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CALCULATION AND COMPARISON OF THE AVAILABILITY OF DIGITAL 64 KB/S CHANNELS WITH UNIFORM AND BURSTY ERRORS

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In this paper one original method of calculating availability of digital 64 kb/s channels in the presence of uniform or random errors will be presented. Also, it will be presented one new method of calculating the availability of digital 64 kb/s channels in the case of bursty distributed errors. Definitions of time availability and unavailability of digital 64 kb/s channel in the presence of random errors are given in the ITT - T recommendation G.821, Annex A. In calculating the availability of digital 64 kb/s channels in the case of bursty errors, we shall consider digital 64 kb/s channel defined by modified or improved Gilbert-Elliott's model. It is shown that the concentration of errors in groups increases availability of channel. Comparison is illustrated by several examples.

Key words: availability and unavailability, digital 64 kb/s channel, random (uniform) errors, bursty errors.

1. INTRODUCTION

Definitions of time availability and unavailability of digital 64 kb/s channel in the presence of random or uniform errors are given in the ITT-T Recommendation G.821, Annex A [1]. These definitions allow the use of finite Markov chains with absorption state for modelling of digital 64 kb/s channels. We can calculate enough accurately the mean duration of the state of availability and unavailability of digital 64 kb/s channels, in the function of the intensity of bit errors (bit error rate – *BER*) in transmission.

The model of digital 64 kb/s channels is very interesting for practice. In order to calculate the availability and unavailability of these channels in the presence of bursty or group errors, we shall consider a digital 64 kb/s channel defined by modified Gilbert-Elliott's model [2].

In this paper, we show how we can calculate the availability or unavailability of digital 64 kb/s channels with randomly distributed errors, as described in [3], and a new way of calculating the availability of digital 64 kb/s channels with bursty errors, as described in [4]. Calculating the availability or unavailability of digital 64 kb/s channels in the case of bursty and randomly distributed errors is given in the function of *BER*. The availabilities of digital 64 kb/s channels in the presence of random and in the presence of bursty errors are compared based on the results of the calculation in this paper.

2. CALCULATION OF THE AVAILABILITY OF DIGITAL 64 KB/S CHANNELS WITH RANDOM ERRORS

In this section, we shall present one way of calculating the availability or unavailability of digital 64 kb/s channel in the case of uniformly distributed errors, as described in [5, 6], in the function of *BER*. First we shall consider digital 64 kb/s channel in a state of availability. With P_{bit} we shall designate the probability that one bit is wrong. The probability that in one one-second interval *BER* is equal to or worse than the 10^{-3}, according to Annex A of ITU-T recommendation G.821, is equal to the probability that k bits (where $k \geq 64$) are erroneous of total 64 000 bits. This can be represented by the following expression:

$$S = P(BER \geq 1 \cdot 10^{-3}) = 1 - F =$$
$$= \sum_{i=64}^{64000} \binom{64000}{i} \cdot P_b^i \cdot (1 - P_b)^{64000-i} \approx 1 - \mathrm{e}^{-\lambda} \cdot \sum_{i=0}^{63} \frac{\lambda^i}{i!}, \ldots\ldots, \lambda = 64\,000 \cdot P_b, \quad (1)$$

where is $\lambda = 64\,000 \cdot P_{bit}$.

We shall call success (*S*) one-second interval during which the $BER \geq 10^{-3}$, and failure (*F*) one-second interval during which the $BER < 10^{-3}$, if each second represents the outcome of Bernoulli trials. As the event *B* (*Better*), will represent the ten consecutive one-second intervals *F*, a similar event *W* (*Worse*), will represent the ten consecutive one-second intervals *S*. The time between events *B* and *W* is called the availability time (*X*) with its mean value *E*(*X*), and the time between events *W* and *B* is called the unavailability time (*Y*) with an average value *E*(*Y*) – Fig. 1. The mean time to occurrence of these events can be calculated using the theory of recurrent events [7]. According to this theory, the mean number of attempts for ten consecutive successes, i.e. average time for ten consecutive one-second intervals where the $BER \geq 10^{-3}$, is the mean recurrent time (expression 7.7, Section XIII in [8]):

$$E(X) = \frac{1 - S^{10}}{F \cdot S^{10}}. \quad (2)$$

Let's now digital 64 kb/s channel be in a state of unavailability. In the same manner as for state of availability, mean time for the event *F* or the average time of unavailability is expressed by the following equation:

$$E(Y) = \frac{1 - F^{10}}{S \cdot F^{10}}. \quad (3)$$

The calculated values for *E*(*X*) and *E*(*Y*) in function of BER are presented in Fig. 1 [6]. On the basis of the mean values of availability time (*E*(*X*)) and unavailability time (*E*(*Y*)) we can easily calculate availability, *A*, and unavailability, $U = 1 - A$, of digital 64 kb/s channels, according to equations (2) and (3) as the function of *BER*. Calculated values for *A* and *UA* as the function of *BER* are presented in Fig. 2 [6].

$$A = E(X) \,/\, (E(X) + E(Y)), \quad (4)$$

$$UA = 1 - A = E(Y) \,/\, (E(X) + E(Y)). \quad (5)$$

If we now replace the probability of *S* in the expressions (2) and (3) by the relation from equation (1), we get a mean duration time of states of availability (*E*(*X*), expression (6)), and unavailability (*E*(*Y*), expression (7)), of a digital channel, depending on the *BER* in transmission over the digital channel [6]

$$E(X) = E(S_{av}) = \frac{1 - (1 - e^{-\lambda} \sum_{k=0}^{63} \frac{\lambda^k}{k!})^{10}}{(e^{-\lambda} \sum_{k=0}^{63} \frac{\lambda^k}{k!})(1 - e^{-\lambda} \sum_{k=0}^{63} \frac{\lambda^k}{k!})^{10}}, \quad (6)$$

$$E(Y) = E(S_{uav}) = \frac{1 - (e^{-\lambda} \sum_{k=0}^{63} \frac{\lambda^k}{k!})^{10}}{(1 - e^{-\lambda} \sum_{k=0}^{63} \frac{\lambda^k}{k!})(e^{-\lambda} \sum_{k=0}^{63} \frac{\lambda^k}{k!})^{10}}, \quad (7)$$

where is $\lambda = 64\,000 \cdot P_{bit}$.

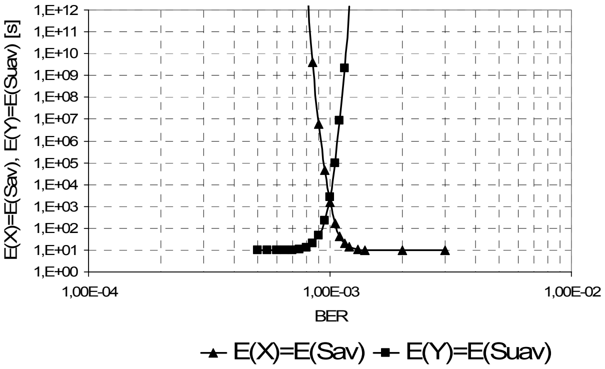

Fig. 1 – The average time of availability and unavailability, in the function of the *BER* in transmission.

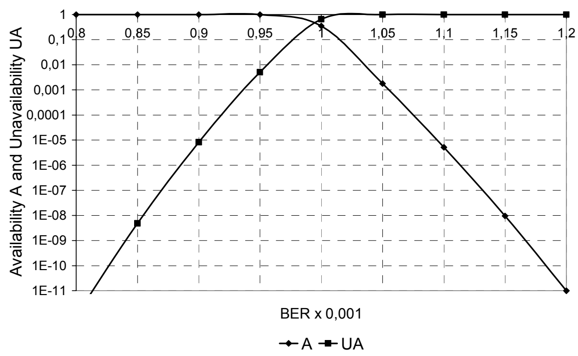

Fig. 2 – Availability and unavailability of digital 64 kb/s channel in function of *BER*, calculated on the basis of the recommendation ITU-T G.821.

3. CALCULATION OF THE AVAILABILITY OF DIGITAL 64 KB/S CHANNELS WITH BURSTY ERRORS

The next step is to calculate the availability of digital 64 kb/s channels in the presence of bursty errors, [4].

Let us consider digital 64 kb/s channel, defined by modified Gilbert-Elliott's model, [2], which may be in the state of small probability of incorrectly transmitted bits (assigned as G (*Good*)) or in a state of higher probability of incorrectly transmitted bits (assigned as B (*Bad*)) – Fig. 3.

Time, while the channel is in state G, is a random variable T_g with a mean value t_g, and the time while the channel is in state B is a random variable T_b, with a mean value t_b.

The *BER* in a state G is designated with BER_g, while the *BER* in state B is designated with BER_b. The probability that digital 64 kb/s channel is in the state G is P_g, and to move from state G to B is P_{gb}. The probability that digital 64 kb/s channel is in the state B is P_b, and to move from a state B to G is P_{bg}. According to Fig. 3, the probabilities P_g (P_b) that the digital 64 kb/s channel is in the state G (B) is equal to:

$$P_g=P_b\cdot P_{bg}+P_g\cdot(1-P_{gb}); \quad P_b=P_g\cdot P_{gb}+P_b\cdot(1-P_{bg}). \tag{8}$$

As it is $P_g+P_b=1$, then from the expression (8) we can obtain expression (9).

$$P_g=P_{bg}/(P_{gb}+P_{bg}); \quad P_b=P_{gb}/(P_{gb}+P_{bg}). \tag{9}$$

From the expression (9) and Fig. 3 follows expression (10), which shows that the ratio of the probabilities P_g and P_b is equal to the ratio of t_g and t_b,

$$P_g / P_b = t_g / t_b. \tag{10}$$

Availability of digital 64 kb/s channels, described by Gilbert-Elliott's model, depends on the values of t_g, t_b, BER_g, BER_b and relationships t_g/t_b and BER_g/BER_b. Based on this dependence, we shall pay attention to some special cases [4], which are listed below.

1. If $t_g = 0$, then the availability A of digital 64 kb/s channel is equal to the availability of digital 64 kb/s channel with uniform error distribution of value BER_b, $A = A_b$. The similar is valid for the case when $t_b = 0$, then the availability A of digital 64 kb/s channel is equal to the availability of digital 64 kb/s channel with uniform error distribution of value BER_g, $A = A_g$, [2].

2. If t_g and t_b, have comparable values and if it is $BER_b < 1\cdot10^{-3}$, then the availability of digital 64 kb/s channels, A, equals $A = P_g\cdot A_g + P_b\cdot A_b$.

3. If t_b is much greater than 10 seconds, $t_b >> 10$s, $BER_b \geq 1\cdot10^{-3}$, and the ratio of the probabilities of bit error in state B and state G, is $BER_b/BER_g >> 10$, then the availability of digital 64 kb/s channel, A, equals $A = t_g/(t_g+t_b)$, because $E(X)$ is very small, if $BER = BER_b$, and $E(Y)$ is also small, if $BER = BER_g < 1\cdot10^{-4}$ (approximately 10s).

For a discussion the most interesting case is between cases 1 and 3. This case is described in [1] as a channel with bimodal error distribution or channel with clusters (groups) in which errors occur. An interval with a cluster in which errors occur is presented in Fig. 4.

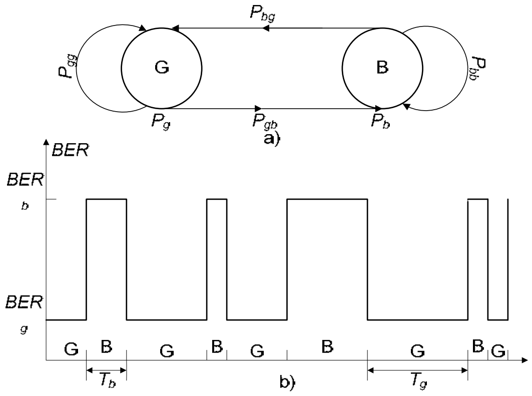

Fig. 3 – Modified Gilbert-Elliott's model.

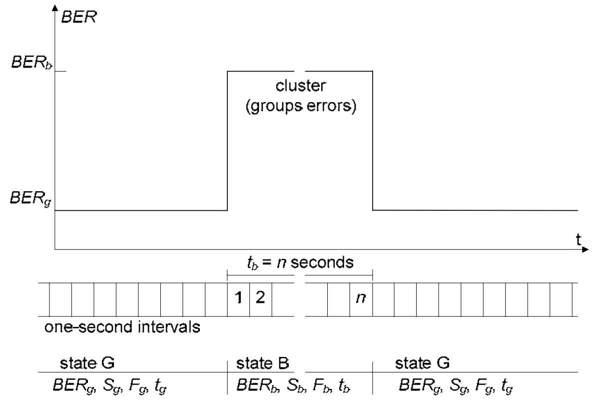

Fig. 4 – Cluster with errors.

This is the case with short time intervals with high *BER*. Then the mean time duration, when digital 64 kb/s channel is in state *B*, t_b, is few seconds, *BER* in state *B*, $BER_b \geq 1\cdot10^{-3}$, the mean time duration when digital 64 kb/s channel is in state *G*, t_g, is much larger than the mean time when digital 64 kb/s channel is in state *B*, t_b, $t_g > t_b$. It is fulfilled the condition that *BER*, when channel is in state *B*, BER_b, is much greater than BER, when channel is in state *G*, BER_g, $BER_b > BER_g$.

If the digital 64 kb/s channel is in state *G*, and if the cluster with errors happens, the probability that in the cluster are 64 errors or more than 64 errors during one-second intervals ($BER \geq 1\cdot10^{-3}$) is S_g, and the probability that there are less than 64 errors ($BER < 1\cdot10^{-3}$) is F_g. And if the digital 64 kb/s channel is in state *B*, if the cluster with errors happens, , the probability that in the cluster are 64 errors or more than 64 errors during one-second intervals (i.e. $BER \geq 1\cdot10^{-3}$) is S_b, and probability that there are less than 64 errors (i.e. $BER < 1\cdot10^{-3}$) is F_b. It is known that the sum of the probabilities of an event that has two options always equal to 1, hence $F_g = 1 - S_g$ and $F_b = 1 - S_b$.

The probability that a cluster with errors causes unavailability of digital 64 kb/s channels is marked with P_u, and this is the probability that ten consecutive one-second intervals appear with the $BER \geq 1\cdot10^{-3}$. Let us suppose that the mean time, when digital 64 kb/s channel is in state *B*, t_b, equals *n* seconds. Using these assumptions, we can calculate the probability P_u, as follows.

We shall consider three cases:

a) The cluster *n* is less than 10 seconds, $n < 10$ seconds.

We assume that the cluster takes one second, $n = 1$. Unavailability of channels can occur if in the condition *G* there are nine consecutive seconds in which the *BER* is greater than $1\cdot10^{-3}$ (probability S_g^9), followed by a second in state *B* with the *BER* greater than 10^{-3} (probability S_b). Probability of this event is $S_g^9\cdot S_b$.

In a similar way the channel can be unavailable if the channel is eight consecutive seconds in state *G* with *BER* greater than 10^{-3}, followed by a second in state *B* with the *BER* greater than $1\cdot10^{-3}$, and then again one second in state *G* with *BER* greater than $1\cdot10^{-3}$. Probability of this event is $S_g^8\cdot S_b\cdot S_g = S_g^9\cdot S_b$.

One second interval in state *B* with the *BER* greater than $1\cdot10^{-3}$ can also occur as the eighth, the seventh, etc… second, so that the total probability of channel transition to the state of unavailability is given by expression $10\cdot S_g^9\cdot S_b$, if the cluster is 1s long.

Let the cluster now lasts two seconds, $n = 2$s, and let us again consider ten one-second intervals. Unavailability of channels can occur if the state *G* has eight consecutive seconds in which the *BER* is greater than 10^{-3} (probability S_g^8), followed by two seconds (ninth and tenth) in state *B* with *BER* greater than 10^{-3} (probability S_b^2). Probability of this event is $S_g^8\cdot S_b^2$.

Unavailability of channels can be achieved by seven consecutive seconds in the state *G* with *BER* greater than 10^{-3}, followed by two seconds (eighth and ninth) in state *B* with increased *BER*, and finally again a second (tenth) in the state *G* with the *BER* greater than 10^{-3}. Probability of this event is $S_g^7\cdot S_b^2\cdot S_g = S_g^8\cdot S_b^2$.

Two seconds in the *B* state with increased *BER* can be in the seventh and eighth, sixth and seventh, etc… seconds, so that the total probability of the transition to the state of the channel unavailability is given by equation $9\cdot S_g^8\cdot S_b^2$, if the cluster duration is 2s.

If we now assume that the cluster duration is three seconds, $n = 3$, according to previous consideration, the probability that the channel becomes unavailable in this case is $8 \cdot S_g^7 \cdot S_b^3$.

The total probability that a cluster with duration n seconds, where $n < 10$ seconds, causes the unavailability of channel is:

$$P_u = P_{u1,n<10} = (10 \cdot S_g^9 \cdot S_b + 9 \cdot S_g^8 \cdot S_b^2 + \ldots + \\ + (10 - n + 1) \cdot S_g^{10-n} \cdot S_b^n) = \sum_{i=1}^{9} (10 - i + 1) \cdot S_g^{10-i} \cdot S_b^i . \quad (11)$$

b) The cluster n is 10 seconds, $n = 10$ seconds.

Digital 64 kb/s channel may become unavailable, if it is nine consecutive seconds in the state G and one (first) second in state B with BER greater than $1 \cdot 10^{-3}$. Probability of this event is $S_g^9 \cdot S_b$. A similar event is the one when channel is during the last second in state B and during the first nine seconds in a state G with BER greater than $1 \cdot 10^{-3}$. Probability of this event is also $S_g^9 \cdot S_b$. The total probability of both events is $2 \cdot S_g^9 \cdot S_b$.

Similarly channel may become unavailable if it is eight consecutive seconds in the state G (preceding the cluster or following it) and two (first or last) seconds are the cluster, both states with the BER greater than 10^{-3}. The total probability of this event is $2 \cdot S_g^8 \cdot S_b^2$. In a similar way, following the previous explanation, we can determine the probability that the channel becomes unavailable for other combinations of seconds before and after clustering. The total probability of these events is:

$$P_u = P_{u2,n<10} = (2 \cdot S_g^9 \cdot S_b + 2 \cdot S_g^8 \cdot S_b^2 + \ldots + \\ + 2 \cdot S_g^{10-n} \cdot S_b^n) = 2 \cdot \sum_{i=1}^{9} S_g^{10-i} \cdot S_b^i . \quad (12)$$

The probability that the channel becomes unavailable during the cluster of duration 10 seconds is $P_{u2,n=10} = S_b^{10}$. We get the total probability that a cluster of duration 10s causes unavailability of information digital 64 kb/s channels by summing of all probabilities, and it is:

$$P_u = P_{u2,n<10} + P_{u2,n=10} = 2 \cdot \sum_{i=1}^{9} S_g^{10-i} \cdot S_b^i + S_b^{10} . \quad (13)$$

c) The cluster n is longer than 10 seconds, $n > 10$ seconds.

Different combinations of evolved S_b events in state G and state B can cause unavailability of information digital 64 kb/s channels. The probability of these events is given by $P_{u2,n<10}$. In addition, the channel can also become unavailable due to the first ten consecutive seconds when channel is in the B state, with BER greater than $1 \cdot 10^{-3}$, and this is presented by the probability $P_{u2,n=10}$. Let us consider further possibilities how the channel may become unavailable.

If the channel is from the second to the eleventh consecutive second in a state B with the BER greater than $1 \cdot 10^{-3}$, the channel becomes unavailable with probability $F_b \cdot S_b^{10}$.

If the channel is from the third to the twelfth consecutive second in state B with the BER greater than $1 \cdot 10^{-3}$, the channel becomes unavailable with probability $F_b \cdot F_b \cdot S_b^{10} + S_b \cdot F_b \cdot S_b^{10} = F_b \cdot S_b^{10}$, because it is $F_b + S_b = 1$.

If the channel is from the fourth to the thirteenth consecutive second in a state B with the BER greater than $1 \cdot 10^{-3}$, the channel becomes unavailable with probability $F_b \cdot S_b^{10}$, because all combinations of events in the first two seconds, give safe event.

In a similar manner it can be shown that the appearance of sequence FSSSSSSSSSS in the state B can begin on (n–10) ways, and the probability is always $F_b \cdot S_b^{10}$. In the case when the length of cluster is $n \geq 10$s, the probability that the channel passes into the state of unavailability is presented by the following expression:

$$P_u = P_{u3,n>10} = P_{u2,n<10} + P_{u2,n=10} + (n - 10) \cdot F_b \cdot S_b^{10} . \quad (14)$$

It should be noted that, in real cases (in all three considered cases for $n < 10$ s, $n = 10$ s and $n > 10$ s), the greatest contribution to the probability of unavailability provide members, that include probability S_b^{10}, while the members, that include S_g, are always of minor importance.

Let digital 64 kb/s channel becomes unavailable, when the first cluster happens. We shall assign with P_u the probability that the digital 64 kb/s channel became unavailable when the first cluster happened. It means that the time of availability of digital 64 kb/s channel is t_g. The probability that the channel becomes unavailable in the second cluster is $P_u{\cdot}(1{-}P_u)$, and the time of availability of the channel is equal $2{\cdot}t_g$. The probability that the channel becomes unavailable in the *j*-th cluster is $P_u{\cdot}(1{-}P_u)^{j-1}$, and the time of availability of the channel is equal to $j{\cdot}t_g$. The mean value of the time of availability of digital 64 kb/s channel is designated by $E(X)$, and it is equal to:

$$E(X)=\sum_{j=1}^{\infty} j\cdot t_g\cdot(1-P_u)^{j-1}\cdot P_u=\frac{t_g}{P_u}\,. \tag{15}$$

The mean value of time of the unavailability is designated by $E(Y)$, and it is very short, provided that $BER_g < 8{\cdot}10^{-4}$, and has a value of 10s, [2]. Based on the expression (12) and (13), and taking into account the above condition for E (Y) can be calculated availability of digital 64 kb/s channels in the presence of bursty errors using an expression for calculating the availability of digital 64 kb/s channels that form:

$$A = E(X) / (E(X) + E(Y)). \tag{16}$$

In the first example, Fig. 5, the availability of digital 64 kb/s channel can be calculated in the function of the duration of clusters, t_b, for the value $BER_b = 1{\cdot}10^{-3}$, $BER_g < 1{\cdot}10^{-4}$ and $t_g = 1\ 000$ s.

From the graphic in Fig. 5 can be seen that, if the length of the time interval is t_b, and the duration of clusters with bursty errors is less than 10s, then practically bursty error does not affect the availability of digital 64 kb/s channel. If, however, the duration of clusters with bursty errors is greater than 10s, then the availability of digital 64 kb/s channels significantly decreases with increasing the length of the cluster with errors.

In the second example, Fig. 6, availability of digital 64 kb/s channel is calculated in the function of the BER_b, and t_g is used as a parameter. The mean time, while the digital 64 kb/s channel is in state *G* takes two values $t_g = 1000$ s or $t_g = 300$ s. In calculating the availability of digital 64 kb/s channels, the values of the *BER* in state *B* are in the range $1{\cdot}10^{-3} < BER_b < 2{\cdot}10^{-3}$, and the values of the *BER* in state *G* are $BER_g < 1{\cdot}10^{-4}$.

4. COMPARISON OF RESULTS

Based on sections, where we discussed separately the impact of uniformly distributed errors, and the impact of bursty errors in digital 64 kb/s channel, we can now compare effects of these two types of errors. In order to compare the effect of uniform and bursty errors in digital 64 kb/s channel, we must first determine the equivalent *BER* for bursty errors, *BERekv*, to fit the *BER* of uniformly distributed errors, i.e. *BER* = *BERekv*, [9]. *BERekv* or mathematical expectation of *BER*, $E(BER)$, is equal to:

$$BERekv = E(BER) = P_b{\cdot}BER_b + P_g{\cdot}BER_g. \tag{17}$$

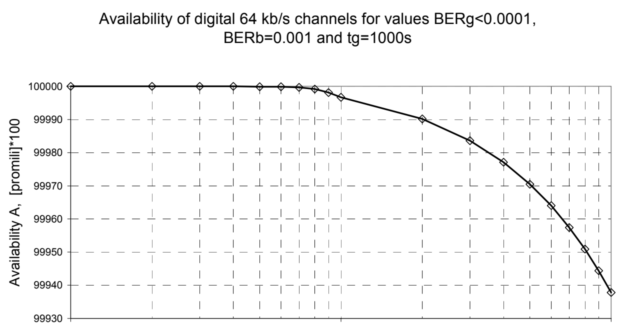

Fig. 5 – Availability of digital 64 kb/s channels in the function of the duration of clusters with errors, t_b.

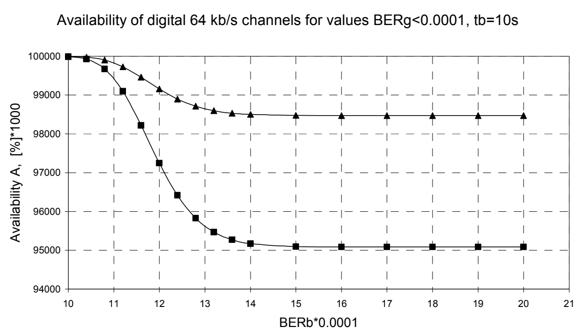

Fig. 6 – Availability of digital 64 kb/s channels, in the function of BER_b and t_g provided that the $BER_g < 1{\cdot}10^{-4}$ and t_b=10s.

On the basis of parameters BER_b = 0.01, BER_g = 0.00001, P_b = 0.1, P_g = 0.9, $P_b = t_b/(t_g + t_b)$, $P_g = t_g/(t_g + t_b)$ and changing the t_b and t_g to get *BERekv* in the range of 0.0004 to 0.009, we can calculate availability of digital 64 kb/s channels in the case of bursty errors. Also, taking the calculated values for the availability of digital 64 kb/s channel in the case of a uniform distribution of errors, we get Fig. 7, where we can compare the effects of uniform and bursty distributed errors.

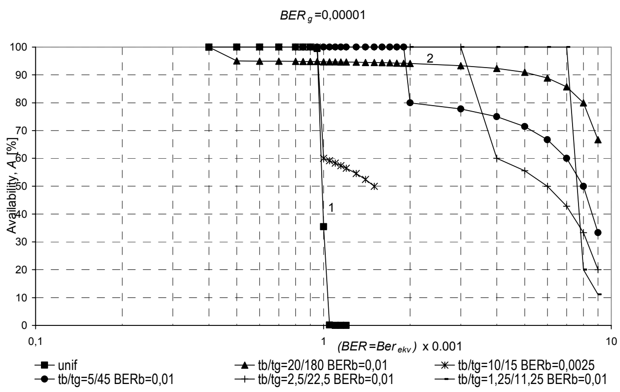

Fig. 7 – Availability of digital 64 kb/s channels in the case of uniform and bursty errors.

From Fig. 7 can be seen that the availability of digital 64 kb/s channel for bursty errors is better than when errors are uniformly distributed. In curves, which represent bursty errors, sudden "jumps" are noticeable, so that digital 64 kb/s channel has the availability of almost 100% when t_b is less than 10s, which means that the clusters of less than 10s have very little impact on the availability of channels. Whereas at the uniform distribution the availability of the channel drops sharply from 100% (*BER* = 0.0009) to 35% (*BER* = 0.001), the channel with bursty errors, depending on the ratio t_g/t_b, for $BER \leq 0.005$ has the channel availability greater than 50%.

The only case when the availability of digital 64 kb/s channels with random errors is greater than the availability of digital 64 kb/s channels with bursty errors is when clusters are longer than 10s (case 2 in Fig. 7 for $BER < 0.001$), [9]. Fortunately, such long clusters are rare.

5. CONCLUSION

Availability or unavailability of digital 64 kb/s channels can be calculated based on the intensity of bit errors, *BER*, for uniformly distributed and bursty errors.

From Fig. 2, which presents the calculated values for the availability, *A*, and unavailability, *UA*, of digital 64 kb/s channels in the function of *BER*, we can conclude the following:

– the time intervals with uniformly distributed errors for values $BER_b < 1\cdot10^{-3}$ have practically no impact on the availability of digital 64 kb/s channels;

– the time intervals with uniformly distributed errors for the value $BER_b = 1\cdot10^{-3}$ have an impact on the availability of digital 64 kb/s channels (for the value $BER_b = 1\cdot10^{-3}$, the value $A = 0.354$);

– the time intervals with uniformly distributed errors for values $BER_b > 1\cdot10^{-3}$ have a large impact on the availability of digital 64 kb/s channels (for value $BER_b = 1.1\cdot10^{-3}$, the value $A = 5.134\cdot10^{-6}$).

Based on the performed calculations and on the presented results on the Fig. 5 and Fig. 6, the following can be concluded:

– the time intervals with bursty errors lasting less than 10 seconds have practically no impact on the availability of digital 64 kb/s channels;

– the value of BER_g has no significant impact on the availability of digital 64 kb/s channels;

– the mean length of time interval t_g, when channel is in the state *G*, between the clusters with error, which are longer than 10s, has a great impact on the availability of digital 64 kb/s channels;

– if it is $BER_b \leq 1\cdot10^{-3}$, it can be considered that the availability of digital 64 kb/s channel is practically one, taking into account that $E(Y)$ = 10s;

– if it is $BER_b > 1\cdot10^{-3}$, the impact of errors on the availability of digital 64 kb/s channels is great in the case where the length of the cluster with errors is $n \geq 10$s and can be approximately calculated as follows:

$$\lim_{BER_b \to 0.002} A = \frac{t_g[\mathrm{s}]}{t_g[\mathrm{s}] + 10\mathrm{s}}. \tag{18}$$

The time interval of 10s, which is mentioned, is defined in ITU-T Recommendation G.821 [1], as the condition that defines the time after which a digital 64 kb/s channel may become available or unavailable for normal function. Concentration of errors in the group has a positive effect on the availability of digital 64 kb/s channels, [9]. The most favourable case is the high concentration of errors in a cluster of less than 10s (Fig. 7).

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