Recommendation T/CAC 4
(Stockholm 1989 (CAC), revised in Nicosia 1990 (CAC) and Vienna (CAT))

MONITORING OF NETWORK PERFORMANCE ASPECTS OF QUALITY OF INTERNATIONAL PACKET-SWITCHED SERVICE USING EXTERNALLY DERIVED INDICATORS

Recommendation proposed by the project team X.25

Text of the Recommendation adopted by the "Telecommunications" Commission:

"The European Conference of Posts and Telecommunications Administrations,

considering

that Recommendation T/CAC 2 E on the measurement of packet network performance and quality of service identifies in particular the need to monitor four indicators, Transmitted throughput (TTP), Received throughput (RTP), Round-trip delay (RTD) and call set-up delay (CSD), derived from information collected by equipment external to the network,

recommends

that the procedures to be used by Administrations for monitoring these indicators should be as defined below."

1. TRANSMITTED THROUGHPUT (TTP) AND RECEIVED THROUGHPUT (RTP)

1.1. Definitions

The Transmitted throughput indicator (TTP) is defined as the average rate of transfer of user data across the calling X.25 interface to the called X.25 interface, expressed in bit/s, under the conditions described below.

The Received throughput indicator (RTP) is defined as the average rate of transfer of user data across the calling X.25 interface from the called X.25 interface, expressed in bit/s, under the conditions described below.

1.2. Requirements

DTEs are connected at the X.25 interfaces which can be used to generate and receive user data and conform to Annex A (DTE performance, measurement precision, etc.).

Both X.25 DTE s should be connected via a standard line interface as used for customer service. They should be located on a switching unit whose characteristics and situation in the network in relation to international interfaces are typical of units connecting actual X.25 users on that network.

The X.25 DTEs should be connected at 9.6 kbit/s and use the following port configuration parameters:
— frame level window of 7;
— default packet level window size of 2;
— default maximum data packet size of 128 octets;
— default throughput class corresponding to 9.6 kbit/s.

There should be no inclusion of any user facility in a call request packet.

There should be no other traffic on either X.25 interface.

All transmitted data packets are full (i.e. contain 128 octets of user data).

1.3. Procedures

1.3.1. *Single measurement*

To make a single measurement of transmitted throughput from an X.25 interface, the DTE makes a call to a drop function in the DTE at the other X.25 interface. To make a single measurement of received throughput from an X.25 interface, the DTE makes a call to a generator function in the DTE at the other X.25 interface.

Each measurement should conform to the following:
— the measured interval is between 55 and 65 seconds;
— the measured interval begins not less than 10 seconds after the start of transmission, or successful receipt, of the first data packet of the call;
— the entire period between the call set-up and end of the measurement interval has no premature clear or reset.

The transmitted throughput is calculated as the number of data packets sent during the measurement interval, multiplied by 1024 bits per packet and divided by the measurement interval length in seconds. The received throughput is calculated as the number of data packets received during the measurement interval, multiplied by 1024 bits per packet and divided by the measurement interval length in seconds.

1.3.2. *Evaluating a daily value*

To evaluate either the transmitted throughput or the received throughput for a particular day, a series of appropriate individual measurements is made:
— one measurement is made during each complete hour of the day;
— if a measurement is invalidated by a premature clear or reset, it should be re-attempted as soon as convenient up to five times;
— if there is any complete hour without a successful measurement, the evaluation for that day is abandoned.

The value applicable to the day is calculated as the average of the three worst values of the 24 obtained.

1.3.3. *Evaluating a monthly value*

To evaluate either the transmitted throughput or the received throughput for a particular month, a set of five appropriate daily values must be obtained during the month. These five values must each apply to a different day of the week, including only those which are normal working days in the countries of both of the X.25 interfaces. The value applicable to the month is calculated as the average of the five daily values obtained.

1.3.4. *Schedule of evaluation*

Every year each operator of a public X.25 network should evaluate the transmitted throughput to each other public X.25 network for the month of October. Similarly, the received throughput should be evaluated every year for the month of March.

Additional evaluations of both transmitted throughput and received throughput for a month, day or other convenient period may be made at the discretion of the network operator. Preference should be given to larger traffic streams, and evaluations should in particular be made after any physical or logical network configuration change affecting a traffic stream (for example, the introduction of an extra X.75 link, or the replacement of a transit route by a direct route).

1.4. Processing

Before the end of November every year, each operator of a public X.25 network will send its results of the transmitted throughput evaluations for October to a body designated by CEPT. Similarly, the results of the received throughput evaluations for March will be sent to the designated body before the end of April.

The designated body will compile each complete set of evaluation results it receives to produce a matrix of throughput values. This will show the values obtained for each identifiable traffic stream and will be made freely available for publication.

Each network operator should, as soon as possible, inform its appropriate partner operators of the results of any additional evaluations which it has made.

2. ROUND-TRIP DELAY (RTD)

2.1. Definition

The Round-trip delay indicator (RTD) is defined as the average time interval between the start of transmission of a data packet at a calling X.25 interface and the end of reception of its echo from the called X.25 interface, expressed in milliseconds, under the conditions described below.

The Round-trip delay indicator reflects the delay encountered by a user between sending a single data packet to a fast host and receiving the first packet in response.

2.2. Requirements

DTEs are connected at the X.25 interfaces which can be used to generate and receive user data and conform to Annex B (DTE performance, measurement precision, etc.).

Both X.25 DTEs should be connected via a standard line interface as used for customer service. They should be located on a switching unit whose characteristics and situation in the network in relation to international interfaces are typical of units connecting actual X.25 users on that network.

The X.25 DTEs should be connected at 9.6 kbit/s and use the following port configuration parameters:
— frame level window of 7;
— default packet level window size of 2;
— default maximum data packet size of 128 octets;
— default throughput class corresponding to 9.6 kbit/s.

Other port parameters are configured as normally used for customer service.

There should be no inclusion of any user facility in a call request packet.

There should be no other traffic on either X.25 interface.

All transmitted data packets are full (i.e. contain 128 octets of user data) and contain an M bit value of 0.

2.3. Procedures

2.3.1. *Single measurement*

To make a single measurement of round-trip delay from an X.25 interface, the DTE makes a call to an echo function in the DTE at the other X.25 interface.

Each measurement should conform to the following:
— ten transactions are performed in sequence within the call;
— each transaction consists of the transmission (as soon as flow control permits) of a data packet and subsequent reception of the echoed data packet;
— each echoed data packet is received within 30 seconds of the start of the transaction;
— each transaction interval begins at the start of transmission of the data packet and ends at the end of reception of the echoed data packet;
— the time between transactions does not exceed 30 seconds:
— the entire period between the call set-up and end of the tenth transaction interval has no unexpected packet level protocol event.

The round-trip delay is calculated as the sum of the ten transaction intervals divided by ten.

2.3.2. *Evaluating a daily value*

To evaluate the round-trip delay for a particular day, a series of appropriate individual measurements is made:
— one measurement is made during each complete hour of the day;
— if a measurement is invalidated either by an unexpected packet level protocol event or by non-receipt of an expected echoed data packet within 30 seconds, it should be re-attempted as soon as convenient up to five times;
— if there is any complete hour without a successful measurement, the evaluation for that day is abandoned.

The value applicable to the day is calculated as the average of the three worst values of the 24 obtained.

2.3.3. *Evaluating a monthly value*

To evaluate the round-trip delay for a particular month, a set of five appropriate daily values must be obtained during the month. These five values must each apply to a different day of the week, including only those which are normal working days in the countries of both of the X.25 interfaces. The value applicable to the month is calculated as the average of the five daily values obtained.

2.3.4. *Schedule of evaluation*

Every year each operator of a public X.25 network should evaluate the round-trip delay to each other public X.25 network for the month of November.

Additional evaluations of round-trip delay for a month, day or other convenient period may be made at the discretion of the network operator. Preference should be given to larger traffic streams, and evaluations should in particular be made after any physical or logical network configuration change affecting a traffic stream (for example, the introduction of an extra X.75 link, or the replacement of a transit route by a direct route).

2.4. Processing

Before the end of December every year, each operator of a public X.25 network will send its results of the round-trip delay evaluations for November to a body designated by CEPT.

The designated body will compile each complete set of evaluation results it receives to produce a matrix of delay values. This will show the values obtained for each identifiable traffic stream and will be made freely available for publication.

Each network operator should, as soon as possible, inform its appropriate partner operators of the results of any additional evaluations which it has made.

2.5. Further analysis

As quoted in Recommendation T/CAC 2 E, the round-trip delay indicator is related to the CCITT X.135 parameter Data packet transfer delay. The nature of this relation is described below.

The round-trip delay indicator includes, while the X.135 parameter values numerically do not, the transmission times of both the generated and echoed data packets over both the calling and called X.25 network access links. At 9.6 kbit/s, the transmission time of a 128 octet data packet is not less than 113 ms, and the component of round-trip delay due to the access links will therefore be just over 450 ms.

Also included in the round-trip delay indicator, and not in the X.135 parameter, are the data packet processing times of both the generating and echoing X.25 DTEs. Each of the two X.25 DTEs involved in a round-trip delay measurement may contribute up to 40 ms of processing delay (see Annex B), and the component due to DTE processing may therefore be up to 80 ms.

Finally, the round-trip delay indicator covers a two-way data packet transfer, whereas the X.135 parameter applies to a one-way transfer. An estimate of the value of the X.135 parameter corresponding to a given round-trip delay indicator can be calculated by taking into account all of the factors described above and assuming that there is no difference between the two directions of data transfer.

3. CALL SET-UP DELAY (CSD)

3.1. Definition

The Call set-up delay indicator (CSD) is defined as the average time interval between the start of transmission of a call request packet at a calling X.25 interface and the end of reception of the corresponding call connected packet, expressed in milliseconds, under the conditions described below.

The Call set-up delay indicator reflects the delay encountered by a user between sending a call request packet to a fast host and receiving the call connected packet in response.

3.2. Requirements

DTEs are connected at the X.25 interfaces which can be used to generate and receive virtual calls and conform to Annex C (DTE performance, measurement precision, etc.).

Both X.25 DTEs should be connected via a standard line interface as used for customer service. They should be located on a switching unit whose characteristics and situation in the network in relation to international interfaces are typical of units connecting actual X.25 users on that network.

The X.25 DTEs should be connected at 9.6 kbit/s and use the following port configuration parameters:
— frame level window of 7;
— default packet level window size of 2;
— default maximum data packet size of 128 octets;
— default throughput class corresponding to 9.6 kbit/s.

Other port parameters are configured as normally used for customer service.

There should be no inclusion of any user facility in a call request packet.

There should be no other traffic on either X.25 interface.

3.3. Procedures

3.3.1. *Single measurement*

To make a single measurement of call set-up delay from an X.25 interface, the DTE makes a call to the DTE at the other X.25 interface.

Each measurement should conform to the following:
— it consists of the transmission (on a free logical channel) of a call request packet and subsequent reception of the call connected packet;
— the call connected packet is received within 30 seconds of the call request;
— the period of the call set-up has no unexpected packet level protocol event;
— the call is eventually cleared.

The call set-up delay is calculated as the time between the start of transmission of the call request packet and the end of reception of the corresponding call connected packet.

Note. The specific requirements for clearing depend on whether other indicators are to be measured once the call has been established.

3.3.2. *Evaluating a daily value*

To evaluate the call set-up delay for a particular day, a series of appropriate individual measurements is made:

— one measurement is made during each complete hour of the day;
— if a measurement is invalidated either by an unexpected packet level protocol event or by non-receipt of an expected call connected packet within 30 seconds, it should be re-attempted as soon as convenient up to five times;
— if there is any complete hour without a successful measurement, the evaluation for that day is abandoned.

The value applicable to the day is calculated as the average of the three worst values of the 24 obtained.

3.3.3. *Evaluating a monthly value*

To evaluate the call set-up delay for a particular month, a set of five appropriate daily values must be obtained during the month. These five values must each apply to a different day of the week, including only those which are normal working days in the countries of both of the X.25 interfaces. The value applicable to the month is calculated as the average of the five daily values obtained.

3.3.4. *Schedule of evaluation*

Every year each operator of a public X.25 network should evaluate the call set-up delay to each other public X.25 network for the month of November.

Note. This process could be combined with measurements of RTD.

Additional evaluations of call set-up delay for a month, day or other convenient period may be made at the discretion of the network operator. Preference should be given to larger traffic streams, and evaluations should in particular be made after any physical or logical network configuration change affecting a traffic stream (for example, the introduction of an extra X.75 link, or the replacement of a transit route by a direct route).

3.4. **Processing**

Before the end of December every year, each operator of a public X.25 network will send its results of the call set-up delay evaluations for November to a body designated by CEPT.

The designated body will compile each complete set of evaluation results it receives to produce a matrix of delay values. This will show the values obtained for each identifiable traffic stream and will be made freely available for publication.

Each network operator should, as soon as possible, inform its appropriate partner operators of the results of any additional evaluations which it has made.

3.5. **Further analysis**

As quoted in Recommendation T/CAC 2 E, the call set-up delay indicator is related to the CCITT X.135 parameter Call set-up delay. The nature or this relation is described below.

The call set-up delay indicator includes, while the X.135 parameter values numerically do not, the transmission times of both the call request/incoming call and call connected/call accepted packets over both the calling and called X.25 network access links. At 9.6 kbit/s, the transmission time of a simple call request/incoming call packet is about 18 ms and of a simple call connected/call accepted packet about 7 ms, and the component of call set-up delay due to the access links will therefore be about 50 ms.

Also included in the call set-up delay indicator, and not in the X.135 parameter, are the call packet processing times of both the calling and called X.25 DTEs. Each of the two X.25 DTEs involved in a call set-up delay measurement may contribute up to 40 ms of processing delay (see Annex C), and the component due to DTE processing may therefore be up to 80 ms.

An estimate of the value of the X.135 parameter corresponding to a given call set-up delay indicator can be calculated by taking into account all of the factors described above.

Annex A

ADDITIONAL MINIMUM REQUIREMENTS FOR IMPLEMENTATION OF TEST-DTE FACILITIES FOR MEASUREMENT OF TRANSMITTED OR RECEIVED THROUGHPUT

Considering that measured throughput figures depend on:

— X.25 access line parameters;

— how the DTEs manage the exchange of packets; and

— the accuracy of the measuring tools;

it is recommended that test-DTE implementations for throughput measurements as defined in CEPT Recommendation T/CAC 4 E meet the following requirements in addition to those already implied by the appropriate Recommendation sections on Requirements and Procedures.

1. X.25 CONNECTION TO THE NETWORK

The test-DTE must be able to meet the conditions described in the appropriate Recommendation section on Requirements. In addition, only one logical channel should be configured.

Note. This additional requirement may be waived in the case of a multi-purpose test-DTE provided that a suitable internal DTE management process is implemented to ensure that throughput tests are not significantly affected by other activity on the link.

2. MANAGEMENT OF THE PACKETS EXCHANGED ON A TEST CALL

2.1. Call request packet and clear request packet issue

The calling function will establish a virtual call from a local drop or generator facility for throughput measurement purposes.

Address information and user data in the call request packet should be selectable in order to meet individual called DTE requirements in the incoming call packet.

The clear request packet should be issued within 1 second after the measurement interval has ended.

2.2. Incoming call packet receipt

A call accepted packet will be issued within 1 second. The virtual call is established with the data packet handling facility (generator, drop or other) corresponding to DTE capabilities and/or incoming call packet address information and user data.

2.3. Clear request packet receipt

After call request packet issue, if a clear request packet is received on the same logical channel with or without previous receipt of a call connected packet, this fact is notified in the results of the call and the test is invalidated. The clearing cause and diagnostic codes are notified to the operator.

A clear request packet received after an incoming call packet is handled normally.

2.4. Generator facility packet handling

The generator facility is activated in the case of TTP measurement by call connected packet receipt or, in the case of RTP measurement, by call accepted packet issue. The first data packet must be issued within 1 second after either the call connected packet is received or the call accepted packet is transmitted.

The time interval between transmission of the last bit of one data packet and transmission of the first bit of the next data packet must not exceed 5 ms, unless the issue of the first data packet resulted in closure of the DTE's packet level transmit window. In this case, the time interval between receipt of the last bit of the RR packet re-opening the DTE's packet level transmit window and transmission of the first bit of the next data packet must not exceed 25 ms. This implies that, while the packet level transmit window is kept open, the DTE will be able to use up to 90% of a 9.6 kbit/s access line capacity for user data.

Any received data packet should be ignored.

Any received reset or interrupt packet must, if the generator is the calling party, be notified to the operator. If the generator is the called party, this event will cause the call to be cleared.

Bit stuffing in the frame containing each transmitted data packet must not exceed 20 bits (i.e. 20 sequences of five contiguous 1 s).

The D bit is not used.

2.5. **Drop facility packet handling**

The drop facility is activated in the case of TTP measurement by call accepted packet issue or, in the case of RTP measurement, by call connected packet receipt.

Each data packet received must be acknowledged by the transmission of an RR packet within 25 ms, except within the first 100 ms following either issue of the call accepted packet or receipt of the call connected packet. In these cases the RR packet must be transmitted within 125 ms.

The drop facility does not transmit any data or interrupt packet.

3. MEASUREMENT FACILITIES ON TEST CALL

The measurement function is associated with the calling DTE.

The quantities to be measured are:

— the time of the start of the measurement interval;
— the time of the end of the measurement interval; and
— the number of data packets either transmitted or received during the measurement interval.

The measurement facilities must be able to achieve an accuracy in the result of $\pm 2\%$ in the range 2 to 9 kbit/s of transmitted or received data.

Annex B

ADDITIONAL MINIMUM REQUIREMENTS FOR IMPLEMENTATION OF TEST-DTE FACILITIES FOR MEASUREMENT OF ROUND-TRIP DELAY

Considering that measured round-trip delay figures depend on:

— X.25 access line parameters;

— how the DTEs manage the exchange of packets; and

— the accuracy of the measuring tools;

it is recommended that test-DTE implementations for round-trip delay measurements as defined in CEPT Recommendation T/CAC 4 E meet the following requirements in addition to those already implied by the appropriate Recommendation sections on Requirements and Procedures.

1. X.25 CONNECTION TO THE NETWORK

The test-DTE must be able to meet the conditions described in the appropriate Recommendation section on Requirements. In addition, only one logical channel should be configured.

Note. This additional requirement may be waived in the case of a multi-purpose test-DTE provided that a suitable internal DTE management process is implemented to ensure that round-trip delay tests are not significantly affected by other activity on the link.

2. MANAGEMENT OF THE PACKETS EXCHANGED ON A TEST CALL

2.1. Call request packet and clear request packet issue

The calling function will establish a virtual call from a local single packet generator facility for round-trip delay measurement purposes.

Address information and user data in the call request packet should be selectable in order to meet individual called DTE requirements in the incoming call packet.

The clear request packet should be issued within 1 second after the measurement interval has ended. If the measurement is invalidated either by an unexpected packet level protocol event or by non-receipt of an expected echo within 30 seconds, a clear request should be issued within 1 second.

2.2. Incoming call packet receipt

A call accepted packet will be issued within 1 second. The virtual call is established with the data packet handling facility (i.e. echo) corresponding to DTE capabilities and/or incoming call packet address information and user data.

2.3. Clear request packet receipt

After call request packet issue, if a clear request packet is received on the same logical channel with or without previous receipt of a call connected packet, this fact is notified in the results of the call and the measurement is invalidated. The clearing cause and diagnostic codes are notified to the operator.

A clear request packet received after an incoming call packet is handled normally.

2.4. Single packet generator facility packet handling

The single packet generator facility is activated by call accepted packet issue. The first transaction must be started within 1 second after the call connected packet is received.

Any unexpected packet level protocol event (for example, reception of a reset, interrupt or unexpected data packet) must be notified to the operator. This event will cause the call to be cleared.

Bit stuffing in the frame containing each transmitted data packet must not exceed 20 bits (i.e. 20 sequences of five contiguous 1 s).

The D bit is not used.

2.5. Echo facility packet handling

The echo facility is activated by call accepted packet issue.

The user data field of each data packet received must be echoed back by the transmission of a data packet with the identical user data field contents within 40 ms, except within the first 100 ms following issue of the call accepted packet. In this case the data packet must be transmitted within 140 ms.

The echo facility does not transmit any interrupt packet nor spontaneously generate any data packet..

3. MEASUREMENT FACILITIES ON TEST CALL

The measurement function is associated with the calling DTE.

The quantities to be measured are:
— the time of the start of each transaction interval; and
— the time of the end of each transaction interval.

The total aggregate of:
i) the time between the measured start of a transaction interval and the start of transmission of the generated data packet,
plus
ii) the time between the end of reception of the echoed data packet and the measured end of the transaction interval,
should not exceed 40 ms.

If transactions are carried out without any intervening delay, only the start of the first transaction interval and the end of the tenth transaction interval need to be measured explicitly.

The measurement facilities must provide a resolution equal to or better than 10 ms.

Annex C

ADDITIONAL MINIMUM REQUIREMENTS FOR IMPLEMENTATION OF TEST-DTE FACILITIES FOR MEASUREMENT OF CALL SET-UP DELAY

Considering that measured call set-up delay figures depend on:
— X.25 access line parameters;
— how the DTEs manage the exchange of packets; and
— the accuracy of the measuring tools;
it is recommended that test-DTE implementations for call set-up delay measurements as defined in CEPT Recommendation T/CAC 4 E meet the following requirements in addition to those already implied by the appropriate Recommendation sections on Requirements and Procedures.

1. X.25 CONNECTION TO THE NETWORK

The test-DTE must be able to meet the conditions described in the appropriate Recommendation section on Requirements. In addition, only one logical channel should be configured.

Note. This additional requirement may be waived in the case of a multi-purpose test-DTE provided that a suitable internal DTE management process is implemented to ensure that call set-up delay tests are not significantly affected by other activity on the link.

2. MANAGEMENT OF THE PACKETS EXCHANGED ON A TEST CALL

2.1. Call request packet and clear request packet issue

The calling function will establish a virtual call from a local call generator facility for call set-up delay measurement purposes.

Address information and user data in the call request packet should be selectable in order to meet individual called DTE requirements in the incoming call packet.

Where the call thereby established is not to be used for any other measurement, the clear request packet should be issued within 1 second after the measurement interval has ended. Where the call thereby established is to be used for some other measurement, the requirements appropriate to that measurement should be met.

If the measurement is invalidated either by an unexpected packet level protocol event or by non-receipt of an expected call connected packet within 30 seconds, a clear request should be issued within 1 second.

2.2. Incoming call packet receipt

A call accepted packet will be issued within 40 ms. The virtual call is established with the data packet handling facility corresponding to DTE capabilities and/or incoming call packet address information and user data.

2.3. Clear request packet receipt

After call request packet issue, if a clear request packet is received on the same logical channel without previous receipt of a call connected packet, this fact is notified in the results of the call and the measurements is invalidated. The clearing cause and diagnostic codes are notified to the operator.

A clear request packet received after an incoming call packet is handled normally.

2.4. Call generator facility packet handling

There are no specific requirements for handling other packet types.

3. MEASUREMENT FACILITIES ON TEST CALL

The measurement function is associated with the calling DTE.

The quantities to be measured are:
— the time of the start of transmission of the call request; and
— the time of the end of reception of the corresponding call connected.

The total of:

i) the time between the measured start and the start of transmission of the generated call request packet, plus

ii) the time between the end of reception of the call connected packet and the measured end,

should not exceed 40 ms.

The measurement facilities must provide a resolution equal to or better than 10 ms.