Network Working Group   ISO
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ISO Transport Protocol Specification
ISO DP 8073

Status of this Memo:

This document is distributed as an RFC for information only. It does not specify a standard for the ARPA-Internet.

Notes:

1) RFC 892 is an older version of the ISO Transport Protocol Specification. Therefore this RFC should be assumed to supercede RFC 892.

2) This document has been prepared by retyping the text of ISO/TC97/SC16/N1576 and then applying proposed editorial corrections contained in ISO/TC97/SC16/N1695. These two documents, taken together, are undergoing voting within ISO as a Draft International Standard (DIS).

3) Although this RFC has been reviewed after typing, and is believed to be substantially correct, it is possible that typographic errors not present in the ISO documents have been overlooked.

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INTRODUCTION

The Transport Protocol Standard is one of a set of International Standards produced to facilitate the interconnection of computer systems. The set of standards covers the services and protocols required to achieve such interconnection.

The Transport Protocol Standard is positioned with respect to other related standards by the layers defined in the Reference Model for Open Systems Interconnection (ISO 7498). It is most closely related to, and lies within the field of application of the Transport Service Standard (DP 8072). It also uses and makes reference to the Network Service Standard (DP 8348), whose provisions it assumes in order to accomplish the transport protocol's aims. The interelationship of these standards is depicted in figure 1.

```
-------------------------TRANSPORT SERVICE DEFINITION------------
Transport     | --- Reference to aims --------------
Protocol      |
Specification | --- Reference to assumptions -------
-------------------------NETWORK SERVICE DEFINITION--------------
```

Relationaship between Transport Protocol and adjacent services
Figure 1 .

The International Standard specifies a common encoding and a number of classes of transport protocol procedures to be used with different network qualities of service.

It is intended that the Transport Protocol should be simple but general enough to cater for the total range of Network Service qualities possible, without restricting future extensions.

The protocol is structured to give rise to classes of protocol which are designed to minimize possible incompatibilities and implementation costs.

The classes are selectable with respect to the Transport and Network Services in providing the required quality of service for the interconnection of two session entities (note that each class provides a different set of functions for enhancement of service qualities).

This protocol standard defines mechanisms that can be used to optimize network tariffs and enhance the following qualities of service:

a) different throughput rates;

b) different error rates;

c) integrity of data requirements;

d) reliability requirements.

It does not require an implementation to use all of these mechanisms, nor does it define methods for measuring achieved quality of service or criteria for deciding when to release transport connections following quality of service degradation.

The primary aim of this International Standard is to provide a set of rules for communication expressed in terms of the procedures to be carried out by peer entities at the time of communication. These rules for communication are intended to provide a sound basis for development in order to serve a variety of purposes:

a) as a guide for implementors and designers;

b) for use in the testing and procurement of equipment;

c) as part of an agreement for the admittance of systems into the open systems environment;

d) as a refinement of the understanding of OSI.

It is expected that the initial users of the International Standard will be designers and implementors of equipment and the International Standard contains, in notes or in annexes, guidance on the implementation of the procedures defined in the standard.

It should be noted that, as the number of valid protocol sequences is very large, it is not possible with current technology to verify that an implementation will operate the protocol defined in this International Standard correctly under all circumstances. It is possible by means of testing to establish confidence that an implementation correctly operates the protocol in a representative sample of circumstances. It is, however, intended that this International Standard can be used in circumstances where two implementations fail to communicate in order to determine whether one or both have failed to operate the protocol correctly.

This International Standard contains a section on conformance of equipment claiming to implement the procedures in this International Standard. Attention is drawn to the fact that the standard does not contain any tests to demonstrate this conformance.

The variations and options available within this International Standard are essential to enable a Transport Service to be provided for a wide variety of applications over a variety of network qualities. Thus, a minimally conforming implementation will not be suitable for use in all possible circumstances. It is important, therefore, to qualify all references to this International Standard with statements of the options provided or required or with statements of the intended purpose of provision or use.

1 SCOPE AND FIELD OF APPLICATION

1.1 This International Standard specifies:

a) five classes of procedures:

1) Class 0. Simple class;
2) Class 1. Basic error recovery class;
3) Class 2. Multiplexing class;
4) Class 3. Error recovery and multiplexing class;
5) Class 4. Error detection and recovery class,

for the connection oriented transfer of data and control information from one transport entity to a peer transport entity;

b) the means of negotiating the class of procedures to be used by the transport entities;

c) the structure and encoding of the transport protocol data units used for the transfer of data and control information;

1.2 The procedures are defined in terms of:

a) the interactions between peer transport entities through the exchange of transport protocol data units;

b) the interactions between a transport entity and the transport service user in the same system through the exchange of transport service primitives;

c) the interactions between a transport entity and the network service provider through the exchange of network service primitives.

These procedures are defined in the main text of the standard supplemented by state tables in annex A.

1.3

These procedures are applicable to instances of communication between systems which support the Transport Layer of the OSI Reference Model and which wish to interconnect in an open systems environment.

1.4

This International Standard also specifies conformance requirements for systems implementing these procedures. It does not contain tests which can be used to demonstrate this conformance.

2 REFERENCES

ISO 7498 Information processing systems - Open systems interconnection - Basic Reference Model

DP 8072 Information processing systems - Open systems interconnection - Transport service definition

DP 8348 Information processing systems - Open systems interconnection - Connection-oriented network service definition.

SECTION ONE. GENERAL

3 DEFINITIONS

NOTE - The definitions contained in this clause make use of abbreviations defined in clause 4.

3.1

This International Standard is based on the concepts developed in the Reference Model for Open Systems Interconnection (DIS 7498) and makes use of the following terms defined in that standard:

a) concatenation and separation;

b) segmenting and reassembling;

c) multiplexing and demultiplexing;

d) splitting and recombining;

e) flow control.

3.2

For the purpose of this International Standard, the following definitions apply:

3.2.1 equipment:

Hardware or software or a combination of both; it need not be physically distinct within a computer system.

3.2.2 transport service user:

An abstract representation of the totality of those entities within a single system that make use of the transport service.

3.2.3 network service provider:

An abstract machine that models the totality of the entities providing the network service, as viewed by a transport entity.

3.2.4 local matter:

A decision made by a system concerning its behavior in the Transport Layer that is not subject to the requirements of this protocol.

3.2.5 initiator:

A transport entity that initiates a CR TPDU.

3.2.6 responder:

A transport entity with whom an initiator wishes to establish a transport connection.

NOTE - Initiator and responder are defined with respect to a single transport connection. A transport entity can be both an initiator and responder simultaneously.

3.2.7 sending transport entity:

A transport entity that sends a given TPDU.

3.2.8 receiving transport entity:

A transport entity that receives a given TPDU.

3.2.9 preferred class:

The protocol class that the initiator indicates in a CR TPDU as its first choice for use over the transport connection.

3.2.10 alternative class:

A protocol class that the initiator indicates in a CR TPDU as an alternative choice for use over the transport connection.

3.2.11 proposed class:

A preferred class or an alternative class.

3.2.12 selected class:

The protocol class that the responder indicates in a CC TPDU that it has chosen for use over the transport connection.

3.2.13 proposed parameter:

The value for a parameter that the initiator indicates in a CR TPDU that it wishes to use over the transport connection.

3.2.14 selected parameter:

The value for a parameter that the responder indicates in a CC TPDU that it has chosen for use over the transport connection.

3.2.15 error indication:

An N-RESET indication, or an N-DISCONNECT indication with a reason code indicating an error, that a transport entity receives from the NS-provider.

3.2.16 invalid TPDU:

A TPDU that does not comply with the requirements of this International Standard for structure and encoding.

3.2.17 protocol error:

A TPDU whose use does not comply with the procedures for the class.

3.2.18 sequence number:

a) The number in the TPDU-NR field of a DT TPDU that indicates the order in which the DT TPDU was transmitted by a transport entity.

b) The number in the YR-TU-NR field of an AK or RJ TPDU that indicates the sequence number of the next DT TPDU expected to be received by a transport entity.

3.2.19 transmit window:

The set of consecutive sequence numbers which a transport entity has been authorized by its peer entity to send at a given time on a given transport connection.

3.2.20 lower window edge:

The lowest sequence number in a transmit window.

3.2.21 upper window edge:

The sequence number which is one greater than the highest sequence number in the transmit window.

3.2.22 upper window edge allocated to the peer entity:

The value that a transport entity communicates to its peer entity to be interpreted as its new upper window edge.

3.2.23 closed window:

A transmit window that contains no sequence number.

3.2.24 window information:

Information contained in a TPDU relating to the upper and the lower window edges.

3.2.25 frozen reference:

A reference that is not available for assignment to a connection because of the requirements of 6.18.

3.2.26 unassigned reference:

A reference that is neither currently in use for identifying a transport connection or which is in a frozen state.

3.2.27 transparent (data):

TS-user data that is transferred intact between transport entities and which is unavailable for use by the transport entities.

3.2.28 owner (of a network connection):

The transport entity that issued the N-CONNECT request leading to the creation of that network connection.

3.2.29 retained TPDU:

A TPDU that is subject to the retransmission procedure or retention until acknowledgement procedure and is available for possible retransmission.

4 SYMBOLS AND ABBREVIATIONS

4.1 Data units

TPDU	Transport protocol data unit
TSDU	Transport service data unit
NSDU	Network service data unit

4.2 Types of transport protocol data units

CR TPDU	Connection request TPDU
CC TPDU	Connection confirm TPDU
DR TPDU	Disconnect request TPDU
DC TPDU	Disconnect confirm TPDU
DT TPDU	Data TPDU
ED TPDU	Expedited data TPDU
AK TPDU	Data acknowledge TPDU
EA TPDU	Expedited acknowledge TPDU
RJ TPDU	Reject TPDU
ER TPDU	Error TPDU

4.3 TPDU fields

LI	Length indicator (field)
CDT	Credit (field)
TSAP-ID	Transport service access point identifier (field)
DST-REF	Destination reference (field)
SRC-REF	Source reference (field)
EOT	End of TSDU mark
TPDU-NR	DT TPDU number (field)
ED-TPDU-NR	ED TPDU number (field)
YR-TU-NR	Sequence number response (field)
YR-EDTU-NR	ED TPDU number response (field)

4.4 Times and associated variables

T1	Elapsed time between retransmissions
N	The maximum number of transmissions
L	Bound on reference
I	Inactivity time
W	Window time
TTR	Time to try reassignment/resynchronization
TWR	Time to wait for reassignment/resynchronization
TS1	Supervisory timer 1
TS2	Supervisory time 2
MLR	NSDU lifetime local-to-remote
MRL	NSDU lifetime remote-to-local
ELR	Expected maximum transit delay local-to-remote
ERL	Expected maximum transit delay remote-to-local
R	Persistence time
AL	Local acknowledgement time
AR	Remote acknowledgement time

4.5 Miscellaneous

TS-user	Transport service user
TSAP	Transport service access point
NS-provider	Network service provider
NSAP	Network service access point
QOS	Quality of service

5 OVERVIEW OF THE TRANSPORT PROTOCOL

NOTE - This overview is not exhaustive and has been provided for guidance to the reader of this International Standard.

5.1 Service provided by the transport layer

The protocol specified in this International Standard supports the transport service defined in DP 8072.

Information is transferred to and from the TS-user in the transport service primitives listed in table 1.

Primitive		Parameter
T-CONNECT	request indication	Called Address, Calling Address, Expedited Data option, Quality of Service, TS User-Data.
T-CONNECT	response confirm	Responding Address, Quality of Service, Expedited Data option, TS User-Data.
T-DATA	request indication	TS User-Data.
T-EXPEDITED DATA	request indication	TS User-Data.
T-DISCONNECT	request	TS User-Data.
T-DISCONNECT	indication	Disconnect reason, TS User-Data.

Table 1. Transport service primitives

5.2 Service assumed from the network layer

The protocol specified in this International Standard assumes the use of the network service defined in DP 8348.

Information is transferred to and from the NS-provider in the network service primitives listed in table 2.

Primitives		X/Y	Parameters	X/Y/Z
N-CONNECT	request	X	Called Address,	X
	indication	X	Calling Address,	X
	response	X	NS User-Data,	Z
	confirm	X	QOS parameter set,	X
			Responding address,	Z
			Receipt confirmation selection.	Y
N-DATA	request	X	NS User-Data,	X
	indication	X	Confirmation request	Y
N-DATA ACKNOWLEDGE				
	request	Y		
	indication	Y		
N-EXPEDITED DATA				
	request	Y	NS User-Data.	Y
	indication	Y		
N-RESET	request	X	Originator,	Z
	indication	X	Reason.	Z
	response	X		
	confirm	X		
N-DISCONNECT	request	X	NS User-Data.	Z
	indication	X	Originator,	Z
			Reason.	Z

Table 2. Network service primitives

Key:

- X - The Transport Protocol assumes that this facility is provided in all networks.
- Y - The Transport Protocol assumes that this facility is provided in some networks and a mechanism is provided to optionally use the facility.
- Z - The Transport Protocol does not use this parameter.

NOTES:

1 - The parameters listed in this table are those in the current network service (first DP 8348).

2 - The way the parameters are exchanged between the transport entity and the NS-provider is a local matter.

5.3 Functions of the Transport Layer

5.3.1 Overview of functions

The functions in the Transport Layer are those necessary to bridge the gap between the services available from the Network Layer and those to be offered to the TS-users.

The functions in the Transport Layer are concerned with the enhancement of quality of service, including aspects of cost optimization.

These functions are grouped below into those used at all times during a transport connection and those concerned with connection establishment, data transfer and release.

NOTE - This International Standard does not include the following functions which are under consideration for inclusion in future editions of this standard:

a) encryption;

b) accounting mechanisms;

c) status exchanges and monitoring of QOS;

d) blocking;

e) temporary release of network connections;

f) alternative checksum algorithm.

5.3.1.1 Functions used at all times

The following functions, depending upon the selected class and options, are used at all times during a transport connection:

a) transmission of TPDUs (see 6.2 and 6.9);

b) multiplexing and demultiplexing (see 6.15), a function used to share a single network connection between two or more transport connections;

c) error detection (see 6.10, 6.13 and 6.17), a function used to detect the loss, corruption, duplication, misordering or misdelivery of TPDUs;

d) error recovery (see 6.12, 6.14, 6.18, 6.19, 6.20, 6.21 and 6.22), a function used to recover from detected and signalled errors.

5.3.1.2 Connection Establishment

The purpose of connection establishment is to establish a transport connection between two TS-users. The following functions of the transport layer during this phase must match the TS-users' requested quality of service with the services offered by the network layer:

a) select network service which best matches the requirement of the TS-user taking into account charges for various services (see 6.5);

b) decide whether to multiplex multiple transport connections onto a single network connection (see 6.5);

c) establish the optimum TPDU size (see 6.5);

d) select the functions that will be operational upon entering the data transfer phase (see 6.5);

e) map transport addresses onto network addresses;

f) provide a means to distinguish between two different transport connections (see 6.5);

g) transport of TS-user data (see 6.5).

5.3.1.3 Data Transfer

The purpose of data transfer is to permit duplex transmission of TSDUs between the two TS-users connected by the transport connection. This purpose is achieved by means of two-way simultaneous communication and by the following functions, some of which are used or not used in accordance with the result of the selection performed in connection establishment:

a) concatenation and separation (see 6.4), a function used to collect several TPDUs into a single NSDU at the sending transport entity and to separate the TPDUs at the receiving transport entity;

b) segmenting and reassembling (see 6.3), a function used to segment a single data TSDU into multiple TPDUs at the sending transport entity and to reassemble them into their original format at the receiving transport entity;

c) splitting and recombining (see 6.23), a function allowing the simultaneous use of two or more network connections to support the same transport connection;

d) flow control (see 6.16), a function used to regulate the flow of TPDUs between two transport entities on one transport connection;

e) transport connection identification, a means to uniquely identify a transport connection between the pair of transport entities supporting the connection during the lifetime of the transport connection;

f) expedited data (see 6.11), a function used to bypass the flow control of normal data TPDU. Expedited data TPDU flow is controlled by separate flow control;

g) TSDU delimiting (see 6.3), a function used to determine the beginning and ending of a TSDU.

5.3.1.4 Release

The purpose of release (see 6.7 and 6.8) is to provide disconnection of the transport connection, regardless of the current activity.

5.4 Classes and options

5.4.1 General

The functions of the Transport Layer have been organized into classes and options.

A class defines a set of functions. Options define those functions within a class which may or may not be used.

This International Standard defines five classes of protocol:

a) Class 0: Simple Class;

b) Class 1: Basic Error recovery Class;

c) Class 2: Multiplexing Class;

d) Class 3: Error Recovery and Multiplexing Class;

e) Class 4: Error Detection and Recovery Class.

NOTE - Transport connections of classes 2, 3 and 4 may be multiplexed together onto the same network connection.

5.4.2 Negotiation

The use of classes and options is negotiated during connection establishment. The choice made by the transport entities will depend upon:

a) the TS-users’ requirements expressed via T-CONNECT service primitives;

b) the quality of the available network services;

c) the user required service versus cost ratio acceptable to the TS-user.

5.4.3 Choice of network connection

The following list classifies network services in terms of quality with respect to error behavior in relation to user requirements; its main purpose is to provide a basis for the decision regarding which class of transport protocol should be used in conjunction with given network connection:

a) Type A. Network connection with acceptable residual error rate (for example not signalled by disconnect or reset) and acceptable rate of signalled errors.

b) Type B. Network connections with acceptable residual error rate (for example not signalled by disconnect or reset) but unacceptable rate of signalled errors.

c) Type C. Network connections with unacceptable residual error rate.

It is assumed that each transport entity is aware of the quality of service provided by particular network connections.

5.4.4 Characteristics of Class 0

Class 0 provides the simplest type of transport connection and is fully compatible with the CCITT recommendation S.70 for teletex terminals.

Class 0 has been designed to be used with type A network connections.

5.4.5 Characteristics of Class 1

Class 1 provides a basic transport connection with minimal overheads.

The main purpose of the class is to recover from network disconnect or reset.

Selection of this class is usually based on reliability criteria. Class 1 has been designed to be used with type B network connections.

5.4.6 Characteristics of Class 2

5.4.6.1 General

Class 2 provides a way to multiplex several transport connections onto a single network connection. This class has been designed to be used with type A network connections.

5.4.6.2 Use of explicit flow control

The objective is to provide flow control to help avoid congestion at transport-connection-end-points and on the network connection. Typical use is when traffic is heavy and continuous, or when there is intensive multiplexing. Use of flow control can optimize response times and resource utilization.

5.4.6.3 Non-use of explicit flow control

The objective is to provide a basic transport connection with minimal overheads suitable when explicit disconnection of the transport connection is desirable. The option would typically be used for unsophisticated terminals, and when no multiplexing onto network connections is required. Expedited data is never available.

5.4.7 Characteristics of Class 3

Class 3 provides the characteristics of Class 2 plus the ability to recover from network disconnect or reset. Selection of this class is usually based upon reliability criteria. Class 3 has been designed to be used with type B network connections.

5.4.8 Characteristics of Class 4

Class 4 provides the characteristics of Class 3, plus the capability to detect and recover from errors which occur as a result of the low grade of service available from the NS-provider. The kinds of errors to be detected include: TPDU loss, TPDU delivery out of sequence, TPDU duplication and TPDU corruption. These errors may affect control TPDUs as well as data TPDUs.

This class also provides for increased throughput capability and additional resilience against network failure. Class 4 has been designed to be used with type C network connections.

5.5 Model of the transport layer

A transport entity communicates with its TS-users through one or more TSAPs by means of the service primitives as defined by the transport service definition DP 8072. Service primitives will cause or be the result of transport protocol data unit exchanges between the peer transport entities supporting a transport connection. These protocol exchanges are effected using the services of the Network Layer as defined by the Network Service Definition DP 8348 through one or more NSAPs.

Transport connection endpoints are identified in end systems by an internal, implementation dependent, mechanism so that the TS-user and the transport entity can refer to each transport connection.

```
          +------+                        +------+
----------| TSAP |------------------------| TSAP |----------
          +------+                        +------+
              |                               |
       +---------------+               +---------------+
       | Transport     |               | Transport     |
       |       entity  |               |       entity  |
       +---------------+               +---------------+
              |                               |
              |                               |
          +------+                        +------+
----------| NSAP |------------------------| NSAP |----------
          +------+                        +------+
              |                               |
              +-------------------------------+
```

Figure 2 . Model of the transport layer

NOTE - For purpose of illustration, this figure shows only one TSAP and one NSAP for each transport entity. In certain instances, more than one TSAP and/or more than one NSAP may be associated with a particular transport entity.

SECTION TWO. TRANSPORT PROTOCOL SPECIFICATION

6 ELEMENTS OF PROCEDURE

This clause contains elements of procedure which are used in the specification of protocol classes in clauses 7 to 12. These elements are not meaningful on their own.

The procedures define the transfer of TPDUs whose structure and coding is specified in clause 13. Transport entities shall accept and respond to any TPDU received in a valid NSDU and may issue TPDUs initiating specific elements of procedure specified in this clause.

NOTE - Where network service primitives and TPDUs and parameters used are not significant for a particular element of procedure, they have not been included in the specification.

6.1 Assignment to network connection

6.1.1 Purpose

The procedure is used in all classes to assign transport connections to network connections.

6.1.2 Network service primitives

The procedure makes use of the following network service primitives:

a) N-CONNECT;

b) N-DISCONNECT.

6.1.3 Procedure

Each transport connection shall be assigned to a network connection. The initiator may assign the transport connection to an existing network connection of which it is the owner or to a new network connection (see Note 1) which it creates for this purpose.

The initiator shall not assign or reassign the transport connection to an existing network connection if the protocol class(es) proposed or the class in use for the transport connection are incompatible with the current usage of the network connection with respect to multiplexing (see Note 2).

During the resynchronization (see 6.14) and reassignment after failure (see 6.12) procedures, a transport entity may reassign a transport connection to another network connection joining the same NSAPs, provided that it is the owner of the network connection and that the transport connection is assigned to only one network connection at any given time.

During the splitting procedure (see 6.23), a transport entity may assign a transport connection to any additional network connection joining the same NSAPs, provided that it is the owner of the network connection and that multiplexing is possible on the network connection.

The responder becomes aware of the assignment when it receives

a) a CR TPDU during the connection establishment procedure (see 6.5); or

b) an RJ TPDU or a retransmitted CR or DR TPDU during the resynchronization (see 6.14) and reassignment after failure (see 6.12) procedures; or

c) any TPDU when splitting (see 6.23) is used.

NOTES

1. When a new network connection is created, the quality of service requested is a local matter, although it will normally be related to the requirements of transport connection(s) expected to be assigned to it.

2. An existing network connection may also not be suitable if, for example, the quality of service requested for the transport connection cannot be attained by using or enhancing the network connection.

3. A network connection with no transport connection(s) assigned to it, may be available after initial establishment, or because all of the transport connections previously assigned to it have been released. It is recommended that only the owner of such a network connection should release it. Furthermore, it is recommended that it not be released immediately after the transmission of the final TPDU of a transport connection - either a DR TPDU in response to CR TPDU or a DC TPDU in response to DR TPDU. An appropriate delay will allow the TPDU concerned to reach the other transport entity allowing the freeing of any resources associated with the transport connection concerned.

4. After the failure of a network connection, transport connections which were previously multiplexed together may be assigned to different network connections, and vice versa.

6.2 Transport protocol data unit (TPDU) transfer

6.2.1 Purpose

The TPDU transfer procedure is used in all classes to convey transport protocol data units in user data fields of network service primitives.

6.2.2 Network Service Primitives

The procedure uses the following network service primitives:

a) N-DATA;

b) N-EXPEDITED DATA

6.2.3 Procedure

The transport protocol data units (TPDUs) defined for the protocol are listed in 4.2.

When the network expedited variant has been selected for class 1, the transport entities shall transmit and receive ED and EA TPDUs as NS-user data parameters of N-EXPEDITED DATA primitives.

In all other cases, transport entities shall transmit and receive TPDUs as NS-user data parameters of N-DATA primitives.

When a TPDU is put into an NS-user data parameter, the significance of the bits within an octet and the order of octets within a TPDU shall be as defined in 13.2.

NOTE - TPDUs may be concatenated (see 6.4).

6.3 Segmenting and reassembling

6.3.1 Purpose

The segmenting and reassembling procedure is used in all classes to map TSDUs onto TPDUs.

6.3.2 TPDUs and parameter used

The procedure makes use of the following TPDU and parameter:

DT TPDUs;

- End of TSDU.

6.3.3 Procedure

A transport entity shall map a TSDU on to an ordered sequence of one or more DT TPDUs. This sequence shall not be interrupted by other DT TPDUs on the same transport connection.

All DT TPDUs except the last DT TPDU in a sequence greater than one shall have a length of data greater than zero.

NOTES

1. The EOT parameter of a DT TPDU indicates whether or not there are subsequent DT TPDUs in the sequence.

2. There is no requirement that the DT TPDUs shall be of the maximum length selected during connection establishment.

6.4 Concatenation and separation

6.4.1 Purpose

The procedure for concatenation and separation is used in classes 1, 2, 3 and 4 to convey multiple TPDUs in one NSDU.

6.4.2 Procedure

A transport entity may concatenate TPDUs from the same or different transport connections.

The set of concatenated TPDUs may contain:

a) any number of TPDUs from the following list: AK, EA, RJ, ER, DC TPDUs, provided that these TPDUs come from different transport connections;

b) no more than one TPDU from the following list: CR, DR, CC, DT, ED TPDUs; if this TPDU is present, it shall be placed last in the set of concatenated TPDUs.

NOTES

1. The TPDUs within a concatenated set may be distinguished by means of the length indicator parameter.

2. The end of a TPDU containing data is indicated by the termination of the NSDU.

3. The number of concatenated TPDUs referred to in 6.4.2.a is bounded by the maximum number of transport connections which are multiplexed together except during assignment or reassignment.

6.5 Connection establishment

6.5.1 Purpose

The procedure for connection establishment is used in all classes to create a new transport connection.

6.5.2 Network service primitives

The procedure uses the following network service primitive:

N-DATA

6.5.3 TPDUs and parameters used

The procedure uses the following TPDUs and parameters:

a) CR TPDU;

- CDT;
- DST-REF (set to zero);
- SRC-REF
- CLASS and OPTIONS (i.e. preferred class, use of extended format, non-use of explicit flow control in class 2);
- calling TSAP-ID;
- called TSAP-ID;
- TPDU size (proposed);
- version number;
- security parameter;
- checksum;
- additional option selection (i.e. use of network expedited in class 1, use of receipt confirmation in class 1, non-use of checksum in class 4, use of transport expedited data transfer service);
- alternative protocol class(es);
- acknowledge time;
- throughput (proposed);
- residual error rate (proposed);
- priority (proposed);
- transit delay (proposed);
- reassignment time;
- user data.

b) CC TPDU;

- CDT;
- DST-REF;

- SRC-REF;
- CLASS and OPTIONS (selected);
- calling TSAP-ID;
- called TSAP-ID;
- TPDU size (selected);
- security parameter;
- checksum;
- additional option selection (selected);
- acknowledge time;
- throughput (selected);
- residual error rate (selected);
- priority (selected);
- transit delay (selected);
- user data.

NOTE - The transport service defines transit delay as requiring a previously stated average TSDU size as a basis for any specification. This protocol, as specified in 13.3.4(n), uses a value of 128 octets. Conversion to and from specifications based upon some other value is a local matter.

6.5.4 Procedure

A transport connection is established by means of one transport entity (the initiator) transmitting a CR TPDU to the other transport entity (the responder), which replies with a CC TPDU.

Before sending the CR TPDU, the initiator assigns the transport connection being created to one (or more if the splitting procedure is being use) network connection(s). It is this set of network connections over which the TPDUs are sent. During this exchange, all information and parameters needed for the transport entities to operate shall be exchanged or negotiated.

NOTE - Except in class 4, it is recommended that the initiator starts an optional timer TS1 at the time the CR TPDU is sent. This timer should be stopped when the connection is considered as accepted or refused or unsuccessful. If the timer expires, the initiator should reset or disconnect the network connection and, in classes 1 and 3 freeze the reference (see 6.18). For all other transport connection(s) multiplexed on the same network connection the procedures for reset or disconnect as appropriate should be followed.

After receiving the CC TPDU for a class which includes the procedure for retention until acknowledgement of TPDUs the initiator shall acknowledge the CC TPDU as defined in table 5 (see 6.13).

When the network expedited variant of the expedited data transfer (see 6.11) has been agreed (possible in class 1 only), the responder shall not send an ED TPDU before the CC TPDU is acknowledged.

The following information is exchanged:

a) references. Each transport entity chooses a reference which is to be used by the peer entity is 16 bits long and which is arbitrary except for the following restrictions:

   1) it shall not already be in use or frozen (see 6.18),

   2) it shall not be zero.

   This mechanism is symmetrical and provides identification of the transport connection independent of the network connection. The range of references used for transport connections, in a given transport entity, is a local matter.

b) addresses (optional). Indicate the calling and called transport service access points. When either network address unambiguously defines the transport address this information may be omitted.

c) initial credit. Only relevant for classes which include the explicit flow control function.

d) user data. Not available if Class 0 is the preferred class (see note). Up to 32 octets in other classes.

NOTE - If class 0 is a valid response according to table 3, inclusion of user data in the CR TPDU may cause the responding entity to refuse the connection (e.g. if it only supports class 0).

e) acknowledgement time. Only in class 4.

f) checksum parameter. Only in class 4.

g) security parameter. This parameter and its semantics are user defined.

The following negotiations take place:

h) protocol class. The initiator shall propose a preferred class and may propose any number of alternative class which permit a valid response as defined in table 3. The initiator should assume when it sends the CR TPDU that its preferred class will be agreed to, and commence the procedures associated with that class, except that if class 0 or class 1 is an alternative class, multiplexing shall not commence until a CC TPDU selecting the use of classes 2, 3 or 4 has been received.

   NOTE - This means, for example, that when the preferred class includes resynchronization (see 6.14) the resynchronization will occur if a reset is signalled during connection establishment.

The responder shall select one class defined in table 3 as a valid response corresponding to the preferred class and to the class(es), if any, contained in the alternative class parameter of the CR TPDU. It shall indicate the selected class in the CC TPDU and shall follow the procedures for the selected class.

If the preferred class is not selected, then on receipt of the CC TPDU the initiator shall adjust its operation according the procedures of the selected class.

Preferred class	Alternative class					
	0	1	2	3	4	none
0	not valid	not valid	not valid	not valid	not valid	class 0
1	class 1 or 0	class 1 or 0	not valid	not valid	not valid	class 1 or 0
2	class 2 or 0	not valid	class 2	not valid	not valid	class 2
3	class 3,2 or 0	class 3, 2,1 or 0	class 3 or 2	class 3 or 2	not valid	class 3 or 2
4	class 4,2 or 0	class 4, 2,1 or 0	class 4 or 2	class 4,3 or 2	class 4 or 2	class 4 or 2

Table 3.

Valid responses corresponding to the preferred class and any alternative class proposed in the CR TPDU

NOTES:

1. The valid responses indicated in table 3 result from both explicit negotiation, whereby each of the classes proposed is a valid response, and implicit negotiation whereby:

   a) if class 3 or 4 is proposed then class 2 is a valid response;
   b) if class 1 is proposed then class 0 is a valid response.

2. Negotiation from class 2 to class 1 and from any class to an higher-numbered class is not valid.

3. Redundant combinations are not a protocol error.

j) TPDU size. The initiator may propose a maximum size for TPDUs, and the responder may accept this value or respond with any value between 128 and the proposed value in the set of values available (see 13.3.4.b).

NOTE - The length of the CR TPDU does not exceed 128 octets (see 13.3).

k) normal or extended format. Either normal or extended is available. When extended is used this applies to CDT, TPDU-NR, ED-TPDU-NR, YR-TU-NR and YR-EDTU-NR parameters.

m) checksum selection. This defines whether or not TPDUs of the connection are to include a checksum.

n) quality of service parameters. This defines the throughput, transit delay, priority and residual error rate.

p) the non-use of explicit flow control in class 2.

q) the use of network receipt confirmation and network expedited when class 1 is to be used.

r) use of expedited data transfer service. This allows both TS-users to negotiate the use or non-use of the expedited data transport service as defined in the transport service (ISO 8072).

The following information is sent only in the CR TPDU:

s) version number. This defines the version of the transport protocol standard used for this connection.

t) reassignment time parameter. This indicates the time for which the initiator will persist in following the reassignment after failure procedure.

The negotiation rules for the options are such that the initiator may propose either to use or not to use the option. The responder may either accept the proposed choice or select an alternative choice as defined in table 4.

In class 2, whenever a transport entity requests or agrees to the transport expedited data transfer service or to the use of extended formats, it shall also request or agree (respectively) to the use of explicit flow control.

Option	Proposal Made by the Initiator	Valid Selection by the Responder
Transport expedited data transfer service (Classes 1,2,3,4 only)	Yes No	Yes or No No
Use of receipt confirmation (Class 1 only)	Yes No	Yes or No No
Use of the network expedited variant (Class 1 only)	Yes No	Yes or No No
Non-use of checksum (Class 4 only)	Yes No	Yes or No No
Non-use of explicit flow control (Class 2 only)	Yes No	Yes or No No
Use of extended format (Classes 2,3,4 only)	Yes No	Yes or No No

Table 4. Negotiation of options during connection establishment

NOTE - Table 4 defines the procedures for negotiation of options. This negotiation has been designed such that if the initiator proposes the mandatory implementation option specified in clause 14, the responder has to accept use of this option over the transport connection except for the use of the transport expedited data transfer service which may be rejected by the TS-user. If the initiator proposes a non-mandatory implementation option, the responder is entitled to select use of the mandatory implementation option for use over the transport connection.

6.6 Connection refusal

6.6.1 Purpose

The connection refusal procedure is used in all classes when a transport entity refuses a transport connection in response to a CR TPDU.

6.6.2 TPDUs and parameters used

The procedure makes use of the following TPDUs and parameters:

a) DR TPDU;

- SRC-REF;
- reason;
- user data.

b) ER TPDU;

- reject code;
- rejected TPDU parameter.

6.6.3 Procedure

If a transport connection cannot be accepted, the responder shall respond to the CR TPDU with a DR TPDU. The reason shall indicate why the connection was not accepted. The source reference field in the DR TPDU shall be set to zero to indicate an unassigned reference.

If a DR TPDU is received the initiator shall regard the connection as released.

The responder shall respond to an invalid CR TPDU by sending an ER or DR TPDU. If an ER TPDU is received in response to a CR TPDU, the initiator shall regard the connection as released.

NOTES

1. When the invalid CR TPDU can be identified as having class 0 as the preferred class, it is recommended to respond with an ER TPDU. For all other invalid CR TPDUs either an ER TPDU or DR TPDU may be sent.

2. If the optimal supervisory timer TS1 has been set for this connection then the entity should stop the timer on receipt of the DR or ER TPDU.

6.7 Normal release

6.7.1 Purpose

The release procedure is used by a transport entity in order to terminate a transport connection. The implicit variant is used only in class 0. The explicit variant is used in classes 1,2,3 and 4.

NOTES

1. When the implicit variant is used (i.e. in class 0), the lifetime of the transport connection is directly correlated with the lifetime of the network connection.

2. The use of the explicit variant of the release procedure enables the transport connection to be released independently of the underlying network connection.

6.7.2 Network service primitives

The procedure makes use of the following network service primitives:

a) N-DISCONNECT (implicit variant only),

b) N-DATA

6.7.3 TPDUs and parameters used

The procedure makes use of the following TPDUs and parameters:

a) DR TPDU;

- clearing reason;
- user data;
- SRC-REF;
- DST-REF.

b) DC TPDU.

6.7.4 Procedure for implicit variant

In the implicit variant either transport entity disconnects a transport connection by disconnecting the network connection to which it is assigned. When a transport entity receives an N-DISCONNECT this should be considered as the release of the transport connection.

6.7.5 Procedure for explicit variant

When the release of a transport connection is to be initiated a transport entity

a) if it has previously sent or received a CC TPDU (see note 1), shall send a DR TPDU. It shall ignore all subsequently received TPDUs other than a DR or DC TPDU. On receipt of a DR or DC TPDU it shall consider the transport connection released;

b) in other cases it shall:

   1) For classes other than class 4 wait for the acknowledgement of the outstanding CR TPDU; if it receives a CC TPDU, it shall follow the procedures in 6.7.5.a.

   2) For class 4 either send a DR TPDU with a zero value in the DST-REF field or follow the procedure in 6.7.5.b.1.

A transport entity that receives a DR TPDU shall

c) if it has previously sent a DR TPDU for the same transport connection, consider the transport connection released;

d) if it has previously sent a CR TPDU that has not been acknowledged by a CC TPDU, consider the connection refused (see 6.6).

e) in other cases, send a DC TPDU and consider the transport connection released.

NOTES

1) This requirement ensures that the transport entity is aware of the remote reference for the transport connection.

2) When the transport connection is considered as released the local reference is either available for re-use or is frozen (see 6.18).

3) After the release of a transport connection the network connection can be released or retained to enable its re-use for the assignment of other transport connections (see 6.1.).

4) Except in class 4, it is recommended that, if a transport entity does not receive acknowledgement of a DR TPDU within time TS2, it should either reset or disconnect the network connection, and freeze the reference when appropriate (see 6.18). For all other transport connection(s) multiplexed on this network connection the procedures for reset or disconnect as appropriate should be followed.

5) When a transport entity is waiting for a CC TPDU before sending a DR TPDU and the network connection is reset or released, it should consider the transport connection released and, in classes other than classes 0 and 2, freeze the reference (see 6.18).

6.8 Error Release

6.8.1 Purpose

This procedure is used only in classes 0 and 2 to release a transport connection on the receipt of an N-DISCONNECT or N-RESET indication.

6.8.2 Network service primitives

The procedure makes use of the following service primitives:

a) N-DISCONNECT indication;

b) N-RESET indication.

6.8.3 Procedure

When, on the network connection to which a transport connection is assigned, an N-DISCONNECT or N-RESET indication is received, both transport entities shall consider that the transport connection is released and so inform the TS-users.

NOTE - In other classes, since error recovery is used, the receipt of an N-RESET indication or N-DISCONNECT indication will result in the invocation of the error recovery procedure.

6.9 Association of TPDUs with transport connections

6.9.1 Purpose

This procedure is used in all classes to interpret a received NSDU as TPDU(s) and, if possible, to associate each such TPDU with a transport connection.

6.9.2 Network service primitives

This procedure makes use of the following network service primitives:

a) N-DATA indication;

b) N-EXPEDITED DATA indication.

6.9.3 TPDUs and parameters uses

This procedure makes use of the following TPDUs and parameters:

a) any TPDU except CR TPDU, DT TPDU in classes 0 or 1 and AK TPDU in class 1;

   - DST-REF

b) CR, CC, DR and DC TPDUs;

   - SCR-REF.

c) DT TPDU in classes 0 or 1 and AK TPDU in class 1.

6.9.4 Procedures

6.9.4.1 Identification of TPDUs

If the received NSDU or Expedited NSDU cannot be decoded (i.e. does not contain one or more correct TPDUs) or is corrupted (i.e. contains a TPDU with a wrong checksum) then the transport entity shall:

a) if the network connection on which the error is detected has a class 0 or class 1 transport connection assigned to it, then treat as a protocol error (see 6.22) for that transport connection;

b) otherwise

   1) if the NSDU can be decoded but contains corrupted TPDUs, ignore the TPDUs (class 4 only) and optionally apply 6.9.4.b.2.

   2) if the NSDU cannot be decoded issue an N-RESET or N-DISCONNECT request for the network connection and for all the transport connections assigned to this network connection (if any), apply the procedures defined for handling of network signalled reset or disconnect.

   If the NSDU can be decoded and is not corrupted, the transport entity shall:

c) if the network connection on which the NSDU was received has a class 0 transport connection assigned to it, then consider the NSDU as forming TPDU and associate the TPDU with the transport connection (see 6.9.4.2).

d) otherwise, invoke the separation procedures and for each of the individual TPDUs in the order in which they appear in the NSDU apply the procedure defined in 6.9.4.2.

6.9.4.2 Association of individual TPDUs

If the received TPDU is a CR TPDU then, if it is a duplicate, as recognized by using the NSAPs of the network connection, and the SRC-REF parameter, then it is associated with the transport connection created by the original value of the CR TPDU; otherwise it is processed as requesting the creation of a new transport connection.

If the received TPDU is a DT TPDU and the network connection has a class 0 or 1 transport connection assigned to it, or an AK TPDU where a class 1 transport connection is assigned, then the TPDU is associated with the transport connection.

Otherwise, the DST-REF parameter of the TPDU is used to identify the transport connection. The following cases are distinguished:

a) if the DST-REF is not allocated to a transport connection, the transport entity shall respond on the same network connection with a DR TPDU if the TPDU is a CC TPDU, with a DC TPDU if the TPDU is a DR TPDU and shall ignore the TPDU if neither a DR TPDU nor CC TPDU. No association with a transport connection is made.

b) if the DST-REF is allocated to a connection, but the TPDU is received on a network connection to which the connection has not been assigned then there are three cases:

   1) if the transport connection is of class 4 and if the TPDU is received on a network connection with the same pair of NSAPs as that of the CR TPDU then the TPDU is considered as performing assignment,

   2) if the transport connection is not assigned to any network connection (waiting for reassignment after failure) and if the TPDU is received on a network connection with the same pair of NSAPs as that of the CR TPDU then the association with that transport connection is made.

   3) Otherwise, the TPDU is considered as having a DST-REF not allocated to a transport connection (case a).

c) If the TPDU is a DC TPDU then it is associated with the transport connection to which the DST-REF is allocated, unless the SRC-REF is not the expected one, in which case the DC TPDU is ignored.

d) If the TPDU is a DR TPDU then there are three cases:

   1) if the SRC-REF is not as expected then a DC TPDU with DST-REF equal to the SRC-REF of the received DR TPDU is sent back and no association is made;

2) if a CR TPDU is unacknowledged then the DR TPDU is associated with the transport connection, regardless of the value of its SRC-REF parameter;

3) otherwise, the DR TPDU is associated with the transport connection identified by the DST-REF parameter.

e) if the TPDU is a CC TPDU whose DST-REF parameter identifies an open connection (one for which a CC TPDU has been previously received), and the SRC-REF in the CC TPDU does not match the remote reference, then a DR TPDU is sent back with DST-REF equal to the SRC-REF of the received CC TPDU and no association is made.

f) if none of the above cases apply then the TPDU is associated with the transport connection identified by the DST-REF parameter.

6.10 Data TPDU numbering

6.10.1 Purpose

Data TPDU numbering is used in classes 1, 2 (except when the non-use of explicit flow control option is selected), 3 and 4. Its purpose is to enable the use of recovery, flow control and re-sequencing functions.

6.10.2 TPDUs and parameters used

The procedure makes use of the following TPDU and parameter:

DT TPDU;

- TPDU-NR.

6.10.3 Procedure

A Transport entity shall allocate the sequence number zero to the TPDU-NR of the first DT TPDU which it transmits for a transport connection. For subsequent DT TPDUs sent on the same transport connection, the transport entity shall allocate a sequence number one greater than the previous one.

When a DT TPDU is retransmitted, the TPDU-NR parameter shall have the same value as in the first transmission of that DT TPDU.

Modulo 2**7 arithmetic shall be used when normal formats have been selected and modulo 2**31 arithmetic shall be used when extended formats have been selected. In this International Standard the relationships 'greater than' and 'less than' apply to a set of contiguous TPDU numbers whose range is less than the modulus and whose starting and finishing numbers are known. The term 'less than' means 'occurring sooner in the window sequence' and the term 'greater than' means 'occurring later in the window sequence'.

6.11 Expedited data transfer

6.11.1 Purpose

Expedited data transfer procedures are selected during connection establishment. The network normal data variant may be used in classes 1, 2, 3 and 4. The network expedited variant is only used in class 1.

6.11.2 Network service primitives

The procedure makes use of the following network service primitives:

a) N-DATA;

b) N-EXPEDITED DATA.

6.11.3 TPDUs and parameter used

The procedure makes use of the following TPDUs and parameters:

a) ED TPDU;

- ED TPDU-NR.

b) EA TPDU;

- YR-EDTU-NR.

6.11.4 Procedures

The TS-user data parameter of each T-EXPEDITED DATA request shall be conveyed as the data field of an Expedited Data (ED) TPDU.

Each ED TPDU received shall be acknowledged by an Expedited Acknowledge (EA) TPDU.

No more than one ED TPDU shall remain unacknowledged at any time for each direction of a transport connection.

An ED TPDU with a zero length data field is a protocol error.

NOTES

1. The network normal data variant is used, except when the network expedited variant (available in Class 1 only), has been agreed, in which case ED and EA TPDUs are conveyed in the data fields of N-EXPEDITED DATA primitives (see 6.2.3).

2. No TPDUs can be transmitted using network expedited until the CC TPDU becomes acknowledged, to prevent the network expedited from overtaking the CC TPDU.

6.12 Reassignment after failure

6.12.1 Purpose

The reassignment after failure procedure is used in Classes 1 and 3 to commence recovery from an NS-provider signalled disconnect.

6.12.2 Network service primitives

The procedure uses the following network service primitive:

N-DISCONNECT indication

6.12.3 Procedure

When an N-DISCONNECT indication is received from the network connection to which a transport connection is assigned, the initiator shall apply one of the following alternatives:

a) if the TTR timer has not already run out and no DR TPDU is retained then:

1) assign the transport connection to a different network connection (see 6.1) and start its TTR timer if not already started.

2) while waiting for the completion of assignment if:

- an N-DISCONNECT indication is received, repeat the procedure from 6.12.3.a,

- the TTR timer expires, begin procedure 6.12.3.b.

3) when reassignment is completed, begin resynchronization (see 6.14) and:

- if a valid TPDU is received as the result of the resynchronization, stop the TTR timer, or

- if TTR runs out, wait for the next event, or

- if an N-DISCONNECT indication is received, then begin either procedure 6.12.3.a or 6.12.3.b depending on the TTR timer.

NOTE - After the TTR timer expires and while waiting for the next event, it is recommended that the initiator starts the TWR timer. If the TWR timer expires before the next event the initiator should begin the procedure in 6.12.3.b.

b) if the TTR timer has run out, consider the transport connection as released and freeze the reference (see 6.18).

c) if a DR TPDU is retained and the TTR timer has not run out, then follow the actions in either 6.12.3.a or 6.12.3.b.

The responder shall start its TWR timer if not already started. The arrival of the first TPDU related to the transport connection (because of resynchronization by the initiator) completes the reassignment after failure procedure. The TWR timer is stopped and the responder shall continue with resynchronization (see 6.14). If reassignment does not take place within this time, the transport connection is considered released and the reference is frozen (see 6.18).

6.12.4 Timers

The reassignment after failure procedure uses two timers:

a) TTR, the time to try reassignment/resynchronization timer;

b) TWR, the time to wait for reassignment/resynchronization timer.

The TTR timer is used by the initiator. Its value shall not exceed two minutes minus the sum of the maximum disconnect propagation delay and the transit delay of the network connections (see note 1). The value for the TTR timer may be indicated in the CR TPDU.

The TWR timer is used by the responder. If the reassignment time parameter is present in the CR TPDU, the TWR timer value shall be greater than the sum of the TTR timer plus the maximum disconnect propagation delay plus the transit delay of the network connections.

If the reassignment time parameter is not present in the CR TPDU, a default value of 2 minutes shall be used for the TWR timer.

NOTES

1. Provided that the required quality of service is met, TTR may be set to zero (i.e. no assignment). This may be done, for example, if the rate of NS-provider generated disconnects is very low.

2. Inclusion of the reassignment time parameter in the CR TPDU allows the responder to use a TWR value of less than 2 minutes.

3. If the optional TS1 and TS2 timers are used, it is recommended:

a) to stop TS1 or TS2 if running when TTR or TWR is started;

b) to restart TS1 or TS2 if necessary when the corresponding TPDU (CR TPDU or DR TPDU respectively is repeated);

c) to select for TS1 and TS2 values greater than TTR.

6.13 Retention until acknowledgement of TPDUs

6.13.1 Purpose

The retention until acknowledgement of TPDUs procedure is used in classes 1, 3 and 4 to enable and minimize retransmission after possible loss of TPDUs.

The confirmation of receipt variant is used only in Class 1 when it has been agreed during connection establishment (see note).

The AK variant is used in classes 3 and 4 and also in Class 1 when the confirmation of receipt variant has not been agreed during connection establishment.

NOTE - Use of confirmation of receipt variant depends on the availability of the network layer receipt confirmation service and the expected cost reduction.

6.13.2 Network service primitives

The procedure uses the following network service primitives:

a) N-DATA;

b) N-DATA ACKNOWLEDGE.

6.13.3 TPDUs and parameters used

The procedure uses the following TPDUs and parameters:

a) CR, CC, DR and DC TPDUs;

b) RJ and AK TPDUs;

- YR-TU-NR.

c) DT TPDU;

- TPDU-NR.

d) ED TPDU;

- ED-TPDU-NR.

e) EA TPDU;

- YR-EDTU-NR.

6.13.4 Procedures

Copies of the following TPDUs shall be retained upon transmission to permit their later retransmission:

CR, CC, DR, DT and ED TPDUs

except that if a DR is sent in response to a CR TPDU there is no need to retain a copy of the DR TPDU.

In the confirmation of receipt variant, applicable only in Class 1, transport entities receiving N-DATA indications which convey DT TPDUs and have the confirmation request field set shall issue an N-DATA ACKNOWLEDGE request (see notes 1 and 2).

After each TPDU is acknowledged, as shown in table 5, the copy need not be retained. Copies may also be discarded when the transport connection is released.

NOTES

1. It is a local matter for each transport entity to decide which N-DATA requests should have the confirmation request parameter set. This decision will normally be related to the amount of storage available for retained copies of the DT TPDUs.

2. Use of the confirmation request parameter may affect the quality of network service.

RETAINED TPDU	VARIANT	RETAINED UNTIL ACKNOWLEDGED BY
CR	both	CC, DR or ER TPDU.
DR	both	DC or DR (in case of collision) TPDU.
CC	confirmation of receipt variant	N-DATA Acknowledge indication, RJ, DT, EA or ED TPDU.
CC	AK variant	RJ, DT, AK, ED or EA TPDU.
DT	confirmation of receipt variant	N-DATA ACKNOWLEDGE indication corresponding to an N-DATA request which conveyed, or came after, the DT TPDU.
DT	AK variant	AK or RJ TPDU for which the YR-TU-NR is greater than TPDU-NR in the DT TPDU.
ED	both	EA TPDU for which the YR-EDTU-NR is equal to the ED-TPDU-NR in the ED TPDU.

Table 5. Acknowledgement of TPDUs

6.14 Resynchronization

6.14.1 Purpose

The resynchronization procedures are used in Classes 1 and 3 to restore the transport connection to normal after a reset or during reassignment after failure according to 6.12.

6.14.2 Network service primitives

The procedure makes use of the following network service primitive:

N-RESET indication.

6.14.3 TPDUs and parameters used

The procedure uses the following TPDUs and parameters:

a) CR, DR, CC and DC TPDUs

b) RJ TPDUs;

- YR-TU-NR.

c) DT TPDU;

- TPDU-NR

d) ED TPDU;

- ED TPDU-NR.

e) EA TPDU;

- YR-EDTU-NR.

6.14.4 Procedure

A transport entity which is notified of the occurence of an N-RESET or which is performing 'reassignment after failure' according to 6.12 shall carry out the active resynchronization procedure (see 6.14.4.1) unless any of the following hold:

a) the transport entity is the responder (see note). In this case the passive resynchronization procedure is carried out (see 6.14.4.2).

b) the transport entity has elected not to reassign (see 6.12.3.c). In this case no resynchronization takes place.

6.14.4.1 Active resynchronization procedures

The Transport entity shall carry out one of the following actions:

a) if the TTR timer has been previously started and has run out (i.e. no valid TPDU has been received), the transport connection is considered as released and the reference is frozen (see 6.18).

b) otherwise, the TTR timer shall be started (unless it is already running) and the first applicable of the following actions shall be taken:

   1) if a CR TPDU is unacknowledged, then the transport entity shall retransmit it;

   2) if a DR TPDU is unacknowledged, then the transport entity shall retransmit it;

   3) otherwise, the transport entity shall carry out the data resynchronization procedures (6.14.4.3).

   The TTR timer is stopped when a valid TPDU is received.

6.14.4.2 Passive resynchronization procedures

The transport entity shall not send any TPDUs until a TPDU has been received. The transport entity shall start its TWR timer if it was not already started (due to a previous N-DISCONNECT or N-RESET indication). If the timer runs out prior to the receipt of a valid TPDU which commence resynchronization (i.e. CR or DR or RJ TPDU) the transport connection is considered as released and the reference is released (see 6.18).

When a valid TPDU is received the transport entity shall stop its TWR timer and carry out the appropriate one of the following actions, depending on the TPDU:

a) if it is a DR TPDU, then the transport entity shall send a DC TPDU;

b) if it is a repeated CR TPDU (see note 1) then the transport entity shall carry out the appropriate action from the following:

    1) if a CC TPDU has already been sent, and acknowledged: treat as a protocol error;

    2) if a DR TPDU is unacknowledged (whether or not a CC TPDU is unacknowledged): retransmit the DR TPDU, but setting the source reference to zero;

    3) if the T-CONNECT response has not yet been received from the user: take no action;

    4) otherwise; retransmit the CC TPDU followed by an unacknowledged ED TPDU (see note 2) and any DT TPDU;

NOTES

1. A repeated CR TPDU can be identified by being on a network connection with the appropriate network addresses and having a correct source reference.

2. The transport entity should not use network expedited until the CC TPDU is acknowledged (see 6.5). This rule prevents the network expedited from overtaking the CC TPDU.

c) if it is an RJ or ED TPDU then one of the following actions shall be taken:

1) if a DR TPDU is unacknowledged, then the transport entity shall retransmit it;

2) otherwise, the transport entity shall carry out the data resynchronization procedures (6.14.4.3).

3) If a CC TPDU was unacknowledge, the RJ or ED TPDU should then be considered as acknowledging the CC TPDU. If a CC TPDU was never sent, the RJ TPDU should then be considered as a protocol error.

6.14.4.3 Data Resynchronization Procedures

The transport entity shall carry out the following actions in the following order:

a) (re)transmit any ED TPDU which is unacknowledged,

b) transmit an RJ TPDU with YR-TU-NR field set to the TPDU-NR of the next expected DT TPDU;

c) wait for the next TPDU from the other transport entity, unless an RJ or DR TPDU has already been received; if a DR TPDU is received the transport entity shall send a DC, freeze the reference, inform the TS-user of the disconnection and take no further action (i.e. it shall not follow the procedures in 6.14.4.3.d). If an RJ TPDU is received, the procedure of 6.14.4.3.d shall be followed. If an ED TPDU is received the procedures as described in 6.11 shall be followed. If it is a duplicated ED-TPDU the transport entity shall acknowledge it, with an EA TPDU, discard the duplicated ED TPDU and wait again for the next TPDU.

d) (re)transmit any DT TPDUs which are unacknowledged, subject to any applicable flow control procedures (see note);

NOTE - The RJ TPDU may have reduced the credit.

6.15 Multiplexing and demultiplexing

6.15.1 Purpose

The multiplexing and demultiplexing procedures are used in Classes 2, 3 and 4 to allow several transport connections to share a network connection at the same time.

6.15.2 TPDUs and parameters used

The procedure makes use of the following TPDUs and parameters:

CC, DR, DC, DT, AK, ED, EA, RJ and ER TPDUs

- DST-REF

6.15.3 Procedure

The transport entities shall be able to send and receive on the same network connection TPDUs belonging to different transport connections.

NOTES

1. When performing demultiplexing the transport connection to which the TPDUs apply is determined by the procedures defined in 6.9.

2. Multiplexing allows the concatenation of TPDUs belonging to different transport connections to be transferred in the same N-DATA primitive (see 6.4).

6.16 Explicit Flow Control

6.16.1 Purpose

The explicit flow control procedure is used in Classes 2, 3 and 4 to regulate the flow of DT TPDUs independently of the flow control in the other layers.

6.16.2 TPDUs and parameters used

The procedure makes use of the following TPDUs and parameters:

a) CR, CC, AK and RJ TPDUs

   - CDT.

b) DT TPDU

   - TPDU-NR.

c) AK TPDU

- YR-TU-NR;
- subsequence number;
- flow control confirmation.

d) RJ TPDU

- YR-TU-NR.

6.16.3 Procedure

The procedures differ in different classes. They are defined in the clauses specifying the separate classes.

6.17 Checksum

6.17.1 Purpose

The checksum procedure is used to detect corruption of TPDUs by the NS-provider.

NOTE - Although a checksum algorithm has to be adapted to the type of errors expected on the network connection, at present only one algorithm is defined.

6.17.2 TPDUs and parameters used

The procedure uses the following TPDUs and parameters:

All TPDUs
- checksum

6.17.3 Procedure

The checksum is used only in Class 4. It is always used for the CR TPDU, and is used for all other TPDUs except if the non-use of the procedure was agreed during connection establishment.

The sending transport entity shall transmit TPDUs with the checksum parameter set such that the following formulas are satisfied:

SUM(from i=1 to i=L) OF a[i] EQUALS <zero> (module 255)

SUM(from i=1 to i=L) OF i*a[i] EQUALS <zero> (module 255)

where

i = number (i.e. position) of an octet within the TPDU (see 13.2);
a[i] = value of octet in position 1;
L = length of TPDU in octets.

A transport entity which receives a TPDU for a transport connection for which the use of checksum has been agreed and which does not satisfy the above formulas shall discard the TPDU (see also note 2).

NOTES

1. An efficient algorithm for determining the checksum parameters is given in annex B.

2. If the checksum is incorrect, it is not possible to know with certainty to which transport connection the TPDU is related; further action may be taken for all the transport connections assigned to the network connection (see 6.9).

3. The checksum proposed is easy to calculate and so will not impose a heavy burden on implementations. However, it will not detect insertion or loss of leading or trailing zeros and will not detect some octets misordering.

6.18 Frozen references

6.18.1 Purpose

This procedure is used in order to prevent re-use of a reference while TPDUs associated with the old use of the reference may still exist.

6.18.2 Procedure

When a transport entity determines that a particular connection is released it shall place the reference which it has allocated to the connection in a frozen state according to the procedures of the class. While frozen, the reference shall not be re-used.

NOTE - The frozen reference procedure is necessary because retransmission or misordering can cause TPDUs bearing a reference to arrive at an entity after it has released the connection for which it allocated the reference. Retransmission, for example, can arise when the class includes either resynchronization (see 6.14) or retransmission on time out (see 6.19).

6.18.2.1 Procedure for classes 0 and 2

The frozen reference procedure is never used for these classes.

NOTE - However for consistency with the other classes freezing the references may be done as a local decision.

6.18.2.2 Procedure for classes 1 and 3

The frozen reference procedure is used except in the following cases (see note 1):

a) when the transport entity receives a DC TPDU in response to a DR TPDU which it has sent (see note 2);

b) when the transport entity sends a DR or ER TPDU in response to a CR TPDU which it has received (see note 3);

c) when the transport entity has considered the connection to be released after the expiration of the TWR timer (see note 4);

d) when the transport entity receives a DR or ER TPDU in response to a CR TPDU which it has sent.

The period of time for which the reference remains frozen shall be greater than the TWR time.

NOTES

1. However, even in these cases, for consistency freezing the reference may be done as a local decision.

2. When the DC TPDU is received it is certain that the other transport entity considers the connection released.

3. When the DR or ER TPDU is sent the peer transport entity has not been informed of any reference assignment and thus cannot possibly make use of a reference (this includes the case where a CC TPDU was sent, but was lost).

4. In 6.18.2.c the transport entity has already effectively frozen the reference for an adequate period.

6.18.2.3 Procedure for classes 4

The frozen reference procedure is always used in class 4. The period for which the reference remains frozen should be greater than L (see 12.2.1.1.6).

6.19 Retransmission on time-out

6.19.1 Purpose

The procedure is used in Class 4 to cope with unsignalled loss of TPDUs by the NS-provider.

6.19.2 TPDUs used

The procedure makes use of the following TPDUs:

CR, CC, DR, DT, ED, AK TPDUs.

6.19.3 Procedure

The procedure is specified in the procedures for Class 4 (see 12.2.1.2.j).

6.20 Resequencing

6.20.1 Purpose

The resequencing procedure is used in Class 4 to cope with misordering of TPDUs by the network service provider.

6.20.2 TPDUs and parameters used

The procedure uses the following TPDUs and parameters:

a) DT TPDU;
   - TPDU-NR.

b) ED TPDU
   - ED TPDU-NR

6.20.3 Procedure

The procedure is specified in the procedures for Class 4 (see 12.2.3.5).

6.21 Inactivity control

6.21.1 Purpose

The inactivity control procedure is used in Class 4 to cope with unsignalled termination of a network connection.

6.21.2 Procedure

The procedure is specified in the procedures for Class 4 (see 12.2.3.3).

6.22 Treatment of protocol errors

6.22.1 Purpose

The procedure for treatment of protocol errors is used in all classes to deal with invalid TPDUs.

6.22.2 TPDUs and parameters used

The procedure uses the following TPDUs and parameters:

a) ER TPDU;
   - reject cause;
   - TPDU in error.

b) DR TPDU;
   - reason code.

6.22.3 Procedure

A transport entity that receives a TPDU that can be associated to a transport connection and is invalid or constitutes a protocol error (see 3.2.16 and 3.2.17) shall take one of the following actions so as not to jeopardize any other transport connections not assigned to that network connection:

a) ignoring the TPDU;

b) transmitting an ER TPDU;

c) resetting or closing the network connection; or

d) invoking the release procedures appropriate to the class.

If an ER TPDU is sent in Class 0 it shall contain the octets of the invalid TPDU up to and including the octet where the error was detected (see notes 3, 4 and 5).

If the TPDU cannot be associated to a particular transport connection then see 6.9.

NOTES

1. In general, no further action is specified for the receiver of the ER TPDU but it is recommended that it initiates the release procedure appropriate to the class. If the ER TPDU has been received as an answer to a CR TPDU then the connection is regarded as released (see 6.6).

2. Care should be taken by a transport entity receiving several invalid TPDUs or ER TPDUs to avoid looping if the error is generated repeatedly.

3. If the invalid received TPDU is greater than the selected maximum TPDU size it is possible that it cannot be included in the invalid TPDU parameter of the ER TPDU.

4. It is recommended that the sender of the ER TPDU starts an optional timer TS2 to ensure the release of the connection. If the timer expires, the transport entity shall initiate the release procedures appropriate to the class. The timer should be stopped when a DR TPDU or an N-DISCONNECT indication is received.

5. In classes other than 0, it is recommended that the invalid TPDU be also included in the ER TPDU.

6.23 Splitting and recombining

6.23.1 Purpose

This procedure is used only in class 4 to allow a transport connection to make use of multiple network connections to provide additional resilience against network failure, to increase throughput, or for other reasons.

6.23.2 Procedure

When this procedure is being used, a transport connection may be assigned (see 6.1) to multiple network connections (see note 1). TPDUs for the connection may be sent over any such network connection.

If the use of Class 4 is not accepted by the remote transport entity following the negotiation rules, then no network connection except that over which the CR TPDU was sent may have this transport connection assigned to it.

NOTES

1. The resequencing function of Class 4 (see 6.20) is used to ensure that TPDUs are processed in the correct sequence.

2. Either transport entity may assign the connection to further network connections of which it is the owner at any time during the life of the transport connection.

3. In order to enable the detection of unsignalled network connection failures, a transport entity performing splitting should ensure that TPDUs are sent at intervals on each supporting network connection, for example, by sending successive TPDUs on successive network connections, where the set of network connections is used cyclically. By monitoring each network connection, a transport entity may detect unsignalled network connection failures, following the inactivity procedures defined in 12.2.3.3. Thus, for each network connection no period I (see 12.2.3.1) may elapse without the receipt of some TPDU for some transport connection.

7 Protocol Classes

Table 6 gives an overview of which elements of procedure are included in each class. In certain cases the elements of procedure within different classes are not identical and, for this reason, table 6 cannot be considered as part of the definitive specification of the protocol.

KEY TO TABLE 6

*	Procedure always included in class
	Not applicable
m	Negotiable procedure whose implementation in equipment is mandatory
o	Negotiable procedure whose implementation in equipment is optional
ao	Negotiable procedure whose implementation in equipment is optional and where use depends on availability within the network service
(1)	Not applicable in class 2 when non-use of explicit flow control is selected
(2)	When non use of explicit flow control has been selected, multiplexing may lead to degradation of quality of service
(3)	This function is provided in class 4 using procedures other than those in the cross reference.

Protocol Mechanism	Cross reference	Variant	0	1	2	3	4
Assignment to network Conn.	6.1		*	*	*	*	*
TPDU Transfer	6.2		*	*	*	*	*
Segmenting and Reassembling	6.3		*	*	*	*	*
Concatenation and Separation	6.4			*	*	*	*
Connection Establishment	6.5		*	*	*	*	*
Connection Refusal	6.6		*	*	*	*	*
Normal Release	6.7	implicit	*				
		explicit		*	*	*	*
Error Release	6.8		*		*		
Association of TPDUs with Transport Connection	6.9		*	*	*	*	*
DT TPDU Numbering	6.10	normal		*	m(1)	m	m
		extended			o(1)	o	o
Expedited Data Transfer	6.11	network normal		m	* (1)	*	*
		network expedited		ao			
Reassignment after failure	6.12			*		*	(3)

Table 6. (First of 2 pages) Allocation of procedures within classes

Retention until Acknowledgement of TPDUs	6.13	Conf.Receipt AK		ao m			*
Resynchronisation	6.14			*		*	(3)
Multiplexing and Demultiplexing	6.15				(2) *	*	*
Explicit Flow Control With Without	6.16		 *	 *	m o	* 	*
Checksum (use of) (non-use of)	6.17		 *	 *	 *	 *	m o
Frozen References	6.18			*		*	*
Retransmission on Timeout	6.19						*
Resequencing	6.20						*
Inactivity Control	6.21						*
Treatment of Protocol Errors	6.22		*	*	*	*	*
Splitting and Recombining	6.23						*

Table 6. (2nd of 2 pages) Allocation of procedures within classes

8 SPECIFICATION FOR CLASS 0. SIMPLE CLASS

8.1 Functions of class 0

Class 0 is designed to have minimum functionality. It provides only the functions needed for connection establishment with negotiation, data transfer with segmenting and protocol error reporting.

Class 0 provides transport connections with flow control based on the network service provided flow control, and disconnection based on the network service disconnection.

8.2 Procedures for class 0

8.2.1 Procedures applicable at all times

The transport entities shall use the following procedures:

a) TPDU transfer (see 6.2);

b) association of TPDUs with transport connections (see 6.9);

c) treatment of protocol errors (see 6.22);

d) error release (see 6.8).

8.2.2 Connection establishment

The transport entities shall use the following procedures:

a) assignment to network connection (see 6.1); then

b) connection establishment (see 6.5) and, if appropriate, connection refusal (see 6.6);

subject to the following constraints:

c) the CR and CC TPDUs shall contain no parameter field other than those for TSAP-ID and maximum TPDU size;

d) the CR and CC TPDUs shall not contain a data field.

8.2.3 Data transfer

The transport entities shall use the segmenting and reassembling procedure (see 6.3).

8.2.4 Release

The transport entities shall use the implicit variant of the normal release procedure (see 6.7).

NOTE - the lifetime of the transport connection is directly correlated with the lifetime of the network connection.

9 SPECIFICATION FOR CLASS 1: BASIC ERROR RECOVERY CLASS

9.1 Functions of Class 1

Class 1 provides transport connections with flow control based on the network service provided flow control, error recovery, expedited data transfer, disconnection, and also the ability to support consecutive transport connections on a network connection.

This class provides the functionality of Class 0 plus the ability to recover after a failure signalled by the Network Service, without involving the TS-user.

9.2 Procedures for Class 1

9.2.1 Procedures applicable at all times

The transport entities shall use the following procedures:

a) TPDU transfer (see 6.2);

b) association of TPDU with transport connections (see 6.9);

c) treatment of protocol errors (see 6.22);

d) reassignment after failure (see 6.12);

e) resynchronization (see 6.14), or reassignment after failure (see 6.12) together with resynchronization (see 6.14);

f) concatenation and separation (see 6.4);

g) retention until acknowledgement of TPDU (see 6.13); the variant used, AK or confirmation of receipt, shall be as selected during connection establishment (see notes);

h) frozen references (see 6.18).

NOTES

1. The negotiation of the variant of retention until acknowledgement of TPDUs procedure to be used over the transport connection has been designed such that if the initiator proposes the use of the AK variant (i.e. the mandatory implementation option), the responder has to accept use of this option and if the initiator proposes use of the confirmation of receipt variant the responder is entitled to select use of the AK variant.

2. The AK variant makes use of AK TPDUs to release copies of retained DT TPDUs. The CDT parameter of AK TPDUs in class 1 is not significant, and is set to 1111.

3. The confirmation of receipt variant is restricted to this class and its use depends on the availability of the network layer receipt confirmation service, and the expected cost reduction.

9.2.2 Connection establishment

The transport entities shall use the following procedures:

a) assignment to network connection (see 6.1); then

b) connection establishment (see 6.5) and, if appropriate, connection refusal (see 6.6).

9.2.3 Data Transfer

9.2.3.1 General

The sending transport entity shall use the following procedures;

a) segmenting (see 6.3); then

b) the normal format variant of DT TPDU numbering (see 6.10).

The receiving transport entity shall use the following procedures;

c) the normal variant of DT TPDU numbering (see 6.10,; then

d) reassembling (see 6.3).

NOTES

1. The use of RJ TPDU during resynchronization (see 6.14) can lead to retransmission. Thus the receipt of a duplicate DT TPDU is possible; such a DT TPDU is discarded.

2. It is possible to decide on a local basis to issue an N-RESET request in order to force the remote entity to carry out the resynchronization (see 6.14).

9.2.3.2 Expedited Data

The transport entities shall use either the network normal data or the network expedited variants of the expedited data transfer procedure (see 6.11) if their use has been selected during connection establishment (see note 1).

The sending transport entity shall not allocate the same ED-TPDU-NR to successive ED TPDUs (see notes 2 and 3).

When acknowledging an ED TPDU by sending and EA TPDU the transport entity shall put into the YR-EDTU-NR parameter of the EA TPDU the value received in the ED-TPDU-NR parameter of the ED TPDU.

NOTES

1. The negotiation of the variant of expedited data transfer procedure to be used over the transport connection has been designed such that if the initiator proposes the use of the network normal data variant (i.e. the mandatory

implementation option), the responder has to accept use of this option and if the initiator proposes use of the network expedited variant, the responder is entitled to select use of the network normal data variant.

2. This numbering enables the receiving transport entity to discard repeated ED TPDUs when resynchronization (see 6.14) has taken place.

3. No other significance is attached to the ED TPDU-NR parameter. It is recommended, but not essential, that the values used be consecutive modulo 128.

9.2.4 Release

The transport entities shall use the explicit variant of the release procedure (see 6.7).

10 SPECIFICATION FOR CLASS 2 - MULTIPLEXING CLASS

10.1 Functions of class 2

Class 2 provides transport connections with or without individual flow control; no error detection or error recovery is provided.

If the network connection resets or disconnects, the transport connection is terminated without the transport release procedure and the TS-user is informed.

When explicit flow control is used, a credit mechanism is defined allowing the receiver to inform the sender of the exact amount of data he is willing to receive and expedited data transfer is available.

10.2 Procedures for class 2

10.2.1 Procedures applicable at all times

The transport entities shall use the following procedures

a) association of TPDUs with transport connection (see 6.9);

b) TPDU transfer (see 6.2);

c) treatment of protocol errors (see 6.22);

d) concatenation and separation (see 6.4);

e) error release (see 6.8).

Additionally the transport entities may use the following procedure:

f) multiplexing and demultiplexing (see 6.15).

10.2.2 Connection establishment

The transport entities shall use the following procedures:

a) assignment to network connection (see 6.1); then

b) connection establishment (see 6.5) and, if applicable connection refusal (see 6.6).

10.2.3 Data transfer when non use of explicit flow control has been selected

If this option has been selected as a result of the connection establishment, the transport entities shall use the segmenting procedure (see 6.3).

The TPDU-NR field of DT TPDUs is not significant and may take any value.

NOTE- -Expedited data transfer is not applicable (see 6.5).

10.2.4 Data transfer when use of explicit flow control has been selected

10.2.4.1 General

The sending transport entity shall use the following procedures:

a) segmenting (see 6.3); then

b) DT TPDU numbering (see 6.10);

The receiving transport entity shall use the following procedures:

c) DT TPDU numbering (see 6.10); if a DT TPDU is received which is out of sequence it shall be treated as a protocol error; then

d) reassembling (see 6.3).

The variant of the DT TPDU numbering which is used by both transport entities shall be that which was agreed at connection establishment.

10.2.4.2 Flow control

The transport entities shall send an initial credit (which may be zero) in the CDT field of the CR or CC TPDU. This credit represents the initial value of the upper window edge allocated to the peer entity.

The transport entity that receives the CR or the CC TPDU shall consider its lower window edge as zero, and its upper window edge as the value of the CDT field in the received TPDU.

In order to authorize the transmission of DT TPDUs, by its peer, a transport entity may transmit an AK TPDU at any time, subject to the following constraints:

a) the YR-TU-NR parameter shall be at most one greater than the TPDU-NR field of the last received DT TPDU or shall be zero if no DT TPDU has been received;

b) if an AK TPDU has previously been sent the value of the YR-TU-NR parameter shall not be lower than that in the previously sent AK TPDU.

c) the sum of the YR-TU-NR and CDT fields shall not be less than the upper window edge allocated to the remote entity (see note 1).

A transport entity which receives an AK TPDU shall consider the YR-TU-NR field as its new lower window edge, and the sum of YR-TU-NR and CDT as its new upper window edge. If either of these have been reduced or if the lower window edge has become more than one greater than the TPDU-NR of the last transmitted DT TPDU, this shall be treated as a protocol error (see 6.22).

A transport entity shall not send a DT TPDU with a TPDU-NR outside of the transmit window (see notes 2 and 3).

NOTES

1. This means that credit reduction is not applicable.

2. This means that a transport entity is required to stop sending if the TPDU-NR field of the next DT TPDU which would be sent would be the upper window edge. Sending of DT TPDU may be resumed if an AK TPDU is received which increases the upper window edge.

3. The rate at which a transport entity progresses the upper window edge allocated to its peer entity constrains the throughput attainable on the transport connection.

10.2.4.3 Expedited data

The transport entities shall follow the network normal variant of the expedited data transfer procedure in 6.11 if its use has been agreed during connection establishment. ED and EA TPDUs respectively are not subject to the flow control procedures in 10.2.4.2. The ED-TPDU-NR and YR-ETDU-NR fields of ED and EA TPDUs respectively are not significant and may take any value.

10.2.5 Release

The transport entities shall use the explicit variant of the release procedure in 6.7.

11 SPECIFICATION FOR CLASS 3: ERROR RECOVERY AND MULTIPLEXING CLASS

11.1 Functions of Class 3

Class 3 provides the functionality of Class 2 (with use of explicit flow control) plus the ability to recover after a failure signalled by the Network Layer without involving the user of the transport service.

The mechanisms used to achieve this functionality also allow the implementation of more flexible flow control.

11.2 Procedures for Class 3

11.2.1 Procedures applicable at all times

The transport entities shall use the following procedures:

a) association of TPDUs with transport connections (see 6.9);

b) TPDU transfer (see 6.2) and retention until acknowledgement of TPDUs (AK variant only) (see 6.13);

c) treatment of protocol errors (see 6.22);

d) concatenation and separation (see 6.4);

e) reassignment after failure (see 6.12), together with resynchronization (see 6.14);

f) frozen references (see 6.18).

Additionally, the transport entities may use the following procedure:

g) multiplexing and demultiplexing (see 6.15);

11.2.2 Connection Establishment

The transport entities shall use the following procedures;

a) assignment to network connections (see 6.1); then

b) connection establishment (see 6.5) and, if appropriate, together with connection refusal (see 6.6).

11.2.3 Data Transfer

11.2.3.1 General

The sending transport entity shall use the following procedures:

a) segmenting (see 6.3), then

b) DT TPDU numbering (see 6.10); after receipt of an RJ TPDU (see 11.2.3.2) the next DT TPDU to be sent may have a value which is not the previous value of TPDU-NR plus one.

The receiving transport entity shall use the following procedures:

c) DT TPDU numbering (see 6.10); the TPDU-NR field of each received DT TPDU shall be treated as a protocol error if it exceeds the greatest such value received in a previous DT TPDU by more than one (see note); then

d) reassembling (see 6.3); duplicated TPDUs shall be eliminated before reassembling is performed.

NOTE - The use of RJ TPDUs (see 11.2.3.2) can lead to retransmission and reduction of credit. Thus the receipt of a DT TPDU which is a duplicate, or which is greater than or equal to the upper window edge allocated to the peer entity, is possible and is therefore not treated as a protocol error.

11.2.3.2 Use of RJ TPDU

A transport entity may send an RJ TPDU at any time in order to invite retransmission or to reduce the upper window edge allocated to the peer entity (see note 1).

When an RJ TPDU is sent, the following constraints shall be respected:

a) the YR-TU-NR parameter shall be at most one greater than the greatest such value received in a previous DT TPDU, or shall be zero if no DT TPDU has yet been received (see note 2);

b) if an AK or RJ TPDU has previously been sent the YR-TU-NR parameter shall not be lower than that in the previously sent AK or RJ TPDU or lower than zero if no AK or RJ TPDU.

When a transport entity receives an RJ TPDU (see note 3):

c) the next DT TPDU to be transmitted, or retransmitted, shall be that for which the value of the TPDU-NR parameter is equal to the value of the YR-TU-NR parameter of the RJ TPDU;

d) the sum of the values of the YR-TU-NR and CDT parameters of the RJ TPDU becomes the new upper window edge (see note 4).

NOTES

1. An RJ TPDU can also be sent as part of the resynchronization (see 6.14) and reassignment after failure (see 6.12) procedures.

2. It is recommended that the YR-TU-NR parameter be equal to the TPDU-NR parameter of the next expected DT TPDU.

3. These rules are a subset of those specified for when an RJ TPDU is received during resynchronization (see 6.14) and reassignment after failure (see 6.12).

4. This means that RJ TPDU can be used to reduce the upper window edge allocated to the peer entity (credit reduction).

11.2.3.3 Flow Control

The procedures shall be as defined in 10.2.4.2, except that:

a) a credit reduction may lead to the reception of a DT TPDU with a TPDU-NR parameter whose value is not, but would have been less than the upper window edge allocated to the remote entity prior to the credit reduction. This shall not be treated as a protocol error;

b) receipt of an AK TPDU which sets the lower window edge more than one greater than the TPDU-NR of the last transmitted DT TPDU shall not be treated as a protocol error, provided that all acknowledged DT TPDUs have been previously transmitted (see notes 1 and 2).

NOTES

1. This can only occur during retransmission following receipt of an RJ TPDU.

2. The transport entity may either continue retransmission as before or retransmit only those DT TPDUs, not acknowledged by the AK TPDU. In either case, copies of the acknowledged DT TPDUs, need not be retained further.

11.2.3.4 Expedited data

The transport entities shall follow the network normal data variant of expedited data transfer procedure in 6.11 if its use has been agreed during connection establishment.

The sending transport entity shall not allocate the same ED-TPDU-NR to successive ED TPDUs.

The receiving transport entity shall transmit an EA TPDU with the same value in its YR-EDTU-NR parameter. If, and only if, this number is different from that of the previously received ED TPDU shall it generate a T-EXPEDITED DATA indication to convey the data to the TS-user (see note 2).

NOTES

1. No other significance is attached to the ED-TPDU-NR parameter. It is recommended, but not essential, that the values be consecutive modulo 2**n, where n is the number of bits of the parameter.

2. This procedure ensures that the TS-user does not receive data corresponding to the same ED TPDU more than once.

11.2.4 Release

The transport entities shall use the explicit variant of the release procedure in 6.7.

12 SPECIFICATION FOR CLASS 4: ERROR DETECTION AND RECOVERY CLASS

12.1 Functions of Class 4

Class 4 provides the functionality of Class 3, plus the ability to detect and recover from lost, duplicated, or out of sequence TPDUs without involving the TS-user.

This detection of errors is made by extended use of the DT TPDU numbering of Class 2 and Class 3, by time-out mechanisms, and by additional procedures.

This class additionally detects and recovers from damaged TPDUs by using a checksum mechanism. The use of the checksum mechanism must be available but its use or its non-use is subject to negotiation.

Further on this class provides additional resilience against network failure and increased throughput capability by allowing a transport connection to make use of multiple network connections.

12.2 Procedures for Class 4

12.2.1 Procedures available at all times

12.2.1.1 Timers used at all times

This subclause defines timers that apply at all times in class 4. These timers are listed in table 7.

This International Standard does not define specific values for the timers, and the derivations described in this subclause are not mandatory. The values should be chosen so that the required quality of service can be provided, given the known characteristics of the network.

Timers that apply only to specific procedures are defined under the appropriate procedure.

Symbol	Name	Definition
MLR	NSDU lifetime local-to-remote	A bound for the maximum time which may elapse between the transmission of an NSDU by a local transport entity and the receipt of any copy of it by a remote peer entity.
MRL	NSDU lifetime remote-to-local	A bound for the maximum time which may elapse between the transmission of an SNDU from a remote transport entity to a remote peer entity.
ELR	Expected maximum transit delay local-to-remote	A bound for the maximum delay suffered by all but a small proportion of NSDUs transferred from the local transport entity to a remote peer entity.
ERL	Expected maximum transit delay remote-to-local	A bound for the maximum delay suffered by all but a small proportion of NSDUs transferred from a remote transport entity to the local peer entity.
AL	Local acknowledge time	A bound for the maximum time which can elapse between the receipt of a TPDU by the local transport entity from the network layer and the transmission of the corresponding acknowledgement.
AR	Remote acknowledgement time	As AL, but for the remote entity.

Table 7. (First of 2 pages) Time Parameters related to class 4

T1	Local retransmission time	A bound for the maximum time that the local transport entity will wait for acknowledgement before retransmitting a TPDU.
R	Persistence time	A bound for the maximum time the the local transport entity will continue to transmit a TPDU that requires acknowledgement.
N	Maximum number of transmissions	A bound for the maximum number of times which the local transport entity will continue to transmit a TPDU that requires acknowledgement.
L	Bound on references and sequence numbers	A bound for the maximum time between the transmission of a TPDU and the receipt of any acknowledgement relating to it.
I	Inactivity time	A bound for the time after which a transport entity will, if it does not receive a TPDU, initiate the release procedure to terminate the transport connection. NOTE - This parameter is required for protection against unsignalled breaks in the network connection.
W	Window time	A bound for the maximum time a transport entity will wait before retransmitting up to date window information.

Table 7. (Second of 2 pages) Time Parameters related to class 4

12.2.1.1.1 NSDU lifetime (MLR, MRL)

The network layer is assumed to provide, as an aspect of its grade of service, for a bound on the maximum lifetime of NSDUs in the network. This value may be different in each direction of transfer through a network between two transport entities. The values, for both directions of transfer, are assumed to be Known by the transport entities. The maximum NSDU lifetime local-to-remote (MLR) is the maximum time which may elapse between the transmission of an NSDU from the local transport entity to the network and receipt of any copy of the NSDU from the network at the remote transport entity. The maximum NSDU lifetime remote-to-local (MRL) is the maximum time which may elapse between the transmission of an NSDU from the remote transport entity to the network and receipt of any copy of the NSDU from the network at the local transport entity.

12.2.1.1.2 Expected maximum transit delay (ELR, ERL)

The network layer is assumed to provide, as an aspect of its grade of service, an expected maximum transit delay for NSDUs in the network. This value may be different in each direction of transfer through a network between two transport entities. The values, for both directions of transfer, are assumed to be Known by the transport entities. The expected maximum transit delay local-to-remote (ELR) is the maximum delay suffered by all but a small proportion of NSDUs transferred through the network from the local transport entity to the remote transport entity. The expected maximum transit delay remote-to-local (ERL) is the maximum delay suffered by all but a small proportion of NSDUs transfer through the network from the remove transport entity to the local transport entity.

12.2.1.1.3 Acknowledge Time (AR, AL)

Any transport entity is assumed to provide a bound for the maximum time which can elapse between its receipt of a TPDU from the Network Layer and its transmission of the corresponding response. This value is referred to as AL. The corresponding time given by the remote transport entity is referred to as AR.

12.2.1.1.4 Local retransmission time (T1)

The local transport entity is assumed to maintain a bound on the time it will wait for an acknowledgement before retransmitting the TPDU. Its value is given by:

T1 = ELR + ERL + AR + X

where:

ELR = Expected maximum transit delay local-to-remote,
ERL = Expected maximum transit delay remote-to-local,
AR = Remote acknowledge time, and
X   = local processing time for a TPDU.

12.2.1.1.5 Persistence Time (R)

The local transport entity is assumed to provide a bound for the maximum time for which it may continue to retransmit a TPDU requiring positive acknowledgement. This value is referred to as R.

The value is clearly related to the time elapsed between retransmission, T1, and the maximum number of transmissions, N. It is not less than T1 * N + X, where X is a small quantity to allow for additional internal delays, the granularity of the mechanism used to implement T1 and so on. Because R is a bound, the exact value of X is unimportant as long as it is bounded and the value of a bound is known.

12.2.1.1.6 Bound on References and Sequence Numbers (L)

A bound for the maximum time between the decision to transmit a TPDU and the receipt of any response relating to it (L) is given by:

L = MLR + MRL + R + AR

where:

MLR = NSDU lifetime local-to-remote,
MRL = NSDU lifetime remote-to-local,
R = Persistence time, and
AR = Remote acknowledgement time.

It is necessary to wait for a period L before reusing any reference of sequence number, to avoid confusion in case a TPDU referring to it may be duplicated or delayed.

NOTES

1. In practice, the value of L may be unacceptably large. It may also be only a statistical figure at a certain confidence level. A smaller value may therefore be used where this still allows the required quality of service to be provided.

2. The relationships between times discussed above are illustrated in figures 3 and 4.

   [Figures 3 and 4 are omitted from this copy.]

12.2.1.2 General Procedures

The transport entity shall use the following procedures:

a) TPDU transfer (see 6.2);

b) association of TPDUs with transport connections (see 6.9);

c) treatment of protocol errors (see 6.22);

d) checksum (see 6.17);

e) splitting and recombining (see 6.23);

f) multiplexing and demultiplexing (see 6.15);

g) retention until acknowledgement of TPDUs (see 6.13);

h) frozen references (see 6.18).

j) retransmission procedures; when a transport entity has some outstanding TPDUs that require acknowledgement, it will check that no T1 interval elapses without the arrival of a TPDU that acknowledges at least one of the outstanding TPDUs.

   If the timer expires, except if the TPDU to be retransmitted is a DT TPDU and it is outside the transmit window due credit reduction, the first TPDU is retransmitted and the timer is restarted. After N transmissions (i.e. N-1 retransmissions) it is assumed that useful two-way communication is no longer possible and the release procedure is used, and the TS-user is informed.

NOTES

1) This procedure may be implemented by different means. For example:

   a) one interval is associated with each TPDU. If the timer expires the associated TPDU will be transmitted and the timer T1 will be restarted for all subsequent TPDUs; or

   b) one interval is associated with each transport connection:

      1) if the transport entity transmits a TPDU requiring acknowledgement, it starts timer T1;

2) if the transport entity receives a TPDU that acknowledges one of the TPDUs to be acknowledged, it restarts timer T1 unless the received TPDU is an AK which explicitly closes the transmit window.

3) if the transport entity receives a TPDU that acknowledges the last TPDU to be acknowledged, it stops timer T1.

For a decision whether the retransmission timer T1 is maintained on a per TPDU or on a per transport connection basis, throughput considerations have to be taken into account.

2. For DT TPDUs it is a local choice to retransmit either only the first DT TPDU or all TPDUs waiting for an acknowledgement up to the upper window edge.

3. It is recommended that after N transmissions of a DT TPDU, the transport entity waits T1 + W + MRL to provide a higher possibility of receiving an acknowledgement before entering the release phase. For other TPDU types which may be retransmitted, it is recommended that after N transmissions the transport entity waits T1 + MRL to provide a higher possibility of receiving the expected reply.

12.2.2 Procedures for Connection Establishment

12.2.2.1 Timers used in Connection Establishment

There are no timers specific to connection establishment.

12.2.2.2 General Procedures

The transport entities shall use the following procedures:

a) assignment to network connection (see 6.1);

b) connection establishment (see 6.5) and if appropriate connection refusal (see 6.6) together with the additional procedures:

   1) a connection is not considered established until the successful completion of a 3-way TPDU exchange. The sender of a CR TPDU shall respond to the corresponding CC TPDU by immediately sending a DT, ED, DR or AK TPDU;

   2) as a result of duplication or retransmission, a CR TPDU may be received specifying a source reference which is already in use with the sending transport entity. If the receiving transport entity is in the data transfer phase, having completed the 3-way TPDU exchange procedure, or is waiting for the T-CONNECT response from the TS-user, the receiving transport entity shall ignore such a TPDU. Otherwise a CC TPDU shall be transmitted;

   3) as a result of duplication or retransmission, a CC TPDU may be received specifying a paired reference which is already in use. The receiving transport entity shall only acknowledge the duplicate CC TPDU according to the procedure in 12.2.2.2.b.1.

   4) a CC TPDU may be received specifying a reference which is in the frozen state. The response to such a TPDU shall be a DR TPDU;

   5) the retransmission procedures (see 12.2.1.2) are used for both the CR TPDU and CC TPDU.

12.2.3 Procedures for Data Transfer

12.2.3.1 Timers used in Data Transfer

The data transfer procedures use two additional timers:

a) Inactivity Time (I)

To protect against unsignalled breaks in the network connection or failure of the peer transport entity (half-open connections), each transport entity maintains an inactivity interval. The interval must be greater than E.

NOTE - A suitable value for I is given by
2 * (N * maximum of (T1, W))
unless local needs indicate another more appropriate value.

b) Window Time (W)

A transport entity maintains a timer interval to ensure that there is a bound on the maximum interval between window updates.

12.2.3.2 General Procedures for data transfer

The transport entities shall use the following procedures:

a) inactivity control (see 6.21);

b) expedited data (see 6.11);

c) explicit flow control (see 6.16).

The sending transport entity shall use the following procedures in the following order:

d) segmenting (see 6.3);

e) DT TPDU numbering (see 6.10).

The receiving transport entity shall use the following procedures in the following order:

f) DT TPDU numbering (see 6.10);

g) resequencing (see 6.20);

h) reassembling (see 6.3).

12.2.3.3 Inactivity Control

If the interval of the inactivity timer I expires without receipt of some TPDU, the transport entity shall initiate the release procedures. To prevent expiration of the remote transport entity’s inactivity timer when no data is being sent, the local transport entity must send AK TPDUs at suitable intervals in the absence of data, having regard to the probability of TPDU loss. The window synchronization procedures (see 12.2.3.8) ensure that this requirement is met.

NOTE - It is likely that the release procedure initiated due to the expiration of the inactivity timer will fail, as such expiration indicates probable failure of the supporting network connection or of the remote transport entity.

12.2.3.4 Expedited Data

The transport entities shall follow the network normal data variant of the expedited data transfer procedures (see 6.11), if the use of transport expedited service option has been agreed during connection establishment.

The ED TPDU shall have a TPDU-NR which is allocated from a separate sequence space from that of the DT TPDUs.

A transport entity shall allocate the sequence number zero to the ED TPDU-NR of the first ED TPDU which it transmits for a transport connection. For subsequent ED TPDU sent on the same transport connection, the transport entity shall allocate a sequence number one greater than the previous one.

Modulo 2**7 arithmetic shall be used when normal formats have been selected and modulo 2**31 arithmetic shall be used when extended formats have been selected.

The receiving transport entity shall transmit an EA TPDU with the same sequence number in its YR-ETDU-NR field. If this number is one greater than in the previously in sequence received ED TPDU, the receiving transport entity shall transfer the data in the ED TPDU to the TS-user.

If a transport entity does not receive an EA TPDU in acknowledgement to an ED TPDU it shall follow the retransmission procedures (see note and 12.2.1.2).

The sender of an ED TPDU shall not send any new DT TPDU with higher TPDU-NR until it receives the EA TPDU.

NOTE - This procedure ensures that ED TPDUs are delivered to the TS-user in sequence and that the TS-user does not receive data corresponding to the same ED TPDU more than once. Also it guarantees the arrival of the ED TPDU before any subsequently sent DT TPDU.

12.2.3.5 Resequencing

The receiving transport entity shall deliver all DT TPDUs to the TS-user in the order specified by the sequence number field.

DT TPDUs received out-of-sequence but within the transmit window shall not be delivered to the TS-user until all in-sequence TPDUs have been received. DT TPDU received out-of-sequence and outside the transmit window shall be discarded.

Duplicate TPDUs can be detected because the sequence number matches that of preciously received TPDUs. Sequence numbers shall not be reused for the period L after their previous use.

Otherwise, a new, valid TPDU could be confused with a duplicated TPDU which had previously been received and acknowledged.

Duplicated DT TPDUs shall be acknowledged, since the duplicated TPDU may be the result of a retransmission resulting from the loss of an AK TPDU.

The data contained in a duplicated DT TPDU shall be ignored.

12.2.3.6 Explicit Flow Control

The transport entities shall send an initial credit (which may take the value 0) in the CDT field of the CR TPDU or CC TPDU. This credit represents the initial value of the upper window edge of the peer entity.

The transport entity which receives the CR TPDU or CC TPDU shall consider its lower window edge as zero and its upper window edge as the value in the CDT field in the received TPDU.

In order to authorize the transmission of DT TPDUs by its peer, a transport entity may transmit an AK TPDU at any time.

The sequence number of an AK TPDU shall not exceed the sequence number of the next expected DT TPDU, i.e. it shall not be greater than the highest sequence number of a received DT TPDU, plus one.

A transport entity may send a duplicate AK TPDU containing the same sequence number, CDT, and subsequence number field at any time.

A transport entity which receives an AK TPDU shall consider the value of the YR-TU-NR field as its new lower window edge if it is greater than any previously received in a YR-TU-NR field, and the sum of YR-TU-NR and CDT as its new upper window edge subject to the procedures for sequencing AK TPDUs (see 12.2.3.8). A transport entity shall not transmit or retransmit a DT TPDU with a sequence number outside the transmit window.

12.2.3.7 Sequencing of received AK TPDUs

To allow a receiving transport entity to properly sequence a series of AK TPDUs that all contain the same sequence number and thereby use the correct CDT value, AK TPDUs may contain a subsequence parameter. For the purpose of determining the correct sequence of AK TPDUs, the absence of the subsequence parameter shall be equivalent to the value of the parameter set to zero.

An AK TPDU is defined to be in sequence if:

a) the sequence number is greater than in any previously received AK TPDU, or

b) the sequence number is equal to the highest in any previously received AK TPDU, and the subsequence parameter is greater than in any previously received AK TPDU having the same value for YR-TU-NR field, or

c) the sequence number and subsequence parameter are both equal to the highest in any previously received AK TPDU and the credit field is greater than or equal to that in any previously received AK TPDU having the same YR-TU-NR field.

A transport entity is not required to include the subsequence number in its AK TPDUs. It may also choose not to use the subsequence parameter in sequencing received AK TPDUs. If a transport entity chooses not to recognize the subsequence parameter it shall still sequence received AK TPDUs according to 12.2.3.7.a.

When the receiving transport entity recognizes an out of sequence AK TPDU it shall ignore it.

12.2.3.8 Procedure for transmission of AK TPDUs

12.2.3.8.1 Retransmission of AK TPDUs for window synchronization

A transport entity shall not allow an interval W to pass without the transmission of an AK TPDU. if the transport entity is not using the procedure following setting CDT to zero (see 12.2.3.8.3) or reduction of the upper window edge (see 12.2.3.8.4), and does not have to acknowledge receipt of any DT TPDU, then it shall achieve this by retransmission of the most recent AK TPDU, with up-to-date window information.

NOTE - The use of the procedures defined in 12.2.3.8.3 and 12.2.3.8.4 are optional for any transport entity. The protocol operates correctly either with or without these procedures which are defined to enhance the efficiency of its operation. However, if these procedures are not used then W must be set to ensure enough retransmissions of the AK TPDU so that release of TC is avoided. The value of W should be approximately W = (T1 * N)/(N-1) when the procedures are not used.

12.2.3.8.2 Sequence control for transmission of AK TPDUs

To allow the receiving transport entity to process AK TPDUs in the correct sequence, as described in 12.2.3.7, the subsequence parameter may be included following reduction of CDT. If the value of the subsequence number to be transmitted is zero, then the parameter should be omitted.

The value of the subsequence parameter, if used, shall be zero (either explicitly or by absence of the parameter) if the sequence number is greater than the field in previous AK TPDUs, sent by the transport entity.

If the sequence number is the same as the previous AK TPDU sent and the CDT field is equal to or greater than the CDT field in the previous AK TPDU sent then the subsequence parameter, if used, shall be equal to that in the previously sent AK TPDU.

If the sequence number is the same as the previous AK TPDU sent and the CDT field is less than the value of the CDT field in the previous AK TPDU sent than the subsequence parameter, if used, shall be one greater than the value in the previous AK TPDU..

12.2.3.8.3 Retransmission of AK TPDUs after CDT set to zero

Due to the possibility of loss of AK TPDUs, the upper window edge as perceived by the transport entity transmitting an AK TPDU may differ from that perceived by the intended recipient. To avoid the possibility of extra delay, the retransmission procedure (see 12.2.1.2) should be followed for an AK TPDU, if it opens the transmit window which has previously been closed by sending an AK TPDU with CDT field set to zero.

The retransmission procedure, if used, terminates and the procedure in 12.2.3.8.1 is used when:

a) an AK TPDU is received containing the flow control confirmation parameter, whose lower window edge and your subsequence fields are equal to the sequence number and subsequence number in the retained AK TPDU and whose credit field is not zero.

b) an AK TPDU is transmitted with a sequence number higher than that in the retained AK TPDU, due to reception of a DT TPDU whose sequence number is equal to the lower window edge;

c) N transmissions of the retained AK TPDU have taken place. In this case the transport entity shall continue to transmit the AK TPDU at an interval of W.

An AK TPDU which is subject to the retransmission procedure shall not contain the flow control confirmation parameter. If it is required to transmit this parameter concurrently, an additional AK TPDU shall be transmitted having the same values in the sequence, subsequence (if applicable) and credit fields.

12.2.3.8.4 Retransmission procedures following reduction of the upper window edge

This subclause specifies the procedure for retransmission of AK TPDUs after a transport entity has reduced the upper window edge (see 12.2.3.6) or for an AK TPDU with the credit field set to zero. This procedure is used until the lower window edge exceeds the highest value of the upper window edge ever transmitted (i.e. the value existing at the time of credit reduction, unless a higher value is retained from a previous credit reduction).

This retransmission procedure should be followed for any AK TPDU which increases the upper window edge, unless an AK TPDU has been received containing a flow control confirmation parameter, which corresponds to an AK TPDU transmitted following credit reduction, for which the sum of the credit and lower window edge fields (i.e. the upper window edge value) is greater than the lower window edge (YR-TU-NR field) of the transmitted AK TPDU.

This retransmission procedure for any particular AK TPDU shall terminate when:

a) an AK TPDU is received containing the flow control confirmation parameter, whose lower window edge and your subsequence fields are equal to the lower window edge and subsequence number in the retained AK TPDU; or

b) N transmissions of the retained AK TPDU have taken place. In this case the transport entity shall continue to transmit the AK TPDU at an interval of W.

An AK TPDU which is subject to the retransmission procedure shall not contain the flow control confirmation parameter. If it is required to transmit this parameter concurrently, an additional AK TPDU shall be transmitted having the same values in the sequence, subsequence (if applicable) and credit fields.

NOTE - Retransmission of AK TPDUs is normally not necessary, except following explicit closing of the window (i.e. transmission of an AK TPDU with CDT field set to zero). If data is available to be transmitted, the retransmission procedure for DT TPDUs will ensure that an AK TPDU is received granting further credit where this is available. Following credit reduction, this may no longer be so, because retransmission may be inhibited by the credit reduction. The rules described in this clause avoid extra delay.

The rules for determining whether to apply the retransmission procedure to an AK TPDU may be expressed alternatively as follows. Let:

LWE = lower window edge
UWE = upper window edge
KUWE = lower bound on upper window edge held by remote transport entity

The retransmission procedure is to be used whenever:

(UWE>LWE) and (KUWE = LWE)

i.e. when the window is opened and it is not known definitely that the remote transport entity is aware of this.

KUWE is maintained as follows. When credit is reduced, KUWE is set to LWE. Subsequently, it is increased only upon receipt of a valid flow control confirmation (i.e. one which matches the retained lower window edge and subsequence). In this case KUWE is set to the implied upper window edge of the flow control confirmation, i.e. the sum of its lower window edge and your credit fields. By this means, it can be ensured that KUWE is always less than or equal to the actual upper window edge in use by the transmitter of DT TPDUs.

12.2.3.9 Use of Flow Control Confirmation parameter

At any time, an AK TPDU may be transmitted containing a flow control confirmation parameter. The lower window edge, your subsequence and your credit fields shall be set to the same values as the corresponding fields in the most recently received in sequence AK TPDU.

An AK TPDU containing a flow control confirmation parameter should be transmitted whenever:

a) a duplicate AK TPDU is received, with the value of YR-TU-NR, CDT, and subsequence fields equal to the most recently received AK TPDU, but not itself containing the flow control confirmation parameter;

b) an AK TPDU is received which increases the upper window edge but not the lower window edge, and the upper window edge was formerly equal to the lower window edge; or

c) an AK TPDU is received which increases the upper window edge but not the lower window edge, and the lower window edge is lower than the highest value of the upper window edge received and subsequently reduced (i.e. following credit reduction).

12.2.4 Procedures for Release

12.2.4.1 Timers used for Release

There are no timers used only for release.

12.2.4.2 General Procedures for Release

The transport entity shall use the explicit variant of normal release (see 6.7).

13 STRUCTURE AND ENCODING OF TPDUs

13.1 Validity

Table 8 specifies those TPDUs which are valid for each class and the code for each TPDU.

KEY:

xxxx (bits 4-1):	used to signal the CDT (set to 0000 in classes 0 and 1)
zzzz (bits 4-1):	used to signal CDT in classes 2, 3, 4 set to 1111 in class 1
NF:	Not available when the non explicit flow control option is selected.
NRC:	Not available when the receipt confirmation option is selected.

NOTE - These codes are already in use in related protocols defined by standards oganizations other than CCITT/ISO.

	Validity within classes					see Clause	Code
	0	1	2	3	4		
CR Connection Request	x	x	x	x	x	13.3	1110 xxxx
CC Connection Confirm	x	x	x	x	x	13.4	1101 xxxx
DR Disconnect Request	x	x	x	x	x	13.5	1000 0000
DC Disconnect Confirm		x	x	x	x	13.6	1100 0000
DT Data	x	x	x	x	x	13.7	1111 0000
ED Expedited Data		x	NF	x	x	13.8	0001 0000
AK Data Acknowledgement		NRC	NF	x	x	13.9	0110 zzzz
EA Expedited Data Acknowledgement		x	NF	x	x	13.10	0010 0000
RJ Reject		x		x		13.11	0101 zzzz
ER TPDU Error	x	x	x	x	x	13.12	0111 0000
not available (see note)						-	0000 0000
						-	0011 0000
						-	1001 xxxx
						-	1010 xxxx

Table 8. TPDU code

13.2 Structure

All the transport protocol data units (TPDUs) shall contain an integral number of octets. The octets in a TPDU are numbered starting from 1 and increasing in the order they are put into an NSDU. The bits in an octet are numbered from 1 to 8, where bit 1 is the low-ordered bit.

When consecutive octets are used to represent a binary number, the lower octet number has the least significant value.

NOTE - When the encoding of a TPDU is represented using a diagram in this clause, the following representation is used:

a) octets are shown with the lowest numbered octet to the left, higher numbered octets being further to the right;

b) within an octet, bits are shown with bit 8 to the left and bit 1 to the right.

TPDUs shall contain, in the following order:

a) the header, comprising:

   1) the length indicator (LI) field;

   2) the fixed part;

   3) the variable part, if present;

b) the data field, if present.

This structure is illustrated below:

```
     octet    1   2 3 4 ... n   n+1  ...    p  p+1 ...end
            +---+-------------+--------------+-----------+
            | LI| fixed part  | variable part| data field|
            +---+-------------+--------------+-----------+
            <---------------   header ------>
```

13.2.1 Length indicator field

This field is contained in the first octet of the TPDUs. The length is indicated by a binary number, with a maximum value of 254 (1111 1110). The length indicated shall be the header length in octets including parameters, but excluding the length indicator field and user data, if any. The value 255 (1111 1111) is reserved for possible extensions. If the length indicated exceeds the size of the NS-user data which is present, this is a protocol error.

13.2.2 Fixed part

13.2.2.1 General

The fixed part contains frequently occurring parameters including the code of the TPDU. The length and the structure of the fixed part are defined by the TPDU code and in certain cases by the protocol class and the formats in use (normal or extended). If any of the parameters of the fixed part have an invalid value, or if the fixed part cannot be contained with the header (as defined by LI) this is a protocol error.

NOTE - In general, the TPDU code defines the fixed part unambiguously. However, different variants may exist for the same TPDU code (see normal and extended formats).

13.2.2.2 TPDU code

This field contains the TPDU code and is contained in octet 2 of the header. It is used to define the structure of the remaining header. This field is a full octet except in the following cases:

```
1110 xxxx     Connection Request
1101 xxxx     Connection Confirm
0101 xxxx     Reject
0110 xxxx     Data Acknowledgement
```

where xxxx (bits 4-1) is used to signal the CDT.

Only those codes defined in 13.1 are valid.

13.2.3 Variable part

The variable part is used to define less frequently used parameters. If the variable part is present, it shall contain one or more parameters.

NOTE - The number of parameters that may be contained in the variable part is indicated by the length of the variable part which is LI minus the length of the fixed part.

Each parameter contained within the variable part is structured as follows:

```
               Bits   8    7    6    5    4    3    2    1
     Octets          +-------------------------------------+
      n+1            |          Parameter Code              |
                     |--------------------------------------|
      n+2            |          Parameter Length            |
                     |          Indication (e.g. m)         |
                     |--------------------------------------|
      n+3            |                                      |
                     |          Parameter Value             |
      n+2+m          |                                      |
                     +--------------------------------------|
```

- The parameter code field is coded in binary;

  NOTE - Without extensions, it provides a maximum number of 255 different parameters. However, as noted below, bits 8 and 7 cannot take every possible value, so the practical maximum number of different parameters is less. Parameter code 1111 1111 is reserved for possible extensions of the parameter code.

- The parameter length indication indicates the length, in octets, of the parameter value field.

  NOTE - The length is indicated by a binary number, m, with a theoretical maximum value of 255. The practical maximum value of m is lower. For example, in the case of a single parameter contained within the variable part, two octets are required for the parameter code and the parameter length indication itself. Thus, the value of m is limited to 248. For larger fixed parts of the header and for each succeeding parameter, the maximum value of m decreases.

- The parameter value field contains the value of the parameter identified in the parameter code field.

- No parameter codes use bits 8 and 7 with the value 00.

- The parameters defined in the variable part may be in any order. If any parameter is duplicated then the later value shall be used. A parameter not defined in this International Standard shall be treated as a protocol error in any received TPDU except a CR TPDU; in a CR TPDU it shall be ignored. If the responding transport entity selects a class for which a parameter of the CR TPDU is not defined, it may ignore this parameter, except the class and option, and alternative protocol class parameters which shall always be interpreted. A parameter defined in this International Standard but having an invalid value shall be treated as a protocol error in any received TPDU except a CR TPDU. In a CR TPDU it shall be treated as a protocol error if it is either the class and option parameter or the alternative class parameter or the additional option parameter; otherwise it shall be either ignored or treated as a protocol error.

13.2.3.1 Checksum Parameter (Class 4 only)

All TPDU types may contain a 16-bit checksum parameter in their variable part. This parameter shall be present in a CR TPDU and shall be present in all other TPDUs except when the non use of checksum option is selected.

```
Parameter Code:    1100 0011
Parameter Length:  2
Parameter Value:   Result of checksum algorithm.  This algorithm
                   is specified in 6.17.
```

13.2.4 Data Field

This field contains transparent user data. Restrictions on its size are noted for each TPDU.

13.3 Connection Request (CR) TPDU

The length of the CR TPDU shall not exceed 128 octets.

13.3.1 Structure

The structure of the CR TPDU shall be as follows:

```
 1    2        3        4       5   6    7    8    p  p+1...end
+--+------+---------+---------+---+---+------+-------+---------+
|LI|CR CDT|     DST - REF     |SRC-REF|CLASS |VARIAB.|USER     |
|  |1110  |0000 0000|0000 0000|   |   |OPTION|PART   |DATA     |
+--+------+---------+---------+---+---+------+-------+---------+
```

13.3.2 LI

See 13.2.1

13.3.3 Fixed Part (Octets 2 to 7)

The structure of this part shall contain:

a) CR : Connection Request Code: 1110. Bits 8-5 of octet 2;

b) CDT : Initial Credit Allocation (set to 0000 in Classes 0 and 1 when specified as preferred class). Bits 4-1 of octet 2;

c) DST-REF : Set to zero;

d) SRC-REF : Reference selected by the transport entity initiating the CR TPDU to identify the requested transport connection;

e) CLASS and OPTION: Bits 8-5 of octet 7 defines the preferred transport protocol class to be operated over the requested transport connection. This field shall take one of the following values:

0000	Class 0
0001	Class 1
0010	Class 2
0011	Class 3
0100	Class 4

The CR TPDU contains the first choice of class in the fixed part. Second and subsequent choices are listed in the variable part if required.

Bits 4-1 of octet 7 define options to be used on the requested transport connection as follows:

BIT	OPTION	
4	0	always
3	0	always
2	=0	use of normal formats in all classes
	=1	use of extended formats in Classes 2,3,4
1	=0	use of explicit flow control in Class 2
	=1	no use of explicit flow control in Class 2

NOTES

1. The connection establishment procedure (see 6.5) does not permit a given CR TPDU to request use of transport expedited data transfer service (additional option parameter) and no use of explicit flow control in Class 2 (bit 1 = 1).

2. Bits 4 to 1 are always zero in Class 0 and have no meaning.

13.3.4 Variable Part (Octets 8 to p)

The following parameters are permitted in the variable part:

a) Transport Service Access Point Identifier (TSAP-ID)

Parameter code:	1100 0001 for the identifier of the Calling TSAP. 1100 0010 for the identifier of the Called TSAP
Parameter length:	not defined in this standard
Parameter value:	identifier of the calling or called TSAP respectively.

If a TSAP-ID is given in the request it may be returned in the confirmation.

b) TPDU size

This parameter defines the proposed maximum TPDU size (in octets including the header) to be used over the requested transport connection. The coding of this parameter is:

Parameter code: 1100 0000
Parameter Length: 1 octet

Parameter value:

0000 1101 8192 octets (not allowed in Class 0)
0000 1100 4096 octets (not allowed in Class 0)
0000 1011 2048 octets
0000 1010 1024 octets
0000 1001 512 octets
0000 1000 256 octets
0000 0111 128 octets

Default value is 0000 0111 (128 octets)

c) Version Number (not used if Class 0 is the preferred class)

Parameter code: 1100 0100
Parameter length: 1 octet
Parameter value field: 0000 0001

Default value is 0000 0001 (not used in Class 0)

d) Security Parameters (not used if Class 0 is the preferred class)

This parameter is user defined.
Parameter code: 1100 0101
Parameter length: user defined
Parameter value: user defined

e) Checksum (used only if class 4 is the preferred class) (see 13.2.3.1)

This parameter shall always be present in a CR TPDU requesting Class 4, even if the checksum selection parameter is used to request non-use of the checksum facility.

f) Additional Option Selection (not used if Class 0 is the preferred class)

This parameter defines the selection to be made as to whether or not additional options are to be used.

Parameter code: 1100 0110
Parameter length: 1
Parameter value:

BIT	OPTION
4	1= Use of network expedited in Class 1 0= Non use of network expedited in Class 1
3	1= Use of receipt confirmation in Class 1 0= Use of explicit AK variant in Class 1
2	0= 16-bit checksum defined in 6.17 is to be used in Class 4 1= 16-bit checksum defined in 6.17 is not to be used on Class 4
1	1= Use of transport expedited data transfer service 0= No use of transport expedited data transfer service

Default value is 000 0001

Bits related to options particular to a class are not meaningful if that class is not proposed and may take any value.

g) Alternative protocol class(es) (not used if Class 0 is the preferred class)

Parameter code: 1100 0111
Parameter length: n

Parameter value encoded as a sequence of single octets. Each octet is encoded as for octet 7 but with bits 4-1 set to zero (i.e. no alternative option selections permitted).

h) Acknowledge Time (used only if class 4 is the preferred class)

This parameter conveys the maximum acknowledge time AL to the remote transport entity. It is an indication only, and is not subject to negotiation (see 12.2.1.1.3)
Parameter code: 1000 0101
Parameter length: 2
Parameter value: n, a binary number where n is the maximum acknowledge time, expressed in milliseconds.

j) Throughput (not used if class 0 is the preferred class)

Parameter code: 1000 1001
Parameter length: 12 or 24
Parameter value:

1st 12 Octets: maximum throughput, as follows:

1st 3 octets: Target value, calling-called user direction
2nd 3 octets: Min. acceptable, calling-called user direction
3rd 3 octets: Target value, called-calling user direction
4th 3 octets: Min. acceptable, called-calling user direction

2nd 12 octets (optional): average throughput, as follows:

5th 3 octets: Target value, calling-called user direction

6th 3 octets:	Min. acceptable, calling-called user direction
7th 3 octets:	Target value, called-calling user direction
8th 3 octets:	Min. acceptable, called-calling user direction

Where the average throughput is omitted, it is considered to have the same value as the maximum throughput.

Values are expressed in octets per second.

k) Residual error rate (not used if class 0 is the preferred class)

Parameter code:	1000 1001
Parameter length:	12
1st 3 octets:	Target value, calling-called user direction
2nd 3 octets:	Min. acceptable, calling-called user direction
3rd 3 octets:	Target value, called-calling user direction
4th 3 octets:	Min. acceptable, called-calling user direction

l) Residual error rate (not used if class 0 is the preferred class)

Parameter code:	1000 0110
Parameter length:	3
Parameter value:	
1st octet:	Target value, power of 10
2nd octet:	Min. acceptable, power of 10
3rd octet:	TSDU size of interest, expressed as a power of 2

m) Priority (not used if class 0 is the preferred class)

Parameter code:	1000 0111
Parameter length:	2
Parameter value:	Integer (0 is the highest priority)

n) Transit delay (not used if class 0 is the preferred class)

Parameter code: 1000 1000
Parameter length: 8
Parameter value:

1st 2 octets:	Target value, calling-called user direction
2nd 2 octets:	Max. acceptable, calling-called user direction
3rd 2 octets:	Target value, called-calling user direction
4th 2 octets:	Max. acceptable, called-calling user direction

Values are expressed in milliseconds, and are based upon a TSDU size of 128 octets.

p) assignment time (not used if class 0, 2 or class 4 is the preferred class)

This parameter conveys the Time to Try Reassignment (TTR) which will be used when following the procedure for Reassignment after Failure (see 6.12).
Parameter code: 1000 1011
Parameter length: 2
Parameter value: n, a binary number where n is the TTR value expressed in seconds.

13.3.5 User Data (Octets p+1 to the end)

No user data are permitted in Class 0, and are optional in the other classes. Where permitted, it may not exceed 32 octets.

13.4 Connection Confirm (CC) TPDU

13.4.1 Structure

The structure of the CC TPDU shall be as follows:

```
  1      2     3   4   5   6     7     8     p   p+1 ...end
+---+----+---+---+---+---+---+-------+--------+-------------+
|LI | CC  CDT|DST-REF|SRC-REF| CLASS |VARIABLE| USER        |
|   |1101|   |   |   |   |   | OPTION|  PART  | DATA        |
+---+----+---+---+---+---+---+-------+--------+-------------+
```

13.4.2 LI

See 13.2.1

13.4.3 Fixed Part (Octets 2 to 7)

The fixed part shall contain:

a) CC: Connection Confirm Code: 1101. Bits 8-5 of octet 2;

b) CDT: Initial Credit Allocation (set to 0000 in Classes 0 and 1). Bits 4-1 of octet 2;

c) DST-REF: Reference identifying the requested transport connection at the remote transport entity;

d) SRC-REF: Reference identifying the requested transport connection at the remote transport entity.

e) Class and Option: Defines the selected transport protocol class and option to be operated over the accepted transport connection according to the negotiation rules specified in 6.5;

13.4.4 Variable Part (Octet 8 to p)

The parameters are defined in 13.3.4 and are subject to the constraints states in 6.5 (connection establishment). Parameters ruled out by selection of an alternative class and option shall not be present.

13.4.5 User Data (Octets p+1 to the end)

No user data are permitted in class 0, and are optional in the other classes. Where permitted, it may not exceed 32 octets. The user data are subject to the constraints of the negotiation rules (see 6.5).

13.5 Disonnect Request (DR) TPDU

13.5.1 Structure

The structure of the DR TPDU shall be as follows:

```
  1     2      3     4    5     6     7    8     p   p+1 ...end
+--+---------+----+-----+----+-----+------+--------+----------+
|LI|    DR   | DST-REF. | SRC-REF. |REASON|VARIABLE| USER     |
|  |1000 0001|    |     |    |     |      |  PART  | DATA     |
+--+---------+----+-----+----+-----+------+--------+----------+
```

13.5.2 LI

See Section 13.2.1

13.5.3 Fixed Part (Octets 2 to 7

The fixed part shall contain:

a) DR: Disconnect Request Code: 1000 0000;

b) DST-REF: Reference identifying the transport connection at the remote transport entity;

c) SRC-REF: Reference identifying the transport connection at the transport entity initiating the TPDU. Value zero when reference is unassigned;

d) REASON: Defines the reason for disconnecting the transport connection. This field shall take one of the following values:

The following values may be used for Classes 1 to 4:

1) 128 + 0 - Normal disconnect initiated by session entity
2) 128 + 1 - Remote transport entity congestion at connect request time
3) *128 + 2 - Connection negotiation failed (i.e. proposed class(es) not supported)
4) 128 + 3 - Duplicate source reference detected for the same pair of NSAPS.
5) 128 + 4 - Mismatched references
6) 128 + 5 - Protocol error
7) 128 + 6 - Not used
8) 128 + 7 - Reference overflow
9) 128 + 8 - Connection request refused on this network connection
10) 128 + 9 - Not used
11) 128 + 10- Header or parameter length invalid

The following values can be used for all classes:

12) 0 - Reason not specified
13) 1 - Congestion at TSAP
14) *2 - Session entity not attached to TSAP
15) *3 - Address unknown

NOTE - Reasons marked with an asterisk (*) may be reported to the TS-user as persistent, other reasons as transient.

13.5.4 Variable Part (Octets 8 to p)

The variable part may contain

a) A parameter allowing additional information related to the clearing of the connection.

Parameter code:	1110 0000
Parameter length:	Any value provided that the length of the DR TPDU does not exceed the maximum agreed TPDU size or 128 when the DR TPDU is used during the connection refusal procedure
Parameter value:	Additional information. The content of this field is user defined.

b) Checksum (see 13.2.3.1)

13.5.5 User Data (Octets p+1 to the end)

This field shall not exceed 64 octets and is used to carry TS-user data. The successful transfer of this data is not guaranteed by the transport protocol. When a DR TPDU is used in Class 0 it shall not contain this field.

13.6 Disconnect Confirm (DC) TPDU

This TPDU shall not be used in Class 0.

13.6.1 Structure

The structure of DC TPDU shall be as follows:

```
  1       2         3     4     5     6    7        p
+----+-----------+-----+-----+-----+-----+-------+--------+
| LI |    DC     |  DST REF  |  SRC REF  | Variable Part  |
|    | 1100 0000 |     |     |     |     |       |        |
+----+-----------+-----+-----+-----+-----+-------+--------+
```

13.6.2 LI

See 13.2.1

13.6.3 Fixed Part (Octets 2 to 6)

The fixed part shall contain:

a) DC: Disconnect Confirm Code: 1100 0000;

b) DST-REF: See 13.4.3;

c) SRC-REF: See 13.4.3.

13.6.4 Variable Part

The variable part shall contain the checksum parameter if the condition in (see 13.2.3.1) applies.

13.7 Data (DT) TPDU

13.7.1 Structure

Depending on the class and the option the DT TPDU shall have one of the following structures.

a) Normal format for Classes 0 and 1

```
  1       2         3          4       5             ... end
+----+-----------+-----------+----------- - - - - - -------+
| LI |    DT     |  TPDU-NR  | User Data                   |
|    | 1111 0000 |  and EOT  |                             |
+----+-----------+-----------+----------- - - - - - -------+
```

b) Normal format for Classes 2, 3 and 4

```
  1      2       3   4     5     6       p    p+1       ... end
+----+---------+---+---+-------+-----+-------+---------- - - -+
| LI |   DT    |DST-REF|TPDU-NR|Variable Part|User Data        |
|    |1111 0000|   |   |and EOT|     |       |                 |
+----+---------+---+---+-------+-----+-------+---------- - - -+
```

c) Extended Format for use in Classes 2, 3 and 4 when selected during connection establishment.

```
  1      2       3   4   5,6 7,8  9     p  p+1      ... end
+----+---------+---+---+---------+--------+--------- - - -+
| LI |   DT    |DST-REF| TPDU-NR |Variable|User Data       |
|    |1111 0000|   |   | and EOT |  Part  |                |
+----+---------+---+---+---------+--------+--------- - - -+
```

13.7.2 LI

See 13.2.1

13.7.3 Fixed Part

The fixed part shall contain:

a) DT: Data Transfer Code: 1111 0000;

b) DST-REF: See 13.4.3;

c) EOT: When set to ONE, indicates that the current DT TPDU is the last data unit of a complete DT TPDU sequence (End of TSDU). EOT is bit 8 of octet 3 in class 0 and 1, bit 8 of octet 5 for normal formats for classes 2, 3 and 4 and bit 8 of octet 8 for extended formats;

d) TPDU-NR: TPDU send Sequence Number (zero in Class 0). May take any value in Class 2 without explicit flow control. TPDU-NR is bits 7-1 of octet 3 for classes 0 and 1, bits 7-1 of octet 5 for normal formats in classes 2, 3 and 4, octets 5, 6 and 7 together with bits 7-1 of octet 8 for extended formats.

NOTE - Depending on the class, the fixed part of the DT TPDU uses the following octets:

Classes 0 and 1:	Octets 2 to 3;
Classes 2,3,4 normal format:	Octets 2 to 5;
Classes 2,3,4 extended format:	Octets 2 to 8.

13.7.4 Variable Part

The variable part shall contain the checksum parameter if the condition in see 13.2.3.1 applies.

13.7.5 User Data Field

This field contains data of the TSDU being transmitted.

NOTE - The length of this field is limited to the negotiated TPDU size for this transport connection minus 3 octets in Classes 0 and 1, and minus 5 octets (normal header format) or 8 octets (extended header format) in the other classes. The variable part, if present, may further reduce the size of the user data field.

13.8 Expedited Data (ED) TPDU

The ED TPDU shall not be used in Class 0 or in Class 2 when the no explicit flow control option is selected or when the expedited data transfer service has not been selected for the connection.

13.8.1 Structure

Depending on the format negotiated at connection establishment the ED TPDU shall have one of the following structures:

a) Normal Format (classes 1, 2, 3, 4)

```
 1     2       3   4      5     6        p    p+1     ... end
+--+---------+---+---+---------+-----+-------+---------------+
|LI|   ED    |DST-REF|EDTPDU-NR|Variable Part|User Data      |
|  |0001 0000|   |   |and EOT  |     |       |               |
+--+---------+---+---+---------+-----+-------+---------------+
```

b) Extended Format (for use in classes 2, 3, 4 when selected during connection establishment).

```
 1     2       3   4   5,6,7,8  9        p    p+1     ... end
+--+---------+---+---+---------+-----+-------+---------------+
|LI|   ED    |DST-REF|EDTPDU-NR|Variable Part|User Data      |
|  |0001 0000|   |   |and EOT  |     |       |               |
+--+---------+---+---+---------+-----+-------+---------------+
```

13.8.2 LI

See 13.2.1

13.8.3 Fixed Part

The fixed part shall contain:

a) ED: Expedited Data code: 0001 0000;

b) DST-REF: see 13.4.3;

c) ED-TPDU-NR: Expedited TPDU identification number. ED-TPDU-NR is used in classes 1, 3 and 4 and may take any value in Class 2. Bits 7-1 of octet 5 for normal formats and octets 5, 6 and 7 together with bits 7-1 of octet 8 for extended formats;

d) EOT: end of TSDU always set to 1 (bit 8 of octet 5 for normal formats and bit 8 of octet 8 for extended formats).

NOTE - Depending on the format the fixed part shall be either octets 2 to 5 or 2 to 8.

13.8.4 Variable Part

The variable part shall contain the checksum parameter if the condition defined in 13.2.3.1 applies.

13.8.5 User Data Field

This field contains an expedited TSDU (1 to 16 octets).

13.9 Data Acknowledgement (AK) TPDU

This TPDU shall not be used for Class 0 and Class 2 when the "no explicit flow control" option is selected, and for Class 1 when the network receipt confirmation option is selected.

13.9.1 Structure

Depending on the class and option agreed the AK TPDU shall have one of the following structures:

a) Normal Format (classes 1, 2, 3, 4)

```
 1     2      3     4        5        6        p
+--+--------+----------+------------+---------------+
|LI| AK CDT | DST-REF  |  YR-TU-NR  | Variable Part |
|  | 0110   |          |            |               |
+--+--------+----------+------------+---------------+
```

b) Extended Format (for use in classes 2, 3, 4 when selected during connection establishment).

```
 1      2      3     4    5,6,7,8   9,10 11    p
+--+---------+---------+----------+-----+--------+
|LI|    AK   | DST-REF | YR-TU-NR | CDT |Variable|
|  |0110 0000|         |          |     |  Part  |
+--+---------+---------+----------+-----+--------+
```

13.9.2 LI

See 13.2.1

13.9.3 Fixed Part

The fixed part shall contain (in octet 2 to 5 when normal format is used, 2 to 10 otherwise) the following parameters:

a) AK: Acknowledgement code: 0110;

b) CDT: Credit Value (set to 1111 in class 1). Bits 4-1 of octet 2 for normal formats and octets 9 and 10 for extended formats;

c) DST-REF: See 13.4.3;

d) YR-TU-NR: Sequence number indicating the next expected DT TPDU number. For normal formats, bits 7-1 of octet 5; bit 8 of octet 5 is not significant and shall take the value 0. For extended formats, octets 5, 6 and 7 together with bits 7-1 of octet 8; bit 8 of octet 8 is not significant and shall take the value 0.

13.9.4 Variable Part

The variable part contains the following parameters:

a) Checksum See 13.2.3.1 if the condition in 13.2.3.1 applies;

b) Subsequence number when optionally used under the conditions defined in class 4. This parameter is used to ensure that AK TPDUs are processed in the correct sequence. If it is absent, this is equivalent to transmitting the parameter with a value of zero.
Parameter code: 1000 1010
Parameter length: 2
Parameter value: 16-bit sub-sequence number;

c) Flow Control Confirmation Class 4 when optionally used under the conditions defined in class 4. This parameter contains a copy of the information received in an AK TPDU, to allow the transmitter of the AK TPDU to be certain of the state of the receiving transport entity (see 12.2.3.10).
Parameter code: 1000 1011
Parameter length: 8
Parameter value: defined as follows

1. Lower Window Edge (32 bits)
Bit 8 of octet 4 is set to zero, the remainder contains the YR-TU-NR value of the received AK TPDU. When normal format has been selected, only the least significant seven bits (bits 1 to 7 of octet 1) of this field are significant.

2. Your Sub-Sequence (16 bits)
Contains the value of the sub-sequence parameter of

the received AK TPDU, or zero if this parameter was not present.

3. Your Credit (16 bits)
Contains the value of the CDT field of the received AK TPDU. When normal format has been selected, only the least significant four bits (bits 1 to 4 of octet 1) of this field are significant.

13.10 Expedited Data Acknowledgement (EA) TPDU

This TPDU shall not be used for Class 0 and Class 2 when the no explicit flow control option is selected.

13.10.1 Structure

Depending on the option (normal or extended format) the TPDU structure shall be:

a) Normal Format (classes 1,2,3,4)

```
 1      2      3     4      5      6        p
+--+---------+---------+----------+------+------+
|LI|   EA    | DST-REF | YR-TU-NR |Variable Part|
|  |0010 0000|         |          |      |      |
+--+---------+---------+----------+------+------+
```

b) Extended Format (for use in classes 2, 3, 4 if selected during connection establishment)

```
 1      2      3     4    5,6,7,8  9        p
+--+---------+---------+----------+------+------+
|LI|   EA    | DST-REF | YR-TU-NR |Variable Part|
|  |0010 0000|         |          |      |      |
+--+---------+---------+----------+------+------+
```

13.10.2 LI

See 13.2.1

13.10.3 Fixed Part

The fixed part shall contain (in octets 2 to 5 when normal format is used, in octets 2 to 8 otherwise):

a) EA: Expedited Acknowledgement code: 0010 0000;

b) DST-REF: See 13.4.3;

c) YR-EDTU-NR: Identification of the ED TPDU being acknowledged. May take any value in Class 2;

   For normal formats bits 7-1 of octet 5; bit 8 of octet 5 is not significant and shall take the value 0. For extended formats, octets 5,6 and 7 together with bits 7-1 of octet 8; bit 8 of octet 8 is not significant and shall take the value 0.

13.10.4 Variable Part

The variable part may contain the checksum parameter (see 13.2.3.1).

13.11 Reject (RJ) TPDU

The RJ TPDU shall not be used in Classes 0, 2 and 4.

13.11.1 Structure

The RJ TPDU shall have one of the following formats:

a) Normal Format (classes 1 and 3)

```
  1      2        3     4       5
+----+----------+----+----+------------+
| LI |  RJ CDT  | DST-REF |  YR-TU-NR  |
|    | 0101     |    |    |            |
+----+----------+----+----+------------+
```

b) Extended Format (for use in classes 3 if selected during connection establishment).

```
 1       2       3     4   5,6,7,8   9,10
+--+-----------+----+----+----------+-----+
|LI|     RJ    | DST-REF | YR-TU-NR | CDT |
|  | 0101 0000 |    |    |          |     |
+--+-----------+----+----+----------+-----+
```

13.11.2 LI

See 13.2.1.

13.11.3 Fixed Part

The fixed part shall contain (in octets 2 to 5 when normal format is used, in octets 2 to 10 otherwise):

a) RJ: Reject Code: 0101. Bits 8-5 of octet 2;

b) CDT: Credit Value (set to 1111 in class 1). Bits 4-1 of octet 2 for normal formats and octets 9 and 10 for extended formats;

c) DST-REF: See 13.4.3;

d) YR-TU-NR: Sequence number indicating the next expected TPDU from which retransmission should occur.

For normal formats, bits 7-1 of octet 5; bit 8 of octet 5 is not significant and shall take the value 0. For extended formats, octets 5,6 and 7 together with bits 7-1 of octet 8; bit 8 of octet 8 is not significant and shall take the value 0.

13.11.4 Variable Part

There is no variable part for this TPDU type.

13.12 TPDU Error (ER) TPDU

13.12.1 Structure

```
  1        2       3     4     5         6   P
+----+-----------+----+----+--------+----------+
| LI |    ER     | DST-REF | Reject | Variable |
|    | 0111 0000 |    |    | Cause  |   Part   |
+----+-----------+----+----+--------+----------+
```

13.12.2 LI

See 13.2.1

13.12.3 Fixed Part

The fixed part shall contain:

a) ER: TPDU Error Code: 0111 0000;

b) DST-REF: See 13.4.3;

c) REJECT CAUSE:
- 0000 0000 Reason not specified
- 0000 0001 Invalid parameter code
- 0000 0010 Invalid TPDU type
- 0000 0011 Invalid parameter value.

13.12.4 Variable Part

The variable part may contain the following parameters:

a) Invalid TPDU

Parameter code: 1100 0001

Parameter length: number of octets of the value field

Parameter Value: Contains the bit pattern of the rejected TPDU up to and including the octet which caused the rejection. This parameter is mandatory in Class 0.

b) Checksum

This parameter shall be present if the condition in 13.2.3.1 applies.

SECTION THREE. CONFORMANCE

14 CONFORMANCE

14.1

A system claiming to implement the procedures specified in this standard shall comply with the requirements in 14.2 - 14.5.

14.2

The system shall implement Class 0 or Class 2 or both.

14.3

If the system implements Class 3 or Class 4, it shall also implement Class 2.

14.4

If the system implements Class 1, it shall also implement Class 0.

14.5

For each class which the system claims to implement, the system shall be capable of:

a) initiating CR TPDUs or responding to CR TPDUs with CC TPDUs or both;

b) responding to any other TPDU and operating network service in accordance with the procedures for the class;

c) operating all the procedures for the class listed as mandatory in table 9;

d) operating those procedures for the class listed as optional in table 9 for which conformance is claimed;

e) handling all TPDUs of lengths up to the lesser value of:

   1) the maximum length for the class;

   2) the maximum for which conformance is claimed.

   NOTE - This requirement indicates that TPDU sizes of 128 octets are always implemented.

14.6 Claims of Conformance Shall State

a) which class or classes of protocol are implemented;

b) whether the system is capable of initiating or responding to CR TPDUs or both;

c) which of the procedures listed as optional in table 9 are implemented;

d) the maximum size of TPDU implemented; the value shall be chosen from the following list and all values in the list which are less than this maximum shall be implemented:

128, 256, 512, 1024, 2048, 4096 or 8192 octets.

PROCEDURE	CLASS 0	CLASS 1
TPDU with checksum	NA	NA
TPDU wihout checksum	mandatory	mandatory
Expedited data transfer	NA	mandatory
No expedited data transfer	mandatory	mandatory
Flow control in Class 2	NA	NA
No flow control in Class 2	NA	NA
Normal formats	mandatory	mandatory
Extended formats	NA	NA
Use of receipt confirmation in Class 1	NA	optional
No use of receipt confirmation in Class 1	NA	mandatory
Use of network expedited in Class 1	NA	optional
No use of network expedited in Class 1	NA	mandatory

NA indicates the procedure is not applicable.

Table 9. (First of 2 pages) Provision of options

PROCEDURE	CLASS 2	CLASS 3	CLASS 4
TPDU with checksum TPDU wihout checksum	NA mandatory	NA mandatory	mandatory optional
Expedited data transfer No expedited data transfer	mandatory mandatory	mandatory mandatory	mandatory mandatory
Flow control in Class 2 No flow control in Class 2	mandatory optional	NA NA	NA NA
Normal formats Extended formats	mandatory optional	mandatory optional	mandatory optional
Use of receipt confirmation in Class 1 No use of receipt confirmation in Class 1	NA NA	NA NA	NA NA
Use of network expedited in Class 1 No use of network expedited in Class 1	NA NA	NA NA	NA NA

NA indicates the procedure is not applicable

Table 9. (Second of 2 pages) Provision of options

ANNEX A - STATE TABLES

This annex is an integral part of the body of this International Standard.

This Annex provides a more precise description of the protocol. In the event of a discrepancy between the description in these tables and that contained in the text, the text takes precedence.

The state table also define the mapping between service and protocol events that TS-users can expect.

This annex describes the transport protocol in terms of state tables. The state tables show the state of a transport connection, the events that occur in the protocol, the actions taken and the resultant state.

[The state tables have been omitted from this copy.]

ANNEX B - CHECKSUM ALGORITHMS

(This annex is provided for information for implementors and is not an integral part of the body of the standard.)

B.1 SYMBOLS

The following symbols are used:

C0 variables used in the algorithms
C1

i number (i.e. position) of an octet within the TPDU (see 12.1)

n number (i.e. position) of the first octet of the checksum parameter

L length of the complete TPDU

X value of the first octet of the checksum parameter

Y value of the second octet of the checksum parameter.

B.2 ARITHMETIC CONVENTIONS

Addition is performed in one of the two following modes:

a) modulo 255 arithmetic;

b) one’s complement arithmetic in which if any of the variables has the value minus zero (i.e. 255) it shall be regarded as though it was plus zero (i.e. 0).

B.3 ALGORITHM FOR GENERATING CHECKSUM PARAMETERS

B.3.1 Set up the complete TPDU with the value of the checksum parameter field set to zero.

B.3.2 Initialize C0 and C1 to zero.

B.3.3 Process each octet sequentially from i = 1 to L by:

a) adding the value of the octet to C0; then

b) adding the value of C0 to C1.

B.3.4 Calculate X and Y such that

X = -C1 + (L-n).CO
Y = C1 - (L-n+1).C0

B.3.5 Place the values X and Y in octets n and (n + 1) respectively.

[A Note describing the above algorithm in mathematical notation has been omitted from this copy.]

B.4 ALGORITHM FOR CHECKING CHECKSUM PARAMETERS

B.4.1 Initialize C0 and C1 to zero.

B.4.2 Process each octet of the TPDU sequentially from i = 1 to L by:

a) adding the value of the octet to C0; then

b) adding the value of C0 to C1.

B.4.3 If, when all the octets have been processed, either or both of C0 and C1 does not have the value zero, the checksum formulas in 6.17 have not been satisfied.

NOTE - The nature of the algorithm is such that it is not necessary to compare explicitly the stored checksum bytes.

Explanatory Report

The Transport Layer Services and Protocols have been under study within TC97/SC16 since 1979. It was agreed by SC16 at its meeting in Berlin, November 1980, that the Service and Protocol documents would be progressed concurrently.

At the SC16 meeting in Tokyo, June 1982, authorization was given (Resolutions 10 and 11, SC16 N 1233) to register both the Transport Service Definition and the Transport Protocol Specification as Draft Proposals and to circulate them for a 90-day ballot.

Following the close of the letter ballot an Editing Group was convened to integrate editorial comments and make recommendations regarding proposed technical changes. The revised texts and proposed recommendations were reviewed by SC16/WG6 at its meeting in Vienna, March 1983. The revised text of the Transport Service Definition (SC16 N 1435) was accepted as presented whereas the revised text of the Transport Protocol (SC16 N 1433) was subjected to an additional 60-day ballot. Consistent with the SC16 decision regarding the parallel progression of both DPs, the Transport Service Definition was held in abeyance pending acceptance by SC16 of the revised Transport Protocol (Second DP 8073).

A second Editing Group was convened in Paris, July 1983, to review comments submitted on Second DP 8073. The Minutes and Report of this meeting are documented in SC16 N1575 and N 1574 respectively. The two negative votes (DIN and NNI) were given full consideration. The NNI concerns have been fully covered in the revised text prepared by the Editing Group. The DIN concerns have been taken into account and incorporated in their large majority.

Upon the recommendation of the Editing Group, DP 8072 and DP 8073 are forwarded for registration as Draft International Standards and letter ballot of ISO Member Bodies.