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DATA NETWORKS AND OPEN SYSTEM COMMUNICATIONS

MESSAGE HANDLING SYSTEMS

ASYNCHRONOUS PROTOCOL SPECIFICATION – PROVISION OF OSI CONNECTION MODE NETWORK SERVICE OVER THE TELEPHONE NETWORK

ITU-T Recommendation X.445

(Previously "CCITT Recommendation")

FOREWORD

The ITU-T (Telecommunication Standardization Sector) is a permanent organ of the International Telecommunication Union (ITU). The ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

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The approval of Recommendations by the Members of the ITU-T is covered by the procedure laid down in WTSC Resolution No. 1 (Helsinki, March 1-12, 1993).

ITU-T Recommendation X.445 was prepared by ITU-T Study Group 7 (1993-1996) and was approved under the WTSC Resolution No. 1 procedure on the 10th of April 1995.

NOTE

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

ITU-T X-SERIES RECOMMENDATIONS

DATA NETWORKS AND OPEN SYSTEM COMMUNICATIONS

(February 1994)

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SUMMARY

This Recommendation specifies the protocols to be used to provide OSI connection mode network service to applications entities such as MHS entities (e.g. UA, MTA, MS) when communicating in an asynchronous environment (i.e. start/stop transmissions) over a telephone network.

The communication can be directly over a telephone network connection, or over a telephone network connection to a PSDN through a PAD, or over a telephone network connection to a PSDN using the packet mode.

INTRODUCTION

This Recommendation establishes the rules for asynchronous OSI communications over the telephone network.

This Recommendation is applicable in MHS (and other) environments requiring optimization of data link and network layer protocols for reliable asynchronous communication over the telephone network.

These environments include:

- communications over direct telephone network connection;
- communications over a telephone network connection to a PSDN through a PAD;
- communications over a telephone network connection to a PSDN using the packet mode.

ASYNCHRONOUS PROTOCOL SPECIFICATION – PROVISION OF OSI CONNECTION MODE NETWORK SERVICE OVER THE TELEPHONE NETWORK

(Geneva, 1995)

1 Scope

This Recommendation is applicable in MHS (and other) environments requiring optimization of data link and network layer protocols for reliable asynchronous communication over the telephone network.

These environments include:

- communications over direct telephone network connection;
- communications over a telephone network connection to a PSDN through a PAD;
- communications over a telephone network connection to a PSDN using the packet mode.

NOTE – For simplicity, the term MHS is used throughout this Recommendation to represent any application environment. For example, other applications environments may include the OSI Directory, etc.

2 References

The following Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision: all users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of currently valid ITU-T Recommendations is regularly published.

- CCITT Recommendation V.42 (1988), *Error-correcting procedures for DCEs using asynchronous-to-synchronous conversion.*
- ITU-T Recommendation X.3 (1993), *Packet Assembly/Disassembly facility (PAD) in a public data network.*
- ITU-T Recommendation X.25 (1993), *Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and connected to public data networks by dedicated circuit.*
- ITU-T Recommendation X.28 (1993), *DTE/DCE interface for a start-stop mode data terminal equipment accessing the Packet Assembly/Disassembly facility (PAD) in a public data network situated in the same country.*
- ITU-T Recommendation X.29 (1993), *Procedures for the exchange of control information and user data between a Packet Assembly/Disassembly (PAD) facility and a packet mode DTE or another PAD.*
- ITU-T Recommendation X.32 (1993), *Interface between Data Terminal Equipment (DTE) and Data Circuit-terminating Equipment (DCE) for terminals operating in the packet mode and accessing a packet switched public data network through a public switched telephone network or an integrated services digital network or a circuit switched public data network.*
- ITU-T Recommendation X.200 (1994) | ISO/IEC 7498-1:1994, *Information technology – Open Systems Interconnection – Basic Reference Model: The Basic Model.*
- ITU-T Recommendation X.210 (1993) | ISO/IEC 10731:1994, *Information technology – Open Systems Interconnection – Conventions for the definition of OSI services.*
- CCITT Recommendation X.213 (1992) | ISO/IEC 8348:1993, *Information technology – Open Systems Interconnection – Network service definition.*

– ITU-T Recommendation X.223 (1993), *Use of X.25 to provide the OSI connection-mode network service for ITU-T applications.*

ISO/IEC 8878:1992, *Information technology – Telecommunications and information exchange between systems – Use of X.25 to provide the OSI connection-mode network service.*

– CCITT Recommendation F.400/X.400 (1992), *Message handling services: Message handling system and service overview.*

ISO/IEC 10021-1:1990, *Information technology – Text Communication – Message-Oriented Text Interchange Systems (MOTIS) – Part 1: System and Service Overview plus Technical Corrigendum 1 (1991), Technical Corrigendum 2 (1991), Technical Corrigendum 3 (1992), and Technical Corrigendum 4 (1992).*

– CCITT Recommendation X.419 (1992), *Message handling systems – Protocol specifications.*

ISO/IEC 10021-6:1990, *Information technology – Text Communication – Message-Oriented Text Interchange Systems (MOTIS) – Part 6: Protocol specifications plus Technical Corrigendum 1 (1991), Technical Corrigendum 2 (1991), Technical Corrigendum 3 (1992), and Technical Corrigendum 4 (1992).*

– ITU-T Recommendation X.500 (1993) | ISO/IEC 9594-1:1994, *Information technology – Open Systems Interconnection – The Directory: Overview of concepts, models and services.*

– CCITT Recommendation X.614 (1992) | ISO/IEC 10732:1993, *Information technology – Use of the X.25 packet layer protocol to provide the OSI connection-mode network service over the telephone network.*

– ISO/IEC 3309:1993, *Information technology – Telecommunications and information exchange between systems – High-level data link control (HDLC) procedures – Frame structure.*

– ISO 7776:1986, *Information processing systems – Datacommunications – High-level data link control procedures – Description of the X.25 LAPB-compatible DTE data link procedures.*

– ISO/IEC 7809:1993, *Information technology – Telecommunications and information exchange between systems – High-level Data Link Control (HDLC) procedures – Classes of procedures.*

– ISO/IEC 8208:1990, *Information technology – Data communications – X.25 Packet Layer Protocol for Data Terminal Equipment.*

– ISO/IEC ISP 10609-9:1992, *Information technology – International Standardized Profiles TB, TC, TD and TE – Connection-mode Transport Service over connection-mode Network Service – Part 9: Subnetwork-type dependent requirements for Network Layer, Data Link Layer, and Physical Layer concerning permanent access to a packet switched data network using virtual calls.*

– ISO/IEC 646:1991, *Information technology – ISO 7-bit coded character set for information interchange.*

– ISO/IEC 4335:1993, *Information technology – Telecommunications and information exchange between systems – High-level Data Link Control (HDLC) procedures – Elements of procedures.*

3 Definitions

For the purposes of this Recommendation, the following definitions apply.

3.1 Reference model definitions

This Recommendation makes use of the following terms defined in ITU-T Rec. X.200 | ISO/IEC 7498-1:

a) Network connection;

b) Network layer;

c) Network service.

3.2 Service conventions definitions

This Recommendation makes use of the following terms defined in ITU-T Rec. X.210 | ISO/IEC 10731:

a) Network service provider;

b) Network service user.

3.3 Network service definitions

This Recommendation makes use of the following terms defined in CCITT Rec. X.213 | ISO/IEC 8348:

a) N-CONNECT request;

b) N-CONNECT indication;

c) N-CONNECT response;

d) N-CONNECT confirm;

e) N-DISCONNECT indication;

f) N-DISCONNECT request;

g) N-DATA request;

h) N-DATA indication.

3.4 X.25 definitions

This Recommendation makes use of the following concepts as developed in Recommendation X.25:

a) Virtual circuit;

b) Virtual call;

c) Data circuit-terminating equipment;

d) Data terminal equipment.

3.5 APS definitions

This Recommendation makes use of the following terms and definitions:

3.5.1 APS layer 1: Provides the same functionality as OSI Layer 1 (Physical Layer). In the case of PAD configuration defined in 5.1, it includes the functions and protocols defined in Recommendations X.3, X.28, and X.29.

3.5.2 APS layer 2: Provides the same functionality as OSI Layer 2 (Data Link Layer).

3.5.3 APS layer 3: Provides the same functionality as OSI Layer 3 (Network Layer).

3.5.4 end system: A client or a server system as defined in clause 5.

3.5.5 underlying connection: An APS layer 1 connection established by the client system and it comprises the telephone network connection and, if in PAD configuration, the PAD virtual call.

4 Abbreviations

For the purposes of this Recommendation, the following abbreviations apply.

4.1 Reference model abbreviations

OSI Open Systems Interconnection

4.2 Network layer abbreviations

CONS Connection-mode Network Service

NPDU Network Protocol Data Unit

NSAP	Network Service Access Point
NSDU	Network Service Data Unit
QOS	Quality of Service

4.3 X.25 abbreviations

DCE	Data Circuit-terminating Equipment
DTE	Data Terminal Equipment
ICRD	Inter-network Call Redirection and Deflection
NPI	Numbering Plan Identification
TOA	Type of Address
PLP	Packet Layer Protocol

4.4 Data link layer abbreviations

DISC	Disconnect (frame)
DL	Data Link
DM	Disconnect Mode
FCS	Frame Check Sequence
LAPB	Link Access Protocol Balanced
LAPM	Link Access Protocol for Modems
SABM	Set Asynchronous Balanced Mode
SABME	Set Asynchronous Balanced Mode Extended
SLP	Single Link Procedures
UI	Unnumbered Information (frame)

4.5 Other abbreviations

APS	Asynchronous Protocol Specification
CR	Carriage Return
DLE	Data Link Escape
MS	Message Store
MTA	Message Transfer Agent
PAD	Packet Assembly/Disassembly
PDU	Protocol Data Unit
PSDN	Packet Switched Data Network
ROA	Recognized Operating Agency
UA	User Agent
UART	Universal Asynchronous Receiver-Transceiver
XOFF	Device Off
XON	Device On

5 Overview

This Recommendation defines protocol mappings to the OSI network service and protocol exchanges between an initiator of a connection called the **client** and a responder called the **server**. In MHS environment, the client is any MHS entity that initiates a connection like for instance, a remote User Agent (UA) or a Message Transfer Agent (MTA); the server is any MHS entity that responds to a connection like for instance, a Message Store (MS), or an MTA. The principle protocol exchanges used are called the **APS Network Protocol** and the **APS Data Link Protocol** defined in 8.1 and 7.3 respectively.

This clause illustrates a set of possible **client-server** configurations that exemplify the interactions in an asynchronous communication environment.

5.1 Configurations

Three configurations for client-server asynchronous communications are considered in this Recommendation as shown in Figure 1:

a) The **Point-to-Point** configuration where the client establishes a connection directly with the server using the telephone network .

b) The **PAD** configuration where the client establishes a connection with the server over a telephone network connection to a PSDN via a PAD.

c) The **Direct Network** configuration where the client establishes a connection with the server over a telephone network connection to a PSDN using the packet mode.

NOTE – In b) and c) configurations the server is connected to the PSDN in the packet mode.

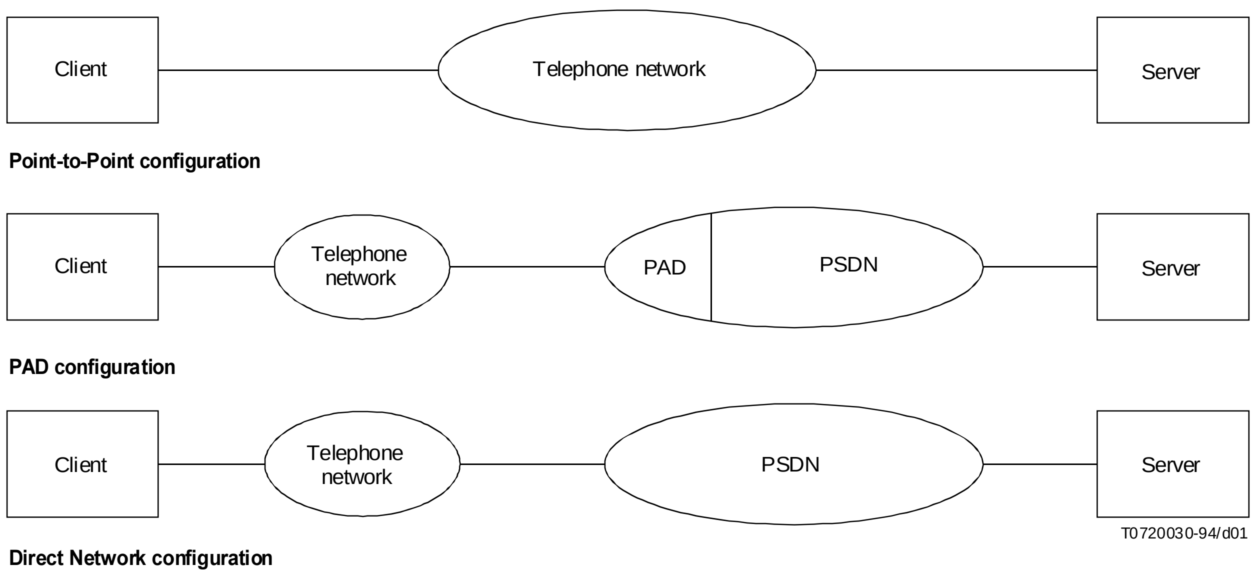


FIGURE 1/X.445

Client-server configurations

5.2 Modes of operation and their APS layers representation

In order to provide reliable asynchronous communications in the configurations described above and to allow several options with regards to complexity of implementation, optimization of traffic volume and network service capabilities, the protocols described in this Recommendation may be combined into three modes:

a) **V.42-dependent mode** where the protocols used in APS layers 2 and 3 provide error-detection and a CONS as specified in 6.3. It relies on services provided by a pair of V.42 modems operating *in error-correcting mode*. This mode can only be used in the Point-to-Point and PAD configurations.

b) **LAPB mode** where the protocols used in APS layers 2 and 3 provide full error detection and correction and a CONS as specified in 6.3. This mode can only be used in the Point-to-Point and PAD configurations.

c) **X.25 mode** where the protocols used in APS layers 2 and 3 provide full error detection and correction and a CONS as specified in 6.2. This mode can be used in the Point-to-Point, PAD and Direct Network configurations.

NOTE – Other modes are for further study.

The V.42-dependent mode and the LAPB mode use an optimized simple network protocol called the *APS network protocol* defined in 8.1. In addition the V.42-dependent mode uses an optimized simple data link protocol called the *APS data link protocol* defined in 7.3.

Use of the V.42-dependent mode, the LAPB mode and the X.25 mode in the configurations described in 5.1 are shown in Figures 2, 3 and 4 using the APS layers representation.

5.2.1 V.42-dependent mode

This mode uses the APS network protocol as defined in 8.1 in conjunction with the APS data link protocol as defined in 7.3. It provides a network connection between two End Systems. Use of the V.42-dependent mode requires both ends of the data link to use modems *operating in error-correcting mode* as follows:

a) in the Point-to-Point configuration the client and the server shall each use an error-correcting modem;

b) in the PAD configuration the client and the PAD service provider shall each use an error-correcting modem.

NOTE – This mode may not provide adequate reliability in some circumstances. More specifically, the path between the V.42 modem and the client is operating without error correction. In the Point-to-Point configuration, the path between the V.42 modem and the server is also operating without error correction and in the PAD configuration, the path between the V.42 modem and the PAD is again operating without error correction (see Figure 5). Some hardware (e.g. a UART – Universal Asynchronous Receiver-Transmitter) may not be able to buffer incoming characters and loss of characters may result. The method for detecting these errors and the action taken are defined in 7.3.

5.2.2 LAPB mode

This mode uses the APS network protocol and LAPB as defined in 8.1 and 7.2. It provides a network connection between two end systems. This mode may be used in the Point-to-Point and PAD configurations.

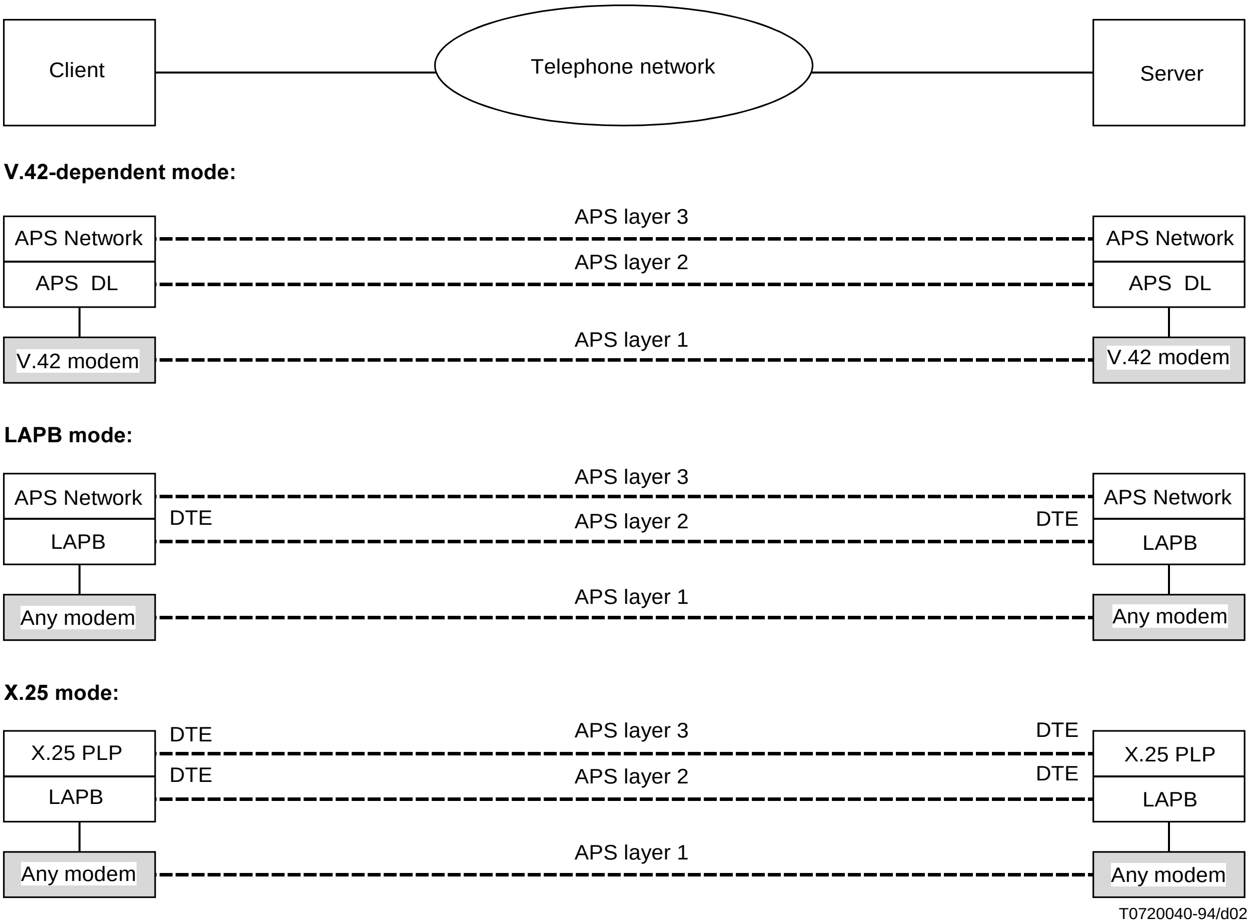
5.2.3 X.25 mode

This mode is defined in Recommendations X.614 , X.25 and X.32 (with start/stop transmission). This mode can provide access to several virtual circuits which allows the client to maintain concurrent network connections on the same underlying connection.

5.2.4 Mode negotiations

The appropriate mode is established by the procedures described in Annex B. In the Direct Network configuration procedures as defined in Recommendations X.614, X.25 and X.32 shall prevail.

NOTE – Only the X.25 mode provides multiplexing at the network layer. Additional transport connections can be provided by using transport protocol classes 2, 3 or 4, however the choice of transport protocol class is outside the scope of this Recommendation.



NOTE – LAPB mode and X.25 mode are included for completeness. However, the V.42-dependent mode is preferred and encouraged.

FIGURE 2/X.445

APS modes in the point-to-point configuration

5.2.5 Mode support

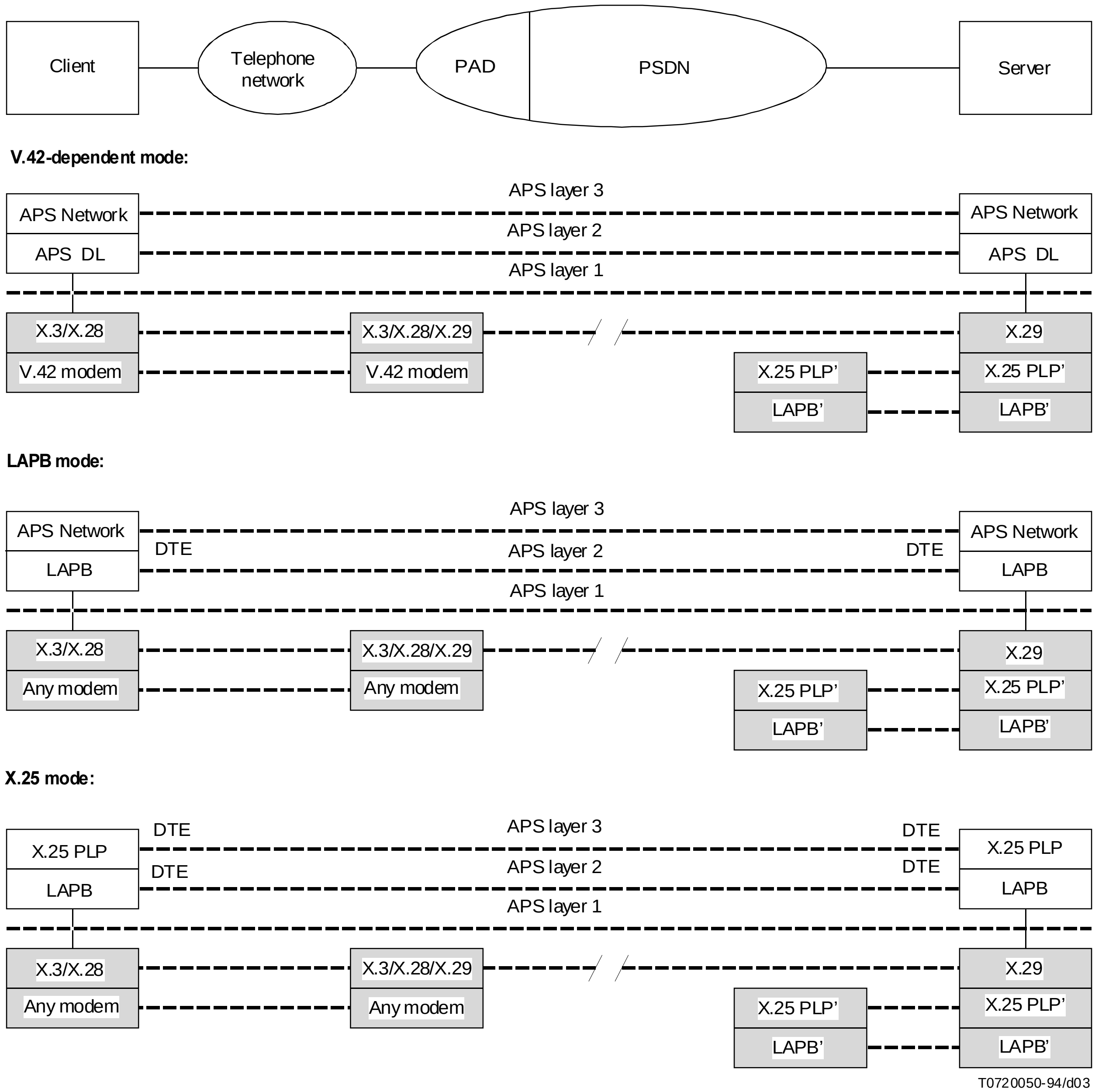
The client and the server shall support one or more configurations as described in 5.1. Depending on the configurations supported, the client and the server which claim conformance to this Recommendation shall implement the required modes as shown in Table 1.

6 Provision of the OSI CONS

This Recommendation defines the method for providing OSI CONS for MHS protocols defined in Rec. X.419 | ISO/IEC 10021-6 through the use of either the APS network protocol defined in 8.1 or the X.25 PLP.

6.1 Control of underlying connections

The receipt of an N-CONNECT request primitive from the network service user shall first cause procedures to be used to establish a telephone network connection (unless already established) and if in PAD configuration a PAD virtual call to the server. The combination of the telephone connection and the eventual PAD connection is referred to as “the underlying connection” in this Recommendation. The establishment procedures are outside the scope of this Recommendation.



NOTES

1 LAPB mode and X.25 modes are included for completeness. However, the V.42-dependent mode is preferred and encouraged.

2 X.25 PLP' and LAPB' denote X.25 PLP and LAPB protocols used in the underlying connection. The apostrophy that follows the "PLP" and "LAPB" words is used for presentation clarity in order to distinguish the X.25 PLP and LAPB protocols used *in* the underlying connection from X.25 PLP and LAPB protocols used *over* the underlying connection.

FIGURE 3/X.445

APS modes in the PAD configuration

Failure to establish the underlying connection is indicated to the network service user by means of an N-DISCONNECT indication primitive with the originator parameter "NS provider" and the reason parameter "connection rejection – reason unspecified – transient condition".

If the network connection is established and the underlying connection is subsequently disconnected, the APS layer 3 entity conveys an N-DISCONNECT indication primitive with the originator parameter "NS Provider" and reason parameter "disconnection – transient condition" to the NS user.

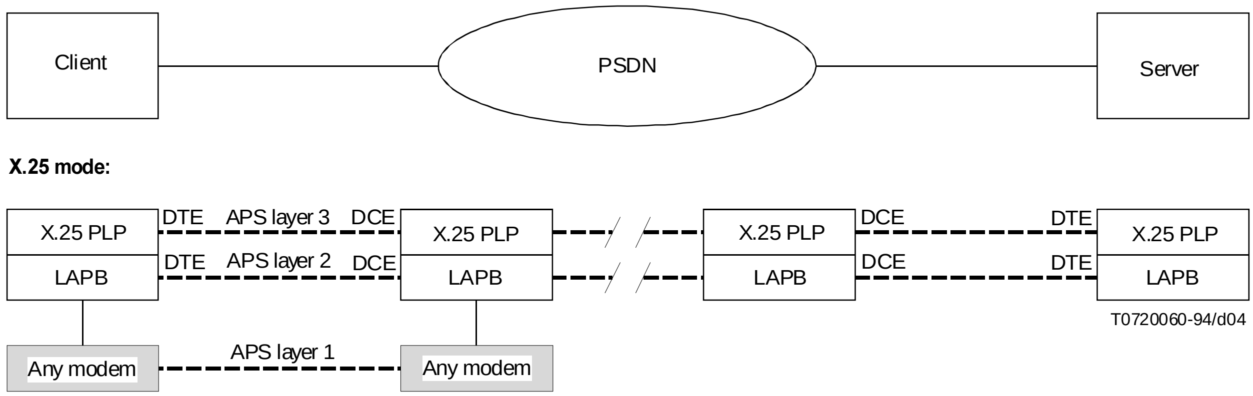


FIGURE 4/X.445

The X.25 mode in the direct network configuration

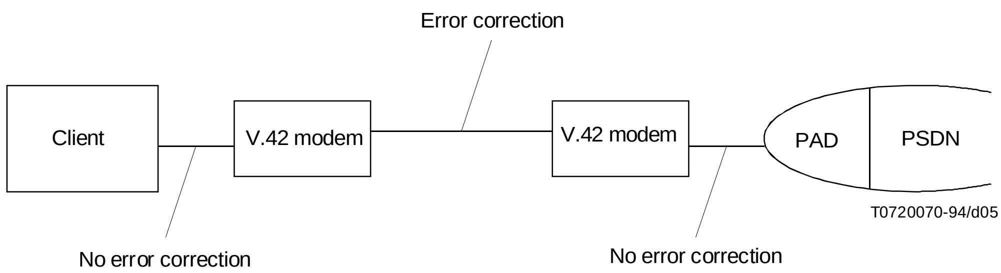


FIGURE 5/X.445

V.42-dependent mode in the PAD configuration

6.2 Mapping OSI CONS to/from X.25 PLP

The X.25 PLP protocol can be used to provide the OSI CONS as defined in CCITT Rec. X.213 | ISO/IEC 8348 in an end system that conforms to this Recommendation.

Subject to the provisions in 8.2, the relationship between the X.25 PLP and CONS is defined in Recommendation X.223.

TABLE 1/X.445

Mandatory and optional modes for client and server

		Configuration					
		Point-to-Point		PAD		Direct Network	
		Client	Server	Client	Server	Client	Server
Mode	V.42-dependent	O.1	M	O.2	M	–	–
	LAPB	O.1	M	O.2	M	–	–
	X.25	O	O	O	O	M	M

O.1 At least one of these shall be implemented.
O.2 At least one of these shall be implemented.
O Optional
M Mandatory
– Not applicable

6.3 Mapping OSI CONS to/from the APS network protocol

The APS network protocol can be used to provide a subset of the OSI CONS as defined in Rec. X.213 | ISO/IEC 8348 in an end system that conforms to this Recommendation. The relationship between the APS network protocol and CONS is defined in Annex C.

7 APS layer 2 protocols

7.1 Introduction

The APS layer 2 protocol may be either LAPB (with start/stop transmission), as defined in Recommendation X.25, and ISO/IEC 7776 operated with the additional requirements described in this Recommendation (referred to as "start/stop LAPB"), or the APS data link protocol as defined in 7.3.

7.2 Start/stop LAPB

The operation of start/stop LAPB shall be as specified in ISO/IEC ISP 10609-9, clause 6, with the additional requirements described in 7.5.1 and 7.5.2. The following additional restrictions/defaults apply:

a) Only Single Link Procedures (SLP) shall be supported.

b) Modulo 8 shall be supported.

c) 16-bit FCS shall be supported.

d) The SABME command shall not be supported.

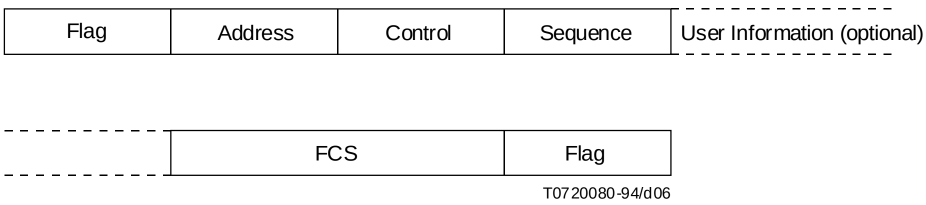
e) Default window size of 7.

Use of other options in LAPB is beyond the scope of this Recommendation.

7.3 APS data link protocol

The **APS data link** protocol is an optimized simple data link protocol. Although it does not recover from link errors, it will, in conjunction with a reliable circuit (e.g. a V.42 modem *in error correcting mode*), be considered to provide an error-free data link service. Procedures for error handling are specified in 7.3.1.

The **APS data link frame** is a UI frame as defined in ISO/IEC 4335 where the first octet of the Information Field is a sequence octet. The Information Field octets, beyond the sequence octet, are optional user information (see Figure 6). The value of the sequence octet shall be a modulo 256 number. The number shall be incremented by one each time a frame is sent. The use of the control and address fields is defined in clause 7 of ISO/IEC 7809. The P/F bit shall be always zero.



FCS Frame Check Sequence

FIGURE 6/X.445

APS data link frame layout

The APS data link frame consists of:

a) a leading flag (one octet);

b) an address octet;

c) a control octet;

d) a sequence octet;

e) optionally, user information;

f) a two-octet frame check sequence;

g) a closing flag (one octet).

7.3.1 Reception of incorrect frames

Incorrectly received frames shall cause the underlying connection to be disconnected. In addition, an end system receiving an APS data link frame shall ensure that the sequence number of a received frame is one higher than the last received frame (modulo 256). Reception of an incorrect sequence number signals that a frame may have been lost. The underlying connection shall be disconnected.

7.4 Transparency

This Recommendation defines three levels of transparency (see Annex A). In the Point-to-Point and PAD configurations, the three transparency levels shall be implemented by the client and the server. The selection of the transparency level to be performed is as specified in 7.5.1.2 and 7.5.2.2. The choice of the transparency level to be operated on a particular data link is outside the scope of this Recommendation as depending on the communication environment and the equipments used.

In the case of the Direct Network configuration, the Basic transparency level shall be performed according to 3.5.2 of ISO/IEC 7776. The selection and the use of other transparency levels is outside the scope of this Recommendation.

7.5 APS layer 2 operation and establishment of the underlying connection

7.5.1 Point-to-Point configuration

7.5.1.1 Establishment of the underlying connection

The client establishes the underlying connection to the server through the telephone network.

The means of establishing the underlying connection are outside the scope of this Recommendation.

7.5.1.2 Data link set-up

Once the underlying connection is established, the client transmits the appropriate APS protocols selection string (see Annex B) to select the mode and transparency level.

If LAPB or X.25 mode was selected, the client will expect an appropriate LAPB frame (i.e. SABM, DISC or DM); any other response will be considered an error and shall be discarded. Receipt of a valid frame shall cause the client to respond as defined in ISO/IEC 7776. The sequence diagram for normal LAPB data link set-up is shown in Figure 7.

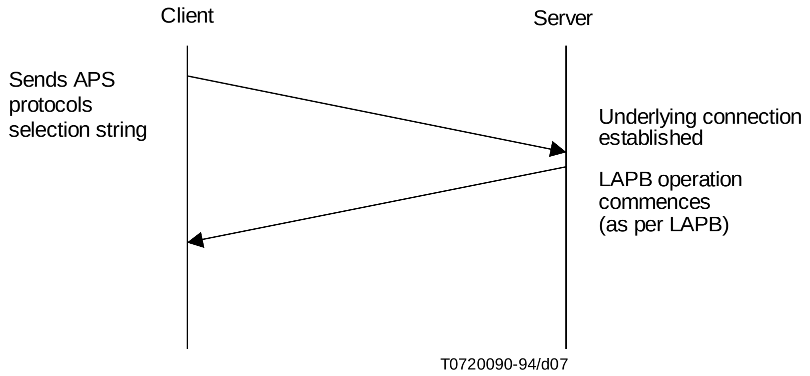


FIGURE 7/X.445

Normal LAPB data link set-up (no errors)

If V.42-dependent mode was selected, the client will expect an APS data link frame (as defined in this Recommendation) with a sequence number of zero and no data from the server; any other response will be considered an error and shall be discarded. Receipt of a correct APS data link frame causes the client to send an APS data link frame with a sequence number of zero (with or without data). The sequence diagram for normal APS data link set-up is shown in Figure 8.

NOTE – The first APS data link frame sent by the client shall, if user data is present, contain a cr-NPDU.

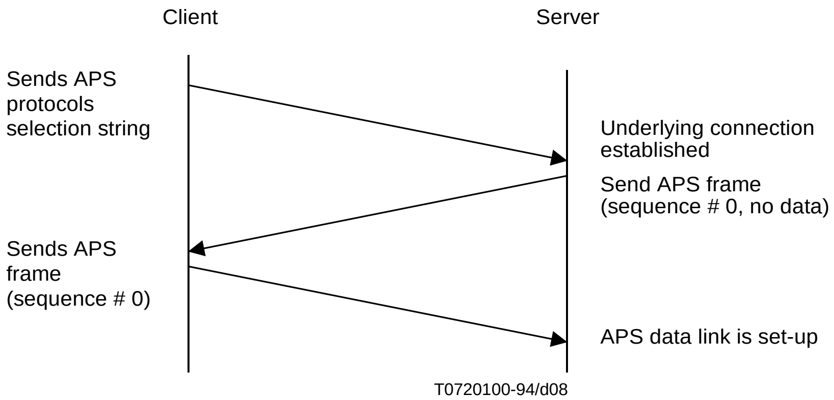


FIGURE 8/X.445

Normal APS data link set-up (no errors)

The client shall repeat retransmission of the APS protocols selection string after a timeout (APS-Tc), until an appropriate data link frame is received, or the retry limit (APS-N) is exceeded. The sequence diagram for client timeout is shown in Figure 9.

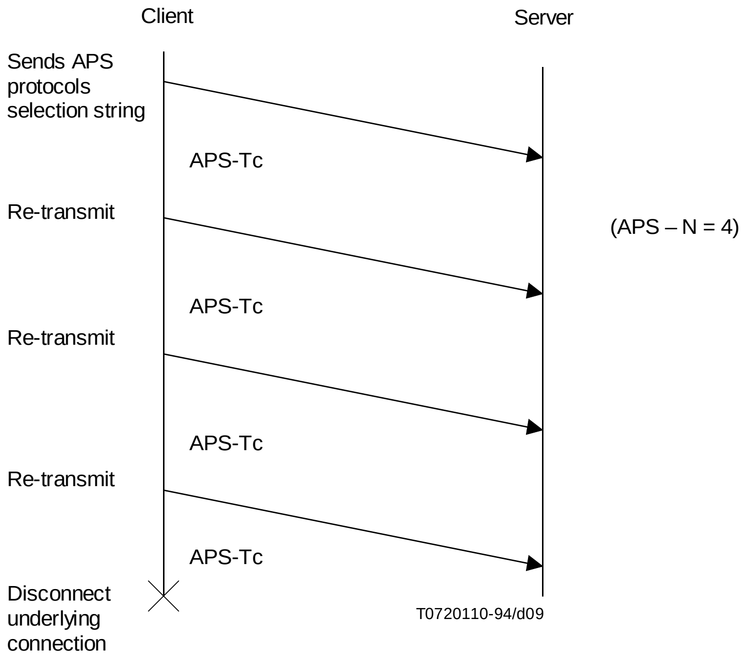


FIGURE 9/X.445

Client timeout during data link set-up

On receipt of a valid APS protocols selection string, the server shall send the appropriate APS layer 2 frame depending upon the mode selected as defined below. The APS layer 2 frame sent shall have the transparency level requested by the client applied prior to transmission. Any data subsequently received by the server which is not recognized as a data link frame shall be discarded.

If V.42-dependent mode was selected by the client, the server shall transmit an APS data link frame with a sequence number of zero and no data, and expect an APS data link frame with a sequence number of zero (with or without data) in response. Receipt of this APS data link frame by the server completes the data link set-up.

If LAPB or X.25 mode was selected by the client, the server will assume that LAPB data link set-up can commence and shall follow the procedures defined in 2.4.4/X.25.

The server may disconnect the underlying connection if the appropriate response frame has not been received before timeout (APS-Ts). The sequence diagram for server timeout is shown in Figure 10.

7.5.1.3 LAPB addressing

In LAPB mode the client is assigned the address "A" and the server the address "B".

7.5.1.4 Time fill

No flags or other characters shall be transmitted between frames. However, an end system shall, for the purpose of APS layer 2 protocols, ignore any characters received between frames. Where a frame is immediately followed by another, both the terminating flag of the first frame and the start flag of the second frame shall be present (see Figure 11).

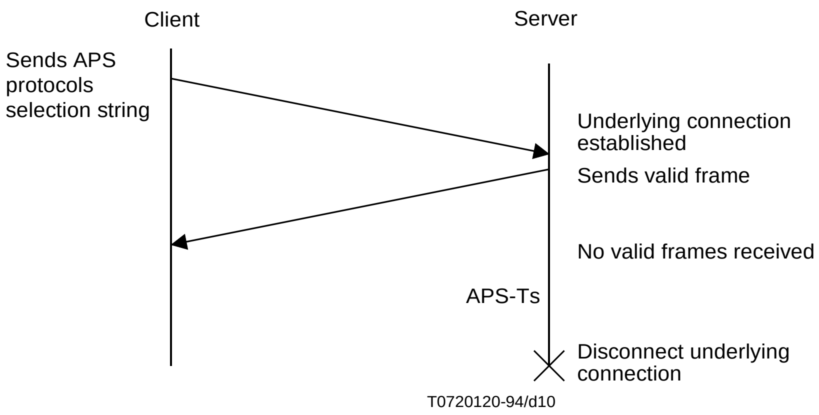


FIGURE 10/X.45

Server timeout during data link set-up

FIGURE 11/X.445

Flags between frames

7.5.2 PAD configuration

7.5.2.1 Establishment of the underlying connection

The client establishes the underlying connection to the server. The underlying connection is established through the telephone network and one or more PSDNs, where a PAD is provided at the initial PSDN boundary.

The functions of the PSDN, including those of the PAD that are used to bring the PAD into the data transfer state and to achieve effective data transfer over the PAD connection, are regarded, for the purpose of this Recommendation, as providing part of APS layer 1, i.e. comprise part of the underlying connection over which an APS layer 2 protocol is run. The underlying connection is considered established when the PAD enters the data transfer state. This is achieved according to Recommendations X.3, X.28 and X.29.

The means of establishing the underlying connection, setting PAD parameters and bringing the PAD into the data transfer state are outside the scope of this Recommendation. Recommended PAD parameter settings are included in Annex D.

7.5.2.2 Data link set-up

Data link set-up proceeds as described in 7.5.1.2, except that the first transmission of the APS protocols selection string may be sent in a data packet or in the user data of the X.25 call request issued by the PAD. If call user data was used to transmit the first instance of the APS protocols selection string (see B.3) any subsequently retransmitted strings shall be sent as regular data packets (i.e. after the PAD call is connected). The server shall be able to handle the APS protocols selection string received in the PAD call user data field. It shall not ignore the PAD call user data field and rely on subsequent retransmission of the string as regular data packets (see 7.5.1.2).

7.5.2.3 LAPB addressing

In LAPB mode the client is assigned the address "A" and the server the address "B".

7.5.2.4 Time fill

No flags or other fill characters shall be transmitted between frames. However, an end system may use the fill interval to send Carriage Return (CR) characters to provoke packet forwarding and to transmit and receive PAD signals. An end system shall , for the purpose of APS layer 2 protocols, ignore any characters received between frames. Where a frame is immediately followed by another, both the terminating flag of the first frame and the start flag of the second frame shall be present (see Figure 11).

7.5.2.5 Mapping of APS layer 2 frames to packets

Servers that are connected directly to a PSDN shall transmit (and may expect) APS layer 2 frames in the user data of the underlying X.25 data packets without the Q-bit set.

7.5.2.6 Exception conditions

On the reception of X.25 interrupts and resets, in V.42-dependent mode the APS data link protocol of the server shall disconnect the underlying connection. In LAPB and X.25 modes the LAPB data link protocol of the server shall acknowledge them without taking any further action.

Clearing the X.25 virtual call shall cause the APS layer 2 at the server to enter the disconnected phase.

Handling of PAD service signals by the client is a local matter.

7.5.3 Direct network configuration

7.5.3.1 Establishment of the underlying connection

The client establishes the circuit to the network access point.

The means of establishing the circuit are outside the scope of this Recommendation.

7.5.3.2 LAPB data link set-up

Data link set-up shall follow the procedures defined in 2.4.4/X.25.

NOTE – The APS protocols selection string is not required in this configuration.

7.5.3.3 LAPB addressing

Addressing is as per Recommendation X.25.

7.5.3.4 Time fill

Time fill is as per Recommendation X.25.

8 APS layer 3 protocols

The APS layer 3 protocol may be either the APS network protocol as specified in 8.1 or X.25 PLP as defined in Rec. X.25 | ISO/IEC 8208 with the provisions in 8.2.

8.1 The APS network protocol

The **APS network protocol** is an optimized simple connection-mode network layer protocol providing the following functions:

a) connection establishment with optional identification of called and calling addresses, version negotiation and optional user data;

b) unconfirmed data transfer with optional segmentation and reassembly;

c) confirmed release.

8.1.1 APS network protocol elements of procedure

The protocol consists of six states:

– *idle*;

– *connecting*;

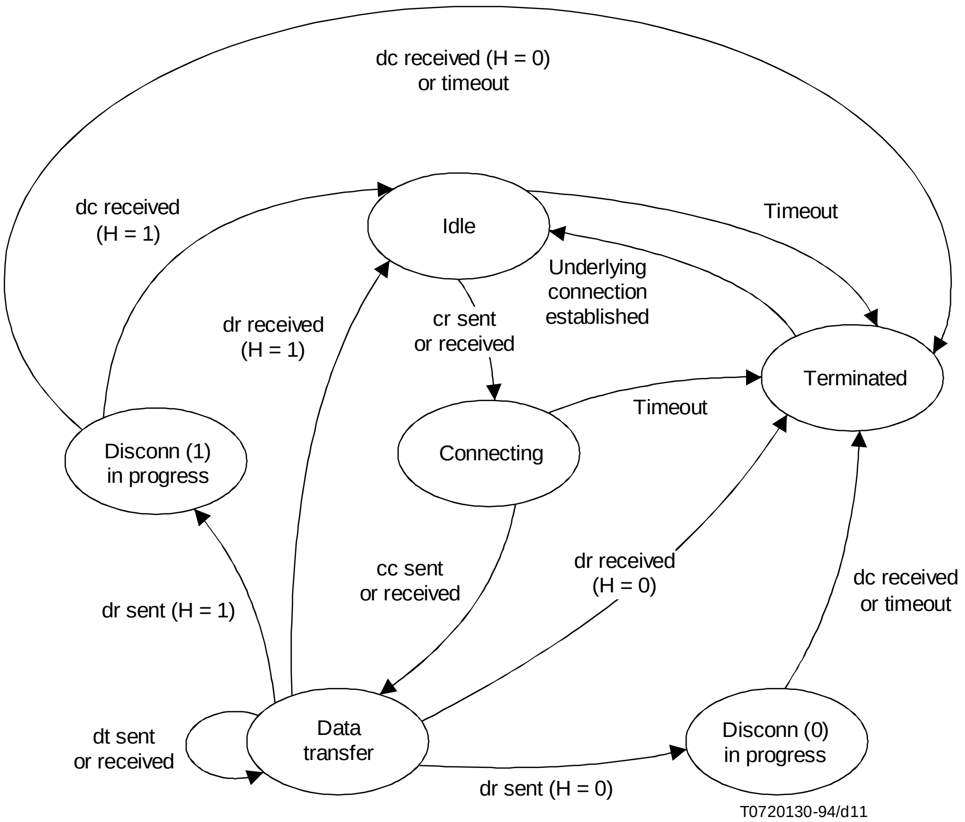
– *data transfer*;

– *disconnect (0) in progress*;

– *disconnect (1) in progress*; and

– *terminated.*

In the *idle* state the underlying connection is connected, but the network connection is disconnected. In the *terminated* state both the underlying connection and the network connection are disconnected. For illustrative reasons, Figure 12 shows the main state transitions.



NOTE – Any end system may send or receive a dr-NPDU (H = 0) from any state except disconnect (0) in progress.

FIGURE 12/X.445

APS network protocol states

8.1.1.1 Connection establishment procedure

Only the client may send a cr-NPDU. When a cr-NPDU is sent, the client enters the *connecting* state. Upon receiving a cr-NPDU the server may respond with either a cc-NPDU or a dr-NPDU (H = 0). If the server responds with a cc-NPDU, it immediately enters the *data transfer* state. When the cc-NPDU is received by the client it enters the *data transfer* state.

In the *connecting* state, if the client does not receive a cc-NPDU within APS-Tq time, it shall send a dr-NPDU (H = 0) with a diagnostic code of "Time Expired" and enter the *terminated* state.

In the *idle* state, if the server does not receive a cr-NPDU within APS-Th time, it may disconnect the underlying connection and enter the *terminated* state.

The client includes in its cr-NPDU a list of protocol version(s) that are supported. Each bit set to 1 in the version code corresponds to a protocol version. The least significant bit corresponds to version one which is defined in this Recommendation. If the proposed list is set to 0000, the server shall assume that higher version(s) than version four are proposed.

If the server is capable of supporting any of the proposed protocol versions, it shall respond with one version bit set to indicate the chosen protocol version. If the server cannot accept any of the proposed protocol versions or if the proposed versions are 0000, it shall send a dr-NPDU with a diagnostic code indicating "version not supported", and version bits set to indicate the protocol version that are supported by the server. The server shall enter the *disconnect (0) in progress* state.

The server shall upon reception of an invalid cr-NPDU send a dr-NPDU (H = 0) with a diagnostic code indicating "invalid NPDU".

If the called NSAP address is not valid, the server shall respond with a dr-NPDU (H = 0) and a diagnostic code indicating "no such address".

If a connect request cannot be progressed by the server due to a temporary condition, it shall respond with a dr-NPDU (H = 0) and a diagnostic code indicating "network congestion".

If a connect request cannot be progressed by the server due to a permanent termination of a Network access point (but the NSAP Address is otherwise valid), it shall respond with a dr-NPDU (H = 0) and a diagnostic code of "subscription terminated".

8.1.1.2 Data transfer procedure

The transfer of a dt-NPDU is not confirmed. An end system continues to send dt-NPDUs as desired. See C.3.1 for use of the M-bit.

When an end system receives a dr-NPDU, it shall immediately cease sending dt-NPDUs.

An end system shall upon reception of an invalid dt-NPDU return a dr-NPDU (H = 0) with a diagnostic code indicating "invalid NPDU" and enter the *disconnect (0) in progress* state (see 8.1.1.3).

The client shall not send cr-NPDUs while in the *data transfer* state. If a cr-NPDU is received in this state, the receiving end system shall send a dr-NPDU (H = 0) with a diagnostic code indicating "invalid NPDU" and enter the *disconnect in (0) progress* state.

8.1.1.3 Disconnect procedure

An end system may send a dr-NPDU if it wishes to disconnect or if an error has occurred. The sender of the dr-NPDU enters one of the *disconnect (0 or 1) in progress* states when it has sent the PDU. It shall ignore any dt-NPDUs while it is in this state. The end system enters the *disconnect (0) in progress* state if it wishes to disconnect the underlying connection. It enters the *disconnect in (1) progress* state if it wishes to maintain the underlying connection in the *connected* state.

The receiver of a dr-NPDU shall cease sending dt-NPDUs and send an appropriate dc-NPDU as follows:

If the H-bit of a received dr-NPDU is zero [dr-NPDU (H = 0)], the receiving end system shall acknowledge by sending a dc-NPDU (H = 0) and disconnect the underlying connection after APS-Td time. The value of APS-Td is a local matter, however, it should be chosen suitably large to allow for the complete transfer of the PDU.

If the H-bit is one and the end system allows it, the end system shall respond with a dc-NPDU (H = 1) and enter the *Idle* state. In this case, the underlying connection may be maintained for a period of (APS-Th) or until a dr-NPDU with the H-bit set to zero is received.

If the H-bit is one and the end system does not wish to hold the underlying connection, the response shall be identical to the response to receiving a dr-NPDU (H = 0).

An end system in one of the *disconnect (0 or 1) in progress* states shall, when it receives dc-NPDU (H = 0) immediately disconnect the underlying connection and enter the *terminated* state.

An end system in the *disconnect (0) in progress* state shall, when it receives a dr-NPDU, enter the *terminated* state.

An end system in the *disconnect (1) in progress* state shall:

a) if it receives a dr-NPDU (H = 0) enter the *terminated* state.

b) if it receives a dr-NPDU (H = 1) enter the *idle* state.

An end system in the *disconnect (1) in progress* state shall, when it receives a dc-NPDU (H = 1), enter the *idle* state.

If an end system in one of the *disconnect (0 or 1) in progress* states does not receive a dc-NPDU within APS-Tr time, it shall disconnect the underlying connection and enter the *terminated* state.

A dr-NPDU contains a single octet diagnostic code. The following values are defined:

- X'00 Normal;
- X'01 Unit busy;
- X'02 No such address;
- X'03 Time expired;
- X'04 Invalid user data;
- X'05 Network congestion;
- X'06 Invalid NPDU;
- X'07 Incompatible destination;
- X'08 Other abnormal condition;
- X'09 Subscription terminated;
- X'0A Version not supported.

Values X'0B-7F are reserved for future use.

Values X'80-FF are available for private use.

A disconnection due to failure of lower layers (including the underlying connection) causes local procedures described in 6.1 to occur. The APS layer 3 entity will upon detection of failure of lower layers enter the *terminated* state. No APS NPDU is sent.

8.1.2 APS network protocol structure

The APS network protocol general format is shown in Figure 13. It consists of five PDU types:

a) the connect request PDU (cr-NPDU) as defined in 8.1.2.1;

b) the connect confirm PDU (cc-NPDU) as defined in 8.1.2.2;

c) the data transfer PDU (dt-NPDU) as defined in 8.1.2.3;

d) the disconnect request PDU (dr-NPDU) as defined in 8.1.2.4;

e) the disconnect confirm PDU (dc-NPDU) as defined in 8.1.2.5.

Octets \ Bits	8	7	6	5	4	3	2	1
1	E	L	L	L	L	L	L	L
2	T	T	T	T	P	P	P	P

Header variable part (optional – allowed in some PDUs)

•

•

n User data (optional – allowed in some PDUs)

•

•

NOTES

1 E and L are used as follows:

E is the length extension bit. It is reserved for future use and shall be zero.

LLLLLLL is the length of the PDU header (less the length field itself) in octets. Encoding is binary.

2 TTTT is the PDU type.

3 PPPP is PDU-dependent.

4 The most significant bit of each octet is shown leftmost and has the number 8. The least significant bit is shown rightmost and has the number 1.

5 The first octet of each PDU is always shown at the top and has the number 1.

FIGURE 13/X.445

General format of APS NPDUs

8.1.2.1 The connect request PDU

The format of the connect request PDU shall be as shown in Figure 14.

8.1.2.2 The connect confirm PDU

The format of the connect confirm PDU shall be as shown in Figure 15.

8.1.2.3 The data transfer PDU

The format of the data transfer PDU shall be as shown in Figure 16.

8.1.2.4 The disconnect request PDU

The format of the disconnect request PDU shall be as shown in Figure 17.

8.1.2.5 The disconnect confirm PDU

The format of the disconnect confirm PDU shall be as shown in Figure 18.

8.1.2.6 Maximum user data in APS NPDUs

The user data in the cr-NPDU shall not exceed 128 octets.

The user data in the dt-NPDU shall not exceed 2048 octets. Whenever possible, each NSDU shall map to one APS NPDU. Only in cases where the NSDU size exceeds 2048 octets shall multiple APS NPDUs be used (an M-bit sequence, see C.3.1).

E	L	L	L	L	L	L	L
1	1	1	0	V	V	V	V
I	I	I	I	I	I	I	I

•

•

Calling NSAP address (optional)

•

•

F	F	F	F	F	F	F	F

•

•

Called NSAP address (optional)

•

•

User data (optional)

NOTES

1 ELLLLLLL is the length of the PDU header as described in the Notes to Figure 13.

2 VVVV is the proposed list of protocol versions. Each bit set to 1 corresponds to a proposed version number with higher order bits corresponding to higher versions. The version defined by this Recommendation is version 1 and has the bit 1 set to 1. Encoding of higher versions (higher than version four) is for further study.

3 IIIIIIII is the length of the calling address in octets. Encoding is binary. If the calling address is absent, the length field shall be zero.

4 FFFFFFFF is the length of the called address in octets. Encoding is binary. If the called address field is absent, the length field shall be zero.

5 The NSAP address comprises up to 20 octets and shall use binary encoding as per Rec. X.213 ISO/IEC 8348.

FIGURE 14/X.445

Format of the cr-NPDU

8.2 X.25 PLP operation

For the Point-to-Point configuration and the Direct Network configuration, the procedures defined in Rec. X.614 | ISO/IEC 10732, Rec. X.25 and Rec. X.32 shall apply as constrained by 8.2.1, (see Figures 2 and 4).

For the PAD configuration the procedures defined in Recommendations X.25 and X.32 shall apply as constrained by 8.2.1, (see Figure 3).

0	0	0	0	0	0	0	1
1	1	0	1	V	V	V	V

NOTE – VVVV is the chosen protocol version number. Only one bit shall be set to 1. The version defined by this Recommendation is version 1 and has the bit number 1 set to 1.

FIGURE 15/X.445

Format of the cc-NPDU

0	0	0	0	0	0	0	1
1	1	1	1	M	R	R	R

•

•

User data (optional)

•

•

NOTES

1 M is the More bit. This is described in C.3.1.

2 RRR is reserved for future use and shall be zero.

FIGURE 16/X.445

Format of the dt-NPDU

8.2.1 Optional and negotiable parameters

End systems that work in the Point-to-Point and PAD configurations shall be able to work with the following X.25 PLP parameters:

a) at least one logical channel;

b) a logical channel group number of zero;

c) a logical channel number starting with one;

d) default packet size of 128 octets. However, the client may propose any packet size in the range 16 to 4096 octets inclusive.

0	0	0	0	0	0	1	0
1	0	0	0	H/V	R/V	R/V	R/V
Diagnostic code							

NOTES

1 H is the Hold bit. It shall be set to zero if termination of the underlying connection is desired and set to one if the APS layer 3 wishes to re-use the underlying connection.

2 VVVV is the list of protocol versions supported by the server. They are set only if the diagnostic code is "version not supported".

3 RRR are reserved for future use and shall be zero.

4 Diagnostic codes are defined in 8.1.1.3.

FIGURE 17/X.445

Format of the dr-NPDU

0	0	0	0	0	0	0	1
1	1	0	0	H	R	R	R

NOTES

1 H is the Hold bit. It shall be set to one if the corresponding dr-NPDU had its H-bit set to one and the sender of the dc-NPDU agrees to holding the underlying connection. It shall be set to zero otherwise.

2 RRR are reserved for future use and shall be zero.

FIGURE 18/X.445

Format of the dc-NPDU

Implementations that work in the Point-to-Point and PAD configurations are not required to support:

a) permanent virtual circuits;

b) diagnostic packets;

c) on-line facility registration;

d) D-bit modification;

e) throughput negotiation;

f) extended packet sequence numbering;

g) packet retransmission;

h) closed user groups;

i) fast select;

j) reverse charging;

k) call redirection;

l) call deflections;

m) transit delay selection and indication;

n) ICRD facilities;

o) called line address modified notification;

p) TOA/NPI address subscription;

q) ROA Selection.

Address mode usage (data network address or address extension facilities) is subject to bilateral agreement between the client and the server. However, the server shall be able to accept the address extension facilities.

The client may propose any window size in the range of 2 to 7 inclusive.

Other or additional use of the parameters listed above is allowed by bilateral agreement.

8.2.1.1 Parameter usage in the Direct Network configuration

In the Direct Network configuration, packet and window sizes and other optional parameters may be determined by registration or by negotiation for each call.

Annex A

Transparency

(This annex forms an integral part of this Recommendation)

A.0 Transparency

A.1 Introduction

This Recommendation defines three levels of transparency processing for use with start/stop mode transmission. These are :

– *Basic transparency* that provides transparency processing for the flags and the control escape octets as described in 4.5.2 of ISO/IEC 3309;

– *APS PAD transparency* specified in A.2;

– *Seven-Bit Data Path transparency* as specified in 4.5.2.1 of ISO/IEC 3309 and used in conjunction with the control-character octet transparency described in 4.5.3.2 of ISO/IEC 3309.

A.2 APS PAD transparency

The transparency procedure defined in 4.5.2 of ISO/IEC 3309 is applied to the FE5/CR, TC7/DLE, DC1/XON and DC3/XOFF control characters (i.e. x0001101, x0010000, x0010001 and x0010011, respectively, where “x” may be either “0” or “1”), in addition to the flag and control escape octets. This has the effect of assuring that the octet stream does not contain values which could be interpreted by a PAD as control characters (regardless of parity).

NOTE – Character encoding shown in this subclause is represented with the most significant bit to the left.

Annex B

APS protocols selection string

(This annex forms an integral part of this Recommendation)

B.0 APS protocols selection string

B.1 Introduction

As part of the **data link** set-up procedures defined in 7.5.1.2 and 7.5.2.2, the client informs the server of the mode and the transparency level to be used. The selection information is transmitted as a character string as the first data transmitted by the client following establishment of the underlying connection. In the PAD configuration, the selection string may optionally be sent in the user data field of the X.25 call request issued by the PAD, (see B.3).

B.2 APS protocols selection string format

The **selection string** shall be in the format **APSptpt,** where:

- **APS** is the introduction string.
- **p** is the mode selector character. The following characters are defined:

  A – V.42-dependent mode;

  H – LAPB mode;

  X – X.25 mode.
- **t** is the transparency level selector character. The following characters are defined:

  B – Basic transparency;

  8 – APS PAD transparency;

  7 – Seven-Bit Data Path transparency.

The APS protocols selection string may be terminated by one or more carriage return characters, for example to trigger packet forwarding by a PAD. Leading and trailing carriage return characters shall be ignored by the server.

All the characters in the APS protocols selection string are ISO/IEC 646 characters. The alphabetic characters shall be upper case. The most significant bit of each character shall be set to zero when characters are sent unless it's used to meet parity requirements when the Seven-Bit Data path transparency is to be operated. However the most significant bit of each character is ignored on reception.

As an example:

APSHBHB<cr>

specifies LAPB mode/Basic transparency.

B.3 Use of the call user data in X.25 call requests

When the underlying connection is using an X.25 virtual call via a PAD, the X.25 call user data may be used to carry the APS protocols selection string. Since the first four octets of the call user data field are dictated by the PAD according to Recommendation X.29 (i.e. the client has no direct control over these octets), the APS protocols selection string starts at the fifth octet.

According to Recommendation X.28, some networks may not make the call user data field available to the PAD user. Consequently, the client that uses normally the PAD call user data to send the first APS protocols selection string shall be able to send it as data when the PAD call user data field is unavailable.

Annex C

Use of the APS network protocol to provide the OSI Connection-mode network service

(This annex forms an integral part of this Recommendation)

C.0 Use of the APS network protocol to provide the OSI connection-mode network service

C.1 Introduction

This annex describes the provision of a subset of the OSI Connection-mode Network Service (CONS) using the APS network protocol.

C.2 Network connection establishment phase

Table C.1 shows the relationships between CONS primitives and APS NPDUs used during connection establishment. Table C.2 shows the mapping between service parameters and APS NPDU fields.

TABLE C.1/X.445

Mapping between CONS connect primitives and APS NPDUs

CONS primitive	APS NPDU
N-CONNECT request	cr-NPDU (sent)
N-CONNECT indication	cr-NPDU (received)
N-CONNECT response	cc-NPDU (sent)
N-CONNECT confirm	cc-NPDU (received)

C.3 Data transfer phase

Table C.3 shows the mapping between CONS primitives and APS NPDUs used for data transfer. The NS-user-data is mapped as described in 6.2.1.

C.3.1 Handling of NS-user-data

When an APS layer 3 entity receives an N-DATA request primitive from a network service user, it transmits a sequence of one or more dt-NPDUs, known as an M-bit sequence, to the remote end system. The number of APS NPDUs needed in an M-bit sequence depends on the amount of NS-user-data and the PDU size. All dt-NPDUs except the last one in an M-bit sequence contain the maximum number of octets and have their M-bit set to 1. The last dt-NPDU has its M-bit set to 0.

When an APS layer 3 entity receives an M-bit sequence, it signals an N-DATA indication primitive to the network service user.

TABLE C.2/X.445

Mapping between CONS connect parameters and cr-NPDU fields

CONS parameters	APS NPDU field
Called address	Called address
Calling address	Calling address
Responding address	(Not supported)
Receipt confirmation set	(Not supported)
Expedited data selection	(Not supported)
QOS-parameter set	(Not supported)
NS-user-data	User data

TABLE C.3/X.445

Mapping between CONS data primitives and APS NPDUs

CONS primitive	APS NPDU
N-DATA request	dt-NPDU (sent)
N-DATA indication	dt-NPDU (received)

C.3.2 The reset service

The reset service is not supported by the APS network protocol.

C.4 Network connection release phase

Table C.4 shows the relationships between CONS primitives and APS NPDUs during connection release. When the APS layer 3 entity receives an N-DISCONNECT request from the Network Service user, it transmits a dr-NPDU to the remote end system with a diagnostic code as specified in C.4.1.

NOTE 1 – The APS layer 3 may choose to set the H-bit to one or zero. The management of the H-bit is a local matter.

When an APS layer 3 entity receives a dr-NPDU, it transmits a dc-NPDU and signals an N-DISCONNECT indication primitive to the network service user. The APS layer 3 diagnostic code is mapped to a network service reason code as defined in C.4.1.

NOTE 2 – Receipt of a dc-NPDU does not cause any network service primitive to be generated.

C.4.1 Mapping of N-DISCONNECT Parameters

The N-DISCONNECT originator parameters in conjunction with the reason parameters are mapped to dr-NPDU *reason codes* as shown in Table C.5.

The NS-user-data parameter and the responding address parameter are not supported by this Recommendation.

TABLE C.4/X.445

Mapping between CONS disconnect primitives and APS NPDUs

CONS primitive	APS NPDU
N-DISCONNECT request	dr-NPDU (sent)
N-DISCONNECT indication	dr-NPDU (received)

TABLE C.5/X.445

Mapping between CONS originator/reason parameters and APS NPDU diagnostic code

CONS reason parameter	CONS originator parameter	dr-NPDU diagnostic code
Disconnection-normal condition	NS user	Normal
Disconnection-abnormal condition	NS user	Other abnormal condition
Connection rejection permanent condition	NS user	Incompatible destination
Connection rejection transient condition	NS user	Unit busy
Connection rejection-QOS not available transient condition	NS provider	(Local matter)
Connection rejection-QOS not available permanent condition	NS provider	Version not supported
Connection rejection-QOS not available transient condition	NS user	(Not supported)
Connection rejection-QOS not available permanent condition	NS user	(Not supported)
Connection rejection-incompatible information in NS-user-data	NS user	Invalid user data
Connection rejection-reason unspecified-transient condition	NS provider	(Clause 6)
Connection rejection-reason unspecified-permanent condition	NS provider	Invalid NPDU
Disconnection-permanent condition	NS provider	(Not supported)
Disconnection-transient condition	NS provider	Time expired
Connection rejection-NSAP address unknown (permanent condition)	NS provider	No such address
Connection rejection-NSAP unreachable-transient condition	NS provider	Network congestion
Connection rejection-NSAP unreachable-permanent condition	NS provider	Subscription terminated

Annex D

Recommended practices for use in MHS environment

(This annex does not form an integral part of this Recommendation)

D.0 Recommended practices

D.1 APS layer 3 protocols

D.1.1 Use of the APS network protocol for simultaneous communications

The APS network protocol allows only a single data stream on a given underlying connection. This may impact some communications configurations where, for example, a client wants to establish simultaneous communications with multiple servers, or two systems want to establish simultaneous communications between each other either in one or both directions (for example, simultaneous associations between two MTAs).

In such configurations, simultaneous communications can be achieved either by using a “multiplexing feature” in the higher layers or by establishing additional underlying connections.

D.1.2 Handling of future versions

In order to ensure any compatibility with future extensions to this protocol, an end system should ignore any octets in the header of the cr-NPDU that are not defined.

D.2 APS layer 2 protocols

D.2.1 LAPB retransmission timer

It is recommended that the value used for the retransmission timer be based upon the round-trip delay experienced on the link. The end system should maintain, and continually update, an estimate of the round-trip delay for the link. From this estimate, a value for the retransmission timer (**T1**) is calculated each time it is started. Example techniques for maintaining the estimate and calculating the retransmission timer are described below.

As network load increases, the variability of round-trip delay also increases. In environments where load fluctuates widely, it is therefore useful to estimate the variability of round-trip delay measurements and use this estimate in the calculation of retransmission timer values. An estimate of the variability of round-trip delay measurements can be efficiently calculated as an exponentially weighted average of the differences between round-trip delay measurements and the average round-trip delay. This represents the mean deviation of the round-trip delays, which is a useful approximation of the standard deviation and can be much more efficiently computed. The formula is:

$$\mathbf{D} \;{<}{-}{-}{-}\; \mathbf{D} + (\mathbf{1} - \mathbf{a})\,(|\mathbf{S} - \mathbf{E}| - \mathbf{D})$$

where

D is the estimate of variability in round-trip delays;

S is the new sample;

E is the current estimate of the round-trip delay as defined below;

a is a locally administered factor which can be set to some value between **0** and **1**.

The value of **E** may be calculated using an exponentially weighted average based upon regular sampling of the interval between transmitting a frame and receiving the corresponding acknowledgment. Samples are taken by recording the time of day when a frame requiring acknowledgment is transmitted and calculating the difference between this and the time of day when the corresponding acknowledgment is received. New samples are incorporated with the existing average according to the following formula:

$$\mathbf{E} \;{<}{-}{-}{-}\; \mathbf{E} + (\mathbf{1} - \mathbf{a})\,(\mathbf{S} - \mathbf{E})$$

A value for **a** should be chosen to keep the retransmission timer sufficiently small such that lost frames will be detected quickly, but not so small that false alarms are generated causing unnecessary retransmission.

As before the value of **a** shall be between **0** and **1** and the choice of a value of $\mathbf{(1 - 2^{-n})}$ allows for efficient update of the average. The value of **a** for the variability estimation, however, does not need to be the same as that used for the round-trip delay estimate. A smaller value for **a** is useful in the variability estimation to cause a more rapid response to changes in round-trip delays. **D** can then be used to calculate retransmission timer values according to the formula:

$$\mathbf{T1 \leftarrow E + kD}$$

where

T1 is the retransmission timer value;

E is the estimated average round-trip delay;

k is a locally administered factor.

Since **D** approximates the standard deviation of the round-trip delays, but is greater than or equal to the standard deviation, round-trip delays within **k** standard deviations of the mean would be accounted for by the retransmission timer value (e.g. **k** = **2**, if round-trip delays were normally distributed, would account for 95% of the variability).

Round-trip time measurements based on acknowledgment of any retransmitted data should not be used to update the round-trip delay estimate or the estimate of variability. Such measurements are not reliable since it is ambiguous which transmission of the data is being acknowledged.

One strategy for handling a retransmission timeout is to retransmit the frame and reset the timer with a value that is twice the previous value. In this case, a new round-trip delay estimate and estimate of variability should be calculated only when an acknowledgment of data is received where none of the acknowledged data has been retransmitted. This calculation uses the new round-trip delay measurement and the last estimate before the retransmission timeout(s).

D.3 Start/stop framing

D.3.1 Fast Frame Control Check (FCS) implementation

The following "C" code illustrates a table look-up computation for calculating the FCS used in LAPB as defined in 7.2 and the APS data link protocol as defined in 7.3.

```
/*
 * u16 represents an unsigned 16-bit number. Adjust the typedef for your hardware.
 */

typedef unsigned short u16;

static u16 fcstab[256] = {

        0x0000, 0x1189, 0x2312, 0x329b, 0x4624, 0x57ad, 0x6536, 0x74bf,
        0x8c48, 0x9dc1, 0xaf5a, 0xbed3, 0xca6c, 0xdbe5, 0xe97e, 0xf8f7,
        0x1081, 0x0108, 0x3393, 0x221a, 0x56a5, 0x472c, 0x75b7, 0x643e,
        0x9cc9, 0x8d40, 0xbfdb, 0xae52, 0xdaed, 0xcb64, 0xf9ff, 0xe876,
        0x2102, 0x308b, 0x0210, 0x1399, 0x6726, 0x76af, 0x4434, 0x55bd,
        0xad4a, 0xbcc3, 0x8e58, 0x9fd1, 0xeb6e, 0xfae7, 0xc87c, 0xd9f5,
        0x3183, 0x200a, 0x1291, 0x0318, 0x77a7, 0x662e, 0x54b5, 0x453c,
        0xbdcb, 0xac42, 0x9ed9, 0x8f50, 0xfbef, 0xea66, 0xd8fd, 0xc974,
        0x4204, 0x538d, 0x6116, 0x709f, 0x0420, 0x15a9, 0x2732, 0x36bb,
        0xce4c, 0xdfc5, 0xed5e, 0xfcd7, 0x8868, 0x99e1, 0xab7a, 0xbaf3,
        0x5285, 0x430c, 0x7197, 0x601e, 0x14a1, 0x0528, 0x37b3, 0x263a,
        0xdecd, 0xcf44, 0xfddf, 0xec56, 0x98e9, 0x8960, 0xbbfb, 0xaa72,
        0x6306, 0x728f, 0x4014, 0x519d, 0x2522, 0x34ab, 0x0630, 0x17b9,
        0xef4e, 0xfec7, 0xcc5c, 0xddd5, 0xa96a, 0xb8e3, 0x8a78, 0x9bf1,
        0x7387, 0x620e, 0x5095, 0x411c, 0x35a3, 0x242a, 0x16b1, 0x0738,
        0xffcf, 0xee46, 0xdcdd, 0xcd54, 0xb9eb, 0xa862, 0x9af9, 0x8b70,
        0x8408, 0x9581, 0xa71a, 0xb693, 0xc22c, 0xd3a5, 0xe13e, 0xf0b7,
        0x0840, 0x19c9, 0x2b52, 0x3adb, 0x4e64, 0x5fed, 0x6d76, 0x7cff,
        0x9489, 0x8500, 0xb79b, 0xa612, 0xd2ad, 0xc324, 0xf1bf, 0xe036,
        0x18c1, 0x0948, 0x3bd3, 0x2a5a, 0x5ee5, 0x4f6c, 0x7df7, 0x6c7e,
        0xa50a, 0xb483, 0x8618, 0x9791, 0xe32e, 0xf2a7, 0xc03c, 0xd1b5,
```

```
	0x2942, 0x38cb, 0x0a50, 0x1bd9, 0x6f66, 0x7eef, 0x4c74, 0x5dfd,
	0xb58b, 0xa402, 0x9699, 0x8710, 0xf3af, 0xe226, 0xd0bd, 0xc134,
	0x39c3, 0x284a, 0x1ad1, 0x0b58, 0x7fe7, 0x6e6e, 0x5cf5, 0x4d7c,
	0xc60c, 0xd785, 0xe51e, 0xf497, 0x8028, 0x91a1, 0xa33a, 0xb2b3,
	0x4a44, 0x5bcd, 0x6956, 0x78df, 0x0c60, 0x1de9, 0x2f72, 0x3efb,
	0xd68d, 0xc704, 0xf59f, 0xe416, 0x90a9, 0x8120, 0xb3bb, 0xa232,
	0x5ac5, 0x4b4c, 0x79d7, 0x685e, 0x1ce1, 0x0d68, 0x3ff3, 0x2e7a,
	0xe70e, 0xf687, 0xc41c, 0xd595, 0xa12a, 0xb0a3, 0x8238, 0x93b1,
	0x6b46, 0x7acf, 0x4854, 0x59dd, 0x2d62, 0x3ceb, 0x0e70, 0x1ff9,
	0xf78f, 0xe606, 0xd49d, 0xc514, 0xb1ab, 0xa022, 0x92b9, 0x8330,
	0x7bc7, 0x6a4e, 0x58d5, 0x495c, 0x3de3, 0x2c6a, 0x1ef1, 0x0f78
};

#define APSINITFCS    0xffff    /* Initial FCS value */
#define APSGOODFCS  0xf0b8   /* Good final FCS value */

/*
 * Calculate a new fcs given the current fcs and the new data.
 */

u16 apsfcs(fcs, cp, len)
register u16 fcs;
register unsigned char *cp;
register int len;

{
while (len--)

		fcs = (fcs >> 8) ^ fcstab[(fcs ^ *cp++) & 0xff];

	return (fcs);
}
```

FCS calculation and checking procedures defined in 4.6.2 of ISO/IEC 3309 imply the following operations to be done on the FCS calculated by the above procedure.

On the transmitter side:

1) the initial FCS value is set to APSINIT;
2) the resulting FCS value is ones complemented;
3) the low order octet is inserted first in the frame to be transmitted followed by the high order octet.

On the receiver side:

1) the initial FCS value is set to APSINITFCS;
2) an FCS is calculated using the above procedure on the frame received including the FCS octet;
3) the resulting FCS is checked to be equal to APSGOODFCS.

D.4 Modems

D.4.1 V.42 modems

V.42 modems can operate in three modes:

a) LAPM, which provides full error correction.
b) The "Alternative Procedure" in V.42, which provides full error correction.
c) Non-error correcting mode.

Since V.42-dependent mode relies on the use of an error correcting mode, it is recommended that end systems ensure that the modem is effectively operating in an error correcting mode after the underlying connection has been established. Failure to do so may cause unrecoverable transmission errors to occur and cause the link to be disconnected.

D.4.2 Modems with automatic data rate switching

Modems that adapt transmitted data rates to link conditions may cause problems in conjunction with adjustable timers.

D.4.3 Modem flow control

It is recommended that end systems are able to support modem hardware flow control. This is particularly important if the Basic transparency (see B.1) is operated as the XON and XOFF characters appearing in the data to be transmitted will not be hidden.

D.5 PAD operation

D.5.1 Recommended PAD parameters

If the operation of the PAD permits, it is recommended that the client sets the PAD parameters to the relevant values before the X.25 virtual call is set up. Rec. X.28 envisages the possibility of PADs which automatically initiate the connection process without giving an opportunity for the PAD parameters to be altered, on the assumption that the PAD has *a priori* knowledge of the values required. Such PADs can be used provided that *a priori* parameter settings are done according to this subclause.

The following suggestions apply to PAD parameter settings and associated operations:

a) PAD parameter 1 is set to 0 or 1.

   If set to 1 this allows the client to force the PAD into the PAD command state from the data transfer state by transmitting a DLE character.

   NOTE 1 – The APS PAD transparency and the Seven-Bit Data Path transparency mechanisms specified in Annex A ensure that any DLE character in the data to be transmitted will be hidden.

b) PAD parameter 3 is set to the value 2.

   This value should cause the PAD to forward data when it gets a CR character.

   NOTE 2 – The APS PAD transparency and the Seven-Bit Data Path transparency mechanisms specified in Annex A ensure that any CR character in the data to be transmitted will be hidden.

   It is recommended that the client should normally add an un-escaped carriage return after each frame. The exception to this is if there is an immediately following frame, in which case the carriage return may be omitted provided that delay in delivery of the first frame until the second frame can be delivered will not cause expiry of any retransmission timer, e.g. the LAPB timer T1, at either system.

   If there is a delay in transmitting a following frame and the PAD parameter 4 is set to zero, it's necessary to add a CR character after the frame to provoke frame forwarding.

c) PAD parameter 5 is set either to the value 1 or to the value 2.

   This ensures that the PAD can use XON/XOFF signaling to control the flow of data from the client.

   NOTE 3 – The APS PAD transparency and the Seven-Bit Data Path transparency mechanisms specified in Annex A ensure that any XON or XOFF character in the data to be transmitted will be hidden.

   The client shall act on any received XOFF and XON characters and cease and restart transmission accordingly.

d) The remainder of parameters 2, 4, 7 to 10, 12 to 15, and 21 to 22 are normally set to zero. However, when Seven-Bit Data Path transparency is operated, parameter 21 can be adjusted to meet the parity requirements of the system, the PAD or intermediate equipment. Parameter 6 may not be set to zero if the client chooses to handle the PAD service signals in some circumstances.

e) An end system may be capable of using different PAD parameter values from those given above if there is a requirement to work with non-standard PADs which do not support the above values. In particular, the Seven-Bit Data Path transparency mechanism would make it possible to work with PADs which do not support the zero values of parameters relating to the insertion of padding.

   With either the APS PAD transparency or Seven-Bit Data Path transparency level it would also be possible to operate with parameter 4 set to a small non-zero value, so that the PAD forwards data from the client across the network whenever there is a delay in receiving more incoming data; this would make it possible to operate (although less efficiently) without the use of the CR character to indicate forwarding.

D.5.2 Remote PAD parameters

The server should not modify the remote PAD parameters after a client has established a connection. Any changes in the PAD parameters could adversely affect the operation of the connection.

D.6 Timers and counters

D.6.1 APS layer 2

The following values are recommended for timers and counters:

a) APS-Tc 5 seconds (client retransmit time);

b) APS-N 4 (number of re-tries);

c) APS-Ts 15 seconds (Data Link timeout).

D.6.2 APS layer 3

The following values are recommended for timers:

a) APS-Th local matter (idle disconnection time);

b) APS-Td local matter (underlying connection disconnect time);

c) APS-Tq 30 seconds (network connection reply timeout);

d) APS-Tr 5 seconds (network disconnect reply timeourt).