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Title : Some consideration on quality requirements and network performance

1 - INTRODUCTION

CCITT Recommendation G.821 defines the "Error Performance of an International Digital Connection Forming Part of an ISDN". It recommends to meet the requirements set out in Table 1/G.821. This table defines the concept of errored seconds, degraded minutes and severely errored seconds. Two Bit Error Rates (BERs) are referred to : 10^{-6} and 10^{-3}. A time interval T_L is also defined, on which the percentages are assessed. It should be noted that G.821 refers to 64 kbit/s only and that higher bitrates are under consideration in SG XVIII. However the error performance of ISDN is based on G.821, hence G.821 may be considered as a basis.

2 - APPLICATION OF G.821 TO VIDEOCONFERENCING

The value of T_L, the period over which the error performance is averaged, is not specified in G.821 and should "depend upon the application" but should be counted in months since it is a long term assessment. Two hours may be considered as relevant for a videoconference session. According to G.821 and for long term considerations, the following conditions should apply :

(a) BER of zero (error-free seconds) : at last 92 % of T_L. For an average videoconference session of two hours, this would correspond to 576 errored seconds (around 10 mn).

(b) BER between 10^{-3} and 10^{-6} (degraded minutes) : no more than 10 % of T_L. For an average videoconference session of two hours, this would correspond to 12 degraded minutes.

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(c) BER worse than 10^{-3} (severely errored seconds) : no more than 0.2 % of T_L. For an average videoconference session of 2 hours, this would correspond to 15 severely errored seconds.

The times mentioned for a videoconference session of 2 hours are of course indicative and should be increased to conform to the long term average.

In assessing these objectives, periods of unavailability are excluded (see definition of anavailability in Annex A to G.821).

3 - VIDEOCONFERENCE SERVICE REQUIREMENTS

For observed video performance, only two BERs may be referred to for the moment. Taking into account past experience (eg. videoconference codecs to H.120 part I), a BER of 10^{-6} should provide an acceptable quality while a BER of 10^{-3} might give an unusable image. Between 10^{-3} and 10^{-6}, some impairments may appear. The observed performance under these conditions might be described (or wished) as follows :

(a) BER = 0 : **Perfect Service** : no visible nor audible degradation

(b) BER = 10^{-6} to 10^{-3} : **Degraded Service** : until 10^{-4}, some visible impairments but the picture is not broken nor frozen, some clicks in the audio ; between 10^{-4} and 10^{-3}, the picture may be broken or frozen.

(c) BER worse than 10^{-3} : **Unusable Service** : highly degraded picture (broken and/or frozen) ; badly distorted audio.

4 - ADEQUACY OF G.821

G.821 has been studied for 64 kbit/s channels. It gives quality assessment averaged on very long periods (some months). The frontier between the usable and the unsusable service is not very clear (need for an intermediate BER?). On the other hand the impact of G.821 on the construction of digital networks is not yet fully identified. As the performance of the future 384 kbit/s codec against transmission errors is not known, it is difficult to undertake any action towards SG XVIII for the moment. In conclusion, the points raised by this contribution should be further studied by the members of the group and a contribution to SG XVIII via SG XV could be made later.

Anexed to this contribution : CCITT Recommendation G.821.

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A.4 The digital communications system designer is faced with several choices. The clocks in the system may be referred to a single master clock which in turn is referred to UTC. An extended system may be subdivided into regions each having their master clock individually referred to UTC. These two varieties have been examined in Canada with good success. In the first case, the network master was compared to the national frequency standard at the National Research Centre (NRC). In the second case, several master clocks were phase-locked to the signals of the Loran-C navigation system.

A most important design choice is the degree of reliance on the clocks, i.e. the time constant in the frequency control loop versus the quality of the clocks [Kartaschoff, 1980].

Comparison methods via satellite show great potential, especially for areas where other high stability time signals are not available (Report 518).

References

[1] JOHNSON, A., FORCE, M. and OSTERDOCK, T. (1980), Longevity performance of caesium clocks, *34th annual frequency control symposium*, Philadelphia, 1980.

[2] KARTASCHOFF, P. (1980) Reference clock parameters for digital communication system applications, *Proc. 12th annual precise time and time interval applications and planning meeting*, Greenbelt, Md, NASA CP 2175, 515-548.

Bibliography

KARTASCHOFF, P. (1979) Computer simulation on the conventional clock model, *IEEE Trans. on Instrumentation and measurement*, Vol. IM-28,3, 193-197.

ZHUANG QI XIANG (1980), Reliability research of rubidium clock, Annals of Shanghai Observatory, *Academia Sinica*, Vol. 2.

8.2 Quality and availability targets

Recommendation G.821

ERROR PERFORMANCE OF AN INTERNATIONAL DIGITAL CONNECTION FORMING PART OF AN INTEGRATED SERVICES DIGITAL NETWORK

(Geneva, 1980; further amended)

The CCITT,

considering

(a) that services in the future may expect to be based on the concept of an Integrated Services Digital Network (ISDN);

(b) that errors are a major source of degradation in that they affect voice services in terms of distortion of voice, and data type services in terms of lost or inaccurate information or reduced throughout;

(c) that while voice services are likely to predominate, the ISDN is required to transport a wide range of service types and it is therefore desirable to have a unified specification;

(d) that an explanation of network performance objectives and their relationship with design objectives is given in Recommendation G.102,

recommends

that within the following scope and definitions the requirements set out in Table 1/G.821 and subsequent paragraphs should be met.

1 Scope and definitions

1.1 The performance objectives are stated for each direction of a 64 kbit/s circuit-switched connection used for voice traffic or as a "Bearer Channel" for data-type services.

1.2 The 64 kbit/s circuit-switched connection referred to is an all digital Hypothetical Reference Connection (HRX) and is given in Figure 1/G.821. It encompasses a total length of 27 500 km and is a derivative of the Standard Hypothetical Reference Connection given in Figure 1/G.801.

1.3 The performance objective is stated in terms of **error performance parameters** each of which is defined as follows:

> "The percentage of averaging periods each of time interval T_0 during which the bit error ratio (BER) exceeds a threshold value. The percentage is assessed over a much longer time interval T_L" (see Note 3 to Table 1/G.821).

It should be noted that total time (T_L) is split into two parts, namely, time for which the connection is deemed to be available and that time when it is unavailable (see Annex A).

Requirements relating to the permissible percentage of unavailable time will be the subject of a separate Recommendation.

1.4 The following BERs and intervals are used in the statement of objectives:

a) a BER of less than $1 \cdot 10^{-6}$ for $T_0 = 1$ minute;

b) a BER of less than $1 \cdot 10^{-3}$ for $T_0 = 1$ second;

c) zero errors for $T_0 = 1$ second (equivalent to the concept of error free seconds EFS).

These categories equate to those of Table 1/G.821. In assessing these objectives periods of unavailability are excluded (see Annexes A and B.

1.5 The performance objectives aim to serve two main functions:

a) to give the user of future national and international digital networks an indication as to the expected error performance under real operating conditions, thus facilitating service planning and terminal equipment design;

b) to form the basis upon which performance standards are derived for transmission equipment and systems in an ISDN connection.

1.6 The performance objectives represent a compromise between a desire to meet service needs and a need to realize transmission systems taking into account economic and technical constraints. The performance objectives, although expressed to suit the needs of different services are intended to represent a single level of transmission quality.

The performance objective for degraded minutes (Table 1/G.821 a)) as stated, is based on an averaging period of one minute. This averaging period and the exclusion of errors occurring within severely errored seconds which occur during this one minute period (see Table 1/G.821, Note 2), may allow connections with frequent burst errors to meet this particular part of the overall objective, but such events will be controlled to a certain extent by the severely errored seconds objective (Table 1/G.821 b)). However, there is some doubt as to whether the objectives are adequate for proper operation of real-time video services with relatively long holding times, and this is the subject of further study.

1.7 Since the performance objectives are intended to satisfy the needs of the future digital network it must be recognized that such objectives cannot be readily achieved by all of today's digital equipment and systems. The intent, however, is to establish equipment design objectives that are compatible with the objectives in this Recommendation. These aspects are currently the subject of discussion within the CCITT and CCIR.

It is further urged that all technologies, wherever they appear in the network, should preferably be designed to better standards than those indicated here in order to minimize the possibility of exceeding the end-to-end objectives on significant numbers of real connections.

1.8 The objectives relate to a very long connection and recognizing that a large proportion of real international connections will be shorter, it is expected that a significant proportion of real connections will offer a better performance than the limiting value given in § 2. On the other hand, a small percentage of the connections will be longer and in this case may exceed the allowances outlined in this Recommendation

2 Performance objectives

The performance objectives for an international ISDN connection as identified in §§ 1.1 and 1.2 are shown in Table 1/G.821. It is intended that international ISDN connections should meet all of the requirements of Table 1/G.821 concurrently. The connection fails to satisfy the objective if any one of the requirements is not met.

TABLE 1/G.821

Error performance objectives for international ISDN connections

Performance classification	Objective
(a) (Degraded minutes) (Notes 1, 2)	Fewer than 10% of one-minute intervals to have a bit error ratio worse than $1 \cdot 10^{-6}$ (Note 4)
(b) (Severely errored seconds) (Note 1)	Fewer than 0.2% of one-second intervals to have a bit error ratio worse than $1 \cdot 10^{-3}$
(c) (Errored seconds) (Note 1)	Fewer than 8% of one-second intervals to have any errors (equivalent to 92% error-free seconds)

Note 1 – The terms "degraded minutes", "severely errored seconds" and "errored seconds" are used as a convenient and concise performance objective "identifier". Their usage is not intended to imply the acceptability, or otherwise, of this level of performance.

Note 2 – The one-minute intervals mentioned in Table 1/G.821 and in the notes are derived by removing unavailable time and severely errored seconds from the total time and then consecutively grouping the remaining seconds into blocks of 60. The basic one-second intervals are derived from a fixed time pattern.

Note 3 – The time interval T_L, over which the percentages are to be assessed has not been specified since the period may depend upon the application. A period of the order of any one month is suggested as a reference.

Note 4 – For practical reasons, at 64 kbit/s, a minute containing four errors (equivalent to an error ratio of 1.04×10^{-6}) is not considered degraded. However, this does not imply relaxation of the error ratio objective of $1 \cdot 10^{-6}$.

Note 5 – Annex B illustrates how the overall performance should be assessed.

3 Allocation of overall objectives

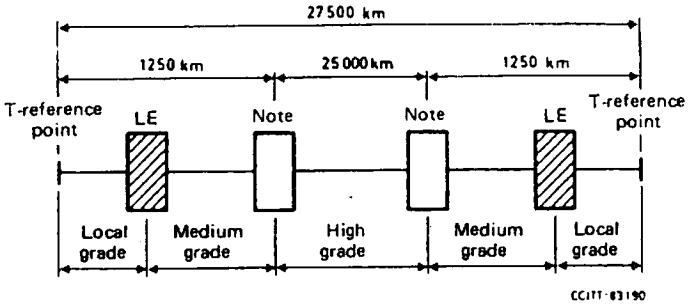
Since the objectives given in § 2 relate to an overall connection it is necessary to sub-divide this to constituent parts. This paragraph outlines the basic principles and strategy for apportioning the performance objectives.

The overall apportionment philosophy involves the use of two slightly different strategies, one applicable to the degraded minutes requirement and the errored seconds requirement (see classifications (a), (c)) and the other applicable to the severely errored seconds requirement (see classification (b)).

3.1 *Basic apportionment principles*

Apportionment is based on the assumed use of transmission systems having qualities falling into one of a limited number of different classifications.

Three distinct quality classifications have been identified representative of practical digital transmission circuits and are independent of the transmission systems used. These classifications are termed local grade, medium grade and high grade and their usage generally tends to be dependent on their location within a network (see Figure 1/G.821).



Note — It is not possible to provide a definition of the location of the boundary between the medium and high grade portions of the HRX. Note 4 to Table 2/G.821 provides further clarification of this point.

FIGURE 1/G.821

Circuit quality demarcation of longest HRX

The following general assumptions apply to the apportionment strategy that follows:

- in apportioning the objectives to the constituent elements of a connection it is the "% of time" that is subdivided;
- an equal apportionment of the objectives applies for both the degraded minutes and errored seconds requirements (classifications (a), (c));
- the error ratio threshold is not sub-divided. The rationale for this is based on the assumption that the performance of real circuits forming the parts of the HRX (Figure 1/G.821) will normally be significantly better than the degraded minute threshold (see Note to § 3.1);
- no account is taken of the error contribution from either digital switching elements or digital multiplex equipments on the basis that it is negligible in comparison with the contribution from transmission systems.

These quality classifications for different parts of the connection are considered to represent the situation for a large proportion of real international connections. Administrations are free to use whatever transmission systems they wish within their own networks and these other arrangements are considered as being completely acceptable provided that the overall performance of the national portion is no worse than it would have been if the standard CCITT arrangements had been employed.

It should be noted that a small percentage of connections will be longer than the 27 500 km HRX. By definition the extra connection length will be carried over high-grade circuits and hence the amount by which such connections exceed the total allowance envisaged in this Recommendation will be proportional to the amount by which the 25 000 km section is exceeded. Administrations should note that if the performance limits in the various classifications could be improved in practical implementations, the occurrence of these situations could be significantly reduced.

Note – For terrestrial systems the apportionment of the "degraded minute" performance classification to smaller entities (e.g. Hypothetical Reference Digital Section) may require sub-division of the error ratio objective, as well as the sub-division of "% of time", with distance. This is the subject of further study.

3.2 *Apportionment strategy for the degraded minutes and errored seconds requirements*

The apportionment of the permitted degradation, i.e. 10% degraded minutes and 8% errored seconds, is given in Table 2/G.821. The derived network performance objectives are given in Annex C.

TABLE 2/G.821

Allocation of the degraded minutes and errored seconds objectives for the three circuit classifications

Circuit classification	Allocation of the degraded minutes and errored seconds objectives given in Table 1/G.821
Local grade (2 ends)	15% block allowance to each end (Notes 1, 4 and 5)
Medium grade (2 ends)	15% block allowance to each end (Notes 2, 4 and 5)
High grade	40% (equivalent to conceptual quality of 0.0016% per km for 25 000 km, but see Note to § 3.1) (Notes 3, 6 and 7)

Note 1 – The local grade apportionment is considered to be a block allowance, i.e. an allowance to that part of the connection regardless of length.

Note 2 – The medium grade apportionment is considered to be a block allowance, i.e. an allowance to that part of the connection regardless of length. The actual length covered by the medium grade part of the connection will vary considerably from one country to another. Transmission systems in this classification exhibit a variation in quality falling between the other classifications.

Note 3 – The high grade apportionment is divided on the basis of length resulting in a conceptual per kilometre allocation which can be used to derive a block allowance for a defined network model (e.g. Hypothetical Reference Digital Link).

Note 4 – The local grade and medium grade portions are permitted to cover up the first 1250 km of the circuit from the T-reference point (see Figure 1/I.411) extending into the network. For example, in large countries this portion of the circuit may only reach the Primary Centre whilst in small countries it may go as far as the Secondary Centre, Tertiary Centre or the International Switching Centre (see Figure 1/G.821).

Note 5 – Administrations may allocate the block allowances for the local and medium grade portions of the connection as necessary within the total allowance of 30% for any one end of the connection. This philosophy also applies to the objectives given for local and medium grades in Table 3/G.821.

Note 6 – Based on the understanding that satellite error performance is largely independent of distance, a block allowance of 20% of the permitted degraded minutes and errored second objectives is allocated to a single satellite HRDP employed in the high-grade portion of the HRX.

Note 7 – If the high-grade portion of a connection includes a satellite system and the remaining distance included in this category exceeds 12 500 km or if the high-grade portion of a non-satellite connection exceeds 25 000 km, then the objectives of this Recommendation may be exceeded. The occurrence of such connections is thought to be relatively rare and studies are continuing in order to investigate this. The concept of satellite equivalent distance (the length of an equivalent terrestrial path) is useful in this respect and it has been noted that a value in the range 10 000 to 13 000 km might be expected.

3.3 *Apportionment strategy for severely errored seconds*

The total allocation of 0.2% severely errored seconds is subdivided into each circuit classification (i.e. local, medium, high grades) in the following manner:

a) 0.1% is divided between the three circuit classifications in the same proportions as adopted for the other two objectives. This results in the allocation as shown in Table 3/G.821.

TABLE 3/G.821

Allocation of severely errored seconds

Circuit classification	Allocation of severely errored seconds objectives
Local grade	0.015% block allowance to each end (Note 5 to Table 2/G.821)
Medium grade	0.015% block allowance to each end (Note 5 to Table 2/G.821)
High grade	0.04% (Note 1)

Note 1 – For transmission systems covered by the high grade classification each 2500 km portion may contribute not more than 0.004%.

Note 2 – For a satellite HRDP operating in the high grade portion there is a block allowance of 0.02% severely errored seconds (see also Note 6 to Table 2/G.821).

b) The remaining 0.1% is a block allowance to the medium and high grade classifications to accommodate the occurrence of adverse network conditions occasionally experienced (intended to mean the worst month of the year) on transmission systems. Because of the statistical nature of the occurrence of worst month effects in a world-wide connection, it is considered that the following allowances are consistent with the total 0.1% figure:

- 0.05% to a 2500 km HRDP for radio relay systems which can be used in the high grade and the medium grade portion of the connection;
- 0.01% to a satellite HRDP (the CCIR are continuing studies on severely errored seconds performance for satellite systems and this value may eventually need to be increased).

ANNEX A

(to Recommendation G.821)

Available and unavailable time

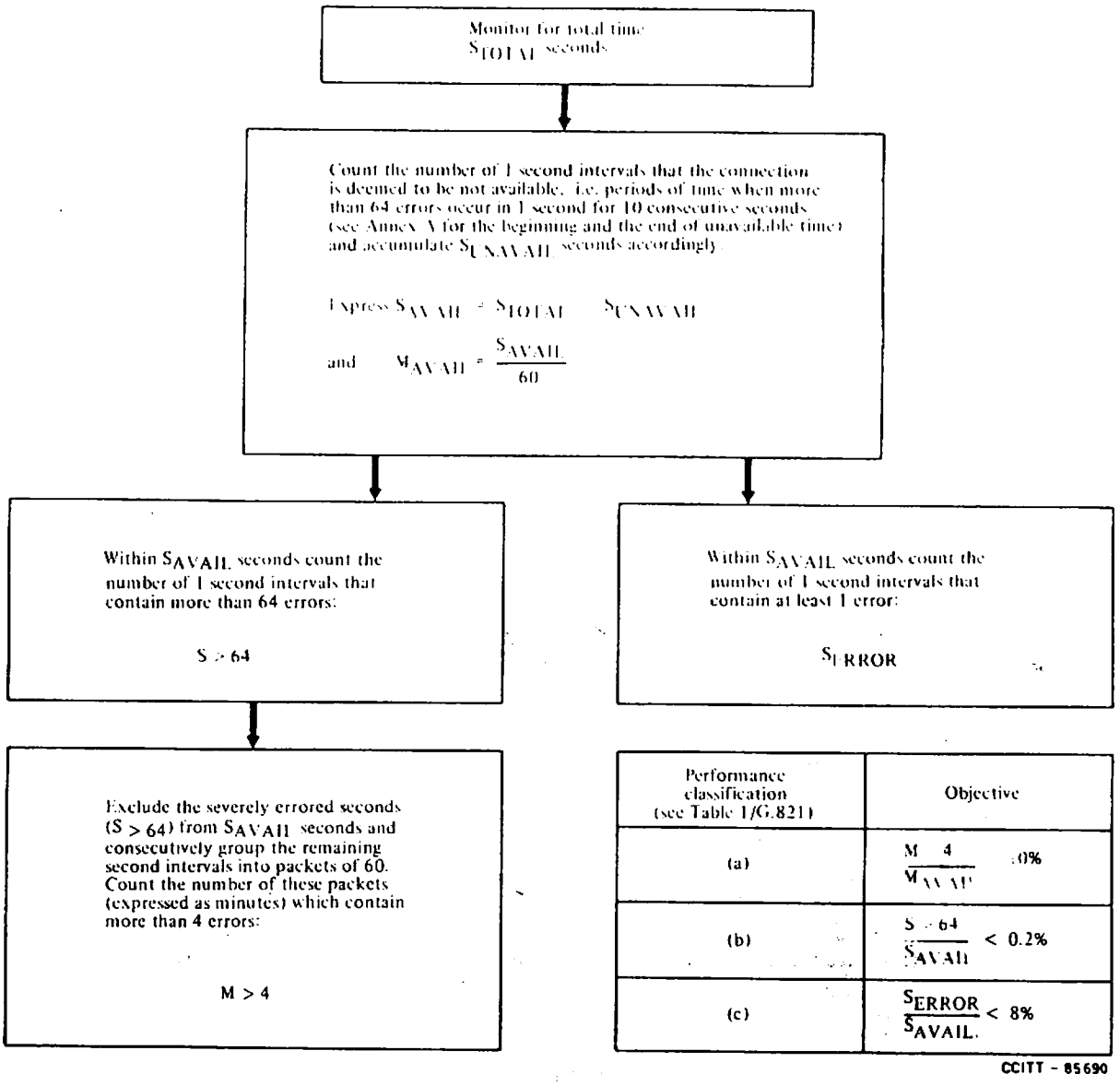
A period of unavailable time begins when the bit error ratio (BER) in each second is worse than $1 \cdot 10^{-3}$ for a period of ten consecutive seconds. These ten seconds are considered to be unavailable time. The period of unavailable time terminates when the BER in each second is better than $1 \cdot 10^{-3}$ for a period of ten consecutive seconds. These ten seconds are considered to be available time.

Definitions concerning availability can be found in Recommendation G.106.

ANNEX B

(to Recommendation G.821)

Guidelines concerning the interpretation of Table 1/G.821



Performance classification (see Table 1/G.821)	Objective
(a)	$\frac{M > 4}{M_{AVAIL}}$ ...0%
(b)	$\frac{S > 64}{S_{AVAIL}} < 0.2\%$
(c)	$\frac{S_{ERROR}}{S_{AVAIL}} < 8\%$

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ANNEX C

(to Recommendation G.821)

Allocation of objectives to constituent parts

TABLE C-1/G.821

Allocation of % degraded minute intervals and errored seconds objectives

Circuit classification (see Figure 2/G.821)	Network performance objectives at 64 kbit/s	
	% degraded minutes	% errored seconds
Local grade	1.5	1.2
Medium grade	1.5	1.2
High grade	4.0	3.2

Reference

[1] CCITT Recommendation *Transmission performance objectives and recommendations*, Vol. III, Rec. G.102.

Recommendation G.822

CONTROLLED SLIP RATE OBJECTIVES ON AN INTERNATIONAL DIGITAL CONNECTION

(Geneva, 1980; further amended)

1 General

This Recommendation deals with end-to-end *controlled octet slip rate* objectives for 64-kbit/s international digital connections. The objectives are presented for various operational conditions in relation to the evaluation of connection quality.

Under design conditions for digital network nodes and within defined normal transmission characteristics, it may be assumed that there are zero slips in a synchronized digital network. However, the defined transmission characteristics can be exceeded under operating conditions and cause a limited number of slips to occur even in a synchronized network.