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SERIES Q: SWITCHING AND SIGNALLING

Digital local, combined, transit and international exchanges in integrated digital networks and mixed analogue-digital networks – Design objectives and measurements

DIGITAL EXCHANGE DESIGN OBJECTIVES – GENERAL

Reedition of CCITT Recommendation Q.541 published in the Blue Book, Fascicle VI.5 (1988)

NOTES

1 CCITT Recommendation Q.541 was published in Fascicle VI.5 of the *Blue Book*. This file is an extract from the *Blue Book*. While the presentation and layout of the text might be slightly different from the *Blue Book* version, the contents of the file are identical to the *Blue Book* version and copyright conditions remain unchanged (see below).

2 In this Recommendation, the expression “Administration” is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Recommendation Q.541

DIGITAL EXCHANGE DESIGN OBJECTIVES – GENERAL

1 General

This Recommendation applies to digital local, combined, transit and international exchanges for telephony in Integrated Digital Networks (IDN) and mixed (analogue/digital) networks, and also to local, combined, transit and international exchanges in an Integrated Services Digital Network (ISDN). The field of application of this Recommendation is more fully defined in Recommendation Q.500. Some objectives only apply to a certain type (or types) of exchange. Where this occurs, the application is defined in the text. Where no such qualification is made, the objective applies to all exchange applications.

2 General design objectives

The exchange and/or any associated operations and maintenance systems/centers shall have the capabilities needed to allow the exchange to be operated and administered efficiently while providing service in accordance with an Administration's performance requirements.

2.1 *Exchange modifications and growth*

The exchange should be capable of having hardware and/or software added or changes made without causing a significant impact on service (see §§ 4.4, 4.10.2 – Planned outages).

2.2 *Service provisioning and records*

There should be efficient means of establishing service, testing, discontinuing service and maintaining accurate records for:

– subscriber lines and services,

– interexchange circuits.

2.3 *Translations and routing information*

There should be efficient means of establishing, testing and changing call processing information, such as translation and routing information.

2.4 *Resource utilization*

There should be efficient means of measuring performance and traffic flows and to arrange equipment configurations as required to insure efficient use of system resources and to provide a good grade of service to all subscribers (e.g., load balancing).

2.5 *Physical design objectives*

The exchange shall have a good physical design that provides:

– adequate space for maintenance activities,

– conformance with environmental requirements,

– uniform equipment identification (conforming with the Administration's requirements),

– a limited number of uniform power up/down procedures for all component parts of the exchange.

3 Integrated Digital Network design objectives

3.1 *Exchange timing distribution*

The timing distribution system of an exchange will be derived from a highly reliable exchange clock system. The distribution of timing within the exchange must be designed so that the exchange will maintain synchronism on 64 kbit/s channel timeslots in a connection through the exchange.

3.2 *Network synchronization*

Within a synchronized IDN/ISDN, different methods of providing timing between exchanges may be used. An exchange should be able to be synchronized:

a) by an incoming digital signal at an interface A (or B, if provided) as defined in Recommendation Q.511; this applies only to signals derived from a Primary Reference Source, as defined in Recommendation G.811;

b) directly by a Primary Reference Source, using an interface complying with Recommendation G.811;

c) optionally, by an analogue signal at one of the frequencies listed in Recommendation G.811.

Plesiochronous operation should also be possible.

The clock of the local, combined or transit exchange shall be responsible for maintaining the synchronization in the part of the network associated with that exchange.

The timing performance of the clocks in local, combined or transit exchanges should comply with Recommendation G.811. The timing performance of clocks at subscriber premises, at digital PABXs, in digital concentrators, at muldexes, etc., require further study.

Synchronized national networks may be provided with exchange clocks not having the frequency accuracy required for international interworking. However, when these synchronized networks within national boundaries are required to interwork internationally as part of the international IDN/ISDN, it will be necessary to provide means to operate these national networks to the internationally recommended value of frequency accuracy in Recommendation G.811.

3.3 *Slip*

The design objective controlled slip rate within a synchronized region (see Note) controlled by the exchange should be zero provided that input jitter and wander remain within the limits given in Recommendation G.823 and G.824.

The design objective controlled slip rate at a digital exchange in plesiochronous operation (or operating to another synchronized region) shall be not more than one slip in 70 days in any 64 kbit/s channel, provided that input jitter and wander remain within the limits given in Recommendations G.823 and G.824.

The operational performance requirements for the rate of octet slips on an international connection or corresponding bearer channel are covered in Recommendation G.822.

The occurrence of a controlled slip should not cause loss of frame alignment.

Note – A synchronized region is defined as a geographic entity normally synchronized to a single source and operating plesiochronously with other synchronized regions. It may be a continent, country, part of a country or countries.

3.4 *Relative Time Interval Error (TIE) at the exchange output*

Relative Time Interval Error (TIE) at the exchange output is defined as the difference in time delay of a given timing signal when compared to a reference timing signal for a given measurement period (see Recommendation G.811).

3.4.1 *Interface V_1*

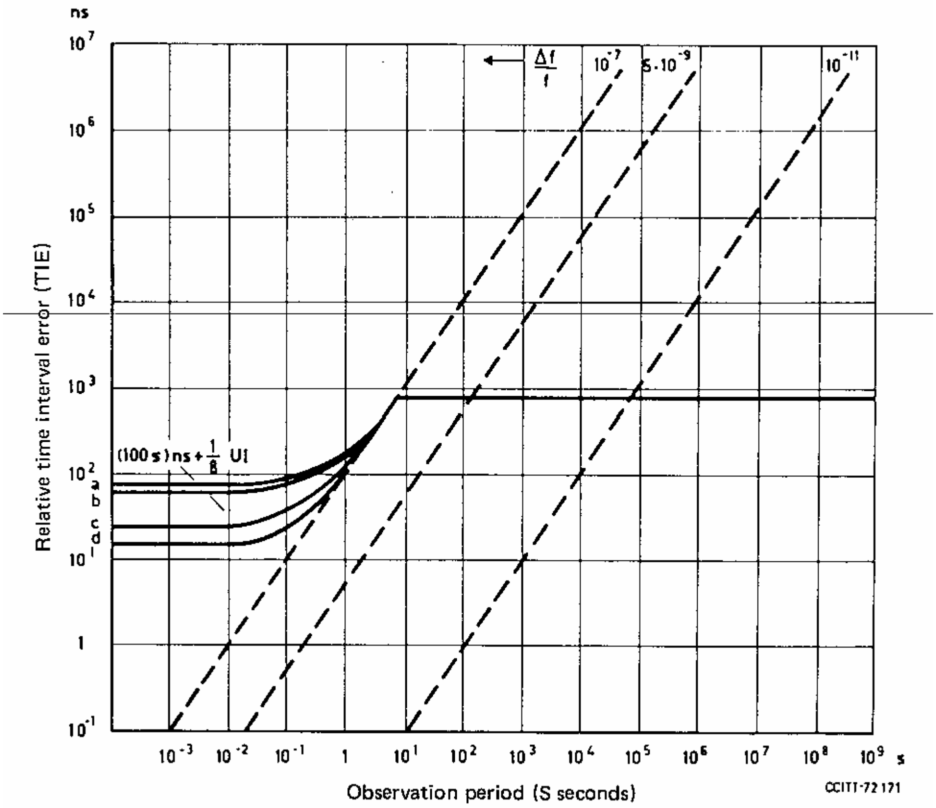
Relative Time Interval Error (TIE) at the exchange output at the interface to the basic access digital section requires further study.

3.4.2 *Interfaces A, B, V_2, V_3 and V_4*

The relative TIE at the output of the digital interfaces A, B, V_2, V_3 and V_4 over the period S seconds should not exceed the following limits:

1) (100 S) ns + 1/8 UI for S < 10.

2) 1000 ns for S ⩾ 10 (see Figure 4/Q.541).



a : 1544 kbit/s
b : 2048 kbit/s
c : 6312 kbit/s
d : 8448 kbit/s

FIGURE 1/Q.541

Limits of relative peak-to-peak TIE at the exchange output interfaces A, B and V_3

In the case of synchronous operation the limits are specified on the assumption of an ideal incoming synchronizing signal (no jitter, no wander and no frequency deviation) on the line delivering the timing information. In the case of asynchronous operation the limits are specified assuming no frequency deviation of the exchange clock, (this is equivalent to taking the output of the exchange clock as the reference timing signal for the relative TIE measurements).

It is recognized that the approach of using relative TIE to specify the performance of an exchange in the case of synchronous operation in some implementations (e.g., when mutual synchronization methods are used) requires further study.

Any internal operation or rearrangement within the synchronization and timing unit or any other cause should not result in a phase discontinuity greater than 1/8 of a Unit Interval (UI) on the outgoing digital signal from the exchange.

The limits given in Figure 4/Q.541 may be exceeded in cases of infrequent internal testing or rearrangement operations within the exchange. In such cases, the following conditions should be met:

The Relative Time Interval Error (TIE) over any period up to 2^{11} unit intervals should not exceed 1/8 of a UI. For periods greater than 2^{11} UI, the phase variation for each interval of 2^{11} UI should not exceed 1/8 UI up to a maximum total Relative TIE defined in Recommendation G.811 for long time periods.

3.5 *Synchronization requirements when interworking with a digital satellite system*

On a provisional basis the following should apply:

The transfer from the timing of the terrestrial digital network to the timing of the satellite system, if required (plesiochronous operation), will not be performed by the digital exchange. The earth station will be equipped with buffer memories of suitable size to compensate for the time delay variations due to shifts of the satellite from its ideal position (and due to any other phenomena with similar effects) and to meet the slip performance requirements established in CCITT Recommendation G.822.

4 Availability design objectives

4.1 *General*

Availability is one aspect of the overall quality of service of an exchange.

Availability objectives are important factors to be considered in the design of a switching system and may also be used by administrations to judge the performance of a system design and to compare the performance of different system designs.

Availability may be determined by collecting and evaluating data from exchanges in operation in accordance with draft Recommendation E.450. Data collection may be facilitated by the use of the Telecommunications Management Network (TMN).

Availability may be expressed as the ratio of the accumulated time during which the exchange (or part of it) is capable of proper operation to a time period of statistically significant duration called the mission time.

$$\text{Availability (A)} = \frac{\text{accumulated up-time}}{\text{mission time}} = \frac{\text{accumulated up-time}}{\text{accumulated up-time} + \text{accumulated down-time}}$$

Sometimes it is more convenient to use the term unavailability (instead of availability) which is defined as:

Unavailability (U) = 1 – A.

The terms used in this section, when they already exist, are in accordance with CCITT Recommendation G.106.

4.2 *Causes of unavailability*

This Recommendation deals with availability as observed from the exchange termination point of view. Both planned and unplanned outages need to be considered, and both types need to be minimized. Unplanned outages reflect on the inherent reliability of the exchange and are therefore considered separately from planned outages in this Recommendation.

Unplanned unavailability counts all failures that cause unavailability. Thus hardware failure, software malfunctions and unintentional outages resulting from craftperson activity are to be counted.

4.3 *Intrinsic and operational unavailability*

Intrinsic unavailability is the unavailability of an exchange (or part of it) due to exchange (or unit) failure itself, excluding the logistic delay time (e.g. travel times, unavailability of spare units, etc.) and planned outages.

Operational unavailability is the unavailability of an exchange (or part of it) due to exchange (or unit) failure itself, including the logistic delay time (e.g. travel times, unavailability of spare units, etc.).

4.4 *Planned outages*

Planned outages are those intentionally induced to facilitate exchange growth or hardware and/or software modifications. The impact of these activities on service depends on their duration, the time of day they are introduced and on the particular system design.

4.5 *Total and partial unavailability*

Exchange unavailability may be either total or partial. Total unavailability affects all terminations, and consequently, all traffic that is offered during the outage is equally affected. A partial outage has an effect only on some terminations.

From the point of view of one termination on an exchange (e.g. a subscriber line termination), the numerical value of mean accumulated downtime (and hence the unavailability) for a specified period of time should not depend on the exchange size or its traffic handling capacity. Similarly, from the point of view of a group of terminations of size *n*, the mean accumulated downtime for a specified period of time, *in case they are simultaneously unavailable*, should not depend on exchange size. However, for two groups of terminals of differing size *n* and *m* such that *n* is greater than *m* ($n > m$), the mean accumulated downtime (and hence the unavailability) for *n* will be less than the mean accumulated downtime (MADT) or the unavailability for *m*.

Thus:

$$\mathrm{MADT}(n) < \mathrm{MADT}(m) \text{ where } n > m$$

and

$$\mathrm{U}(n) < \mathrm{U}(m)$$

The lower limit of *m* is one termination, and it can be specified as having a mean value of *T* minutes per year.

4.6 *Statistical basis*

Any estimation of unavailability is of necessity a statistical quantity, because outages are presumed to occur randomly and they are of random duration. Therefore, availability measurements are significant when made over a statistically significant number of exchanges. It follows then, that a single exchange may exceed the unavailability objectives. Further, to be statistically significant the mission time must be adequate in order to have sufficient collected data. The accuracy of the result is dependent on the amount of collected data.

4.7 *Relevant failure events*

Different types of failure events may occur in an exchange. In order to evaluate the unavailability of an exchange (or part of it) only those events having an adverse effect on the exchange's ability to process calls as required should be taken into account. A failure event which is short in duration and results only in call delay rather than in a call denial can be disregarded.

4.8 *Availability independence*

The design objectives for the unavailability of a single termination or any group of terminations of size *n* are independent of exchange size or internal structure.

4.9 *Intrinsic downtime and unavailability objectives*

The recommended measure for use in determining *intrinsic unavailability* is mean accumulated intrinsic down time (MAIDT) for individual or groups of terminations, for a given mission time, typically one year.

For one termination:

$$\mathrm{MAIDT}(1) \leqslant 30 \text{ minutes per year.}$$

For an exchange termination group of size *n*:

$$\mathrm{MAIDT}(n) < \mathrm{MAIDT}(m) \text{ where } n > m.$$

This reflects the consequences (e.g. traffic congestion, social annoyance, etc.), of the simultaneous outage of a large number of terminations.

The above expression is a statement of principle and means that units serving larger group sizes shall have lower MAIDT.

4.10 *Operational unavailability objectives*

4.10.1 *Logistic delay time*

Due to differing national conditions, logistic delay times may vary from country to country and therefore may not be subject to international Recommendation.

Nevertheless, for design guidance, an indication of the Administration's logistic delays is considered desirable to establish overall operational performance objectives. It is left for the operating Administration to determine how it should be accounted for in the determination of operational unavailability.

4.10.2 *Planned outages*

Planned outages are to be minimized to the greatest extent practicable. They should be scheduled so as to have least impact on service practicable.

4.11 *Initial exchange availability performance*

A system rarely meets all long-term design objectives when first placed into service. The objectives contained in this Recommendation may therefore not be fulfilled for a limited period of time after the newly designed switched system has been put into service; this period of time should be minimized to the greatest extent practicable.

5 Hardware reliability design objectives

A bound on the rate of hardware failures is recommended. It includes all types of hardware failures and the failures counted are independent of whether or not there is a resulting service degradation.

An acceptable hardware failure rate for an exchange is a function of the exchange size and the types of terminations.

The following formula can be used to verify that the maximum failure rate does not exceed the Administration's requirements:

$$F_{max} = C_0 + \sum_{i=1}^{n} C_i T_i$$

where:

F_{max} the maximum acceptable number of hardware failures per unit of time;

T_i the number of terminations of type *i*;

n the number of distinct types of terminations;

C_0 to be determined taking into account all failures which are independent of exchange size;

C_i coefficients for terminations of type *i*, reflecting the number of failures associated with individual terminations of that type. Different hardware used with different types of terminations may result in different values for C_i.

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