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Availability of CCS No7 signalling channel under influence of bursty and random errors

Abstract. *This paper explaines the methods of calculation of CCS No 7 signalling channel availability (or unavailability) under the influence of random and bursty (group) errors. Algorithms for tracking of transmission error rate are used for the calculation of the basic parameters of signalling channel availability under the influence of random errors. The Gilbert-Elliott's model is used to determine the availability of signal link channels under the influence of bursty errors.*

Streszczenie. *W artykule przedstawiono metodę określania dostępności kanału CCS Nr. 7 w zależności od przypadkowych i incydentalnych błędów. Do śledzenia błędu transmisji wykorzystano wyznaczenie podstawowych parametrów kanału w obecności błędów przypadkowych. Dostępność kanału w obecności błędów incydentalnych wykorzystano model Gilberta-Elliotta. (**Dostępność kanału CCS Nr. 7 w obecności błędów przypadkowych i grupowych**)*

Keywords: CCS No7 signalling channel, random errors, bursty (group) errors, channel availability, Gilbert-Elliott's model.
Słowa kluczowe: kanał CCS, błędy przypadkowe, model Gilberta-Eliotta

Introduction

Digital transmission system (level 1 of message transfer part (MTP) protocol) and signalling channel (level 2 of MTP protocol) are two key subsystems within the MTP protocol. The availability of these two parts is very important for the function of the entire CCS No7 (*Common Channel Signalling Number 7, CCS No7*), and is closely related to the bit error rate (or error probability), P_{bit} (quality of transmission).

Several models, which can be used to estimate the basic parameters of signalling channel availability under the influence of random errors, are known in the literature. They are based on algorithms for tracking of transmission error rate. The basic parameters of the signal channels availability are the mean time of the correct operation and the mean time of the signalling channel synchronization. The models, developed in [1] and [2], are used in order to calculate these values.

In this paper the availability of CCS No7 signalling channel under the influence of bursty (group) errors or clusters is determined by Gilbert-Elliott's model. After that, the mean time to outage (mean time of normal operation) for the CCS No7 channel, $E(X)$, and the mean time of CCS No7 channel synchronization (the mean time of CCS No7 channel outage), $E(Y)$, are calculated.

About the CCS No7 signalling channel availability

The term availability is defined for systems and parts of the system with two functional states: the state of correct function and the outage state. These systems have the possibility of recovery. The availability or unavailability of the system is presented using the mean time to failure (*mean-time-to-failure*, MTTF), mean time to recovery (*mean-time-to-repair,* MTTR) and mean time between failure (*mean-time-between-failure*, MTBF). With these values, availability, *A*, and unavailability, *UA*, can be expressed as follows:

(1) $A=(MTBF-MTTR)/MTBF=MTTF/(MTTF+MTTR)=1-UA$

During operation, CCS No7 signalling channel can be in two states. The first state is the state of correct work *("in service state"*), and in this state the transfer of MSU (*Message Signal Unit, MSU*) (i.e. useful information depending on application) is possible. The second state is a state in which the channel is inoperative, "turns out" *("out of service" state*). After entering *"out of service" state* (disabled transmission of MSUs), the signalling channel synchronization starts. Signalling channel is returned in proper working condition after a successful synchronization. As seen, the signalling channel can be viewed as a system with the possibility of recovery (*repairable system*). Very important events in the operation of one signalling channel are: the outage of the channel from correct operation, and the return to correct operation (*signalling link failure - recovery events*).

The rate of incorrectly transferred signalling units over CCS No7 channel in the correct phase of operation is determined using SUER (*Signal Unit Error Rate*) monitor. The second monitor, AER (*Alignment Error Rate*) monitor, is used to track the rate of incorrectly transferred signalling units over CCS No7 channel in the outage phase of the signalling channel [1], i.e. in the procedure of CCS No7 channel synchronization (*alignment procedures*).

The periods of these two channel states are nearly matching the periods of operation of the two error rate monitors. Differences in time are so small that they can be ignored. Proper operation of the channel coincides with the operation of SUER monitor, while the outage state of the channel coincides with the operation of the AER monitor, [3].

Basic parameters for signalling channel availability depending on the intensity of bit errors, P_{bit}, can be calculated using the model of the algorithm of monitors which track error rate in the transmission over signalling channel.

Availability of signalling channel CCS No7 under the influence of random errors

a) Mean time for the synchronization of signalling channel CCS No7

The complete procedure of the signalling channel synchronization, and, therefore, the outage state of the signalling channel, can be presented in the form of a loop of M states, where M is the maximum number of unsuccessful tests within the period of a synchronization procedure.

Let us suppose that the number of test periods, during a synchronization procedure of CCS No7 channel, is random variable, which will be marked by Y1. The random variable, which represents the number of units received during a failed test period, is marked by Y2. Taking into account the above assumptions, the mean time of CCS No7 signalling channel synchronization, E(Y), expressed in seconds, can be presented as:

(2) $$E(Y)=\left[(E(Y_1)-1)\cdot E(Y_2)+\frac{P_n}{l_{LSSU}}\right]\cdot\frac{8\cdot l_{LSSU}}{C}$$

where: C is the bit rate of signalling channel, and P_n / l_{LSSU} is the number of received LSSUs (*Link Status Signal Unit, LSSU*) during a successful test period [1].

This model of calculation is described in detail in [1] and [4]. Besides this model for calculation of mean time of the signailing CCS No7 channel synchronization, one another model is presented in [3]. There is one principal difference between these two models. The model described in [3] assumes that all periods of unsuccessful tests are of the same length and equal to the length of a successful test period. It is supposed in the model described in [1] and [2] that these periods are the random variable, Y_2. This approach is more realistic and corresponds to the real situation in the function of the signalling channels, [4].

b) Mean time of correct operation on signalling channel CCS No7

Mean time of the correct operation of signalling channel as the function of the bit error probability, P_{bit}, can be calculated as proposed in [2]:

$$E(X) = E(X_1) \cdot \frac{8 \cdot l_{SU}}{C} \tag{3}$$

Equation (3) explains that the medium time interval of a valid signalling channel operation, measured in seconds, is obtained if the mean number of received signalling units until the signalling channel outage, $E(X_1)$, is multiplied by the duration of one signalling unit, $8 \cdot l_{SU}$ /C, where l_{SU} is the length of the signalling unit in octets. In all existing models for calculating the mean time interval of a valid signalling channel operation depending on the bit error probability, P_{bit}, it is supposed that the size of l_{SU} is constant, [2], [3] and [5]. So, it is necessary to accurately calculate the value of $E(X_1)$.

The results, which are obtained by the application of different procedures for calculation of the same variables, are very similar [2], [3] and [5]. This is another indication of theoretical correctness of usage of these three models to calculate the mean time of the correct operation of the signalling channel.

The availability of the signalling channel is calculated using the expressions for the mean time of correct operation, *E(X)*, and the mean time of signalling units synchronization, *E(Y)*. Graphical presentation of the availability of a signalling CCS No7 channel is given in Fig. 1.

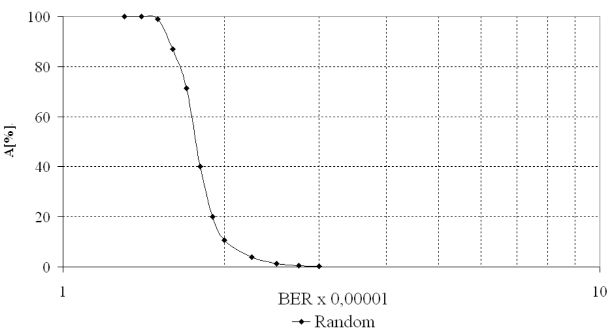

Fig.1. The availability of CCS No7 signalling channel under the influence of random errors

Availability of signalling channel CCS No7 under the influence of bursty errors

Now, let us consider Gilbert's model, [7], in which there is the state of low probability of incorrectly transmitted bits that we mark as G (Good), and the state of higher probability of incorrectly transmitted bits that we mark as B (Bad), Fig. 2a.

The probability that the channel is found in the state G is P_g, and that it is in the state B is P_b. Probability of transition from the channel state G to state B is P_{gb}, and from state B to state G is P_{bg}. The time, which the channel spends in state G is a random variable T_g, with the mean value t_g. T_b and t_b are time and the mean value of time which the channel spends in state B, Fig. 2b. We know that $P_g+P_b=1$, and it follows that $P_g/P_b=t_g/t_b$, i.e. the probability that the channel is found in the state G is $P_g = P_{gb} / (P_{gb} + P_{bg})$, and in the state B is $P_b = P_{bg} / (P_{gb} + P_{bg})$.

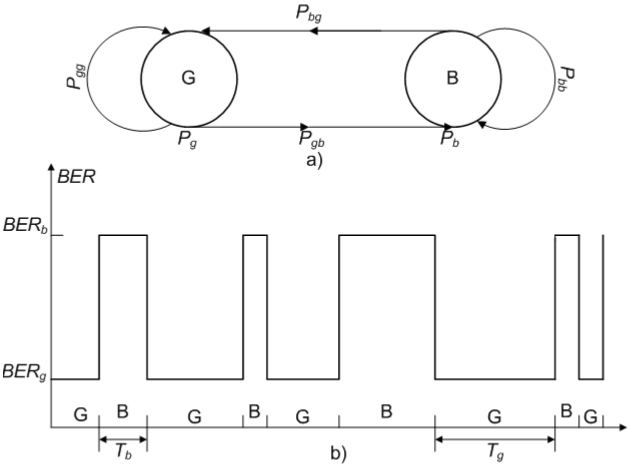

Fig.2. a) Gilbert-Elliott's model; b) distribution of group errors in function of time

a) The mean time to outage of CCS No7 signalling channel

The two-dimensional Markov model sequence is used to calculate the mean time to outage, or the mean time of outage, MTTC (*Mean Time To Changeover*) for the CCS No7 channel, *E*(*X*), Section III in [6]. It is adopted that the probability of incorrect signal units (SU), *Psu*, does not depend on other units and that it has the same value over the entire time interval.

In [6], Section VII, the examples for the case of relatively long clusters with a relatively low error probability, are presented. The calculations for the model with group errors give a shorter mean time to outage than the model with the corresponding random errors. The case of short clusters with very high error probability is more realistic case in practice and is described in [7].

In order to calculate the mean time to outage of the channel with group errors, the following assumptions are adopted:

- errors are uniformly distributed in both states G and B, as in [6];
- as previously mentioned, the channel is in a state B during the time interval T_b, which has the average value t_b and this value may be several tens of milliseconds, [7];
- the bit error rate BER_b, in a state B, can have very high values, up to 0.1, [7]. Typically, the bit error rate BER_g, in a state G, may be less than $1 \cdot 10^{-6}$.

Mean time to outage in the model with group errors will be marked as $E(X_m)$. Calculation of the mean time to outage is based on the probability of receiving wrong signalling unit, P_{SU}, [6]. It is known that in model with group errors, there are two conditions, the Fig. 2a. In the state with a low error probability, the probability of the wrong signalling unit is:

$$P_{SUg} = q_g = 1 - (1 - BER_g)^n \tag{4}$$

while in a state with a high error probability, the probability of the wrong signalling unit is:

(5) $$P_{SUb} = q_b = 1 - (1 - BER_b)^n$$

where n is the number of bits in an average signalling unit.

In the model with short clusters, the process SUERM is under the influence of both error probabilities. In a state with a low error probability, the probability of the wrong signalling unit is P_{SUg}, in state with high error probability, the probability of the wrong signalling unit is P_{SUb}. The average probability of occurrence of errored signalling units is calculated as:

(6) $$P_{SUm}=P_g \cdot P_{SUg}+P_b \cdot P_{SUb}$$

The results for calculation of the mean time to outage for group errors are shown graphically in Fig. 3. Channel with the following parameters is observed: $BER_g=1\cdot10^{-7}$, $BER_b=5\cdot10^{-2}$, $3\cdot10^{-3}<P_b<1\cdot10^{-2}$ and MSUs have a length of 30 octets (n = 30 · 8 = 240 bits). Mean time to outage is shown as a function of BER_m. BER_m is calculated according to the expression,

(7) $$BER_m= P_g \cdot BER_g+P_b \cdot BER_b$$

and has the values $1.5\cdot10^{-4} < BER_m < 5\cdot10^{-4}$.

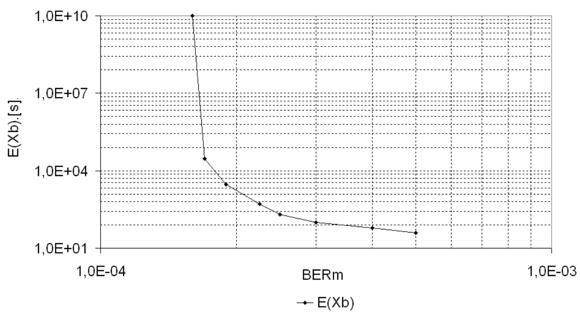

Fig.3. Mean time to outage of CCS No7 signalling channel in case of group errors

Mean time to outage, $E(X_m)$, is calculated according to the procedures that are listed and explained in [8] (subsection 15.1 and 15.2), and the probability of the occurrence of signalling unit error P_{SU} is replaced by the mean probability of occurrence of signalling unit error P_{SUm}, expression (6).

b) Mean time of synchronization of CCS No7 signalling channel

The appearance of short clusters with very high BER is well known and is described in [7]. In [9] the influence of these errors on the mean time of function, or outage of CCS No7 channel, is described. It is shown that, comparing to the channel with random errors and the same error probability, the CCS No7 channel with burst errors has a lower mean time of outage. The impact of short clusters with very high BER on the mean time of channel synchronization (marked as $E(Y)$), will be described in the following text. The analysis of transmission is defined for a period of 2^{16} octets, which constitute LSSU, with less than T_i (T_i=4) wrong units.

In the case of short clusters with high BER, the synchronization process may be failed in the two cases. First, the cluster with high BER may cause T_i (T_i=4) wrong LSSU. P_c is the probability that at least one cluster with a high BER appears in a test period. Second, the testing period in the state G can contain at least T_i wrong LSSUs, which will be marked with probability P_n that can be calculated as follows.

Let us consider the testing period as a result of Bernoulli testing with probability f, representing the failure and the probability $P_n=1-f$, representing the success (test period in the state of G contains at least T_i wrong LSSU). The probability of unsuccessful testing period is the probability to receive less than T_i wrong LSSU, of n received LSSUs, which are the mistake. It can be calculated according to the binomial formula or the Poisson approximation, because n is the large value (number of received LSSU in the test period), and a q_g is the small value (the probability of receiving the wrong LSSU in state G):

(8) $$P_n = 1 - f = 1 - \sum_{k=0}^{T_i-1} e^{-\lambda_g} \cdot \frac{\lambda_g^k}{k!}$$

where $\lambda_g = n \cdot q_g$.

It is clear that $\lambda_g = n \cdot q_g = n_b \cdot BER_g$, where n_b is the number of bits in the test period. As in practice $n_b = 8\cdot2^{16} < 10^6$ and $BER_g<10^{-9}$, it can be seen that $\lambda_g < 10^{-2}$. From this it follows that the probability P_n is the small value and can be neglected.

Let us observe now the process of synchronization of CCS No7 channel. It is assumed that the synchronization of CCS No7 channel is successful only if the test period is without the cluster with a large BER. If the clusters with large BER appear randomly, then the number of clusters during the test period may be represented by Poisson distribution. The probability that the clusters do not appear during the test period, t_p, is:

(9) $$P_0 = e^{-\lambda_k t_p} = 1 - P_c$$

where $\lambda_k=1/t_g$ is the intensity of occurrence of clusters.

The probability of occurrence of at least one cluster with high BER during the test period is P_c, where $P_c=1-P_0$. The synchronization time, Y, is the time to the end of the first test period of the cluster with a large BER. It is assumed that successful and unsuccessful test period have the same length, t_p, as in [6]. P_0 is the probability that the synchronization of CCS No7 channel is achieved in the first test period. The probability that the synchronization of CCS No7 channel is achieved in the n^{th} test period is given by geometrical distribution as $P_c^{n-1}\cdot P_0$. So, the mean time of synchronization $E(Y)$ is given by the expression:

(10) $$E(Y) = \sum_{i=1}^{\infty} i \cdot t_p \cdot P_0 \cdot P_c^{i-1} = \frac{t_p}{P_0}$$

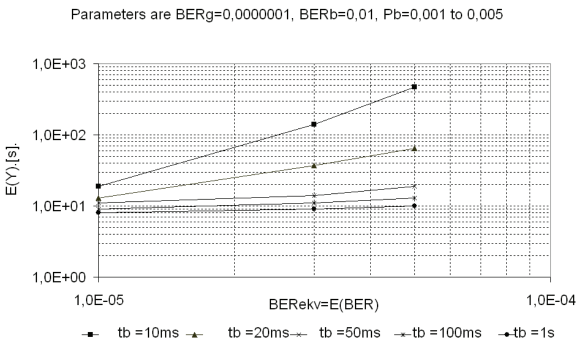

Fig.4. Mean time of synchronization of CCS No7 signalling channel in the function of BER_{ekv} = E(BER) for different values of the parameter t_b in the case of group errors

Fig. 4. graphically presents the mean time of synchronization, $E(Y)$, as the function of $BER_{ekv}=E(BER)$ for different values of t_b (10ms≤ t_b ≤1s).

Characteristics of CCS No7 channels are: $BER_g=1\cdot10^{-7}$, $BER_b=1\cdot10^{-2}$, $P_g=1-P_b$, $1\cdot10^{-3}<P_b<5\cdot10^{-3}$, MSUs have a length of 6 octets. BER_m is calculated according to expression (7) and has the values in the range $1{,}5\cdot10^{-5}<BER_m<5\cdot10^{-5}$. Mean time of synchronization, $E(Y)$, is calculated according to expressions (8) and (9), where the relation $P_g=t_g/(t_g+t_b)$ is valid, because it has already been mentioned that equality $t_g/t_b=P_g/P_b$ is valid, and t_p takes the value of time for normal synchronization, which is equal to 8,2 s.

Based on the calculated values for the mean time to outage, $E(X)$, Fig. 3, and mean time of synchronization, $E(Y)$, Fig. 4, one can now calculate availability of CCS No7 signalling channel according to the expression $A=E(X)/(E(X)+E(Y))$, or unavailability according to $UA=1-A$.

Dependence of CCS No7 signalling channel availability in the function of equivalent BER is shown in Fig. 5. BER_m (BER_{ekv}) is calculated according to the expression (7).

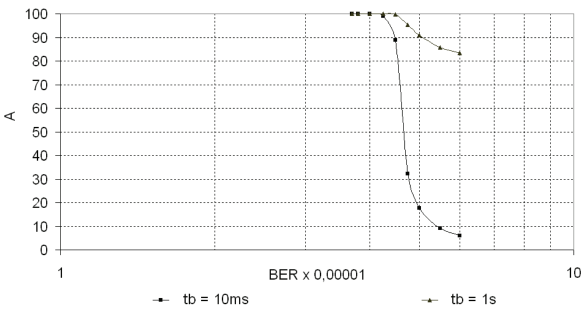

Fig.5. The availability of CCS No7 signalling channel for group errors for two values of t_b (t_b = 10ms and t_b = 1s)

Availability is always near the value 1, expression (1), if the mean time to outage, $E(X)$, is the order of magnitude greater than the mean time of synchronization, $E(Y)$. Based on the graphic in Fig. 4 we see that the curve defined by the parameter t_b=1s, the mean time of synchronization, has values in the range $8s<E(Y)<9s$. This means that the CCS No7 signalling channel, always synchronizes during the normal period of synchronization, 8.2s, while the values for the mean time to outage are pretty greater ($40s<E(X)<1\cdot10^{10}s$). That's why the availability, defined for the parameter t_b=1s, is always close to 1. This statement can be seen in Fig. 5. It is explained by the fact that long T_b period is followed by long T_g. Otherwise availability may have value in the range $0<A<1$, (Fig. 5, the curve defined for the parameter t_b=10ms). This means that CCS No7 signalling channel can not always synchronize during the normal period of synchronization, because the mean synchronization time (Fig. 4) for the value t_b=10ms is in the range $18s<E(Y)<500s$, for the mentioned values of the mean time to outage ($40s<E(X)<1\cdot10^{10}s$).

Conclusion

Based on the displayed curves of the availability, Fig. 1 and Fig. 5, one can notice that for different values of BER curves for both models of CCS No7 signalling channels have the same value. To explain this conclusion, for imagery and better understanding, consider these curves in the two extreme cases, when the availability of CCS No7 signalling channel tends to one or to zero.

Curve representing availability for models of group errors for t_b=10ms approaches zero for values $BER_m>6\cdot10^{-5}$, while the curve for the availability in the case of random errors tends to zero for the values of $BER>2{,}75\cdot10^{-5}$, supposing that $BER_m=BER$.

Curves of availability, A, for models of group errors and t_b≤1s, tend to value 1 for $BER=4\cdot10^{-5}$, and for models of random error tend to 1 for $BER=1{,}4\cdot10^{-5}$.

It can be considered that the availability of CCS No7 channel, is greater in case of group errors than the availability of channels with random errors, provided that the random errors are under the limit for the maximum value of BER ($BER \cong 1{,}7\cdot10^{-5}$), [1].

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