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BER ANALYSIS USING RECOMMENDATIONS ITU G.821 AND ITU G.826

Aleksandar Lebl
Institute for Telecommunications and Electronics, IRITEL a.d. BELGRADE, Serbia

Dragan Mitić
Institute for Telecommunications and Electronics, IRITEL a.d. BELGRADE, Serbia

Verica Vasiljević
Faculty of Information Technology, University Slobomir P, Bjeljina, Bosnia and Herzegovina

Abstract

The standards for measurements and testing procedures in ISDN networks are defined in the ITU recommendation G. 821. ITU recommendation G. 826 deals with the error rate for data transmission on high flow-rates links. The decisive factor applied to determine the quality of high flow-rate digital networks is bit error rate (BER). In this paper the main goal is to analyse and suggest the model to determine BER for three relative error parameters defined in the G.821 and G.826 recommendations: Errored Second Ratio (ESR), Background Block Error Ratio (BBER) and Severely Errored Second (SES).

Keywords: Bit Error Rate, Errored Second , Severely errored second, Background Block Error Ratio.

INTRODUCTION

The relative error parameters presented in various definitions must be perceived in order to implement ITU recommendations G.821 and G826. It is first necessary to explain the relation between bit errors defined in the Recommendation ITU G.821 [1] and errored blocks defined in the Recommendation ITU G.826, [2]. The distribution of faulty bits has a great influence on these relations. After that in the Section 3 is explained the dependence of Errored Second Ratio (ESR) on the Bit Error Rate (BER), assuming that error distribution is Poissonian. The BER dependence on the part of blocks with error Y assuming that error distribution is expressed by Poissonian distribution is presented in the Section 4. The dependence of BBER according to the Recommendation ITU G.826 and ESR according to the Recommendation ITU G.821 on the value of BER assuming that error distribution is Poissonian is considered in the Section 5. At the end, the conclusions are in the Section 6.

MATHEMATICAL MODEL AND ERROR PARAMETER DEFINITION - ITU RECOMMENDATION G. 826

In the following sections the highly simplified statistical model for the time distribution of bit errors is going to be considered and presented. It is further supposed that the error probability of each bit is the same and that bit errors are mutually independent. Such a model may be designed using binomial distribution [3] [4], or, under some assumptions, Poissonian distribution may be applied [4] [5].

The Recommendation ITU G.826 defines four main parameters for bit error estimation [2]:

- **Errored Block (EB):** a block in which one or more bits are in error;
- **Errored Second (ES):** A one second period with one or more errored blocks or at least one defect (see Note 1 in 5.1.1.3, [2]);
- **Severely Errored Second (SES):** a one-second period, which contains more than or equal to 30% errored blocks or at least one defect. SES is a subset of ES;
- **Background Block Error (BBE):** an errored block not occurring as a part of SES.

Parameter Degraded Minute (DM) is not defined in the Recommendation G.826, [2], because it is also not defined in the Recommendation G.821 [1]. The Recommendation ITU G.826 defines three relative error parameters:

- **Errored Second Ratio (ESR):** the ratio of ES to total seconds in available time during a fixed measurement interval;
- **Severely Errored Seconds Ratio (SESR)**: the ratio of SES to total seconds in available time during a fixed measurement interval;
- **Background Block Error Ratio (BBER):** is the ratio of errored blocks to total blocks during a fixed measurement interval, excluding all blocks during SES and unavailable time.

Error parameter determination is applied only when the supervised system is in the operation.

ERRORED SECOND

According to the Recommendation G.821, errored second occurs if at least one error happens during one second interval (ES). The principle of the error in a block measurement is applied, according to G.826 – one second is errored if it contains at least one errored block (EB). In this case a block is designated as faulty if it contains one or more errors, meaning that two recommendations have the same definition. The difference is that the Recommendation G.826 is related to the higher transmission rates, while the Recommendation G.821 is related to the channel with the fixed bit rate 64 kbit/s. The parameter which does not depend on the transmission rate is BER. That’s why it is important to calculate ES rate (ESR) as a function of BER [6], [7].

Generally speaking, the relation between ES number and BER may be represented approximately applying a Poisson distribution:

$$ESR = 1 - \exp(-BER \cdot R) \qquad (1)$$

where R is transmission rate.

The Figure 1 is formed on the base of equation (1). The graphs in this figure correspond to four flow-rates. Three of these flow-rates are defined in the Recommendation G.826 (graphs 1, 2 and 3) and one in the Recommendation G.821 (graph 4). The graphs present ESR as a function of BER for the following systems: the graph 1 is for Plesiochronous Digital Hierarchy (PDH) system at a flow-rate 2048 kbit/s, the graph 2 is for Synchronous Digital Hierarchy (SDH) (virtual container, VC) VC-3, whose rate is 48,96 Mbit/s, the graph 3 is for SDH VC-4 at a flow-rate 150,336 Mbit/s, while the graph 4 is related to the channel which operates at a flow-rate 64 kbit/s according to ITU G.821. Figure 2 gives graphical presentation of the equation (1), where the arrows point to the following allowed error rate values:

-- for the curve 1 and the allowed error ESR $4 \cdot 10^{-2}$ BER is $1.4843 \cdot 10^{-9}$,
-- for the curve 2 and the allowed error ESR $8 \cdot 10^{-2}$ BER is $1.7031 \cdot 10^{-9}$,
-- for the curve 3 and the allowed error ESR 2 10^{-1} BER is $1.3317 \cdot 10^{-8}$ and
-- for the curve 4 and the allowed error ESR 8 10^{-2} BER is $1.3028 \cdot 10^{-6}$.

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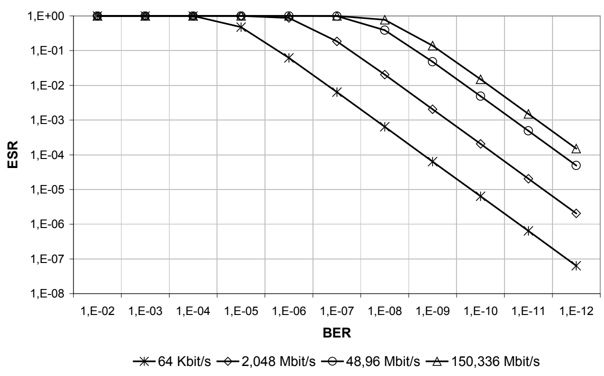

Fig. 1. *Errored Second Rate (ESR) as a function of BER when errors are distributed according to Poissonian distribution.*

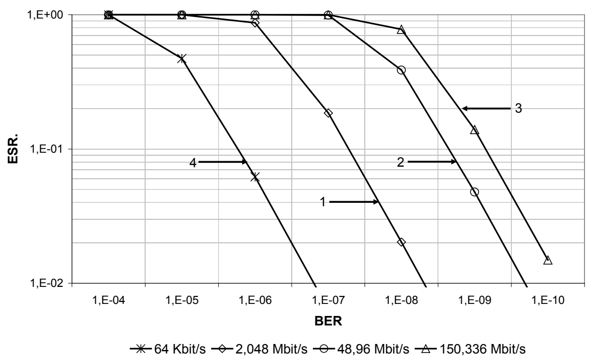

***Fig. 2.** Errored Second Rate (ESR) as a function of BER, where arrows point to the values of allowed error probability.*

The conclusions from the Fig. 1 are the following:

-- The Recommendation G.821 is related to the channel with the flow-rate 64 kbit/s. If the flow-rate of such a channel is increased, it may be noticed sharpening the requests for ESR about 60 times (the ratio between graphs 1 and 3 for BER=10^{-9} is 68.3).

-- The curves 1 to 3 show that the parameter ESR, defined in the Recommendation G.826, is increased when the flow-rate is increased. This increasing is not proportional, as it may be expected, but deviation is negligible (if the value ESR=10^{-2} is selected, then it is BER=$4.9074\cdot10^{-9}$ for the curve 1, BER=$2.0528\cdot10^{-10}$ for the curve 2, BER=$6.6852\cdot10^{-11}$ for the curve 3 and BER=$1.5704\cdot10^{-7}$ for the curve 4). The value ESR as a function of BER is decreased as the flow-rate increases, for example: in the case of BER=10^{-9} ESR=$6.40\cdot10^{-5}$ for the curve 4, ESR=$2.05\cdot10^{-3}$ for the curve 1, ESR=$4.78\cdot10^{-2}$ for the curve 2 and ESR=$1.40\cdot10^{-1}$ for the curve 3.

Appearance of errored seconds is not always caused by independent disturbances in the transmission system, but often the cause is extern errors, which are not connected with the system function. These disturbances are related to the fixed time interval independent of the flow-rate of the considered transmission line.

SEVERELY ERRORED SECOND (SES)

In order to compare these parameters in both recommendations, [1] and [2], the following questions have to be answered:

What is the definition of the parameter Severely Errored Second (SES) in the recommendations [1] and [2] ?

What is the allowed part of SESs in the investigated area?

Before comparison of these parameters in both recommendations, the answer to the first and then to the second question is given. It follows the answer to the first question.

In the Recommendation ITU G.821 SES is defined as the BER value greater than 10^{-3}. In the Recommendation ITU G.826 SES is modelled by the following two criteria:

1. errored second (ES): A one-second period with one or more errored blocks or at least one defect.
2. severely errored second (SES): A one-second period which contains ≥30% errored blocks or at least one defect. SES is a subset of ES.

The first criterion expresses the number of errored bits in a block [2]. The second criterion investigates whether also severe errors in a second come to the consideration. This corresponds to the events with extreme level of errors.

From the assumption that errors may be modelled by Poissonian distribution it follows that the first criterion is more severe than the second one. The ratio of the part of blocks with errors Y and its corresponding error BER(Y) may be approximately expressed by the equation:

$$BER(Y) = -\frac{1}{N}\ln(1-Y) \qquad (2)$$

where N is the number of bits in a block.

The value of N is not constant in the Recommendation G.826, but it is variable when the bit rate is variable [2]. However, the critical value of Y for the determination of SES is equal 0.3 for all data flow-rates. According to the equation (2), it follows that the equivalent value BER(Y) for some Y decreases when data flow-rate increases. Similar to the definition of ES, the definition of SES is stricter when flow-rate is increased. The relations of N and Y according to (2) are presented in the Figure 3 for different flow-rates.

For example, it may be seen that $BER(Y)=2 \cdot 10^{-5}$ for Y=0.3 if the flow-rate is 150.336Mbit/s which corresponds to VC-4 systems. This value is 50 times more strict than the value defined in the Recommendation ITU G.821 (SESR=0.001 in [1]). The value of BER is 3 to 10 times less strict for the remaining two flow-rates comparing to VC-4.

When answering to the second question, it is necessary to note that both recommendations allow the same SESR=0.002 in the end-to-end connection. The Recommendation ITU G.826 is more strict than the Recommendation ITU G.821, because the equivalent BER(Y) is lower than 10^{-3} for the critical Y values when SES=0.3 for all data flow-rates, Figure 3.

The differences in SESR concepts in the Recommendations ITU G.821 and G 826 have two important effects:

1. For the transmission systems in the international connections, the parameter SESR in the Recommendation G.826 is less strict than in the Recommendation G.821. The corresponding requirements in the Recommendation G.826 do not directly guarantee fulfilling the requirements from the Recommendation G.821.
2. For the long-distance radio-systems the Recommendation G.826 requests significantly lower SESR than the target value in the Recommendation G.821. When planning new routes, the requests may be increased taking into the consideration the selection of the route length and device dimensions.

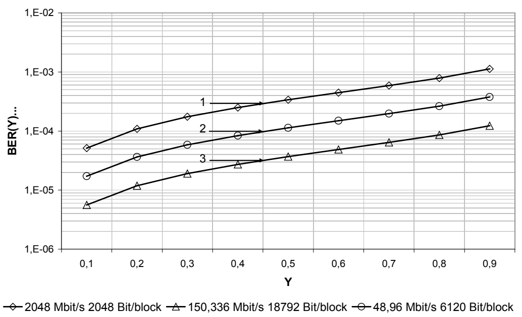

Fig. 3. *BER as the function of the part of blocks with errors Y assuming that error distribution is Poissonian.*

ERRORS IN A BLOCK

The variable BBE, which is associated to the parameter BBER and which is defined in G.826, is not defined in the Recommendation G.821. However, comparison is possible.

These parameters have the similar function as the other error parameters in G.821. That's why it is suitable to compare BBER parameter in G.826 and ESR in G.821.

It is first necessary to calculate the values of BBER for the desired BER. If it is supposed that error distribution is Poissonian, the approximate relation is:

$$BBER = 1 - e^{-BER \cdot N} \qquad (3)$$

The equation (3) does not present the results if the error value is over the equivalent BER (Y) given by (2) for severe errors in a second. BBE definition in G.826, as it is already explained, refers to the seconds without severe errors. The equation (3) is graphically presented in the Figure 4.

The arrows in the Figure 4 point to the values of the allowed errors in the following cases:

-- on the curve 1 for the allowed error $BBER=3 \cdot 10^{-3}$ the achieved value is $BER=1.4670 \cdot 10^{-6}$,
-- on the curve 2 for the allowed error $BBER=2 \cdot 10^{-3}$ the achieved value is $BER=3.2712 \cdot 10^{-7}$,
-- on the curve 3 for the allowed error $BBER=2 \cdot 10^{-3}$ the achieved value is $BER=1.3317 \cdot 10^{-8}$ and
-- on the curve 4 for the allowed error $ESR=8 \cdot 10^{-2}$ the achieved value is $BER=1.4670 \cdot 10^{-6}$.

Comparing the Figures 1 and 4, it is concluded that BBER end points are in the area which corresponds to the end points from G.826. The BBER value in G.826 is lower than the ratio of errored seconds from the Recommendation G.821.

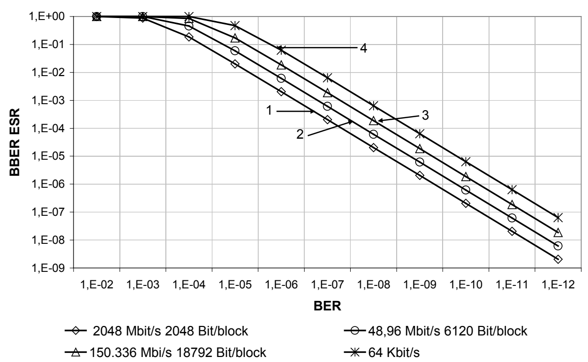

Fig. 4. *Variables BBER and ESR as a function of BER assuming that error distribution is Poissonian.*

From the Figure 4 it is also possible to see that BBER target value is significantly lower than the ESR value from the Recommendation G.821. This is the proof that the Recommendation G.826, with the regard that BBER is a parameter, set higher requirements for the data transmission than the Recommendation G.821. Such assumptions may be expressed in the case that error distribution is Poissonian.

CONCLUSION

The Recommendation G.826 does not include the analysis of the errored bits in an errored block except if it exists SESR time period Recommendation G.826 is tolerant of burst errors, since in this case a large number of erroneous bits in one second results in a significantly smaller number of error blocks.

In this case a high number of errored bits in a second time interval is the cause of significantly smaller number of errored blocks. Second time interval existence causes a lower number of errored blocks. In the case that the same number of errored bits is uniformly distributed during one second, each single errored bit may produce errored block. In the Recommendation G.821 the total number of errored bits is only important, not their distribution in second time intervals.

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