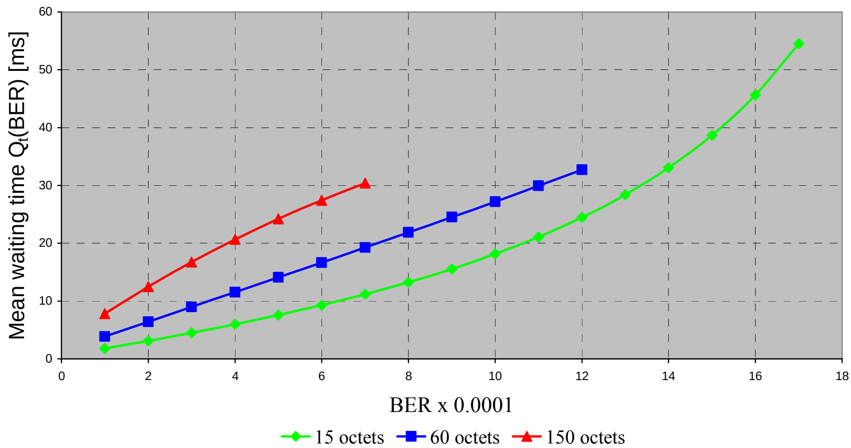

Figure 1

The average waiting time for sending MSU units, a = 0.2 Erl

Parameters: a = 0.2 Erl, length MSU 15, 60 and 150 octets

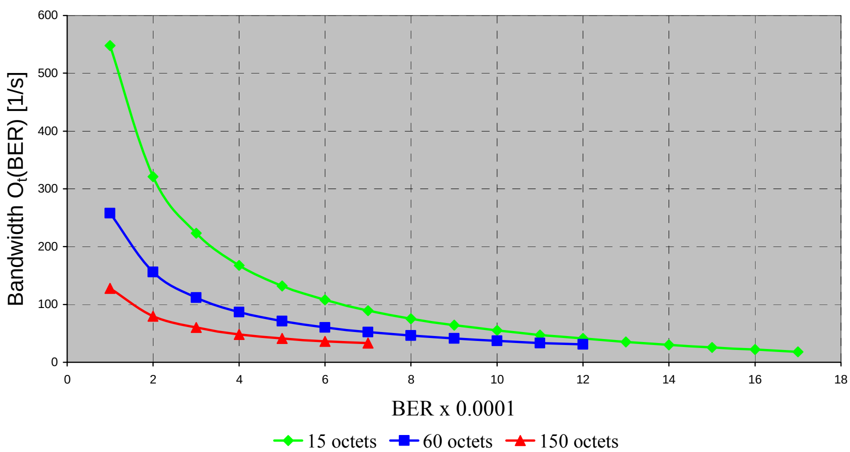

Figure 2

Bandwidth of signaling channel in the function of *BER*, a = 0.2 Erl

Bandwidth, $O_t(BER)$, of the signaling CCS No7 channel can be defined as $O_t(BER) = 1/(Q_t(BER)+T_m)$. In real situations, according to [1], the value of T_m is less than 2 ms, and thus can be neglected comparing to $Q_t(BER)$. That is why we can simplify the last expression to $O_t(BER) \approx 1/Q_t(BER)$. Upon conversion of the calculated $Q_t(BER)$ for certain values of BER, we get the curves presented in Fig. 2.

From Fig. 1 and Fig. 2, it can be seen that as the signaling messages become longer, the mean waiting time for the sending of messages increases, and therefore the bandwidth of the signaling CCS No7 channel decreases. In addition, the mean waiting time on MSU units for sending increases with the increase in *BER*, and thus causes a reduction in bandwidth of the signaling CCS No7 channels.

3 Determination of the Signaling Channel Bandwidth under Influence of Bursty Errors

Later in this section, special attention will be paid to the impact of bursty errors on the bandwidth of the signaling CCS No 7 channel. We will describe one simple method for determining the properties of the signaling CCS No7 channel in the case of bursty errors, which are corrected using the primary method of retransmission. This method is based on the application of Jensen's inequality, [6].

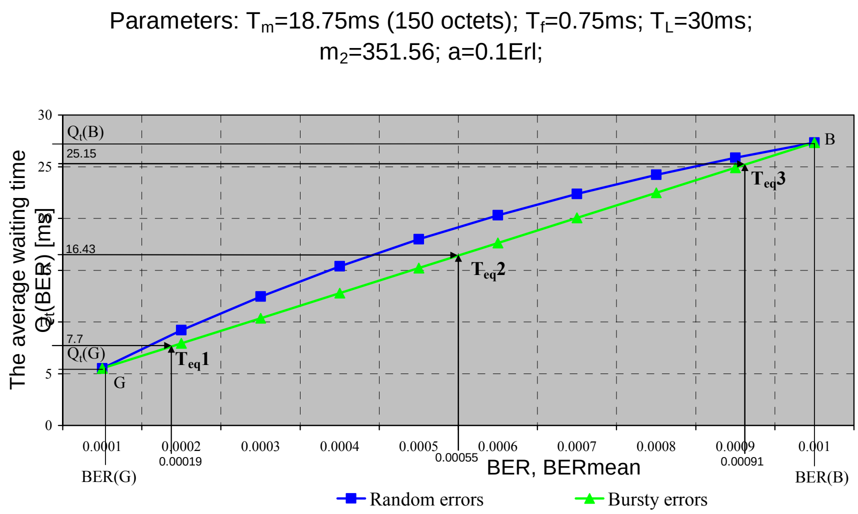

Figure 3

Average waiting time for sending signaling messages by signaling CCS No7 channel for random errors (concave curve) and for bursty errors (straight line)

Mean waiting time for sending signaling messages by the signaling channel is given as a function of traffic, $Q_t(a)$ in recommendation Q.706, (1). In order to obtain the mean waiting time for sending signaling messages by the signaling channel in function of *BER*, $Q_t(BER)$, in this section the offered traffic, *a*, is taken as a parameter (4), and the probability of incorrectly received message, P_{SU}, is expressed by *BER* (2). So, we obtain an expression that gives the average waiting time for sending the signaling messages by the signaling channel as a function of variable *BER*. Based on the calculated values for $Q_t(BER)$ in the function of variable *BER*, the curves in Fig. 3 and Fig. 4 are obtained.

Parameters: T_m=1.875ms (150 octets); T_f=0.75ms; T_L=30ms;
m_2=3.5156; a=0.8 Erl;

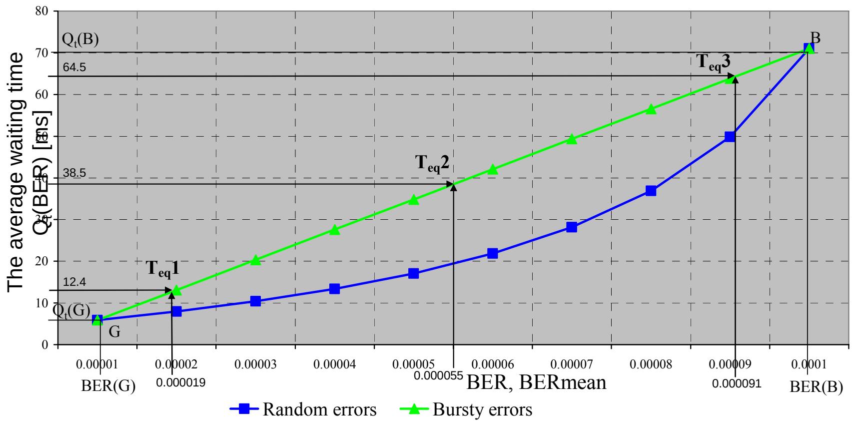

Figure 4
Average waiting time for sending signaling messages by the signaling channel for random errors (convex curve) and bursty errors (straight line)

The shape of the function $Q_t(BER)$, calculated using Eq. (1), depends on the used parameters given in Fig. 3 and Fig. 4. On the basis of the selected parameters, the curve $Q_t(BER)$ can be concave (convex upstairs) or convex (convex downstairs), and in special cases it can be approximately straight lines.

Let us now suppose that the signaling CCS No7 channel is under the influence of bursty errors, so it can be modeled using the well-known Gilbert-Elliot model. According to this model, the signaling CCS No7 channel can be found in a "good" state G or in a "bad" state B. In the graphs (Fig. 3 and Fig. 4), the left-most points are defined as states with less bit error rate *BER(G)* and marked by G, and the right-most points are defined as states with greater bit error rate *BER(B)* and marked by B [7]. It is assumed, that the signaling CCS No7 channel can be found in a state G with probabilities P_G1, P_G2 and P_G3, or in a state B with probabilities P_B1, P_B2 and P_B3, wherein always $P_Gi + P_Bi = 1$, (i = 1, 2, 3) [7]. After these assumptions, the equivalent *BER*, BER_{eq}, and equivalent mean waiting time, Q_{eq}, can be very easily calculated, according to (5) and (6) for couples P_Gi and P_Bi, (i = 1, 2, 3):

$$BER_{eq}(P_Gi,P_Bi) = P_Gi \cdot BER(G) + P_Bi \cdot BER(B) \qquad (5)$$

$$Q_{eq}(P_Gi,P_Bi) = Q_t(G) \cdot P_Gi + Q_t(B) \cdot P_Bi \qquad (6)$$

where:

- $Q_t(G)$ - mean waiting time for sending signaling messages in the point G;
- $Q_t(B)$ - mean waiting time for sending signaling messages in the point B;
- $BER(G)$ - intensity of bit errors at the point G;
- $BER(B)$ - intensity of bit errors at the point B.

Points $T_{eq}1$, $T_{eq}2$ and $T_{eq}3$, which are defined by the pairs $BER_{eq}1$ and $Q_{eq}1$, $BER_{eq}2$ and $Q_{eq}2$, $BER_{eq}3$ and $Q_{eq}3$, [4], are displayed in Fig. 3 and Fig. 4. If we now draw the line that connects the end points G and B (Fig. 3 and Fig. 4), we shall see that points $T_{eq}1$, $T_{eq}2$ and $T_{eq}3$ lie on the line drawn through the points G and B. Therefore, the line drawn through points G and B is the set of points that represents the mathematical expectation for the mean waiting time for sending signaling messages by the signaling channel in the case of bursty distributed errors, because for any pair of values P_Gx and P_Bx, the calculated values $BER_{eq}x$, (5), $Q_{eq}x$, (6), are represented by the point $T_{eq}x$, which is situated on this line, [2].

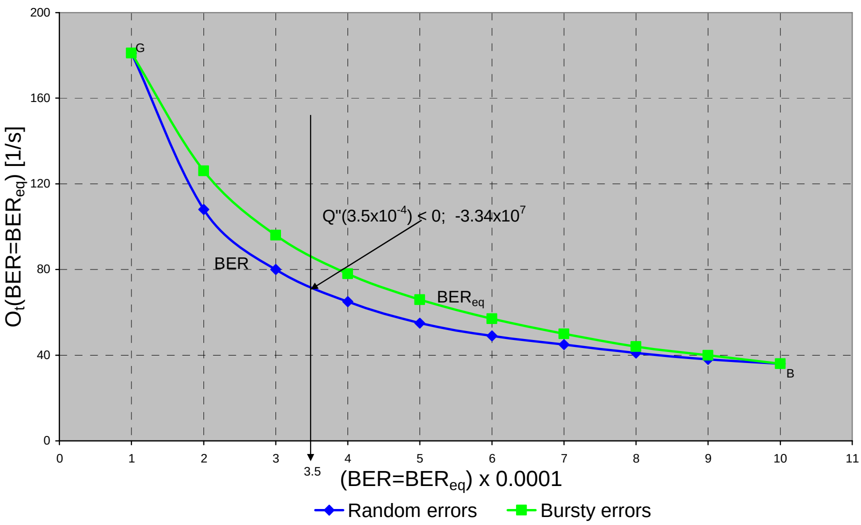

Figure 5

Bandwidth of the signaling CCS No7 channel for random and bursty errors, when the curve $Q_t(BER)$ for random errors is concave

From aforementioned, it can be concluded that if we know the curve of a mean waiting time for sending signaling messages by the signaling channel for the channel model with random errors, $Q_t(BER)$, then the graph of the mean waiting time for the channel model with bursty errors can be easily obtained as a line (chord) drawn between the end points of the curve $Q_t(BER)$ [2].

The bandwidth of the signaling CCS No7 channel that affects the random or bursty error was calculated over the function $O_t = 1/Q_t(BER)$ and $O_t = 1/Q_t(BER_{eq})$ for the two cases: for the concave curve, Fig. 5, and for the convex curve, Fig. 6.

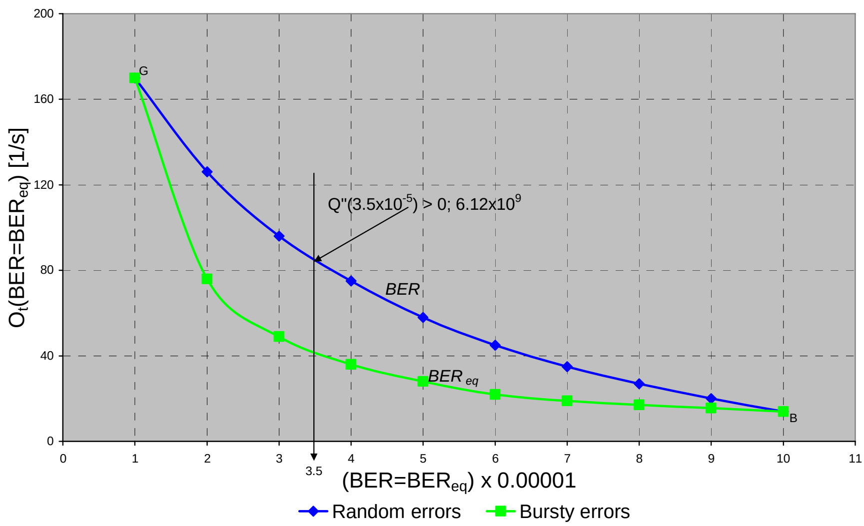

Figure 6

Bandwidth of the signaling CCS No7 channel for random and bursty errors, when the curve $Q_t(BER)$ for random errors is convex

4 A Simple Way of Comparing the Bandwidth of the Signaling CCS No7 Channel under the Influence of Bursty Errors

In the case of curve $Q_t(BER)$, which is concave/convex, Fig. 3/Fig. 4, bursty errors have less/more influence on the function of the signaling channel, because all values that represent the mathematical expectation of the waiting time for sending signaling messages over the signaling channel in the presence of bursty errors are less/greater than if errors are uniformly distributed with the same value of BER (Jensen's inequality [2]). As discussed in the previous section, based on the curve of $Q_t(BER)$, it can be said that the bursty errors have more or less impact on the operation of the signaling channel than the random errors.

In practice, however, it is very annoying always to draw the graph of curves $Q_t(BER)$ as a function of BER for certain signaling CCS No7 channels and then to calculate the values of $Q_t(BER)$, Q_{eq} and BER_{eq}. That is why we propose a simpler method.

As was said in the introduction, the simple method for determining the impact of bursty errors on the function of the signaling CCS No7 channel starts with the calculation of the waiting time for sending a signaling message by the No7 digital signaling CCS channel, $Q_t(BER)$, in the case of a uniform distribution of errors, according to (1) from [1]. Then we calculate the second derivative of the function $Q_t(BER)$ and the second derivative values at a certain point using some mathematical programs, such as MATHEMATICA, MATLAB or any other program capable of calculating the second derivative of the function.

The calculated and obtained values of the second derivative of the function $Q_t(BER)$ can immediately provide information on whether bursty errors have more ($Q_t``(BER) > 0$) or less ($Q_t``(BER) < 0$) influence on the function of the signaling CCS No7 channel. Thus, we avoid the graphing of curves $Q_t(BER)$ as a function of BER for certain signaling CCS No7 channels and calculating the values of $Q_t(BER)$, Q_{eq} and BER_{eq}. Thus we obtain a faster and simpler method for determining the impact of bursty errors on the operation of the signaling CCS No7 channels.

Let us now choose the values for the BER to get a concave (convex) function. For $BER = 3.5\cdot10^{-4}$, we have the concave function and for $BER = 3.5\cdot10^{-5}$ we have the convex function, provided that the $BER = BER_{eq}$. The choice of values for BER is made so that the differences in the bandwidth of the signaling channels (which are under the influence of random or bursty errors) are more obvious. The figures show that in the case of concave function, the numeric value of the second derivative for $BER = 3.5\cdot10^{-4}$ is less than zero (Fig. 5, $Q_t''(3.5\cdot10^{-4}) = -3.34\cdot10^{7}$). Bursty errors have less impact on the function of the signaling CCS No7 channels; the bandwidth of the signaling channel is larger in the case of bursty errors. In the case of the convex function, the numeric value of the second derivative for $BER = 3.5\cdot10^{-5}$ is greater than zero (Fig. 6, $Q_t''(3.5\cdot10^{-5}) = 6.12\cdot10^{9}$), which means that bursty errors have a greater impact on the function of the signaling CCS No7 channels; i.e. the bandwidth of the signaling CCS No7 channel is smaller in this case.

Conclusions

In this paper the bandwidth of the signaling CCS No7 channel under the influence of random and bursty errors is considered. After all above, the following very important conclusions can now be drawn:

- The bandwidth of the signaling CCS No7 channel for the model with random errors is different from the bandwidth of the same channel under the influence of bursty errors;

- The bandwidth of the signaling CCS No7 channel with bursty errors is larger than bandwidth of the signaling CCS No7 channel with random errors if the function $Q_t(BER)$ is convex (small traffic and long MSU) and vice versa;

- The differences in bandwidth can be up to 100% (Fig. 6);

- Based on the shape of the curve of $Q_t(BER)$ and on the calculated value of the second derivative of the function $Q_t(BER)$, it can be determined whether the bursty errors have more or less impact on the bandwidth of the signaling channel than random errors, without calculating the value of the curve $O_t(BER) = 1/Q_t(BER)$.

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