ATIS-1000618.1991(R2013)

Integrated Services Digital Network (ISDN) – Core Aspects of Frame Protocol for Use with Frame Relay Bearer Service

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ATIS-1000618.1991(R2013), *Integrated Services Digital Network (ISDN) – Core Aspects of Frame Protocol for Use with Frame Relay Bearer Services*

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American National Standard
for Telecommunications –

Integrated Services Digital Network (ISDN) – Core Aspects of Frame Protocol for Use with Frame Relay Bearer Service

Secretariat

Exchange Carriers Standards Association

Approved October 24, 1991

American National Standards Institute, Inc.

Abstract

This standard provides a description of the protocol to support the data transfer phase of the Frame Relay bearer service as defined in ANSI T1.606, *Frame relaying bearer service – Architectural framework and service description* including Addendum 1. The protocol defined in this standard is a protocol operating in the lowest sublayer of the data link layer of the OSI reference model and is based on a subset of ANSI T1.602 (LAPD) called the "core aspects." These procedures are used by both demand and semipermanent virtual calls.

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Contents

Foreword (This foreword is not part of American National Standard T1.618-1991.)

This standard and ANSI T1.617 were developed in parallel over a period of five years within committee T1S1 and its predecessor committee T1D1. All work on these standards has been done in close cooperation with parallel work in CCITT to develop an extension to CCITT Recommendation Q.921 and a new CCITT Recommendation Q.922 that reflects the material contained in this document. At the time of publication this document is closely aligned with a stable draft CCITT Recommendation for Q.922.

Although the material in this standard is directed towards usage with high-quality ISDN services, a significant portion has application for use with any other digital low-error-rate services. Usage with non-ISDN services is not clearly delineated in the text and may be a subject for further standardization. The application of this standard to higher speed digital services is also a subject for future work.

This standard contains two annexes for information only and they are designated informative.

Suggestions for improvement of this standard will be welcome. They should be sent to the Exchange Carriers Standards Association, 1200 G Street, NW, Suite 500, Washington, DC 20005.

This standard was processed and approved for submittal to ANSI by Accredited Standards Committee on Telecommunications, T1. Committee approval of this standard does not necessarily imply that all committee members voted for its approval. At the time it approved this standard, Committee T1 had the following members:

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ii

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iv

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American National Standard
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Integrated Services Digital Network (ISDN) – Core Aspects of Frame Protocol for Use with Frame Relay Bearer Service

1 Scope and purpose

This standard provides a description of the protocol to support the data transfer phase of the Frame Relay bearer service as defined in ANSI T1.606, *Frame relaying bearer service – Architectural framework and service description* including Addendum 1. The protocol defined in this standard is a protocol operating in the lowest sublayer of the data link layer of the OSI reference model and is based on a subset of ANSI T1.602 (LAPD) called the "core aspects." These procedures are used by both demand and semipermanent virtual calls.

This protocol is intended to support multiple simultaneous frame relay bearer connections (i.e., connections at core sublayer) within a single bearer channel (i.e., a connection at the physical layer). This protocol provides for transparent transfer of user data and does not restrict the contents, format, or coding of the information, or interpret its structure. This standard is applicable to Frame Relay Bearer Service (FRBS). It is intended for use on any bearer channel, and when operating on the D-channel, it is used concurrently with ANSI T1.602 procedures.

The core functions of the LAPD protocol that are used to provide this function are:

– frame delimiting, alignment, and transparency provided by the use of HDLC flags and zero bit insertion/extraction;

– frame multiplexing/demultiplexing using the address field;

– inspection of the frame to ensure that it consists of an integer number of octets prior to zero bit insertion or following zero bit extraction;

– inspection of the frame to ensure that it is not too long or too short;

– detection of (but not recovery from) transmission errors; and

– congestion control functions.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below.

ANSI T1.602-1990, *Telecommunications — Integrated Services Digital Network (ISDN) — Data link layer signaling specification for application at the user–network interface*

ANSI T1.606-1989, *Telecommunications – Integrated Services Digital Network (ISDN) – Architectural framework and service description for frame-relaying bearer service*

3 Definitions

3.1 B-channel: A 64-kbit/s channel accompanied by timing, intended to carry a wide variety of user information streams, such as voice encoded at 64 kbit/s, data information at bit rates less than or equal to 64 kbit/s, wideband voice encoded at 64 kbit/s, and voice encoded

at bit rates less than 64 kbit/s alone or combined with other digital information streams.

3.2 basic rate interface: An ISDN user–network interface where the interface structure is composed of two B-channels and one D-channel, 2B+D. The bit rate of the D-channel in this structure is 16 kbit/s.

3.3 bidirectional asymmetric: The condition in which the information flow characteristics provided by the service are different in the two directions.

3.4 bidirectional symmetric: The condition in which the information flow characteristics provided by the service are the same between two (or more) reference points in the forward and backward directions.

3.5 CCITT (International Telegraph and Telephone Consultative Committee): The CCITT is a permanent organization of the International Telecommunications Union (ITU), a specialized agency of the United Nations since 1948. As the oldest international treaty organization, the ITU traces its formal beginnings to 1865. The CCITT was founded in 1954 for the purpose of promoting and ensuring the operation of international telecommunications systems.

3.6 D-channel: A 16- or 64-kbit/s channel carrying control and signaling information and, optionally, packetized information and telemetry.

3.7 default: The term "default" implies that the value defined should be used in the absence of any predefined assignment or per call negotiation of alternative values.

3.8 functional group: Sets of functions that may be needed in ISDN user access arrangements. In a particular access arrangement, specific functions in a functional group may or may not be present, and may be performed in one or more pieces of equipment.

3.9 H-channel: A 384-, 1472-, or 1536-kbit/s channel (H_0, H_{10}, and H_{11} respectively) accompanied by timing, intended to carry a wide variety of user information streams, such as fast facsimile, video, high-speed data, high-quality audio, information streams each at rates less than the respective H-channel bit rates that have been rate-adapted or multiplexed together, and packet-switched information.

3.10 ISDN (Integrated Services Digital Network): A network, in general evolving from an existing telephony network, which provides end-to-end digital connectivity to support a wide range of both voice and nonvoice services. User access to an ISDN is via a limited set of standard multipurpose interfaces.

3.11 network or network side: The system or equipment on one side of the ISDN user–network interface (basic rate or primary rate) that provides a port through which the user gains access to the telecommunication services offered by the ISDN.

3.12 Network Termination 1 (NT1): A functional group that includes functions broadly equivalent to layer 1 (physical) of the OSI reference model. These functions are associated with the proper physical and electromagnetic termination of the network, and include line transmission termination layer 1, the maintenance functions, performance monitoring, timing, power transfer, layer 1 multiplexing, and interface termination.

3.13 Network Termination 2 (NT2): A functional group that includes functions broadly equivalent to layer 1 and higher layers of the CCITT Recommendation X.200 reference model. PBXs, local area networks, and terminal controllers are examples of equipment or combinations of equipment that provide NT2 functions. These functions include layer 2 and layer 3 protocol handling, layer 2 and layer 3 multiplexing, switching, concentration, maintenance functions, and interface termination.

3.14 primary rate interface: An ISDN user–network interface where the interface structure is composed of multiple B-channels and one D-channel. The bit rate of the D-channel in this structure is 64 kbit/s. When a 1544-kbit/s primary rate interface is provided, the interface structure is 23B+D.

3.15 reference point: A conceptual point dividing functional groups in an ISDN access arrangement. In a specific access arrangement, a reference point may correspond to a physical interface between pieces of equipment, or there may not be any physical interface corresponding to the reference point.

3.16 S reference point: The conceptual reference point dividing the TE1 and the NT2 in a particular ISDN access arrangement.

8	7	6	5	4	3	2	1	Octet
Flag								
0	1	1	1	1	1	1	0	1
Address (high-order octet)								2
(low-order octet)								3 Note
Frame relay information field								4 to n-3
FCS (first octet)								n-2
(second octet)								n-1
Flag								
0	1	1	1	1	1	1	0	n
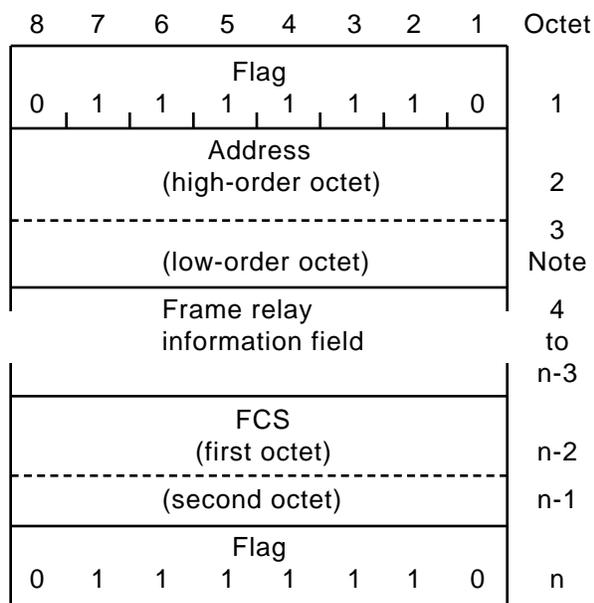
NOTE – The default address field length is two octets. It may be extended to either three or four octets by bilateral agreement.

Figure 1 – Frame relay frame format with two-octet address

3.17 T reference point: The conceptual reference point dividing the NT2 and the NT1 in a particular ISDN access arrangement.

3.18 Terminal Equipment (TE): A functional group that includes functions broadly belonging to layer 1 and higher layers of the CCITT Recommendation X.200 reference model. Digital telephones, data terminal equipment, and integrated work stations are examples of equipment (or combinations of equipment) that provide these functions. These functions include protocol handling, maintenance functions, interface functions, and connection functions to other equipment.

3.19 U reference point: A conceptual reference point on the network side of the NT1 in a particular ISDN access arrangement.

3.20 unidirectional: The condition in which the information flow of messages is provided only in one direction.

3.21 user or user side: The call control in the user equipment that communicates to the network across the basic or primary rate interface.

4 Frame relay frame structure

4.1 General

The frame relay frame format is shown in figure 1. The fields shown in the figure are described in the following subclauses.

4.2 Flag sequence

All frames start and end with the flag sequence consisting of one 0 bit followed by six contiguous 1 bits and one 0 bit. The flag preceding the address field is defined as the opening flag. The flag following the Frame Check Sequence (FCS) field is defined as the closing flag. The closing flag may also serve as the opening flag of the next frame; however, receivers must be able to accommodate reception of one or more consecutive flags on a bearer channel.

4.3 Address field

The address field consists of at least two octets as illustrated in figure 1, but may optionally be extended up to four octets. The address field format is defined in 5.2.

4.4 Control field

There is no control field for frame relay core services.

4.5 Frame relay information field

The frame relay information field follows the address field (see 4.3) and precedes the frame check sequence (see 4.7). The contents of the frame relay information field consist of an integral number of octets (no partial octets). The maximum size of the frame relay information field is a system parameter and is identified as N203.

The default maximum information field size to be supported by networks is 262 octets. This default maximum size was chosen for compatible operation with LAPD on the D-channel, which has a two-octet control field and a 260-octet maximum information field. All other maximum values are negotiated between users and networks and between networks. The minimum frame relay information field size is one octet. The support by networks of a negotiated maximum value of at least 1600 octets is strongly recommended for applications such as LAN interconnect, to minimize the need for segmentation and reassembly by the user equipment.

4.6   Transparency

A transmitting data link layer entity must examine the frame content between the opening and closing flag sequences (address, frame relay information, and FCS fields) and must insert a 0 bit after all sequences of five contiguous 1 bits (including the last five bits of the FCS) to ensure that a flag or an abort sequence is not simulated within the frame. A receiving data link layer entity must examine the frame contents between the opening and closing flag sequences and must discard any 0 bit that directly follows five contiguous 1 bits.

4.7   Frame checking sequence (FCS) field

The FCS field is a 16-bit sequence. It is the ones complement of the sum (modulo 2) of:

– the remainder of (X^k) * $(X^{15} + X^{14} + X^{13} + X^{12} + X^{11} + X^{10} + X^9 + X^8 + X^7 + X^6 + X^5 + X^4 + X^3 + X^2 + X^1 + 1)$ divided (modulo 2) by the generator polynomial $X^{16} + X^{12} + X^5 + 1$, where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency, and

– the remainder of the division (modulo 2) by the generator polynomial $X^{16} + X^{12} + X^5 + 1$, of the product of X^{16} by the content of the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding bits inserted for transparency.

At a typical implementation of the transmitter, the initial contents of the register of the device computing the remainder of the division is preset to all ones, and is then modified by division by the generator polynomial (as described above) on the address and frame relay information fields; the ones complement of the resulting remainder is transmitted as a 16-bit FCS sequence.

At a typical implementation of the receiver, the initial contents of the register of the device computing the remainder is preset to all ones. The final remainder after multiplication by X^{16} and then division (modulo 2) by the generator polynomial $X^{16} + X^{12} + X^5 + 1$ of the serial incoming protected bits and the FCS, is "0001 1101 0000 1111" (X^{15} through X^0, respectively) in the absence of transmission errors.

4.8   Format convention

4.8.1   Numbering convention

The basic convention used in this clause is illustrated in figure 2. The bits are grouped into octets. The bits of an octet are shown horizontally and are numbered from 1 to 8. Multiple octets are shown vertically and are numbered from 1 to n.

4.8.2   Order of bit transmission

The octets are transmitted in ascending numerical order; inside an octet bit 1 is the first bit to be transmitted.

4.8.3   Field mapping convention

When a field is contained within a single octet, the lowest bit number of the field represents the lowest order value.

When a field spans more than one octet, the order of bit values progressively decreases as the octet number increases within each octet. The lowest bit number associated with the field represents the lowest order value.

For example, a bit number can be identified as a couple (o,b) where o is the octet number and b is the relative bit number within the octet. Figure 3 illustrates a field that spans from bit (1,3) to bit (2,7). The high-order bit of the field is mapped on bit (1,3) and the low-order bit is mapped on bit (2,7).

An exception to the preceding field mapping convention is the data link layer FCS field, which spans two octets. In this case, bit 1 of the first octet is the high-order bit and bit 8 of the second octet is the low-order bit (see figure 4).

4.9   Invalid frames

An invalid frame is a frame that:

– is not properly bounded by two flags (e.g., a frame abort), or

– has fewer than three octets between the address field and the closing flag, or

– does not consist of an integral number of octets prior to zero bit insertion or following zero bit extraction, or

– contains a frame check sequence error, or

– contains a single octet address field, or

8	7	6	5	4	3	2	1	Octet

1

2

n
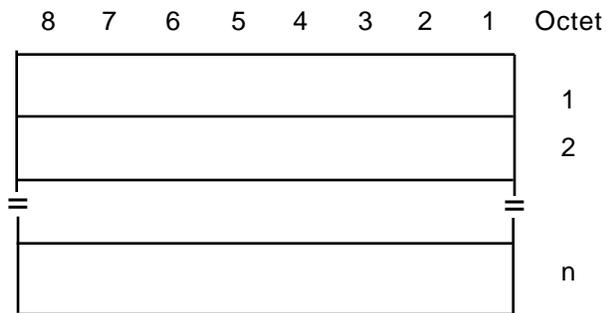
Figure 2 – Format convention

8	7	6	5	4	3	2	1	
					2^4	2^3	2^2	1st octet
2^1	2^0							2nd octet
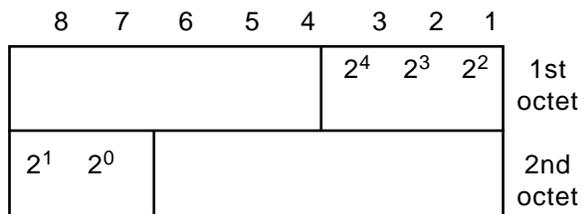
Figure 3 – Field mapping conventions

8	7	6	5	4	3	2	1	
2^8							2^{15}	1st octet
2^0							2^7	2nd octet
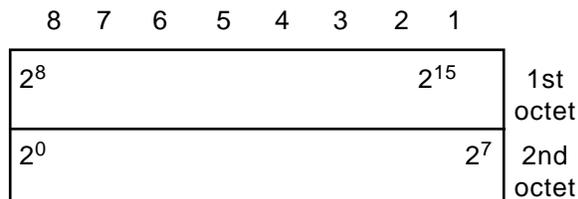
Figure 4 – FCS mapping conventions

–   contains a data link connection identifier (DLCI) that is not supported by the receiver.

Invalid frames are discarded without notification to the sender with no further action.

If a frame that is too long is received by the network, the network may:

–   discard the frame;

–   send part of the frame toward the destination user, then abort the frame; or,

–   send the complete frame toward the destination user with valid FCS.

Selection of one or more of these behaviors is an option for designers of frame relay network equipment, and is not subject to further standardization. Users shall not make any assumption as to which of these actions the network will take. In addition, the network may optionally clear the frame relay call if the number or frequency of too-long frames exceeds a network-specified threshold.

4.10   Frame abort

Receipt of seven or more contiguous 1 bits is interpreted as an abort and the data link layer ignores the frame currently being received.

5   Elements of procedures and format of fields for core services sublayer

5.1   General

The elements of procedures contained in this standard are used by the DL-CORE sublayer to implement optional procedures for congestion management. These are defined in clause 7.

5.2   Address field format

The format of the address field is shown in figure 5. This field includes the address field extension bits; a bit reserved for use by end user equipment intended to support a Command/Response indication bit; Forward and Backward explicit congestion indicator bits; Discard eligibility indicator; a data link connection identification (DLCI) field; and a bit to indicate whether the final octet of a three- or four- octet address field is the low-order part of the DLCI or DL-CORE control information. The minimum and default length of the address field is two octets; however, the address field length may be extended to three or four octets. To support a larger DLCI address range, the three-octet or four-octet address fields may be supported at the user–network interface or the network–network interface based on bilateral agreement.

5.3   Address field variables

5.3.1   Address field extension bit (EA)

The address field range is extended by reserving the first transmitted bit of the address field octets to indicate the final octet of the address field. The presence of a 0 in the first bit of an address field octet signals that another octet of the address field follows this one. The pres-

5

8	7	6	5	4	3	2	1	Octet
DLCI (high-order)						C/R 0/1	EA 0	1
DLCI (low-order)				FECN	BECN	DE	EA 1	2

(a) Address Field Format – 2 octets (default)

8	7	6	5	4	3	2	1	Octet
DLCI (high-order)						C/R 0/1	EA 0	1
DLCI				FECN	BECN	DE	EA 0	2
DLCI (low-order) or DL – CORE control						D/C	EA 1	3

(b)   Address Field Format – 3 octets

8	7	6	5	4	3	2	1	Octet
DLCI (high-order)						C/R 0/1	EA 0	1
DLCI				FECN	BECN	DE	EA 0	2
DLCI							EA 0	3
DLCI (low-order) or DL – CORE control						D/C	EA 1	4

(c)   Address Field Format – 4 octets

C/R Bit intended to support a command/ response indication. The use of this field is application-specific.

EA   Address field extension bit

DE   Discard Eligibility indicator

BECN   Backward Explicit Congestion Notification

FECN   Forward Explicit Congestion Notification

DLCI   Data link connection identifier

D/C   DLCI or DL-CORE control indicator

Figure 5 – Address field format

ence of a 1 in the first bit of an address field octet signals that it is the final octet of the address field. For example, the two-octet address field has bit one of the first octet set to a 0 and bit one of the second octet set to 1.

The support of address fields longer than two octets is an option. This option allows the address field length to be configurable on an interface basis or per channel basis.

5.3.2   Command/Response field bit (C/R)

The C/R bit is not used by the DL-CORE protocol. The use of this field is application-specific. The C/R bit is conveyed transparently by DL-CORE protocol between DL-CORE services users.

5.3.3   Forward explicit congestion notification (FECN)

This bit may be set by a congested network to notify the user that congestion avoidance procedures should be initiated where applicable for traffic in the direction of the frame carrying the FECN indication. This bit is set to "1" to indicate to the receiving end-system that the frames it receives have encountered congested resources. This bit may be used to adjust the rate of destination controlled transmitter.

While setting this bit by the network or user is optional, no network shall ever clear (set to "0") this bit. Networks that do not provide FECN shall pass this bit unchanged.

5.3.4   Backward explicit congestion notification (BECN)

This bit may be set by a congested network to notify the user that congestion avoidance procedures should be initiated where applicable for traffic in the opposite direction of the frame carrying the BECN indicator. This bit is set to "1" to indicate to the receiving end-system that the frames it transmits may encounter congested resources. This bit may be used to adjust the rate of source-controlled transmitters.

While setting this bit by the network or user is optional, no network shall ever clear (set to "0") this bit. Networks that do not provide BECN shall pass this bit unchanged.

5.3.5   Discard eligibility indicator (DE)

This bit, if used, is set to "1" to indicate a request that a frame should be discarded in

preference to other frames in a congestion situation. Setting of this bit by the network or user is optional. No network shall ever clear (set to "0") this bit. Networks that do not provide DE shall pass this bit unchanged. Networks are not constrained to only discard frames with DE equal to 1 in the presence of congestion.

5.3.6   Data link connection identifier

The DLCI is used to identify the logical connection, multiplexed within the physical channel, with which a frame is associated. All frames carried within a particular physical channel and having the same DLCI value are associated with the same logical connection.

The DLCI is an unstructured field. For two-octet addresses, bit 5 of the second octet is the least significant bit. For three- and four-octet addresses, bit 3 of the last octet is the least significant bit. In all cases bit 8 of the first octet is the most significant bit.

The structure of the DLCI field may be established by the network at the user-to-network interface or at a network-to-network interface subject to bilateral agreements.

5.3.6.1   DLCI values on bearer channels

In order to allow for compatibility of call control and layer management between B/H and D channels, the following ranges of DLCIs are reserved and pre-assigned. The DLCIs have local significance only.

5.3.6.2   DLCI on the D-channel

The six most significant bits (bits 8 to 3) in the first octet of the address correspond to the service access point identifier (SAPI) field in ANSI T1.602.

The DLCI subfield (bits 8–3 of first octet) values that apply on a D-channel are reserved for specific functions to ensure compatibility with operation on the D-channel that may also use the ANSI T1.602 protocols. A two-octet address format for the DLCI is assumed when used on the D-channel.

> NOTE – Use of three- and four-octet address formats on the D-channel is for further study.

> For frame relay in the D-channel, only DLCI values in the range 512 – 991 (SAPI = 32 to 61) will be assigned.

Table 1 – DLCI values for B-channel and H-channel applications

DLCI values	Function
0	in-channel signaling
1-15	reserved
16-991	assigned using frame relay connection procedures (see Note)
992-1007	layer 2 management of frame relay bearer service
1008-1022	reserved
1023	in-channel layer management

(a)   Two-octet address format

DLCI values	Function
0	in-channel signaling
1-1023	reserved
1024-63,487	assigned using frame relay connection procedures (see Note)
63,488-64,511	layer 2 management of frame relay bearer service
64,512-65,534	reserved
65,535	in-channel layer management

(b)   Three-octet address format with D/C = 0

DLCI values	Function
0	in-channel signaling
1-131,071	reserved
131,072-8,126,463	assigned using frame relay connection procedures (see Note)
8,126,464-8,257,535	layer 2 management of frame relay bearer service
8,257,536-8,388,606	reserved
8,388,607	in-channel layer management

(c)   Four-octet address format with D/C = 0

NOTE – Some of these values may be assigned to permanent frame relay calls.

Table 2 – DLCI values for D-channel

DLCI values	Function
512-991	assigned using frame relay connection procedures

Two-octet address format

Table 3 – DL-CORE sublayer management primitives and parameters

Primitives	Parameters
MC-ASSIGN.request	DLCI value, Core-CEI, Ph-CEI
MC-REMOVE.request	Core-CEI

5.3.7   DLCI or DL-CORE control indicator (D/C)

The D/C indicates whether the remaining six usable bits of that octet are to be interpreted as the lower DLCI bits or as DL-CORE control bits. This bit is set to "0" to indicate that the octet contains DLCI information. This bit is set to "1" to indicate that the octet contains DL-CORE control information. This indicator is limited to use in the last octet of the three- or four-octet type "address field." The use of this indication for DL-CORE control is reserved as there have not been any additional control functions defined that need to be carried in the address field; this indicator has been added to provide for possible future expansion of the protocol.

6   Placement of the DL-CORE protocol in the ISDN protocol architecture

This clause describes the placement of the DL-CORE protocol in the context of a layered architecture. The concepts of the OSI reference model (CCITT Recommendation X.200), the OSI service conventions (CCITT Recommendation X.210), and the ISDN protocol reference model (CCITT Recommendation I.320) are used.

6.1   Support by the underlying physical layer service

The physical layer service is defined in the OSI physical layer service definition (CCITT Recommendation X.211). Only duplex (two-way simultaneous), point-to-point synchronous transmission is used. The optional PH-connection activation and deactivation services of the physical layer are not presently used to support the DL-CORE protocol.

6.2   DL-CORE service

CCITT Recommendation I.233 provides a layer service description for the DL-CORE sublayer. The DL-CORE protocol is used to provide and support this layer service.

6.3   Layer management

Table 3 shows the primitives exchanged between the DL-CORE sublayer management entity and the DL-CORE sublayer entity.

6.3.1   Primitives

6.3.1.1   MC-ASSIGN.request

The MC-ASSIGN.request primitive is used by the layer management entity to:

– signal to the DL-CORE sublayer entity that a connection has been established;

– convey the DLCI agreed to be used between entities in support of that DL-CORE connection;

– convey the associated DL-CORE connection endpoint identifier(core-CEI) to be used to uniquely identify the connection, and convey the physical connection endpoint identifier used to support the connection.

6.3.1.2   MC-REMOVE.request

The MC-REMOVE.request primitive is used by the layer management entity to:

– signal to the DL-CORE sublayer entity that a connection has been released, and

– identify (i.e., by means of the core-CEI) the connection that has been released.

6.3.2   Parameters

6.3.2.1   DLCI value

The DLCI value parameter conveys the DLCI agreed to be used between core entities in support of DL-CORE connection. Its syntax

and usage by the protocol are defined in clause 5.

6.3.2.2 DL-CORE connection endpoint identifier (CEI)

The DL-CORE CEI uniquely identifies the DL-CORE connection.

6.3.2.3 Physical connection endpoint identifier

The physical connection endpoint identifier (ph-CEI) uniquely identifies a physical connection to be used in support of a DL-CORE connection.

6.3.3 Procedures

For permanent frame relay bearer connections, information related to the operation of the DL-CORE protocol in support of DL-CORE connection is maintained by DL-CORE layer management. For demand frame relay bearer connections, layer 3 establishes and releases DL-CORE connections on behalf of the DL-CORE sublayer. Therefore, information related to the operation of the DL-CORE protocol is maintained by coordination of layer 3 management and DL-CORE sublayer management through the operation of the local system environment.

6.3.3.1 Connection establishment

When it is necessary to notify the DL-CORE sublayer entity (either because of establishment of a demand frame relay call, because of notification of re-establishment of a permanent frame relay bearer connection, or because of system initialization) that a DL-CORE connection is to be established, the DL-CORE layer management entity signals an MC-ASSIGN.request primitive to the DL-CORE sublayer entity.

The DL-CORE sublayer entity establishes the necessary mapping between the supporting ph-connection, the core-CEI, and the DLCI. In addition, if it has not already done so, it begins to transmit flags on the physical connection except on the D-channel.

6.3.3.2 Connection release

When it is necessary to notify the DL-CORE sublayer entity (either because of release of a demand frame relay call or because of notification of failure of a permanent frame relay bearer connection) that a DL-CORE connection is to be released, the DL-CORE layer management entity signals an MC-REMOVE.request primitive to the DL-CORE sublayer entity.

7 Congestion control

The definition of objectives and requirements for congestion management is provided in addendum 1 of ANSI T1.606.

Congestion in the user plane occurs when traffic arriving at a resource exceeds the network's capacity. It can also occur for other reasons (e.g., equipment failure). Network congestion affects the throughput, delay, and frame loss experienced by the end user.

End users should reduce their offered load in the face of network congestion. Reduction of offered load by an end user may well result in an increase in the effective throughput available to the end user during congestion.

Congestion avoidance procedures (including optional explicit congestion notification) are used at the onset of congestion to minimize its negative effects on the network and user.

Explicit notification is a procedure used for congestion avoidance and is a part of the data transfer phase. Users should react to explicit congestion notification (i.e., optional but highly desirable). Users that are not able to act on explicit congestion notification shall have the capability to receive and ignore explicit notification generated by the networks.

Congestion recovery, and the associated implicit congestion indication due to frame discard, is used to prevent network collapse in the face of severe congestion. Implicit congestion detection involves certain events available to the protocols operating above the core functions to detect the frame loss (e.g., receipt of a REJECT frame, timer recovery). Upon detection of congestion, the user reduces the offered load to the network. Use of such reduction by users is optional.

Congestion avoidance and congestion recovery are effective and complementary forms of congestion control in frame relay networks.

7.1 Network response to congestion

Explicit congestion signals are sent in both forward (towards frame destination) and backward (towards frame source) directions.

Forward explicit congestion notification is provided by using the FECN bit in the address field. Backward explicit congestion notification is provided by one of two methods. When timely reverse traffic is available, the BECN bit in an appropriate address field may be used. Otherwise, a single consolidated link layer management message may be generated by the network (see clause 8). The consolidated link layer management (CLLM) message travels on the U-plane physical path. The generation and transport of CLLM by the network is optional.

All networks shall transport the FECN and BECN bits without resetting.

7.2   User response to congestion

Reaction by the end user to the receipt of explicit congestion notification is rate-based. An example of user reaction to the forward and backward congestion indications is provided in annex A.

7.2.1   End-user equipment employing destination-controlled transmitters

End-user reaction to implicit congestion detection or explicit congestion notification (FECN indication), when supported, shall be based on the values of the FECN indications that are received over a period of time. This method is consistent with commonly used destination-controlled protocol suites, such as the OSI class 4 Transport protocol operated over the OSI connectionless network service.

7.2.2   End-user equipment employing source-controlled transmitters

End-user reaction to implicit congestion detection or explicit congestion notification (BECN indication), when supported, shall be immediate when a BECN indication or a CLLM is received. This method is consistent with implementation as a function of the data link layer elements of procedure, commonly used in source-controlled protocols such as CCITT Recommendation Q.922 elements of procedures.

8   Consolidated link layer management (CLLM) message

The consolidated link layer management message is based on the ISO 8885 definition of the use of XID frames for the transport of functional information. The generation and transport of the CLLM is optional. Figures 6 and 7 illustrate the format of this frame. Each parameter is described using the sequence **type - length - value.** The following subclauses describe the functional fields for the consolidated link layer management congestion message. All fields are binary encoded unless otherwise specified.

8.1   Address octets

The default address size of two octets is used in the following specification.

Octets 1 and 2 represent the address field for a default two-octet address. The first octet includes the 6-bit upper DLCI subfield. The second octet includes the 4-bit lower DLCI subfield.

The CLLM message is sent in an XID response frame. Except when delivered on a D-channel, it is sent in the management DLCI as shown in figure 6. The congestion indication bits and the discard eligibility indicator are not used in this case and should be set to "0". When delivered on the D-channel, it is sent using a two-octet address field with bits 8–4 of the first address octet and bits 8–2 of the second address octet set to "1" and bit 3 of the first octet set to "0", as shown in figure 7. The congestion indication bits and discard eligibility indicator do not exist in this case.

> NOTE – The use of the CLLM for permanent frame relay connections using D-channel access requires further study.

Octets 1 and 2 of the XID frame represent the address field and bit 2 of octet 2 is the command/response bit (C/R). In a congestion control application, the receipt of a congestion message should not result in transmission of a subsequent frame, which would add to the traffic congestion. Therefore, the CLLM shall be sent in an XID response frame, that is the C/R bit shall be set to "1".

8.2   Control field

Octet 3 contains the control field code point for this type of message. This represents the control field for XID.

8.3   XID information field

8.3.1   Format identifier field

Octet 4 contains the format identifier field. ISO 8885 defines the format identifier field to have

```
Octet                        Bits                          Field name
                 8   7   6   5   4   3   2   1

  1             1   1   1   1   1   0   R   0     Address octet 1 (R indicates response)
  2             1   1   1   1   X   X   X   1     Address octet 2 (X indicates don't care)
  3             1   0   1   0   1   1   1   1     XID control field
  4             1   0   0   0   0   0   1   0     Format identifier (130)
  5             0   0   0   0   1   1   1   1     Group identifier=15 (Priv. param. neg.)
  6                                               Group length octet 1
  7                                               Group length octet 2
  8             0   0   0   0   0   0   0   0     Parameter identifier=0 (Param set. id)
  9             0   0   0   0   0   1   0   0     Parameter length (4)
 10             0   1   1   0   1   0   0   1     Parameter value=105 (IA5 character "I")
 11             0   0   1   1   0   0   0   1     Parameter value=49 (IA5 character "1")
 12             0   0   1   1   0   0   1   0     Parameter value=50 (IA5 character "2")
 13             0   0   1   1   0   0   1   0     Parameter value=50 (IA5 character "2")
 14             0   0   0   0   0   0   1   0     Parameter identifier=2 (Cause identifier)
 15             0   0   0   0   0   0   0   1     Parameter length (1)
 16                                               Cause value
 17             0   0   0   0   0   0   1   1     Parameter value=3 (DLCI identifier)
 18                                               Parameter length
 19                                               DLCI value octet 1 (1st DLCI)
 20                                               DLCI value octet 2 (1st DLCI)
          =                                   =
2n+17                                             DLCI value octet 1 (nth DLCI)
2n+18                                             DLCI value octet 2 (nth DLCI)
2n+19                                             FCS octet 1
2n+20                                             FCS octet 2
```

**Figure 6 – A consolidated link layer management message (B- or H-channel)
using a two-octet address field**

```
Octet                        Bits                          Field name
                 8   7   6   5   4   3   2   1

  1             1   1   1   1   1   0   R   0     Address octet 1 (SAPI=62)
                                                  (R indicates response)
  2                     TEI                 1     Address octet 2 (TEI=127)
  3             1   0   1   0   1   1   1   1     XID control field
  4             1   0   0   0   0   0   1   0     Format identifier (130)
  5             0   0   0   0   1   1   1   1     Group identifier=15 (Priv. param. neg.)
                                                  Octets 6 to 2n+18 (see B- or H-channel
                                                     CLLM – figure 6)
          =                                   =
2n+19                                             FCS octet 1
2n+20                                             FCS octet 2
```
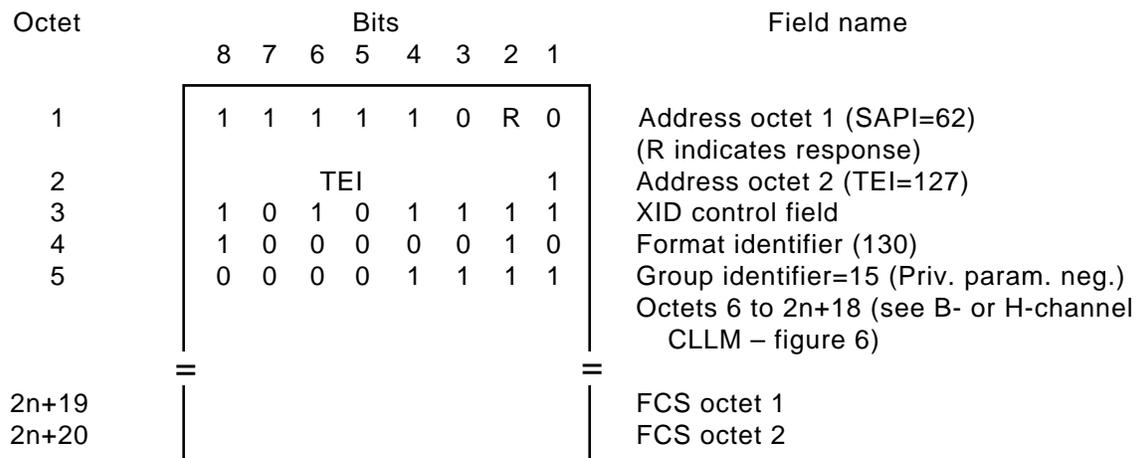
**Figure 7 – A consolidated link layer management message (D-channel)
using a two-octet address field**

11

a length of one octet. ISO 8885 assigns the value of 130 decimal as a general-purpose format identifier, and it is used by ISDN layer management for parameter negotiation as discussed in CCITT Recommendation Q.922, Appendix III.

8.3.2   Group field

8.3.2.1   Group identifier field

Octet 5 contains the group identifier field. The group identifier field is 15 decimal, which is assigned by ISO 8885 to indicate private parameters.

In the context of ISO 8885 addendum 3, "private" is taken to mean a parameter beyond the scope of the HDLC specific parameters defined in ISO 8885.

8.3.2.2   Group length field

Octets 6 and 7 contain the group length field. This 16-bit field describes the "length" of the octets in the remainder of the group field. The maximum value of the group length field is 256 octets when used on the D-channel.

8.3.2.3   Group value field

The group value field consists of one or more parameter fields. The parameter set identification, parameter 0 identifies the set of private parameters within the group value field in accordance with ISO 8885/DAD 3. The other parameters shall appear in the following order: cause identifier, network identifier field, and DLCI identifier.

8.3.3   Parameter for parameter set identification

The parameter set identification shall always be present; otherwise, the frame shall be rejected.

8.3.3.1   Parameter identifier field

Octet 8 contains the parameter identifier field for the first parameter and is set to 0 in accordance with ISO 8885/DAD 3. Parameter 0 identifies the set of private parameters within this group.

8.3.3.2   Parameter length field

Octet 9 contains the length of parameter 0 and is set to binary 4.

8.3.3.3   Parameter value field

Octets 10–13 identify that this usage of the XID frame private parameter group is for I.122 private parameters. Octet 10 contains the IA5 value of "I" (binary 105). Octet 11 contains the IA5 value of "1" (binary 49). Octets 12 and 13 contain the IA5 value of "2" (binary 50).

8.3.4   Parameter field for network identifier

The network identifier parameter is identified by the type field being 1. The length of the parameter and actual coding of the network identifier are for further study.

8.3.5   Parameter field for cause identifier

The cause identifier shall always be present; otherwise, the frame shall be ignored.

8.3.5.1   Parameter identifier field

When the cause identifier field is set to 2, the following octets of this parameter contain a cause identifier.

8.3.5.2   Parameter length field

Octet 15 contains the length of the cause identifier. This shall be set to binary "1".

8.3.5.3   Cause value

This octet identifies the cause of this message, as determined by the congested network node, specifying which layer management module originated the message.

Bits

<u>8765 4321</u>

0000 0010	Network congestion due to excessive traffic – short term
0000 0011	Network congestion due to excessive traffic – long term
0000 0110	facility or equipment failure – short term
0000 0111	facility or equipment failure – long term
0000 1010	maintenance action – short term
0000 1011	maintenance action – long term
0001 0000	unknown – short term
0001 0001	unknown – long term

All other values are reserved.

The CLLM message shall not be ignored solely because of an unknown cause value.

> NOTE – Cause values shall be coded as "short term" if the CLLM is sent due to a transient condition (e.g., one anticipated to last on an order of seconds or minutes); otherwise they shall be coded as "long term." Specific usage shall be network-specific.

8.3.6 Parameter field for DLCI identifier

If the DLCI identifier is missing, then the frame shall be ignored

8.3.6.1 Parameter identifier field

When the parameter identifier field is set to 3, then the following octets of this parameter contain the DLCI(s) of the frame relay bearer connection that are congested.

8.3.6.2 Parameter length field

Octet 18 contains the length of the DLCI(s) being reported, in octets. For example, if (n) DLCIs are being reported and they are of length two octets each, this will be (n) times (2) in octet size.

> NOTE – For an extended three- or four-octet address format, the individual DLCI length will be three or four respectively. The parameter length field will be (n) times three or four in octet size.

8.3.6.3 Parameter value field

Octets 19 and onward present the DLCI value(s) that identify logical link(s) that have encountered a congested state. The DLCI field is 10 bits long and contained in bits 8 to 3 of the first octet pair and bits 8 to 5 of the next octet of the pair. The bit 8 of the first octet is the most significant bit and bit 5 of the second octet is the least significant. The bits 2 to 1 in the first octet and bits 4 to 1 in the second octet are reserved.

For a three-octet address field format with D/C equal to zero, the DLCI field is 16 bits long and contained in a three-octet group. The DLCI is contained in bits 8 to 3 of the first octet, bits 8 to 5 of the second octet and bits 8 to 3 of the third octet as described in figure 5b.

For a four-octet address field format with D/C equal to zero, the DLCI field is 23 bits long and is contained in a four-octet group. The DLCI is contained in bits 8 to 3 of the first octet, bits 8 to 5 of the second octet, bits 8 to 2 of the third octet, and bits 8 to 3 of the fourth octet as described in figure 5c.

8.4 FCS field

The last two octets of the frame contain the frame check sequence field.

8.5 Action of the congested node

When a node becomes congested, it may send notification of the congested state by either setting forward and backward congestion bits to "1" in the address field, or using a consolidated link layer management message on the management data link, or both. The purpose of the explicit congestion notification is:

– to inform the edge node at the network ingress of the congestion so that the edge node can take appropriate action to reduce network congestion, or

– to notify the source that negotiated throughput has been exceeded, or

– to do both.

The consolidated link layer management message contains a list of DLCIs that correspond to the congested frame relay bearer connections. These DLCIs will correspond both to sources that are currently active and to those that are not. The purpose of the latter is to prevent those sources that are not active from becoming active and hence increasing congestion. It may be necessary to send more than one consolidated link layer management message, if all DLCIs cannot fit into a single frame.
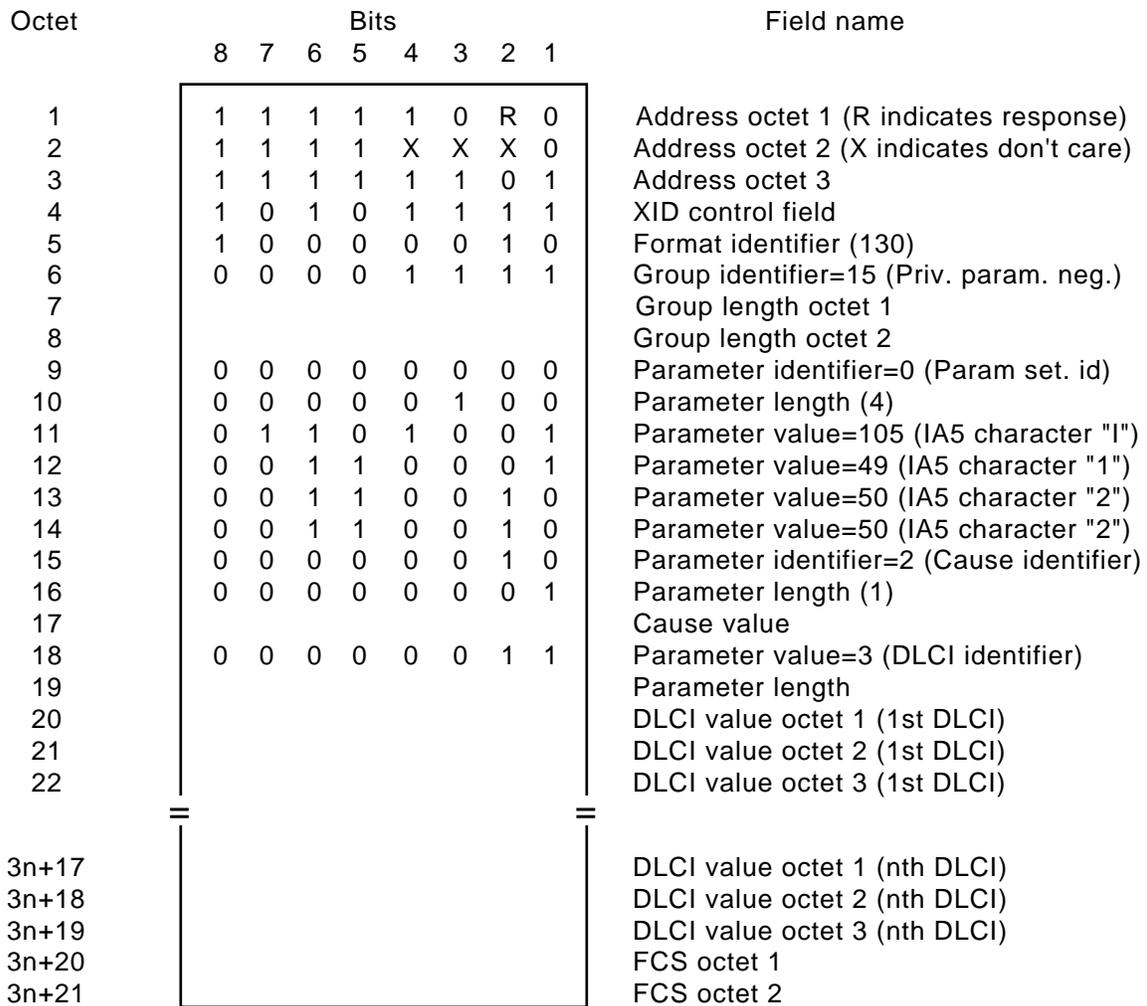
Octet	8	7	6	5	4	3	2	1	Field name
1	1	1	1	1	1	0	R	0	Address octet 1 (R indicates response)
2	1	1	1	1	X	X	X	0	Address octet 2 (X indicates don't care)
3	1	1	1	1	1	1	0	1	Address octet 3
4	1	0	1	0	1	1	1	1	XID control field
5	1	0	0	0	0	0	1	0	Format identifier (130)
6	0	0	0	0	1	1	1	1	Group identifier=15 (Priv. param. neg.)
7									Group length octet 1
8									Group length octet 2
9	0	0	0	0	0	0	0	0	Parameter identifier=0 (Param set. id)
10	0	0	0	0	0	1	0	0	Parameter length (4)
11	0	1	1	0	1	0	0	1	Parameter value=105 (IA5 character "I")
12	0	0	1	1	0	0	0	1	Parameter value=49 (IA5 character "1")
13	0	0	1	1	0	0	1	0	Parameter value=50 (IA5 character "2")
14	0	0	1	1	0	0	1	0	Parameter value=50 (IA5 character "2")
15	0	0	0	0	0	0	1	0	Parameter identifier=2 (Cause identifier)
16	0	0	0	0	0	0	0	1	Parameter length (1)
17									Cause value
18	0	0	0	0	0	0	1	1	Parameter value=3 (DLCI identifier)
19									Parameter length
20									DLCI value octet 1 (1st DLCI)
21									DLCI value octet 2 (1st DLCI)
22									DLCI value octet 3 (1st DLCI)
=								=	
3n+17									DLCI value octet 1 (nth DLCI)
3n+18									DLCI value octet 2 (nth DLCI)
3n+19									DLCI value octet 3 (nth DLCI)
3n+20									FCS octet 1
3n+21									FCS octet 2

**Figure 8 – A consolidated link layer management message (B- or H-channel)
using a three-octet address field**

Octet	8	7	6	5	4	3	2	1	Field name
1	1	1	1	1	1	0	R	0	Address octet 1 (SAPI=62) (R indicates response)
2			TEI					1	Address octet 2 (TEI=127)
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	0	Format identifier (130)
5	0	0	0	0	1	1	1	1	Group identifier=15 (Priv. param. neg.)
									Octets 7 to 3n+19 (see B- or H-channel CLLM – figure 8)
=								=	
3n+19									FCS octet 1
3n+20									FCS octet 2
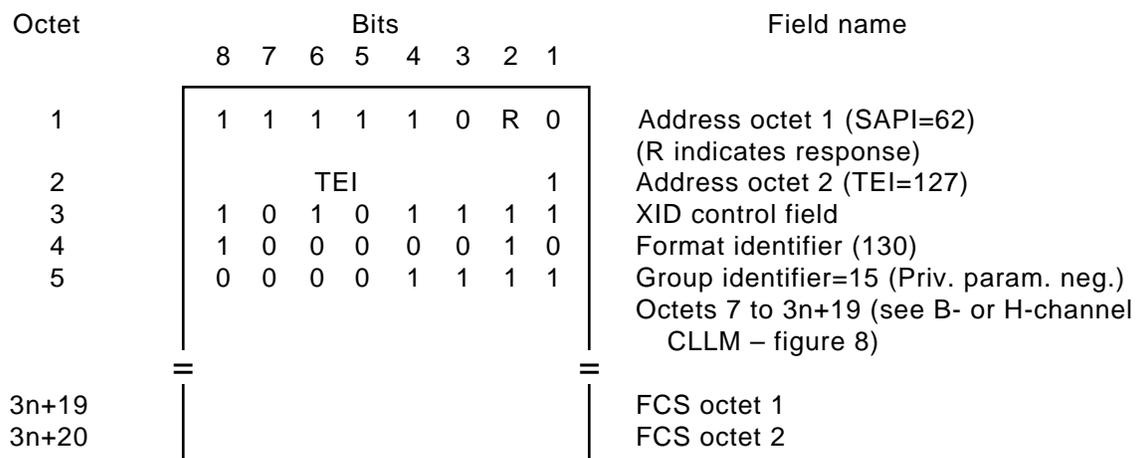
**Figure 9 – A consolidated link layer management message (D-channel)
using a three-octet address field**

Octet	_	Bits								Field name

Octet | Bits 8 7 6 5 4 3 2 1 | Field name

Octet	8	7	6	5	4	3	2	1	Field name
1	1	1	1	1	1	0	R	0	Address octet 1 (R indicates response)
2	1	1	1	1	X	X	X	0	Address octet 2 (X indicates don't care)
3	1	1	1	1	1	1	1	0	Address octet 3
4	1	1	1	1	1	1	0	1	Address octet 4
5	1	0	1	0	1	1	1	1	XID control field
6	1	0	0	0	0	0	1	0	Format identifier (130)
7	0	0	0	0	1	1	1	1	Group identifier=15 (Priv. param. neg.)
8									Group length octet 1
9									Group length octet 2
10	0	0	0	0	0	0	0	0	Parameter identifier=0 (Param set. id)
11	0	0	0	0	0	1	0	0	Parameter length (4)
12	0	1	1	0	1	0	0	1	Parameter value=105 (IA5 character "I")
13	0	0	1	1	0	0	0	1	Parameter value=49 (IA5 character "1")
14	0	0	1	1	0	0	1	0	Parameter value=50 (IA5 character "2")
15	0	0	1	1	0	0	1	0	Parameter value=50 (IA5 character "2")
16	0	0	0	0	0	0	1	0	Parameter identifier=2 (Cause identifier)
17	0	0	0	0	0	0	0	1	Parameter length (1)
18									Cause value
19	0	0	0	0	0	0	1	1	Parameter value=3 (DLCI identifier)
20									Parameter length
21									DLCI value octet 1 (1st DLCI)
22									DLCI value octet 2 (1st DLCI)
23									DLCI value octet 3 (1st DLCI)
24									DLCI value octet 4 (1st DLCI)
4n+17									DLCI value octet 1 (nth DLCI)
4n+18									DLCI value octet 2 (nth DLCI)
4n+19									DLCI value octet 3 (nth DLCI)
4n+20									DLCI value octet 4 (nth DLCI)
4n+21									FCS octet 1
4n+22									FCS octet 2

**Figure 10 – A consolidated link layer management message (B- or H-channel)
using a four-octet address field**

Octet | Bits 8 7 6 5 4 3 2 1 | Field name

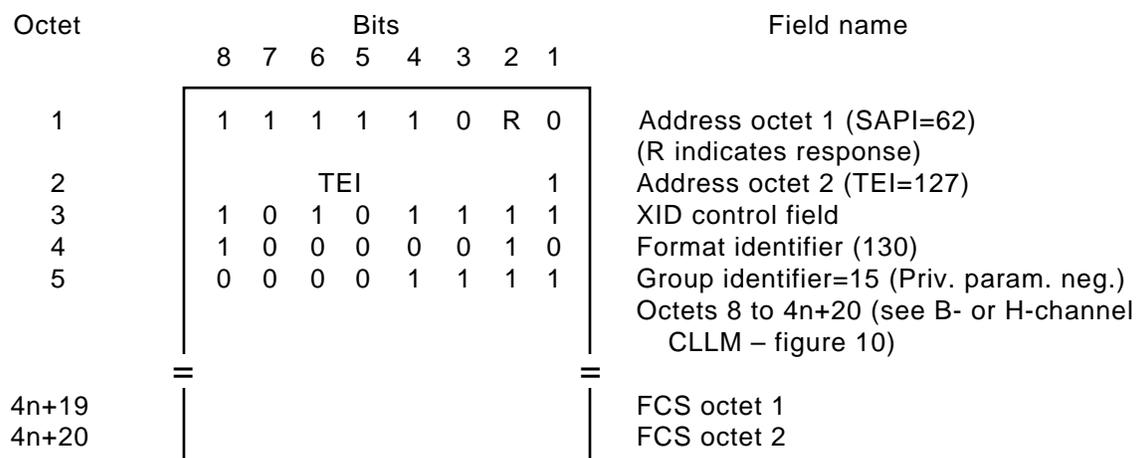| Octet	8	7	6	5	4	3	2	1	Field name
1	1	1	1	1	1	0	R	0	Address octet 1 (SAPI=62) (R indicates response)
2			TEI					1	Address octet 2 (TEI=127)
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	0	Format identifier (130)
5	0	0	0	0	1	1	1	1	Group identifier=15 (Priv. param. neg.)
									Octets 8 to 4n+20 (see B- or H-channel CLLM – figure 10)
4n+19									FCS octet 1
4n+20									FCS octet 2

**Figure 11 – A consolidated link layer management message (D-channel)
using a four-octet address field**

Annex A
(informative)

Sample algorithms for using FECN and BECN

This annex contains sample procedures for setting the forward and backward congestion indications and examples of user reaction to these indications.

A.1 FECN usage

A.1.1   User behavior on receipt of the FECN bit

Users should compare the number of frames in which the FECN bit is set with the number of frames in which the FECN bit is cleared, over a measurement interval $\triangledown$. If the number of set FECN bits is equal to or exceeds the number of clear FECN bits received during this period, then the user shall reduce its current throughput to 7/8 (0.875) of its previous value. If the number of set FECN bits is less than the number of clear FECN bits, then the user may increase its information rate by 1/16 of its throughput.

The suggested measurement interval $\triangledown$ is approximately equal to four times the end-to-end transit delay. However, other mechanisms not dependent on timers may be used by the terminal if the effect is similar.

A "slow-start" mechanism is recommended, so as to cause convergence toward equilibrium on the connection. The initial rate should be set to the throughput value agreed during call establishment or less, in order to avoid an impulse load on the network at the time the user begins transmitting. If the connection has been idle for a long period of time (e.g., on the order of tens of seconds), the offered rate should be returned to the throughput or less.

A.1.1.1   General descriptions

A.1.1.2   Use of windows as an approximation to rate-based control

For some implementations, it may be convenient to use a window-based mechanism as an approximation to rate-based control. Such implementations may or may not be able to measure their offered rate, or to relate it to the throughput negotiated with the network during connection establishment. The actual offered rate is limited by end-to-end transit delay, access rate, window size, and frame size.

> NOTE – The mechanism described in the paragraphs below is consistent with the stable OSI implementers agreement for the class 4 transport protocol. The use of window-based mechanisms to approximate rate-based control is reasonably accurate only if the statistical variance of the frame size is relatively small.

In the event that a windowed protocol is in use, then the user, in responding to the FECN bit, shall compare the number of frames received with the FECN bit set with the number of frames received with the FECN bit clear. The measurement interval for this shall be twice the interval during which the number of frames equal to the current working window size is transmitted and acknowledged (i.e., two window turns). If the number of set FECN bits is equal to or exceeds the number of clear FECN bits received during this period, then the user shall reduce its working window size variable to 7/8 (0.875) of its previous value; however, it need never reduce its working window below the size of one frame. If the number of set FECN bits is less than the number of clear FECN bits, then the user may increase its window size variable by the size of one frame, not to exceed the maximum window size for that virtual circuit. After the adjustment is made, the set and clear FECN bit counters should be reset to zero and the comparison should begin again.

The working window should be initialized at a small value, such as one frame, in order to avoid an impulse load upon the network at the time that a user begins transmitting. If the connection has been idle for a long period of time (e.g., on the order of tens of seconds), it may be appropriate to again reduce the window size to its initial value. There may be a maximum window size or information rate that a connection can accommodate, as limited by the end system policies; the working window should not be adjusted beyond such a value. It should also be observed that this algorithm

is relatively insensitive to the loss of acknowledgments carried in the user data when they are used to carry window adjustment information back to the source.

A.1.2 Recommended behavior of the FECN bit user in response to implicit notification

A.1.2.1 General descriptions

If the user has the capability to determine that a frame has been lost, reaction should be implemented to this loss. This should be regarded as complementary to (rather than mutually exclusive from) explicit congestion notification.

Upon determining that a frame has been dropped, the user should reduce its offered rate to 0.25 times the previous value.

> NOTE – This value is provided as part of an example, and is consistent with the stable OSI implementers agreement for Transport class 4. A higher value (e.g., 0.5) may be used, but might lengthen the duration of the congestion event while possibly shortening the period required to return to the throughput.

If the network is known to be providing explicit congestion notification and no frames received during the prior measurement interval $\triangledown$ were received with the FECN bit set, there is a moderate likelihood that the frame loss is due to transmission error and not to congestion. In such cases, the offered throughput should be reduced to 0.625 times its previous value.

The user may increase its throughput by a factor of 0.125 times throughput after any measurement interval in which no further frame loss is detected. Once this throughput rate reaches 0.5 times the value in use when the initial frame loss was detected, this increase factor should change to 1/16 times throughput. These increase factors may be limited by the increase factors specified for explicit congestion notification in A.1.1.

A.1.2.2 Use of windows as an approximation to rate-based control

Users may use a window-based mechanism as an approximation to rate-based control.

Upon determining that a frame has been dropped, the user should reduce its current working window size to the greater of 1 or 0.25 times the previous value.

If the network is known to be providing explicit congestion notification and no frames received during the prior window turn were received with the FECN bit set, there is a moderate likelihood that the frame loss is due to transmission error and not to congestion. In such cases, the working window size should be reduced to the greater of 1 or 0.625 its previous value.

The user may increase its working window size by 1 after any window turn in which no further frame loss is detected. If the current working window size is less than 8, the user may optionally increase its window size after receipt of five frames, rather than waiting for an entire window turn. These increase factors may be limited by the increase factors specified for explicit congestion notification in A.1.1.

A.1.3 Network use of FECN bit

The FECN bit may be set by any entity within the network that detects a state of incipient congestion. The condition for setting this bit is a network option, with the following procedure being illustrative.

The frame relay switching system monitors the size of each queue in the system. Determination of incipient congestion is a function of network system design and is not subject to standardization. However, an example of an implementation is described.

This subclause describes one possible way that networks can determine incipient congestion. It is included to illustrate the concept of incipient congestion and to demonstrate the role of the network in the operation of the feedback loop using the FECN bit. The inclusion of this material does not endorse its use to the exclusion of, or in preference to, other implementations that give similar results.

A regeneration cycle begins when the outgoing circuit goes from idle (queue empty) to busy (nonzero queue size, including the current frame). During the period between the start of the previous regeneration cycle and the present time within the present cycle, the average size of the queue is computed. If the average size of the queue exceeds a threshold value, then the circuit is in a state of incipient congestion. Beginning at that time, and continuing until the average queue size falls below the threshold, the bit shall be set on all outgoing frames.

The algorithm makes use of the following variables:

t	=	current time
t_i	=	time of the i_{th} arrival or departure event
q_i	=	number of packets in the system after the event
T_0	=	time at the beginning of the previous cycle
T_1	=	time at the beginning of the current cycle

The algorithm consists of three components:

1   Queue length update: Beginning with $q_0 = 0$,

If the i_{th} event is an arrival event, $q_i = q_i + 1$

If the i_{th} event is a departure event, $q_i = q_i - 1$

2   Queue area (integral) update:

Area of the previous cycle =

$$\sum_{t1 \in [T1, t)} q_{i-1} (t_i - t_{i-1})$$

Area of the current cycle =

$$\sum_{t1 \in [T1, t)} q_{i-1} (t_i - t_{i-1})$$

3   Average queue length update:

Average queue length over the two cycles =

$$\frac{\text{Area of the two cycles}}{\text{Time of the two cycles}} = \frac{\text{Area of the two cycles}}{t - T_0}$$

Figure A.1 – Example of an implementation of incipient congestion determination

The average queue length may be computed by determining the area (the product of the queue size and the time interval) over the previous and current cycles and dividing by the time of the two cycles. An example of the queue length averaging algorithm is shown in figure A.1.

A.2   BECN usage

A.2.1   Recommended behavior of user in response to explicit congestion notification

A.2.1.1   General descriptions

For use with the BECN mechanism, a step count, S, is defined. S is used to determine when the transmitter may increase or decrease its rate, based on the state of the BECN bits received. If the user expects the number of frames received to be approximately equal to the number transmitted (e.g., if a protocol like LAPD, which requires immediate acknowledgment to I frames is used), the ratio frame rate backward (F_b)/frame rate forward (F_f) will equal 1.

$$IR_f = \frac{Th_f}{8} + \left(\frac{Be_f}{Be_f + Bc_f} \right) \frac{Ar_f}{8}$$

$$IR_b = \frac{Th_b}{8} + \left(\frac{Be_b}{Be_b + Bc_b} \right) \frac{Ar_b}{8}$$

$$S = \frac{F_b}{F_f} \left(IR_f \frac{EETD}{N202_f} + IR_b \frac{EETD}{N202_b} \right)$$

where

IR_f is the information rate in the forward direction;

IR_b is the information rate in the backward direction;

S is the step function count;

Th_f is the throughput in the forward direction agreed during call establishment;

Th_b is the throughput in the backward direction agreed during call establishment;

$EETD$ is the end-to-end transit delay;

$N202_f$ is the maximum information field length in the forward direction;

$N202_b$ is the maximum information field length in the backward direction;

Ar_f is the access rate forward;

Ar_b is the access rate backward;

Be_f is the excess burst size forward;

Be_b is the excess burst size backward;

Bc_f is the committed burst size forward;

Bc_b is the committed burst size backward;

F_b/F_f is the ratio (either expected or measured over some implementation-dependent period of time) of frames received to frames sent.

If a frame with a BECN bit is received, and the user's offered rate is greater than throughput, the user should reduce its offered rate to the throughput agreed for the frame relay connection.

If S consecutive frames are received with the BECN bit set, the user should reduce its rate to the next "step" rate below the current offered rate. Further rate reduction should not occur until an additional S consecutive frames are received with the BECN bit set. The "step" rates are:

0.675 times throughput

0.5 times throughput

0.25 times throughput

NOTE – Networks should be engineered such that reduction below 0.5 times throughput never becomes necessary, and may take alternative action (e.g., rerouting) to prevent such an occurrence.

When the user has reduced its rate due to receipt of BECN, it may increase its rate by a factor of 0.125 times throughput after any $S/2$ consecutive frames are received with the BECN bit clear.

A slow-start mechanism is recommended, so as to cause convergence toward equilibrium on the connection. The initial rate should be set to the throughput value agreed during call

19

establishment or less, in order to avoid an impulse load on the network at the time the user begins transmitting. If the connection has been idle for a long period of time (e.g., on the order of tens of seconds), the offered rate should be returned to the throughput.

A.2.1.2   Use of windows as an approximation to rate-based control

For some implementations, it may be convenient to use a window-based mechanism as an approximation to rate-based control. Such implementations may or may not be able to measure their offered rate, or relate it to the throughput negotiated with the network during connection establishment. The actual offered rate is limited by end-to-end transit delay, access rate, window size, and frame size.

For use with the BECN, a step count, S, is defined, S is used to determine when the transmitter may increase or should decrease its rate, based on the state of the congestion bits. For approximation by use of windows, S is defined as an interval during which one frame is transmitted and acknowledged (i.e., one window turn).

If a frame with a BECN bit set to "1" is received, the user should reduce its working window size variable to 0.625 times the previous value. If S consecutive frames are subsequently received with the BECN bit set, this reduction should be repeated. However, the window size need never be reduced to less than one frame.

The user may increase its working window size by one frame after any $S/2$ consecutive frames are received with the BECN bit clear. However, the maximum window size shall not be exceeded.

A slow-start mechanism is recommended, so as to cause convergence toward equilibrium on the connection. The initial working window should be initialized to a small value (e.g.,0.5 times last working window size) in order to avoid an impulse load on the network at the time the user begins transmitting. If the connection has been idle for a long period of time (e.g., on the order of seconds), the window size should be reinitialized.

> NOTE – The use of window-based mechanisms to approximate rate-based control is reasonably accurate only if the statistical variance of the frame size is relatively small.

A.2.2   BECN user response to implicit congestion indication

A.2.2.1   General descriptions

If the user has the capability to determine that a frame has been lost, reaction should be implemented to this loss. This should be regarded as complementary to (rather than mutually exclusive from) explicit congestion notification.

Upon determining that a frame has been dropped, the user should reduce its offered rate to 0.25 times throughput if the rate is presently reduced due to explicit congestion notification, or if the network is not known to provide BECN.

> NOTE – This value is provided as part of an example. A higher value (e.g., 0.5) may be used, but might lengthen the duration of the congestion event while possibly shortening the period required to return to the throughput.

If the network is known to be providing explicit congestion notification and no frames received during the prior measurement interval S, were received with the BECN bit set, there is a moderate likelihood that the frame loss is due to transmission error and not to congestion. In such cases, the information rate should be reduced to 0.625 times its previous value.

When the user has reduced its rate due to frame loss, it may increase its rate by a factor of 0.125 times throughput after any $S/2$ consecutive frames are received with the BECN bit clear.

A.2.2.2   Use of windows as an approximation to rate-based control

Users may use a window-based mechanism as an approximation to rate-based control.

Upon determining that a frame has been dropped, the user should reduce its current working window size to the greater of 1 or 0.25 times the previous value.

If the network is known to be providing explicit congestion notification and no frames received during the prior window turn were received with the BECN bit set, there is a moderate likelihood that the frame loss is due to transmission error and not to congestion. In such cases, the working window size should be reduced to the greater of 1 or 0.625 times its previous value.

20

The user may increase its working window size by 1 after any window turn in which no further frame loss is detected. If the current working window size is less than 8, the user may optionally increase its window size after receipt of five frames, rather than waiting for an entire window turn. These increase factors may be limited by the increase factors specified for explicit congestion notification in A.2.1.

> NOTE – The use of window-based mechanisms to approximate rate-based control is reasonably accurate only if the statistical variance of the frame is relatively small.

A.2.3 Network procedures for setting the BECN bit

The network should, if possible, set the BECN bit before it becomes necessary to discard frames. The network should continue to set the BECN bit whenever it is in such a condition and may elect to provide some hysteresis to prevent oscillation.

If the congestion condition deteriorates, the network should discard frames sent in excess of throughput at the access node, and those marked with the DE bit in preference to other frames. At this stage, the network is in a moderately congested state, and BECN bits should continue to be set on frames that are not discarded.

If the congestion condition further deteriorates to the point that frames that are neither in excess of throughput nor are marked with the DE bit are being discarded, a severe congestion condition exists. The network should continue to use the BECN to encourage users to reduce their rates, and may need to take further actions (e.g., clear or reroute calls) to restore control.

A.3 CLLM usage

A.3.1 Network procedures for sending CLLM

In 8.5 the actions taken when in a congested node are described. The congested node must also keep edge nodes informed. In the case of a congestion situation, the network node sends the CLLM towards the source node. The cause code of the CLLM defines the reason for congestion and the edge node signals the user to initiate congestion control procedures. Since any or all nodes in the network may send CLLMs, multiple congestion conditions may affect a user equipment's frame-relaying connection through the network.

A.3.2 Recommended behavior of the end user upon reception of CLLM

The end-user equipment is not allowed to generate CLLMs.

When the end user receives a CLLM, the end user follows the step or rate reduction procedures in A.2.1.

A.3.3 CLLM user response to implicit detection of congestion

The end-user reaction is described in A.2.2.

Annex B
(informative)

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[1] All CCITT Recommendations are from the 1988 CCITT Blue Book.

[2] Available from the American National Standards Institute, 11 West 42nd Street, New York, NY 10036.