INTERNATIONAL TELECOMMUNICATION UNION

CCITT

THE INTERNATIONAL
TELEGRAPH AND TELEPHONE
CONSULTATIVE COMMITTEE

X.136

(11/1988)

SERIES X: DATA COMMUNICATION NETWORKS: TRANSMISSION, SIGNALLING AND SWITCHING, NETWORK ASPECTS, MAINTENANCE AND ADMINISTRATIVE ARRANGEMENTS

Data communication networks – Network aspects

ACCURACY AND DEPENDABILITY PERFORMANCE VALUES FOR PUBLIC DATA NETWORKS WHEN PROVIDING INTERNATIONAL PACKET-SWITCHED SERVICES

Reedition of CCITT Recommendation X.136 published in the Blue Book, Fascicle VIII.3 (1988)

NOTES

1 CCITT Recommendation X.136 was published in Fascicle VIII.3 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 X.136

ACCURACY AND DEPENDABILITY PERFORMANCE VALUES FOR PUBLIC DATA NETWORKS WHEN PROVIDING INTERNATIONAL PACKET-SWITCHED SERVICES

(Malaga-Torremolinos, 1984; amended at Melbourne, 1988)

The CCITT,

considering

(a) that Recommendation X.1 specifies the international user classes of service in public data networks;

(b) that Recommendation X.2 specifies the international data transmission services and optional user facilities in public data networks;

(c) that Recommendation X.25 specifies the DTE/DCE interface for packet mode terminals connected to public data networks by dedicated circuit;

(d) that Recommendation X.75 specifies the packet-switched signalling system between public data networks providing data transmission services;

(e) that Recommendation X.323 specifies general arrangements for interworking between packet-switched public data networks;

(f) that Recommendation X.96 specifies call progress signals in public data networks;

(g) that Recommendation X.110 specifies the international routing principles and routing plan for public data networks;

(h) that Recommendation X.213 defines the OSI Network Layer service;

(i) that Recommendation X.140 defines general quality of service parameters for communication via public data networks;

(j) that Recommendation X.134 specifies portion boundaries and packet layer reference events for defining packet-switched performance parameters;

(k) that Recommendation X.135 specifies speed of service performance values for public data networks when providing international packet-switched service;

(l) that Recommendation X.137 specifies availability performance values for public data networks when providing international packet-switched service,

unanimously declares

(1) that the accuracy and dependability parameters defined in this Recommendation shall be used in the planning and operation of international packet-switched data communication services provided in accordance with Recommendations X.25 and X.75;

(2) that in such services, the performance values specified in this Recommendation shall be taken as worst-case limits under the conditions specified herein.

1 Introduction

1.1 This Recommendation is the third in a series of four CCITT Recommendations (X.134-X.137) that define performance parameters and values for international packet-switched data communication services. Figure 1/X.136 illustrates the scope of these four Recommendations and the relationships among them.

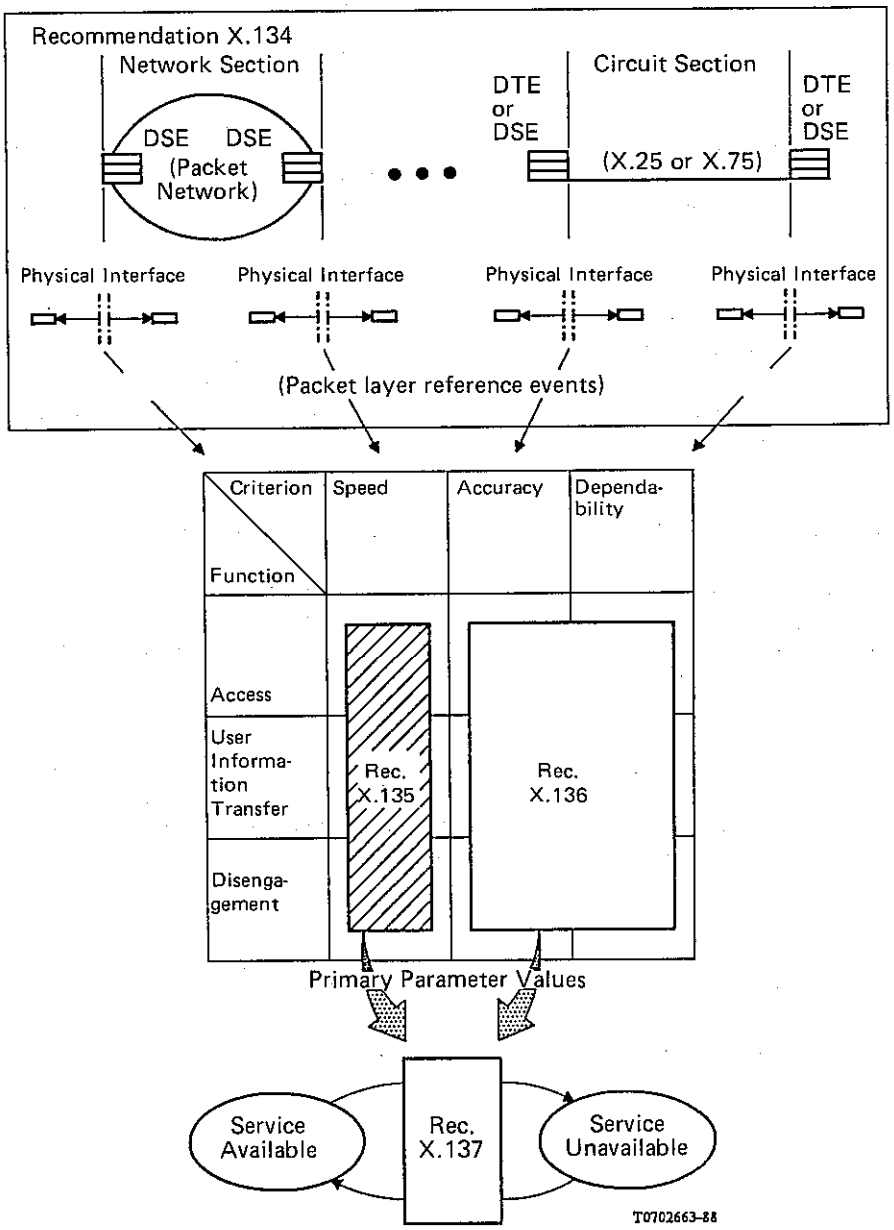

FIGURE 1/X.136

Packet-switched service performance description framework

1.2 Recommendation X.134 divides a virtual connection into basic sections whose boundaries are associated with X.25 and X.75 interfaces; defines particular collections of basic sections, called virtual connection portions, for which performance values will be specified; and defines a set of packet layer reference events (PEs) which provide a basis for performance parameter definition. The basic sections consist of network sections and circuit sections. They are delimited, in each case, by physical data terminal equipment (DTE) or data switching equipment (DSE) interfaces. Virtual connection portions are identified either as national portions or international portions. Each PE is defined to occur when a packet crossing a section boundary changes the state of the packet layer interface.

1.3 For comparability and completeness, packet-switched network performance is considered in the context of the 3 × 3 performance matrix defined in Recommendation X.140. Three protocol-independent data communication functions are identified in the matrix: access, user information transfer, and disengagement. These general functions correspond to call set-up, data (and interrupt), transfer, and call clearing in packet-switched virtual call services conforming to the X.25 and X.75 Recommendations. Each function is considered with respect to three general performance concerns (or "performance criteria"): speed, accuracy, and dependability. These express, respectively, the delay or rate, degree of correctness, and degree of certainty with which the function is performed.

1.4 Recommendation X.135 defines protocol-specific speed of service parameters and values associated with each of the three data communication functions. This Recommendation defines protocol-specific accuracy and dependability parameters and values associated with each function. The Recommendation X.135 and X.136 parameters are called "primary parameters" to emphasize their direct derivation from packet layer reference events.

1.5 An associated two-state model provides a basis for describing overall service availability. A specified availability function compares the values for a subset of the primary parameters with corresponding outage thresholds to classify the service as "available" (no service outage) or "unavailable" (service outage) during scheduled service time. Recommendation X.137 specifies the availability function and defines the availability parameters and values that characterize the resulting binary random process.

1.6 Eight accuracy and dependability parameters are defined in this Recommendation: two access parameters (call set-up error probability and call set-up failure probability), five user information transfer parameters (residual error rate, reset stimulus probability, reset probability, premature disconnect stimulus probability, and premature disconnect probability), and one disengagement parameter (call clear failure probability). Each parameter can be applied to any basic section or portion of a virtual connection. This generally makes the parameters useful in performance allocation and concatenation.

1.7 This Recommendation specifies accuracy and dependability values for national and international portions of two types (Table 1/X.136). Performance values for data terminal equipment are not specified, but the parameters defined in this Recommendation may be employed in such specification to assist users in establishing quantitative relationships between network performance and quality of service (see Recommendation X.140).

TABLE 1/X.136

Virtual connection portion types for which performance values are specified [a)]

Portion type	Typical characteristics
National A	Terrestrial connection via an access network section
National B	Connection via an access network section with one satellite circuit; or via an access network section and one or more transit network sections
International A	Connection via a direct terrestrial internetwork section
International B	Connection via two satellite circuits and one transit network section; or via one satellite circuit and two or more transit network sections

[a)] The values specified for Type B portions also apply to virtual connection portions not explicitly identified as Type A or Type B.

1.8 Worst-case values for each of the eight accuracy and dependability parameters are specified below for each virtual connection portion type identified in Table 1/X.136. The term "worst case" means that these values should be met during the normal busy hour in the worst-performing virtual connection portion used in providing international packet-switched services. The performance of a virtual connection portion may be better than the worst-case values specified in this Recommendation. Design objectives that take into account more demanding user applications and network performance and connectivity enhancements are for further study.

Numerical methods for combining individual portion performance values to estimate end-to-end performance are also provided in this Recommendation. DTE to DTE values for two particular hypothetical reference connections are derived using these methods in Annex B.

2 Access parameters

This section specifies worst-case values for two access parameters: call set-up error probability and call set-up failure probability.

Call set-up error and call set-up failure are defined between pairs of section boundaries (B_i, B_j). B_j is one of the set of boundaries to which the call attempt can properly be routed. Figure 2/X.136 identifies the sequence of four particular events that occur at these boundaries during a successful call set up[1]. A call set-up attempt over this section is an occurrence of event (a). A successful call set-up attempt over this section is a sequential occurrence of corresponding events (a, b, c and d) within a 200-second timeout period[2]. Call set-up errors and call set-up failures within this section are defined below. Any other unsuccessful call set-up attempt is caused by problems outside the section and is excluded from the measurement.

2.1 *Call set-up error probability*

Call set-up error probability applies to virtual call services. It does not apply to permanent virtual circuit establishment. This parameter is used to measure the accuracy of the general user function of access in public packet-switched services conforming to Recommendations X.25 and X.75.

2.1.1 **call set-up error probability** *definition*

Call set-up error probability is the ratio of total call attempts that result in call set-up error to the total call attempts in a population of interest.

With reference to Figure 2/X.136, a call set-up error is defined to occur on any call attempt in which event (d) occurs, but event (c) does not occur within a 200-second timeout period.

Call set-up error is essentially the case of a “wrong number”. It occurs when the network responds to a valid call request by erroneously establishing a virtual call to a destination DTE other than the one designated in the call request, and does not correct the error prior to entry to the data transfer state. It may be caused, for example, by network operator administrative or maintenance actions.

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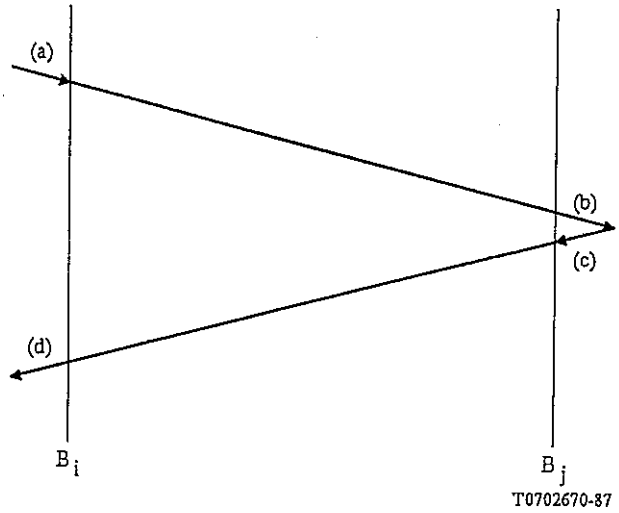
1) The PE numbers in Figure 2a/X.136 refer to Tables 1 and 2 in Recommendation X.134.

2) This period corresponds to timer T21 in Recommendation X.25.

Boundary/Event / Interface	B_i		B_j	
	(a)	(d)	(b)	(c)
X.25	2	3	1	4
X.75	1	2	1	2

a) Packet layer reference events (PEs)



b) Event sequence

FIGURE 2/X.136

Packet layer reference events occurring during successful call set-up

Call set-up error is distinguished from successful call set-up by the fact that the intended called user is not contacted and committed to the data communication session during the call set-up attempt.

Call set-up error probability does not apply to the fast select mode of data transfer. The optional user call redirection facilities in X.25 (including hunt group, call redirection, call forwarding subscription, call forwarding selection, call redirection or forwarding notification, and called line address modified notification) are assumed not to be used in the calculation of this parameter.

The specific X.134 PEs used in measuring call set-up error probability at each section boundary are those identified in Figure 2/X.136.

2.1.2 *Values*

The contribution from each network portion to the overall call set-up error probability under the conditions described in this Recommendation shall not exceed the values specified in Table 2/X.136.

TABLE 2/X.136

Worst-case call set-up error probability values for virtual connection portions

Statistic	Virtual connection portion type			
	National		International	
	A	B	A	B
Probability	10^{-5}	2×10^{-5}	a)	2×10^{-5}

a) The Type A international virtual connection portion consists only of a physical circuit. Its contribution to call set-up error probability is expected to be negligible.

Note – All specified values are provisional.

2.2 *Call set-up failure probability*

Call set-up failure probability applies only to virtual call services. This parameter is used to measure the dependability of the general user function of access in public packet-switched services conforming to Recommendations X.25 and X.75.

2.2.1 **call set-up failure probability** *definition*

Call set-up failure probability is the ratio of total call attempts that result in call set-up failure to the total call attempts in a population of interest.

With reference to Figure 2/X.136, call set-up failure is defined to occur on any call attempt in which either one of the following outcomes is observed within a 200-second timeout period[3)].

1) Both events (b) and (d) do not occur.

2) Events (b) and (c) occur, but event (d) does not.

Call attempts that are cleared by the section as a result of incorrect performance or nonperformance on the part of an entity outside the section are excluded. The specific X.134 PEs used in measuring call set-up failure probability at each section boundary are those identified in Figure 2/X.136.

2.2.2 *Values*

The contribution from each network portion to the overall call set-up failure probability under the conditions described in this Recommendation shall not exceed the values specified in Table 3/X.136.

3) Recommendation X.96 places limits on the frequency at which a DTE can repeat call attempts to a given destination.

TABLE 3/X.136

Worst-case call set-up failure probability values for virtual connection portions

Statistic	Virtual connection portion type			
	National		International	
	A	B	A	B
Probability	5×10^{-3}	10^{-2}	[a]	10^{-2}

[a] The Type A international virtual connection portion consists only of a physical circuit. Its contribution to call set-up failure probability is expected to be negligible.

Note – All specified values are provisional.

2.2.3 *Excluded call attempts*

A call set-up attempt can also fail as a result of user blocking. Such failures are excluded from network performance measurement. Examples of user blocking include the following:

1) Either the originating or the called user issues a clear request to reject the call set-up attempt.
2) The called user delays excessively in generating the call accepted packet during the connection period, with the result that a connection is not established before the timeout.
3) All logical channels at the called DTE are in use.

3 User information transfer parameters

This section specifies worst-case values for five user information transfer parameters; residual error rate, reset stimulus probability, reset probability, premature disconnect stimulus probability, and premature disconnect probability. These parameters describe impairments observed during the data transfer state of a virtual call or permanent virtual circuit.

3.1 *Residual error rate*

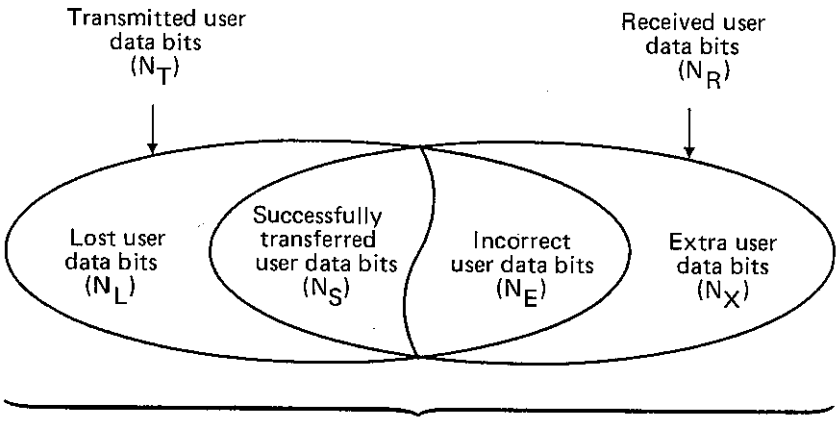
Residual error rate applies to both virtual call and permanent virtual circuit services. This parameter is used to measure the accuracy of the general function of user information transfer in public packet-switched services conforming to Recommendations X.25 and X.75.

3.1.1 **residual error rate** *definition*

Residual error rate is the ratio of total incorrect, lost, and extra (e.g. duplicate) user data bits to total user data bits transferred across either section boundary in a population of interest.

User data bits are the bits of the user data field in data packets of the X.25 or X.75 packet layer (protocols and data above the packet layer). Framing routing, bit stuffing, error control, and other protocol fields introduced by all protocols at or below the packet layer are excluded.

Relationships among the quantities identified above are defined in Figure 3/X.136. Incorrect user data bits are user data bits that are inverted in transfer between the section boundaries, i.e., bits whose binary value observed at the section boundary on the destination side of a virtual connection portion is the opposite of that observed at the section boundary on the source side. Lost user data bits are user data bits that are transferred into a virtual connection portion at one section boundary, but are not transferred out of the virtual connection portion at the other within 200 seconds of non-flow-controlled transmission. Bits lost in association with a reset or premature disconnect are excluded in calculating residual error rate. Extra user data bits are user data bits that are transferred out of a virtual connection portion at one section boundary, but were not previously transferred into the virtual connection portion at the other. Extra user data bits include duplicated user data bits and misdelivered user data bits.



$$RER = \frac{N_E + N_L + N_X}{N}$$

$$N = N_L + N_S + N_E + N_X$$

FIGURE 3/X.136

Components of residual error rate

The specific X.134 PEs used in measuring residual error rate at each section boundary are identified in Table 4/X.136. Only user data bits in data packets that create the specified PEs are counted in calculating residual error rate estimates.

TABLE 4/X.136

Packet layer reference events (PEs) used in measuring residual error rate

Circuit section	Starting/Ending PE
Source access circuit section	10a (X.25)
Destination access circuit section	9a (X.25)
Internetwork circuit section	5a (X.75)

In practice, it is not possible in all cases to distinguish lost, errored, and extra bit occurrences without detailed knowledge of the problems within the boundaries. A simple, approximate method of calculating residual error rate values is presented in Annex A. Other methods of equivalent or superior accuracy are acceptable.

3.1.2 *Values*

The contribution from each network portion to the overall residual error rate of a virtual connection provided under the conditions described in this Recommendation shall not exceed the values specified in Table 5/X.136. This specified values are based on an assumed data packet length of 128 octets.

TABLE 5/X.136

Worst-case residual error rate values for virtual connection portions

Statistic	Virtual connection portion type			
	National		International	
	A	B	A	B
Probability	10^{-10}	2×10^{-10}	a)	2×10^{-10}

a) The Type A international virtual connection portion consists only of a physical circuit. Its contribution to residual error rate is expected to be negligible.

Note – All specified values are provisional.

3.1.3 *Components of residual error rate*

In some applications, it may be important to specify probability limits for the individual failure outcomes illustrated in Figure 3/X.136 in addition to the overall residual error rate. The general user information error, user information loss, and extra user information delivery probabilities defined in Recommendation X.140 may be specialized to the corresponding user data bit-oriented measures as follows.

- User data bit error probability $P_1(E)$ is the ratio of total incorrect user data bits (N_E) to total successfully transferred user data bits *plus* incorrect user data bits ($N_S + N_E$) in a population of interest.
- User data bit loss probability $P_1(L)$ is the ratio of total lost user data bits (N_L) to total transmitted user data bits (N_T) in a population of interest.
- Extra user data bit delivery probability $P_1(X)$ is the ratio of total (unrequested) extra user data bits (N_X) to total received user data bits (N_R) in a population of interest.

The denominators of these ratios are chosen to ensure that each defined probability is properly normalized; i.e., each failure outcome is expressed in proportion to the total number of opportunities for that outcome to occur. The mathematical relationship between residual error rate (*RER*) and the three user data bits transfer failure probabilities defined above is as follows.

$$RER = \frac{[P_1(E)]\,[N_E + N_S] + [P_1(L)]\,[N_T] + [P_1(X)]\,[N_R]}{N}$$

3.2 *Reset parameters*

Reset stimulus probability and reset probability are related parameters used to describe the dependability of the general function of user information transfer in public packet-switched services conforming to Recommendations X.25 and X.75.

3.2.1 **reset stimulus probability** *definition*

A reset stimulus is observed at a single section boundary. It is any event or combination of events that according to the protocol should result in a reset (or, in the case of a PVC, a reset or restart) being generated by the recipient[4)]. An example of a reset stimulus is a DTE transmitting a reject packet when the packet retransmission facility has not been subscribed.

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4) For the purpose of performance parameter definition it is assumed that the reset stimuli for an X.25 DTE are equivalent to the reset stimuli for an X.25 DCE.

The **reset stimulus probability of a section at a boundary** is the expected number of reset stimuli generated within that section and transferred across the boundary per virtual connection second.

3.2.2 **reset probability** *definition*

A reset event is defined to have been generated within a section when, in the absence of an external reset stimulus, two packets exit the section - one at each boundary - creating any one of the pairs of Recommendation X.134 packet layer reference events listed in Table 6/X.136.

TABLE 6/X.136

Packet layer reference events (PEs) used in measuring reset probability

Boundaries of section	Pair of PEs
X.25 X.25	[20(X.25) 20(X.25)]
X.25 X.75	[20(X.25) 10(X.75)]
X.75 X.75	[10(X.75) 10(X.75)]

a) Pairs of PEs resulting from reset events

Boundaries of section	Pair of PEs
X.25 X.25	[20(X.25) 24(X.25)]
X.25 X.75	[20(X.25) 12(X.75)] or [24(X.25) 10(X.75)]
X.75 X.75	[10(X.75) 12(X.75)]

b) Additional PE pairs resulting from reset events on PVCs

The reset probability for a virtual connection section is the probability, in any given second, that a reset event is generated within that section.

Reset events generated within a section may be estimated by counting the number of reset request and reset indication packets exiting the section during a measurement period; subtracting the number of reset request and reset indication packets entering the section during the same period; dividing the difference by 2; and then substracting from the result any reset stimuli that enter the section during the period.

Note – Reset events may be associated with a loss of packets.

The specific X.134 PEs used in measuring reset probability at each section boundary are identified in Table 6/X.136.

3.2.3 *Values*

The contribution from each network portion to overall reset stimulus probability and reset probability under the conditions described in this Recommendation shall not exceed the values specified in Table 7/X.136.

TABLE 7/X.136

Worst-case reset stimulus probability and reset probability values for virtual connection portions

Statistic	Virtual connection portion type			
	National		International	
	A	B	A	B
Reset stimulus probability (reset stimuli per VC second)	10^{-6}	10^{-6}	a)	10^{-6}
Reset probability (resets per VC second)	10^{-5}	2×10^{-5}	N/A	2×10^{-5}

a) The Type A international virtual connection portion consists only of a physical circuit. Its contribution to reset stimulus probability is expected to be negligible.

Note – All specified values are provisional.

The reset stimulus and reset probabilities for a set of concatenated virtual connection portions may be estimated from the individual portion probabilities as follows. Assume between boundaries (B_i, B_j) the reset probability is R_1 and the reset stimulus probabilities are S_{1i}, S_{1j} Assume between boundaries (B_j, B_k) the reset probability is R_2 and the reset stimulus probabilities are S_{2j}, S_{2k}. Then on a VC passing through B_j the reset probability between B_i and B_k is approximately ($R_1 + R_2 + S_{1j} + S_{2j}$). See Figure 4/X.136. The reset stimulus probability at B_i is S_{1i} and the reset stimulus probability at B_k is S_{2k}.

3.3 *Premature disconnect parameters*

Premature disconnect stimulus probability and premature disconnect probability are related parameters used to describe the dependability of user information transfer in public packet-switched networks conforming to Recommendations X.25 and X.75.

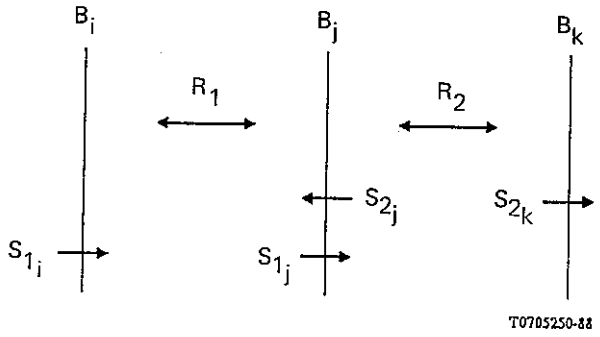

FIGURE 4/X.136

Reset stimulus and reset probabilities for concatenated virtual connection portions

3.3.1 **premature disconnect stimulus probability** *definition*

A premature disconnect stimulus is observed at a single section boundary. It is any event or combination of events that according to the protocol should result in a clear or restart being generated by the recipient[5]. An example of of a premature disconnect stimulus is the transmission of an incorrect packet type into a virtual connection section. A premature disconnect stimulus applies only to virtual call services.

The **premature disconnect stimulus probability of a section at a boundary** is the probability of a premature disconnect stimulus generated within that section and transferred across the boundary per virtual connection second.

3.3.2 **premature disconnect probability** *definition*

A premature disconnect event is defined to have been generated within a section when, in the absence of an external premature disconnect stimulus, two packet exit the section - one at each boundary - creating any one of the pairs of packet layer reference events listed in Table 8/X.136. A premature disconnect event applies only to virtual call services.

TABLE 8/X.136

Packet layer reference events (PEs) used in measuring premature disconnect probability

(Pairs of PEs resulting from premature disconnect events)

Boundaries of section	Pair of PEs
X.25 X.25	[5(X.25) 5(X.25)] or [5(X.25) 24(X.25)]
X.25 X.75	[5(X.25) 3(X.75)] or [5(X.25) 12(X.75)] or [24(X.25) 3(X.75)]
X.75 X.75	[3(X.75) 3(X.75)] or [3(X.75) 12(X.75)]

The premature disconnect probability for a virtual connection section is the probability, in any given second, that a virtual call experiences a premature disconnect event generated within that section.

Premature disconnect events generated within a section may be estimated by counting the number of clear request or clear indication packets exiting the section during a measurement period; subtracting the number of clear request and clear indication packets entering the section during the same period; dividing the difference by two; and then substracting from the result any premature disconnect stimuli that enter the section during that period.

Note – Premature disconnect events may be associated with a loss of packets.

The specific X.134 PEs used in measuring premature disconnect probability at each section boundary are identified in Table 8/X.136.

3.3.3 *Values*

The contribution from each network portion to overall premature disconnect stimulus probability and premature disconnect probability under the conditions described in this Recommendation shall not exceed the values specified in Table 9/X.136.

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5) For the purpose of performance parameter definition, it is assumed that the premature disconnect stimuli for an X.25 DTE are equivalent to the premature disconnect stimuli for an X.25 DCE.

TABLE 9/X.136

Worst-case premature disconnect stimulus probability and premature disconnect probability values for virtual connection portions

Statistic	Virtual connection portion type			
	National		International	
	A	B	A	B
Premature disconnect stimulus probability (premature disconnect stimuli per VC second)	10^{-7}	10^{-7}	10^{-7}	10^{-7}
Premature disconnect probability (premature disconnects per VC second)	5×10^{-6}	10^{-5}	N/A	10^{-5}

Note – All specified values are provisional.

The premature disconnect stimulus and premature disconnect probabilities for a set of concatenated virtual connection portions may be estimated from the individual portion probabilities in a manner analogous to that described in § 3.2.3.

4 Disengagement performance - call clear failure probability

Call clear failure probability applies only to virtual call services. This parameter is used to measure the accuracy and dependability of the general function of disengagement in public packet-switched services conforming to Recommendations X.25 and X.75.

4.1 **call clear failure probability** *definition*

Call clear failure is defined with reference to events at the boundaries of a virtual connection section (B_i, B_j). A call clear attempt occurs when a clean request or clear indication packet enters the section creating a packet layer reference event at B_i. A call clear failure occurs when no corresponding clear indication packet layer reference event occurs at B_j within 180 seconds. The relevant PEs are listed in Table 10/X.136.

TABLE 10/X.136

Packet layer reference events (PEs) used in measuring call clear failure probability

Circuit section	X.134 Packet layer reference event	
	Starting PE	Ending PE
Clearing DTE access circuit section	6(X.25)	–
Cleared DTE access circuit section	–	5(X.25) (does not occur)
Internetwork circuit section	3(X.75)	3(X.75) (does not occur)

Call clear failure probability for a virtual connection section is the ratio of call clear failures to call clear atempts in a population of interest.

4.2 *Values*

The contribution from each virtual connection portion to the overall call clear failure probability under the conditions described in this Recommendation shall not exceed the values specified in Table 11/X.136.

TABLE 11/X.136

Worst-case call clear failure probability values for virtual connection portions

Statistic	Virtual connection portion type			
	National		International	
	A	B	A	B
Probability	10^{-5}	2×10^{-5}	a)	2×10^{-5}

a) The Type A international virtual connection portion consists only of a physical circuit. Its contribution to call clear failure probability is expected to be negligible.

Note – All specified values are provisional.

4.3 *Local clear confirmation*

The failure of a section to respond to a clear request or clear indication packet with a clear confirmation packet is not addressed in this Recommendation. Recovery mechanisms for such occurrences are defined in both the Recommendations X.25 and X.75 protocols. Clear confirmation at X.25 interfaces is a national matter.

ANNEX A

(to Recommendation X.136)

Ancilliary information on accurancy and dependability measurement

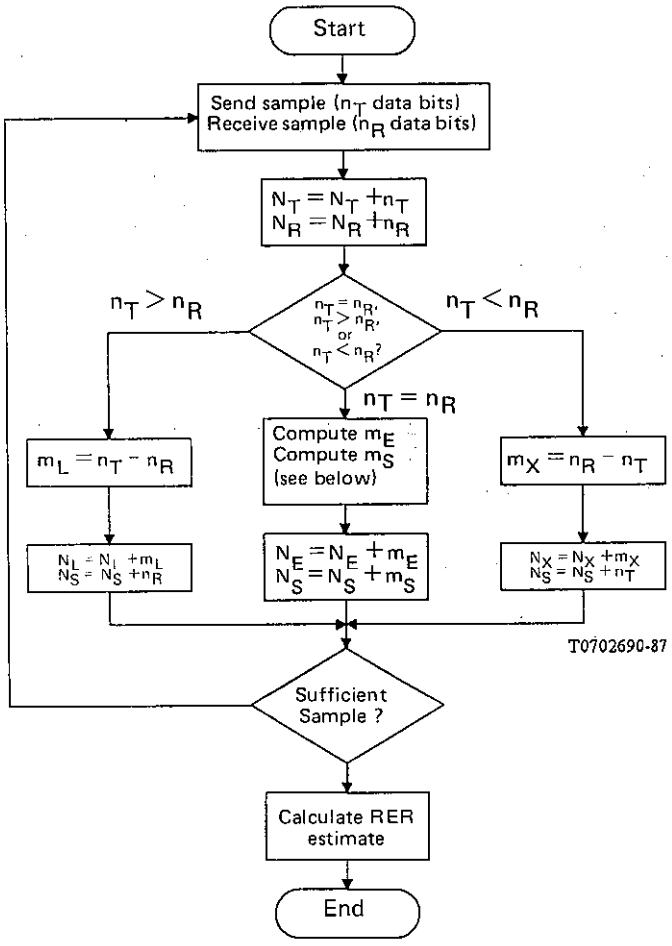
The following points should be noted with regard to accuracy and dependability measurement:

– The ratios used to calculate the probabilities are understood to be estimates of the true probabilities.

– The periods of observation for accuracy – and dependability – related probabilities, as well as the concept of busy hour itself, for packet services, are for further study.

Figure A1/X.136 illustrates a simple approximate method of calculating residual error rate. A sample consisting of n_T user data bits is transmitted typically in many successive packets. (A 128-octet packet length is assumed.) A corresponding sample consisting of n_R user data bits is received. If $n_T = n_R$, the transmitted and received user data bits are compared bit for bit, and the number of incorrect data bits in the sample is estimated by m_E, the number of corresponding transmitted and received bits that do not match. If $n_T > n_R$, the number of lost data bits in the sample is estimated by $m_L = (n_T - n_R)$. If $n_T < n_R$, the number of extra data bits in the sample is estimated by $m_x = (n_R - n_T)$. If a reset request or clear request is issued during the transfer of a measurement sample, that sample is excluded in calculating the RER estimate.

The outcome totals in each sample are accumulated over a number of samples sufficient to calculate the residual error rate with the desired precision. Guidelines for relating overall sample size with desired precision are for further study. It should be noted that the approximate method of residual error rate estimation presented here will not produce unbiased estimates if more than one category of bit transfer failure occurs in the same sample. Other, more exact methods of estimating residual error rate may also be employed.



$$m_E = \sum_{i=1}^{n_T} b_i^T \oplus b_i^R \qquad i = \text{bit position}$$

$$m_S = n_T - m_E$$

FIGURE A-1/X.136

An approximate method of calculating residual error rate

ANNEX B

(to Recommendation X.136)

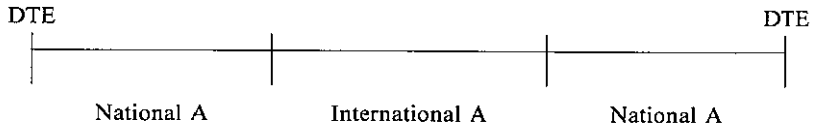
Representative end-to-end accuracy and dependability performance

This annex provides two examples to illustrate how end-to-end (DTE to DTE) accuracy and dependability performance can be estimated from the individual virtual connection portion performance values specified in Recommendation X.136. Two example concatenations of Type A and Type B virtual connection portions are defined. The end-to-end call set-up error probability, call set-up failure probability, residual error rate, reset stimulus probability, reset probability, premature disconnect stimulus probability, premature disconnect probability, and call clear failure probability are calculated for each example. Although alternative network models and statistical assumptions are possible, the methods presented in this annex provide one practical way of estimating end-to-end performance from the performance of the individual network portions.

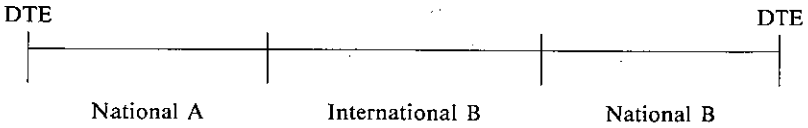
B.1 *Definition of the example end-to-end connections*

For ease of reference, the two example end-to-end (i.e., DTE to DTE) connections presented in this annex will be referred to as "Type 1" and "Type 2" configurations. These hypothetical, but representative, configurations use the portion boundaries and packet layer reference events described in Recommendation X.134. Table 1/X.136 defines the virtual connection portion Types.

The Type 1 configuration is defined to be:



The Type 2 configuration is defined to be:



B.2 *End-to-end accuracy and dependability performance for the Type 1 and Type 2 configuration examples*

End-to-end accuracy and dependability performance values have been calculated for the example Type 1 and Type 2 connection configurations and are reported below in Tables B-1/X.136 and B-2/X.136. These calculations have been made by applying the methods described below to the individual network portions that, for convenience in defining these examples, are characterized by the worst-case accuracy and dependability performance values specified in Recommendation X.136.

Assuming that the performance associated with the individual network portions are statistically independent, then a very close approximation to the end-to-end performance can be obtained for the call set-up error probability, call set-up failure probability, residual error rate probability, and call clear failure probability by simply summing the respective probabilities for the concatenated individual connection portions. Note that this procedure assumes that the approximation error caused by dropping the higher order terms in combining these individual portion probabilities is usually not significant and therefore can be ignored for most cases of practical interest.

Example: To compute the end-to-end probability of call set-up error for the Type 1 configuration, refer to Table 2/X.136 to obtain the individual portion probabilities (National A: probability = 10^{-5}; International A: probability = 0). The end-to-end probability of call set-up error is then $10^{-5} + 0 + 10^{-5} = 2 * 10^{-5}$.

The approximate end-to-end performance at each boundary for the reset probability, reset stimulus probability, premature disconnect stimulus probability, and premature disconnect probability can be calculated using methods in §§ 3.2.3 and 3.3.3 of Recommendation X.136.

Example: To compute the end-to-end performance for the reset probability for the Type 2 configuration, refer to Table 7/X.136 to obtain the individual portion probabilities. The end-to-end probability of reset at the boundaries can be calculated as $10^{-5} + 0 + 10^{-5} + 0 + 10^{-6} + 0 + 10^{-6} = 2.2 * 10^{-5}$.

Example: To compute the end-to-end performance for the reset stimulus probability for the Type 1 configuration, refer to Table 7/X.136 to obtain the individual portion probabilities. The end-to-end probability of reset stimulus at the boundaries can be determined by inspection as 10^{-6}.

TABLE B-1/X.136

End-to-end accuracy and dependability performance for the Type 1 configuration example

Type 1 configuration	
Statistic	End-to-end value
Call set-up error probability	$2 * 10^{-5}$
Call set-up failure probability	$1 * 10^{-2}$
Residual error rate	$2 * 10^{-10}$
Reset stimulus probability	$1 * 10^{-6}$
Reset probability	$2.2 * 10^{-5}$
Premature disconnect stimulus probability	$1 * 10^{-7}$
Premature disconnect probability	$1.04 * 10^{-5}$
Call clear failure probability	$2 * 10^{-5}$

TABLE B-2/X.136

End-to-end accuracy and dependability performance for the Type 2 configuration example

Type 2 configuration	
Statistic	End-to-end value
Call set-up error probability	$5 * 10^{-5}$
Call set-up failure probability	$2.5 * 10^{-2}$
Residual error rate	$5 * 10^{-10}$
Reset stimulus probability	$1 * 10^{-6}$
Reset probability	$5.4 * 10^{-5}$
Premature disconnect stimulus probability	$1 * 10^{-7}$
Premature disconnect probability	$2.54 * 10^{-5}$
Call clear failure probability	$5 * 10^{-5}$

B.3 *Notes on key assumptions, results and implications*

For further study.

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Printed in Switzerland

Geneva, 2008