
Draft for Development

**Open Systems Interconnection:
transport protocol specification
(ISO/DIS 8073 and DAD 1)**

Projet à développer. Interconnexion des systèmes ouverts: Spécification relative au protocole de transport

Entwurf zur weiteren Ausarbeitung. Kommunikation Offener Systeme: Transportprotokoll

To avoid delay in preparing the content of this publication for printing, it was reproduced from the only available copy of the finally agreed document. The resultant poor print quality is very much regretted. The price has been adjusted accordingly.

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This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature because the subject matter is in the progress of ongoing development within the International Standards Committee (ISO/TC 97/SC 6 Telecommunications and Information Exchange between Systems).

It should be applied on this provisional basis, so that information and experience of its practical application may be obtained.

A review of this Draft for Development will be carried out

not later than two years after its publication. Notification of the start of the review period, with a request for the submission of comments from users of this Draft for Development will be made in an announcement in the appropriate issue of *BSI News*. Observations which it is felt should receive attention before the official call for comments will be welcomed.

According to the replies received, the responsible BSI Committee will judge whether the Draft for Development can be converted into a British Standard or what other action should be taken.

National foreword

This Draft for Development has been prepared under the direction of the Office and Information Standards Committee. The primary objective of this Draft for Development is to give advance guidance to product and systems designers concerned with the Transport Layer of the Basic Reference Model for Open Systems Interconnection (OSI).

The text of the Draft for Development is identical with the revised text of ISO/DIS 8073 submitted to the International Organization for Standardization (ISO) for publication as ISO 8073. National appendix A is identical with the text of draft proposed addendum 1 to ISO/DIS 8073 (reference ISO/TC 97/SC 6 N 3279) issued by ISO on 3 December 1984. National appendix A covers the use of a network connection management subprotocol.

For ease of reproduction the ISO text has been reproduced unchanged.

The UK has actively participated through BSI Technical Committee OIS/6 in the development of the Draft International Standard. The Technical Committee will review any agreed amendments or addenda to the ISO text and will, where appropriate, update the text of this Draft for Development via an amendment or revision. When the ISO draft reaches an appropriate level of agreement and stability, this Draft for Development may then be converted to a British Standard.

The revised text of ISO/DIS 8072, i.e. as approved for publication as ISO 8072, together with the proposed draft addendum 1 covering connectionless-mode transmission, has been published as DD 115.

For information, a list of published British Standards and Drafts for Development (together with those scheduled for publication at the time of publication of this Draft for Development) for OSI, data communications and computer graphics is attached as national appendix B. Press Releases for new OSI, data communications and computer graphics British Standards publications will be issued to the computing press, and details of all new publications will be recorded in full in *BSI News*.

Terminology and conventions. The text of the Draft Proposal has been approved as suitable for publication as a Draft for Development without deviation. Some terminology and certain conventions are not identical with those used in Drafts for Development; attention is drawn especially to the following.

Wherever the words 'International Standard' appear, referring to this Draft for Development, they should be read as 'Draft for Development'.

Wherever page numbers are quoted, they are ISO page numbers.

It should be noted that some text of 7.3 in national appendix A (BS page 137) is unavailable. It will be inserted by the issue of an Amendment as soon as possible.

Cross-references

International standards	Corresponding British Standards
ISO 7498-1984	BS 6568 : 1984 Description of basic reference model for open systems interconnection (Identical)
ISO/DIS 8072	DD 115 : 1985 Open Systems Interconnection: transport service definition (ISO/DIS 8072 and DAD 1) (Identical)
ISO/DIS 8348	DD 119 : 1985 Open Systems Interconnection: connection-mode network service definition (ISO/DIS 8348) (Identical)

0 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 (DIS 8072). It also uses and makes reference to the Network Service Standard (DIS 8348), whose provisions it assumes in order to accomplish the transport protocol's aims. The interrelationship of these standards is depicted in figure 1.

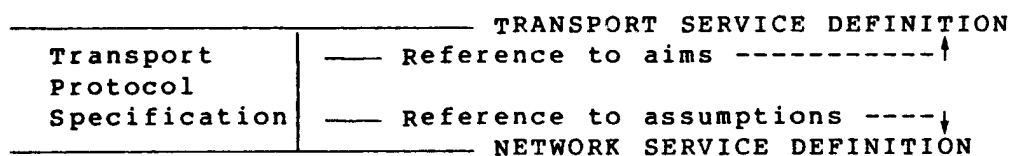


FIGURE 1 - Relationship between the Transport Protocol and adjacent services

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 optimise 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.

[ISO page 5]

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.

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.

[ISO page 7]

2 REFERENCES

- ISO 7498 Information processing systems - Open systems interconnection - Basic Reference Model
- DIS 8072 Information processing systems - Open systems interconnection - Transport service definition
- DIS 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 (ISO 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 behaviour in the Transport Layer that is not subject to the requirements of this protocol.

[ISO page 8]

Documents

This publication is a Draft for Development and is therefore not to be regarded as a British Standard. See page 2.

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.

[ISO page 9]

3.2.19 transmit window: The set of consecutive sequence numbers which a transport entity has been authorised 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 nor 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 and sequence number
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 timer 2
M _{LR}	NSDU lifetime Local-to-remote
M _{RL}	NSDU lifetime remote-to-local
E _{LR}	Expected maximum transit delay local to remote
E _{RL}	Expected maximum transit delay remote to local
R	Persistence time
AL	Local acknowledgment time
AR	Remote acknowledgment 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

[ISO page 11]

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.

TABLE 1 - Transport service primitives

Primitive		Parameters
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.

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.

[ISO page 12]

TABLE 2 - Network service primitives

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

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 and will ignore it when received in the Network Service Primitive.

NOTES :

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

[ISO page 13]

- 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.

[ISO page 14]

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 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 TPDU's 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.

NOTES :

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

2 - Classes 0 to 3 do not specify mechanisms to detect unsignalled network transmission failures.

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 behaviour 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.

[ISO page 17]

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: TPDUs loss, TPDUs delivery out of sequence, TPDUs duplication and TPDUs 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.

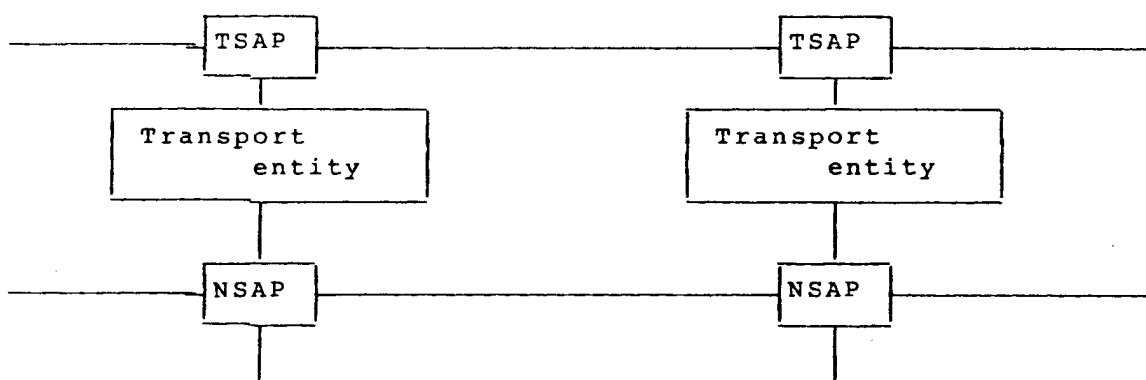
[ISO page 18]

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.



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.

FIGURE 2 - Model of the transport layer.

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 connection6.1.1 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).

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This publication is a Draft for Development and is therefore not to be regarded as a British Standard. See page 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 resynchronisation (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.

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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, while maintaining the order of TPDUs for a given transport connection compatible with the protocol operation.

A valid 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.

A transport entity shall accept a valid 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.

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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);

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Documents

- priority (selected);
- transit delay (selected);
- user data.

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 used) network connection(s). It is this set of network connections over which the TPDUs are sent.

NOTE - Even if the initiator assigns the transport connection to more than one network connection, all the CR TPDUs (if repeated) or DR TPDU(s) with DST-REF set to zero which are sent prior to the receipt of the CC TPDU shall be sent on the same network connection, unless an N-DISCONNECT indication is received. (This is necessary because the remote entity may not support class 4 and therefore may not recognize splitting). If the initiator has made other assignments, it will use them only after receipt of a class 4 CC TPDU (see also the splitting procedure 6.23).

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.

When an unexpected duplicated CR TPDU is received (with class 4 as preferred class) it shall be ignored in classes 0, 1, 2 and 3 and a CC TPDU shall be returned in class 4.

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 to be used by the peer entity which is 16 bits long and which is arbitrary except for the following restrictions:

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- 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 classes 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 resynchronisation (see 6.14) the resynchronisation 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 to the procedures of the selected class.

TABLE 3 - Valid responses corresponding to the preferred class and any alternative class proposed in the CR TPDU

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

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 TPDU's, 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 TPDU's of the connection are to include a checksum.

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

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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 at 128 octets. Conversion to and from specifications based upon some other value is a local matter.

- 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.

TABLE 4 - Negotiation of options during connection establishment

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

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Option	Proposal Made by the Initiator	Valid Selection by the Responder
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

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 cause;
- invalid TPDU.

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.

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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 TPDU's either an ER TPDU or DR TPDU may be sent.
2. If the optional supervisory timer TS1 has been set for this connection then the initiator 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;
 - reason;
 - user data;
 - SRC-REF;
 - DST-REF.
- b) DC TPDU.

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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 acknowledgment 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. In the former case further receipt of a CC TPDU specifying class 4 will be ignored. Receipt of CC TPDU with another class will be processed as follows : if the class is 0 the network connection shall be disconnected, otherwise a DR TPDU with the DST-REF field set to the value of the SRC-REF field of the received CC TPDU shall be sent and the release procedure of the class is continued.

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. If the received DR has the DST-REF field set to zero, then a DC with SRC-REF set to zero shall be sent, regardless of the local reference.

NOTE - If the entity receiving such a DR TPDU has previously decided to negotiate down the class, this entity is always entitled to consider such a DR TPDU as spurious. Since no association has been made the transport connection is not released at responder side but the CC TPDU, when sent, will be answered by a DR TPDU (spurious CC TPDU).

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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 re-leased and, in classes other than classes 0 and 2, freeze the reference (see 6.18).

6.8 Error Release6.8.1 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.

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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;
- c) N-RESET request;
- d) N-DISCONNECT request.

6.9.3 TPDUs and parameters used

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;
 - SRC-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 6.9.4.1.b.2.

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- 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 one 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 TPDU's 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 TPDU's

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 copy 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.

NOTE - If the DR is carrying a SRC-REF field set to zero, then no DC shall be sent.

- 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.

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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 four 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) if the transport entity implements class 4 and if the DST-REF is zero and there is an unacknowledged CC TPDU or T-CONNECT RESPONSE is awaited, then the DR TPDU shall be associated with the transport connection holding the SRC-REF as the remote reference.

4) 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.

[ISO page 35]

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 parameters 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 shall be treated as 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 for 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:

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- 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 TTR expires and while waiting for the next event, it is recommended that the initiator set 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 timer/resynchronization.

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 maximum 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 maximum transit delay of the network connections.

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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 reassignment). 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 acknowledgment of TPDUs

6.13.1 Purpose

The retention until acknowledgment of TPDUs procedure is used in classes 1, 3 and 4 to enable and minimise 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.

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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 TPDUs;
 - TPDU-NR.
- d) ED TPDUs;
 - ED-TPDU-NR.
- e) EA TPDUs;
 - 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 TPDUs there is no need to retain a copy of the DR TPDUs.

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

After each TPDUs 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.

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TABLE 5 - Acknowledgment of TPDUs

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

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6.14.4 Procedure

A transport entity which is notified of the occurrence 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 not 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 commences 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:

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- 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 any 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 unacknowledged, the RJ or ED TPDU should then be considered as acknowledged the CC TPDU. If a CC TPDU was never sent, the RJ or ED 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 TPDU, 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;

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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.

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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 Checksum6.17.1 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:

$$\sum_{i=1}^L a_i \equiv 0 \text{ (modulo 255)}$$

$$\sum_{i=1}^L i a_i \equiv 0 \text{ (modulo 255)}$$

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where

i = number (i.e. position) of an octet within the TPDU
(see 13.2);
 a_i = value of octet in position i ;
 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 shall be used in order to prevent re-use of a reference while TPDU's 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 TPDU's 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.

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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 shall be used in class 4. The period for which the reference remains frozen shall 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.

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