

Information technology — Telecommunications and information exchange between systems — Private telecommunications networks — Digital channel aggregation

ICS 33.040.40

National foreword

This British Standard reproduces verbatim ISO/IEC 13871:1995 and implements it as the UK national standard.

The UK participation in its preparation was entrusted to Technical Committee IST/6, Data communications, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, the ISO/IEC title page, pages ii to v, a blank page, pages 1 to 93 and a back cover.

Amendments issued since publication

Amd. No.	Date	Text affected

This British Standard, having been prepared under the direction of the DISC Board, was published under the authority of the Standards Board and comes into effect on 15 August 1998

© BSI 1998

ISBN 0 580 30311 X

INTERNATIONAL
STANDARD

**ISO/IEC
13871**

First edition
1995-12-15

**Information technology —
Telecommunications and information
exchange between systems — Private
telecommunications networks — Digital
channel aggregation**

*Technologies de l'information — Télécommunications et échange
d'information entre systèmes — Réseaux privés de
télécommunications — Agrégation de canal numérique*



Contents	page
Foreword	iv
Introduction	v
1 Scope	1
2 Normative References	2
3 Definitions	2
4 Symbols and Abbreviations	3
5 Selection of ISO/IEC 13871 or ITU-T H.244 aggregation procedures	3
6 Basic Principles	5
6.1 Modes of operation	5
6.2 Frame Structure	6
6.2.1 Bit Ordering	7
6.2.2 Frame Alignment Word (FAW)	7
6.2.3 Frame Count (FC)	7
6.2.4 Information Channel (IC)	7
6.2.5 Cyclic Redundancy Check (CRC)	8
6.2.6 Distribution of Overhead Octets	8
6.3 Overall Frame alignment	9
6.4 Description of CRC4 procedure	10
6.4.1 Computation of the CRC4 bits	10
6.4.1.1 Multiplication and division process	10
6.4.1.2 Encoding procedure	10
6.4.1.3 Decoding procedure	10
6.4.2 Consequent actions	10
6.4.2.1 Enabling and Disabling the CRC procedures	10
6.4.2.2 Action on bit E	11
6.4.2.3 Monitoring for error performance	11
7 Description of the Information Channel	11
7.1 Information Channel Frame	11
7.1.1 Rate Multiplier and Subrate Multiplier Calculation and Operation	15
7.2 Information Channel (IC) synchronization	19
7.3 Transmission and Recognition of an Information Channel Frame	19
8 Procedures	20
8.1 Call Setup	20
8.1.1 Initial Channel Setup	21
8.1.2 Additional Channel Setup	22

Descriptors: data processing, information interchange, telecommunications, network interconnection, telecommunication network, private network, ISDN, data transmission, services.

8.1.3	Delay Equalization	25
8.1.4	Timeout Conditions	25
8.2	Adding Bandwidth to an Existing Call	26
8.2.1	Negotiation (Calling Endpoint Initiated)	26
8.2.2	Negotiation (Answering Endpoint Initiated)	26
8.2.3	Additional Channel Setup	27
8.2.4	Timeout Conditions	28
8.3	Deleting Bandwidth from an Existing Call	28
8.3.1	Calling Endpoint Initiated	29
8.3.2	Answering Endpoint Initiated	30
8.3.3	Timeout Conditions	30
8.4	Collision Resolution	30
8.5	Call Disconnection	30
8.5.1	Calling Endpoint Initiated	30
8.5.2	Answering Endpoint Initiated	30
8.5.3	Timeout Conditions	31
8.6	Remote Loopback	31
8.6.1	Timeout Conditions	32
8.7	Error Conditions	32
8.7.1	Loss of Channel (Other Than Call Setup)	32
8.7.2	Loss of Delay Equalization	33
9	Transparent Mode Operation	33
9.1	Non Aggregating Unit Calling Aggregating Unit	33
9.2	Aggregating Unit Calling Non Aggregating Unit	34
Annexes		
A	RMULT and SUBMULT Values	35
A.1	Bearer Channel Rate (BCR) = 56 kbit/s	35
A.2	Bearer Channel Rate (BCR) = 64 kbit/s	37
B	Manufacturer's Identifiers	39
C	Phone Number Length Extension	40
D	State Machine Description of Channel Aggregation Control	41
D.1	Reference Architecture	41
D.2	State Definitions	42
D.2.1	DEQ Negotiation Control	42
D.2.2	DEQ MULTIFRAME CONTROL States	44
D.3	Messages and Events	44
D.3.1	Information Channel Messages	45
D.3.2	DEQ Negotiation Control to Call Control Messages	46
D.3.3	DEQ Negotiation Control to DEQ Multiframe Control Primitives	50
D.4	Timers	53
D.5	State Transition Diagrams	54
D.5.1	DEQ Negotiation Control	54
D.5.2	DEQ Multiframe Control	58
D.6	SDL Diagrams	59
D.6.1	DEQ Negotiation Control	60
D.6.2	DEQ Multiframe Control	87

Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work.

In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

International Standard ISO/IEC 13871 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems*.

Annexes A to C form an integral part of this International Standard. Annex D is for information only.

Introduction

This International Standard is one of a set of International Standards designed to facilitate the global interconnection of applications across both private telecommunications networks and public ISDNs. This is achieved by ensuring compatibility and interworking of services offered by the private and public networks.

In line with the above aims, this International Standard defines a service offering flexible bandwidth allocation that provides unrestricted information transfer between special terminal adapters called Channel Aggregation Units. A Channel Aggregation Unit can provide a high bandwidth capability to an attached terminal application by combining multiple 56 kbit/s or 64 kbit/s digital communications channels that are available across public and/or private networks. It also ensures that bit sequence integrity of the aggregated bandwidth is maintained across the network(s). The number of individual communications channels aggregated may range from one up to the practical limits imposed by the Channel Aggregation Unit.

The service defined in this International Standard can be used for a number of applications, including

- o LAN interconnection
- o image transfer
- o bulk file transfer
- o video conferencing.

ITU-T Recommendation H.244 defines the means by which the appropriate choice of channel aggregation procedures may be made, in accordance with the requirements of the application being served. This choice is made from two available sets of procedures, one of which is also defined by ITU-T Recommendation H.244, the other of which is defined in this International Standard.

Information technology - Telecommunications and information exchange between systems - Private telecommunications networks - Digital channel aggregation

1 Scope

This International Standard defines a set of procedures collectively called 'Digital Channel Aggregation', which are used in the provision of an aggregated bearer service. Digital channel aggregation involves a means for the combination of multiple switched or unswitched 56 kbit/s or 64 kbit/s digital communications channels across one or more public and/or private networks into higher bandwidth digital bi-directional channels between Channel Aggregation Units (CAUs) serving terminal applications at network endpoints. Figure 1 below illustrates a typical channel aggregation scenario.

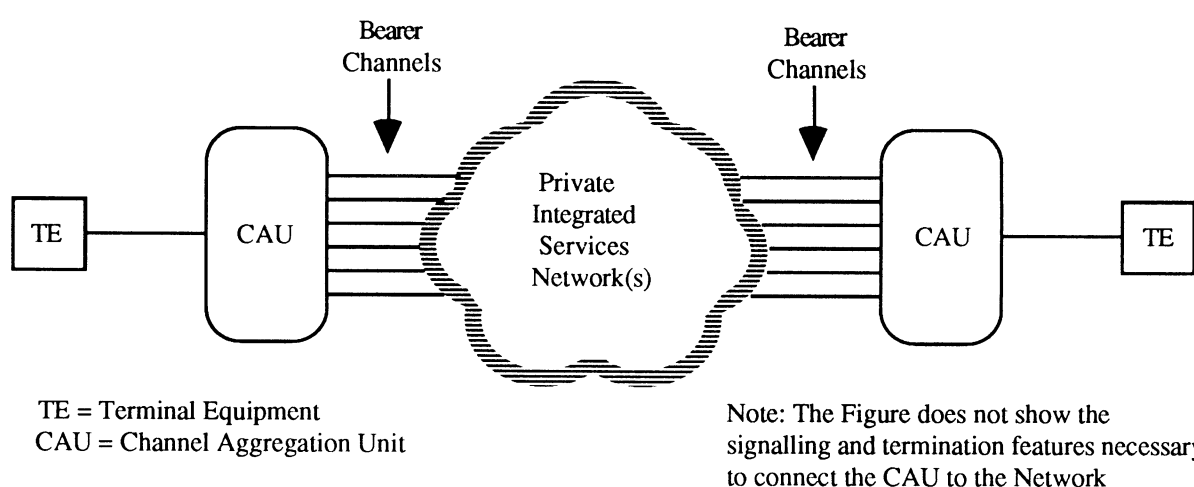


Figure 1 - Channel Aggregation Scenario

In defining the channel aggregation procedures, this International Standard sets out the means used by a CAU to

- o establish the parameters to be used for the aggregated connection
- o synchronise and align multiple communications channels to maintain the bit sequence integrity of the aggregated bandwidth across the network(s)
- o optionally monitor data transfer throughout a call to detect failure modes
- o institute failure recovery procedures
- o optionally dynamically vary the bandwidth on demand during a call.

The channel aggregation procedures above are defined at the interface between the CAU and the network in terms of the frame structure and information messages applied to individual communications channels. Not defined by this International Standard are

- o the call control procedures used to establish and disconnect the individual communications channels that make up the higher bandwidth connections
- o the higher level protocols or applications that use the channel aggregation services
- o the frame structure on the individual communications channels at the physical interface between the CAU and the network as required for 'normal' 56 kbit/s or 64 kbit/s bearer services as opposed to aggregated bearer services
- o the electrical characteristics of the individual communications channels at the physical interface between the CAU and the network.

2 Normative References

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

ISO/IEC 11571:1994, *Information technology - Telecommunications and information exchange between systems - Numbering and sub-addressing in private integrated services networks*.

ITU-T Recommendation G.704 (1991), *Synchronous frame structures used at primary and secondary hierarchical levels*.

ITU-T Recommendation H.221 (1994), *Frame structure for a 64 to 1920 kbit/s channel in audiovisual teleservices*.

ITU-T Draft Recommendation H.244 (1995), *Synchronized aggregation of ISDN-B channels*.

ITU-T Recommendation H.320 (1994), *Narrow-band visual telephone systems and terminal equipment*.

ITU-T Recommendation I.112 (1992), *Vocabulary of terms for ISDNs*.

ITU-T Recommendation T.35 (1991), *Procedure for the allocation of CCITT defined codes for non-standard facilities*.

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 Answering Endpoint: The endpoint that receives the call.

3.1 Bearer Channel: The network provided channel used to carry the data. The framing structure is overlaid on the Bearer Channel to provide the data transport and inverse multiplexing capability. Examples of Bearer Channels are:

- o BRI or PRI B-channels
- o T1 DS0s
- o Switched 56/64 kbit/s connections

3.3 Bearer Channel Rate: The data rate at which the Bearer Channel is clocked.

3.4 Calling Endpoint: The endpoint that initiates the call.

3.5 Channel Aggregation Unit: Any piece of equipment adhering to this International Standard. Note that any reference to other forms of channel aggregation (e.g., H.244) will be stated explicitly.

3.6 CRC Encoder: The function that calculates the CRC for inclusion in the transmitting direction.

3.7 Information Message: The 16 octet message sent and received over the Information Channel in the multiframe structure or over the entire bandwidth of the Master Channel during initial parameter negotiation. This message is transmitted continuously. In this International Standard, the use of the term Information Message, when discussing receipt of a message, indicates a message which has been recognized after the use of some form of detection processing (e.g., 2 out of 3 majority voting).

3.8 Master Channel: The channel used to communicate control information between each endpoint. This includes the initial parameter negotiation for call setup, channel delete, channel addition, remote loopback, call disconnection, etc. See 8.1.1 for further information.

3.9 Overall System Delay: The end-to-end transit delay (length of time it takes for the data to get from the transmitter to the receiver) including following:

- o Delay introduced by the transmitting endpoint (equipment implementing this algorithm).
- o Delay introduced by the network connecting the two endpoints.
- o Delay introduced by the receiving endpoint (equipment implementing this algorithm).

4 Symbols and Abbreviations

ALIGN	-	Alignment Octet
AU	-	Answering Unit
AVT	-	Audio Visual Terminal
BCR	-	Bearer Channel Rate
CAU	-	Channel Aggregation Unit
CID	-	Channel Identifier
CRC	-	Cyclic Redundancy Check
CSU	-	Channel Service Unit
CU	-	Calling Unit
DEQ	-	Delay Equalisation
DN	-	Directory Number
DS0	-	Transmission Standard for bit rate of 64 kbit/s
DS1	-	Transmission Standard for bit rate of 1.544 Mbit/s
DSU	-	Digital Service Unit
EBR	-	Effective Bearer Rate
FAW	-	Frame Alignment Word
FC	-	Frame Count
GID	-	Group Identifier
IC	-	Information Channel
ISO	-	International Organisation for Standardisation
ISDN	-	Integrated Services Digital Network
MF	-	Multiframe
MFG	-	Manufacturing Identifier
PISN	-	Private Integrated Services Network
PMDL	-	Physical Media dependent Layer
PTN	-	Private Telecommunications Network
Res	-	Reserved Bits
REV	-	Revision Level
RI	-	Remote Indicator
RLIND	-	Remote Loopback Indication
RLREQ -		Remote Loopback Request
RMULT -		Rate Multiplier
SI	-	Stream Identifier
SUBMULT	-	Subrate Multiplier
T1	-	Transmission Standard for bit rate of 1.544 Mbit/s
TAa	-	Timer in Answering Endpoint - timer a
TCa	-	Timer in Calling Endpoint - timer a
TXa	-	Timer in Either Endpoint - timer a
XFLAG -		Transfer Flag

5 Selection of ISO/IEC 13871 or ITU-T H.244 aggregation procedures

ITU-T Recommendation H.244 defines both a set of channel aggregation procedures and a means for determining the correct choice of procedures, i.e. either ISO/IEC 13871 or ITU-T H.244, according to the application being served.

A channel aggregation unit which is equipped to operate in both ISO/IEC 13871 and ITU-T H.244 aggregation modes shall select the correct mode of operation according to the process depicted in Figure 2 (reproduced from Figure 9/H.244).

If the CAU is not preset to ISO/IEC 13871 (Condition 1), and if H.221 framing is detected on the single-channel side (Condition 2), and if this framed signal includes either {SM-comp} or {6B-H0-comp} in its capset (Condition 3) - see H.244 - then the CAU shall commence transmission as for H.244 aggregation, and shall continue this if H.221 framing is also received on the master channel from the remote CAU. However, if the signal from the remote CAU is according to 7.1.1 of this International Standard, then transmission shall immediately be switched to be likewise in accordance with 7.1.1.

If any of the Conditions 1, 2, 3 are not met, then the CAU shall commence transmission as set out in 7.1.1.

In the following, it is assumed that Conditions 1, 2, 3 above have not been met and that the CAU has commenced transmission in ISO/IEC 13871 mode.

NOTE -The significance of the test point (4) in Figure 2 is as follows; if the incoming signal is H.221 framed but neither {SM-comp} nor {6B-H0-comp} is included in the capability set, then the remote end-point is a self-aggregating type of H.320 terminal and ISO/IEC 13871 aggregation is not possible.

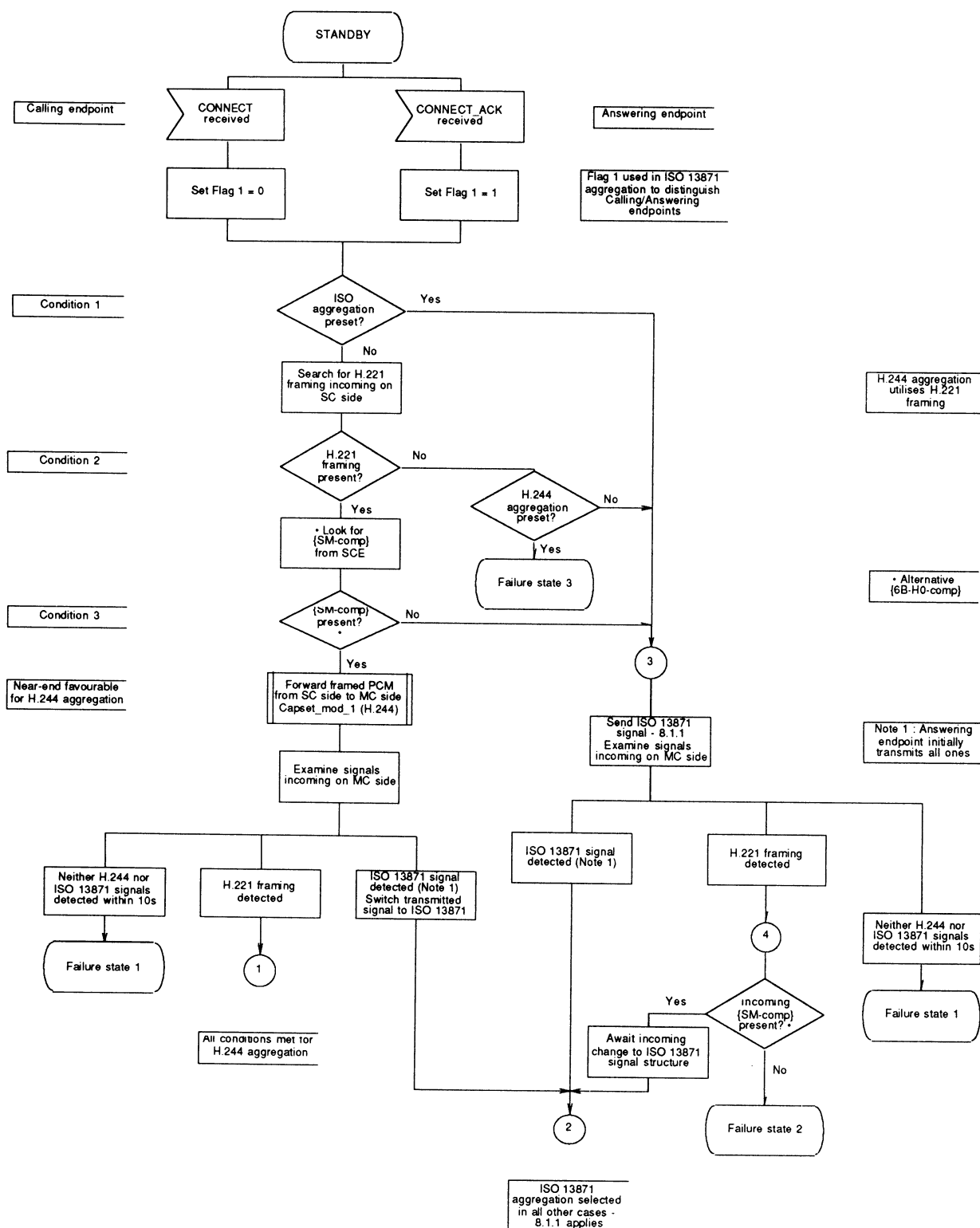


Figure 2 - Selection of ISO/IEC 13871 or ITU-T H.244 aggregation

6 Basic Principles

This International Standard describes a means for providing a high speed serial data stream by use of multiple, independent 56/64 kbit/s channels. These channels are individually connected over the switched digital network (public, private, etc.). At the transmitting end, user data is placed in a framing structure in each bearer channel and transmitted over multiple, independent channels. At the receiving end, all channels are phase aligned and synchronized (using the framing structure) to recreate the original data stream. This framing and synchronization is transparent to the attached application.

Due to the network routing the channels used for the wideband connection independently of each other, the data in each channel might be individually delayed relative to the data in other channels. The frame structure described herein for each 56/64 kbit/s bearer channel provides for the alignment of data octets from the individual channels to their original sequence before reforming the individual channels into a composite serial data stream at the terminating end. Overall transit delay for the end-to-end connection is equal to the longest transit delay from all the channels plus a constant delay due to the frame alignment that depends on implementation.

Once aligned, data transfer may be constantly monitored throughout the call. The failure of a channel, for reasons such as call disconnection, phase slip or high error rate, may be automatically detected. Various fault isolation and recovery procedures are defined in response to these scenarios.

Individual switched 56/64 calls can be combined to form a single transparent N x 56/64 channel.

NOTES

1 This algorithm will maintain bit and octet sequence integrity in that it will deliver user bits and octets to the remote endpoint in the same order and timing relationships as were received on the originating endpoint (except in cases of lost frame alignment). For applications that require octet timing to be maintained across the network (i.e., an octet of user data clocked into the transmitting endpoint must be clocked out as an octet of user data at the receiving endpoint), it is recommended that the first octet of user data transmitted across the network (i.e., the first octet transmitted after delay equalization is achieved) be placed in the first octet of a Channel Aggregation frame and not split across two octets of a Channel Aggregation frame. It is also recommended that only Modes 1, or 3 restricted to multiples of 64 kbit/s be used for this purpose (otherwise octet timing may be lost).

2 Although currently a maximum of 63 channels is specified, this limit is for further study.

6.1 Modes of operation

Five modes of operation are supported. The following two modes are required:

Mode 1:

This mode supports user data rates that are multiples of the bearer rate. It provides the user data rate with the full available bandwidth, but does **not** provide an in-band monitoring function. The overhead octets are removed after the call is phase aligned. Error conditions on one or more channels that disturb overall system synchronization are not recognized automatically after the call is in active state. Recovery from these error conditions during the active state requires manual or external intervention. This intervention is outside the scope of these procedures.

Transparent Mode:

In this mode, incoming (outgoing) channels are "cut-through" to the applications served by the Channel Aggregation Unit. The Channel Aggregation Unit performs no delay equalization or parameter negotiation. This mode is useful when delay equalization is performed by some other means (or is not required) and one endpoint is **not** a Channel Aggregation Unit.

A Channel Aggregation Unit implementing this International Standard **shall** implement Mode 1 and the Transparent Mode. Thus, Mode 1 and the Transparent Mode **shall** be the common modes of operation for all implementations claiming compatibility with this International Standard. Clause 9 describes the Transparent Mode in detail.

The following three modes of operation are optional.

Mode 0:

This mode provides initial parameter negotiation and Directory Number exchange over the master channel, then enters transparent mode without delay equalization. It does **not** provide an inband monitoring function. This mode is useful when the calling endpoint requires Directory Numbers, but the delay equalization is performed by some other means (e.g., attached video codec).

Mode 2:

This mode supports user data rates that are multiples of 63/64 of the bearer rate. An in-band monitor function provides a continuous check for delay equalization and an end-to-end bit error rate test. (Error rate testing is accomplished by performing a cyclic redundancy check calculation on an octet sequence before transmission and testing the same sequence for errors on the receive end.) The user data rate is that bandwidth remaining after the insertion of overhead octets (i.e., 98.4375% or 63/64 of the total network bandwidth).

Mode 3:

This mode supports user data rates that are integral multiples of 8 kbit/s, including $N \times 56$ and $N \times 64$ kbit/sec. All channels use the same bearer channel rate. An in-band monitor function provides a continuous check for delay equalization and an end-to-end bit error rate test. (Error rate testing is accomplished by performing a cyclic redundancy check calculation on an octet sequence before transmission and testing the same sequence for errors on the receive end.) The overhead octets required for monitoring are provided by adding bandwidth (most likely an additional bearer channel), thereby preserving the full user data rate. The overhead octets are included in each bearer channel.

6.2 Frame Structure

Each 56/64 kbit/s channel is organized into a sequence of frames. A frame consists of 256 octets. The octets are numbered 1 to 256. To establish the framing structure and provide for the exchange of information with the far end, each frame carries four octets of overhead (Octet 64, Octet 128, Octet 192 and Octet 256).

Overhead octets contain only seven bits of information so that a common structure can be used for 56 and 64 kbit/s bearer channels. In s 5.2.2 through 5.2.5, bit 8 is depicted as having the value 1. For 64 kbit/s bearer channels, bit 8 is set to "1". For 56 kbit/s bearer channels, the following procedures are followed.

- o At the transmitting endpoint, procedures such as CRC calculation are performed with all octets (data and overhead) having an 8th bit set to "1". If 56 kbit/s baseband bearer channels are used, bit 8 is stripped off of each octet before it is transmitted. Thus, only 7 bits are transmitted in each 125 μ sec interval. If 56 kbit/s bearer channels are provided via 64 kbit/s facilities, 8 bits are transmitted in each 125 μ sec interval, and the 8th bit remains set to "1" in all octets.
- o If the receiving endpoint uses 56 kbit/s baseband bearer channels, the incoming bit stream is serialized and searched for bits 1-7 of the Frame Alignment Word (FAW). When FAW is detected, an 8th bit set to "1" is added to each septet to form octets. All procedures such as CRC are then based on the resulting octets.
- o If the receiving endpoint uses 56 kbit/s bearer channels provided via 64 kbit/s facilities, the 8th bit is stripped upon receipt of each octet. The resulting 56 kbit/s bit stream is serialized, and searched for bits 1-7 of the FAW. When FAW is detected, an 8th bit set to "1" is added to each septet to form octets. All procedures such as CRC are then based on the resulting octets.

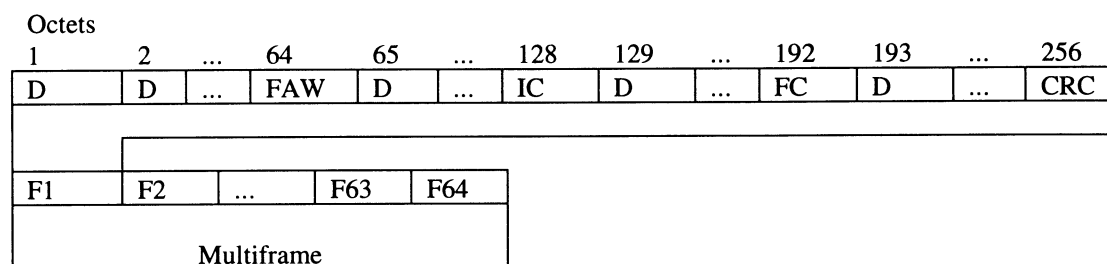
NOTE 1 - The receiving endpoint may initially search for the entire FAW on the incoming 64 kbit/s bit stream, assuming octet alignment. However, if the incoming channel aggregation octets are not aligned with the network octets, FAW will not be detected and the procedure described above will have to be followed.

The receiving endpoint may need to serialize the incoming bit stream for 64 kbit/s bearer channels if one endpoint is not provided with network octet timing. To simplify procedures at the receiving endpoint, the transmitting endpoint **shall** align the channel aggregation octets with network octets if octet timing is provided.

NOTE 2 - Equipment that requires that the channel aggregation frames be synchronized with network provided octet timing will not be able to communicate with equipment connected to networks that do not provide octet timing.

A multiframe (MF) contains 64 consecutive frames numbered 1 to 64. The total duration of a multiframe is 2.048 seconds. Note that the duration of the multiframe must be twice as long as the desired amount of delay compensation. Hence, the frame structure described herein supports a maximum relative delay (between channels) of 1.024 seconds.

The following figure illustrates the framing structure.



FAW: Frame Alignment Word

IC: Information Channel

FC: Frame Count

CRC: Cyclic Redundancy Check

D: Data Octet

F1 - F64: Frames

Figure 3 - Framing Structure

6.2.1 Bit Ordering

In this International Standard, the bits of each octet are numbered b1 to b8 indicating the order of bit transmission. Numeric values are transmitted most significant bit first.

6.2.2 Frame Alignment Word (FAW)

Octet 64 in every frame contains the frame alignment word (FAW). The assignment of bits 1-8 of the FAW is shown below:

	b1	b2	b3	b4	b5	b6	b7	b8
FAW	0	0	0	1	1	0	1	1

As described in 6.2, for 56 kbit/s base bearer channels, only the first 7 bits are transmitted. Therefore, the FAW is a 7 bit word. On the incoming side, the receiver must search for a 7 bit Frame Alignment Word in order to synchronize

6.2.3 Frame Count (FC)

Octet 192 in every frame contains a Frame Count (FC) value. The Frame Count is used to measure the relative delay variance between the individual channels of an N x 56/64 call. This 6-bit, modulo 64 counter is incremented once every frame and rolls over on a multiframe boundary. The first frame of a multiframe **shall** contain a Frame count of zero.

The assignment of bits 1-8 of the FC is shown below. Note that bit 8 of the Frame Count is always set to binary 1.

	b1	b2	b3	b4	b5	b6	b7	b8
FC	1	Frame Count						1

Where 0 2 Frame Count 2 63.

6.2.4 Information Channel (IC)

Octet 128 in every frame contains the information channel (IC). The IC provides for the in band exchange of information with the far end device. A detailed description can be found in clause 7.

For initial parameter negotiation on the master channel, the Information Channel uses the entire bandwidth of the channel.

NOTE - Bit 8 of the Information Channel (b8) is always set to 1. See Figure 5 in Clause 7.

6.2.5 Cyclic Redundancy Check (CRC)

Octet 256 in every frame contains a Cyclic Redundancy Check (CRC). The assignment of bits 1-8 of the CRC octet is shown below. Note that bit 8 of the CRC octet is always set to binary 1.

	b1	b2	b3	b4	b5	b6	b7	b8
CRC	1	A	E	CRC4				1

A: Alignment Bit -- indicates that the remote end has frame alignment when A=1

E: Error Bit -- indicates that the remote end has detected a CRC4 error when E=1

CRC4: Contains the 4 bit CRC calculated for current block (see 6.4)

Use of the CRC4 is optional. A complete description of the CRC4 procedure, including use of the E bit, is given in 6.4. A description of the (A) bit is given in 5.3 below.

When CRC4 is not used, the transmitter **shall** set the E bit to 0 and the CRC4 bits to 1. When a unit receives E bit set to 0 and CRC4 set to all 1's, it **shall** disable the CRC procedure in the receive direction and **shall** ignore subsequent E bits and CRC4 bits. When an endpoint that implements the CRC procedure receives a CRC4 not set to all 1's it **shall** enable the CRC procedures.

6.2.6 Distribution of Overhead Octets

The overhead octets **shall** be distributed in the channels by the transmitting endpoint such that an overhead octet in channel "i+1" **shall** be offset from the corresponding overhead octet in channel "i" by 125 μ sec. For example, if the FAW octet in channel 1 (as identified by the Channel Identifier) is transmitted starting at time $t=0$, the FAW octet in channel 2 **shall** be transmitted starting at time $t = 125 \mu$ sec, the FAW octet in channel 3 **shall** be transmitted starting at time $t = 250 \mu$ sec and in general, the FAW octet in channel "m" **shall** be transmitted starting at time $t = (m-1)*125 \mu$ sec. The other overhead octets are transmitted with the same constraints. The objective of this requirement is to distribute the overhead octets as evenly as possible across all channels. This requirement is independent of the framing structure of the underlying physical medium.

The following example illustrates the distribution of overhead octets when calls are made using a T1 network access and using Mode 3 operation. This example is for T1 frames only and does not imply restriction of this procedure only to T1 transmission systems. In addition, for illustration purposes, this example uses contiguous channel assignment and does not imply restriction of this procedure to contiguous channel assignment. This example also assumes that the Channel Aggregation framing structure aligns with the DS1 framing structure. The Channel Aggregation framing structure is not required to align with the DS1 framing structure.

NOTE 1 - If the Layer 1 used is not clocked with 8 kHz framing (e.g., Layer 1 is V.35 connected to a DSU/CSU), then the DS1 frame can not be used as framing to find FAW. In this case, the incoming bit stream can be serialized before searching for framing.

Based on the requirement for distribution of overhead octets, the overhead octets are distributed within a frame in such a way as to displace only one octet within the 24 octet frame of a T1 system. Figure 4 shows how the overhead octets are dispersed within a sample 6 x 64 kbit/s call. The columns represent individual channels identified by the Channel Identifier. In this example the Channel Identifier is the same as the DS0 number used for the channel. This is not a requirement. An "FAW" or an "IC" indicates an overhead octet. The rows in the chart are instances of T1 frames.

Column 7 shows an N+1 channel used to replace the capacity lost due to overhead octets in Mode 3 operation so as to preserve the full user data rate. In Mode 2, column 7 is not used and the user data rate is that bandwidth remaining after the insertion of overhead octets. In Mode 1, no overhead octets are used and column 7 is not used (the entire bandwidth is available for data). In this example, the user data bytes are numbered in order of transmission up to 48. The rest of the data bytes are ordered in the same manner (across and down) An asterisk (*) indicates an unused octet in which all bits are set to one.

		Channel Aggregation Channels							
		1	2	3	4	5	6	7	24/32
T F R A M E S	1	FAW	D1	D2	D3	D4	D5	D6	
	2	D7	FAW	D8	D9	D10	D11	D12	
	3	D13	D14	FAW	D15	D16	D17	D18	
	4	D19	D20	D21	FAW	D22	D23	D24	
	5	D25	D26	D27	D28	FAW	D29	D30	
	6	D31	D32	D33	D34	D35	FAW	D36	
	7	D37	D38	D39	D40	D41	D42	FAW	
	8	D43	D44	D45	D46	D47	D48	*	
		0							
		0							
		0							
	65	IC	D	D	D	D	D	D	
	66	D	IC	D	D	D	D	D	
	67	D	D	IC	D	D	D	D	
	68	D	D	D	IC	D	D	D	
	69	D	D	D	D	IC	D	D	
	70	D	D	D	D	D	IC	D	
	71	D	D	D	D	D	D	IC	
	72	D	D	D	D	D	D	*	

Figure 4 - Overhead octets dispersed within a sample 6 x 64 kbit/s call (Mode 3 Operation).

NOTE 2 - Figure 4 shows the Channel Aggregation channel number. There is no relation between the Channel Aggregation channel number and the DS0 number.

6.3 Overall Frame alignment

In Modes 1, 2 and 3, the FAW in each channel is used at call setup time to align the individual channels. In Modes 2 and 3, the FAW in each channel is monitored continuously to determine if frame alignment has been lost and to recover frame alignment.

Loss of Frame Alignment:

An endpoint **shall** detect loss of frame alignment when it receives three consecutive frame alignment words (FAW) in error or three consecutive Frame Counts in error. Upon detection of loss of frame alignment, the endpoint **shall** set the Alignment bit (A) in the CRC octet to 0 in the transmit direction.

Frame Alignment Recovery:

An endpoint **shall** start the recovery of frame alignment immediately after detecting loss of frame alignment and at channel connection time. Frame alignment is defined to have been recovered when the endpoint detects the following sequence:

- the correct frame alignment word (FAW);
- the absence of the FAW 128 octets later, detected by verifying that Bit 1 = 1 in the FC octet;
- the presence of the correct frame alignment word (FAW) in the next frame
- the presence of CID = 0 when setting up the initial Master Channel.

To speed the initial establishment of frame alignment, an endpoint **shall** transmit an all ones pattern in the Data bits of the frame on initial establishment of the connection until it receives the remote Alignment (A) bit set to one for two consecutive CRC octets.

An endpoint **shall** begin transmitting an all ones pattern in the Data bits of the frame whenever it receives an A bit set to zero in two consecutive CRC octets. Receipt of an A bit set to zero in two consecutive CRC octets indicates that the remote endpoint has lost frame alignment.

6.4 Description of CRC4 Procedure

The CRC4 procedure can be used to provide an end-to-end quality monitor of each 56/64 kbit/s channel. The four CRC bits (bit positions 4 to 7 of octet 256) contain the CRC computed at the source location. In addition, bit 3 of the same octet, referred to as the E bit, is used to transmit an error indication about the received data in the opposite direction (i.e., whether or not the previous frame was received with errors).

The CRC4 used in these procedures is defined in ITU-T Recommendation G.704.

6.4.1 Computation of the CRC4 Bits

The CRC4 is computed from the whole 56/64 kbit/s channel from the previous 255 octets of the frame before the CRC4 octet. The CRC4 is therefore computed over 255 octets starting with the first octet of the frame (i.e., the octet immediately following the CRC4 octet of the previous frame) and ending with the octet just preceding the CRC4 octet (i.e., Octet 255). The CRC4 octet is not included in the CRC4 calculation.

6.4.1.1 Multiplication and Division Process

A given CRC4 located in Octet 256 is the remainder after multiplication by X^4 and then division (modulo 2) by the generator polynomial $X^4 + X + 1$ of the polynomial representation of the 255 octets preceding the CRC octet in the frame.

When representing contents of a frame as a polynomial, the first bit in the frame **shall** be taken as being the most significant bit. Similarly Bit 4 of the CRC octet is defined to be the most significant bit of the remainder and Bit 7 is the least significant bit of the remainder.

6.4.1.2 Encoding Procedure

Octets 1 through 255 of the frame are acted upon by the multiplication and division process defined in 5.4.1.1. The remainder, resulting from the multiplication and division process, is inserted into the CRC4 field of Octet 256 (the CRC octet) of the frame. The CRC is always computed over 8 bit octets. When using 56 kbit/s bearer channels, bit 8 of each octet **shall** be forced to "1" for consistency.

NOTE - As described in 6.2, for 56 kbit/s bearer channels, an 8th bit set to 1 is stuffed at the end of each septet before CRC encoding. This 8th bit of each octet will be stripped after CRC calculation and before transmission if 56 kbit/s baseband bearer channels are used

6.4.1.3 Decoding Procedure

Octets 1 through 255 of a received frame are acted upon by the multiplication and division process, defined in 6.4.1.1. When using 56 kbit/s bearer channels, an 8th bit set to "1" shall be added to each septet (as derived from FAW alignment) to form octets for consistency. The remainder, resulting from the multiplication and division process is compared on a bit-by-bit basis with the CRC4 received in Octet 256 of the frame. If the decoded, calculated remainder equals the CRC4 received in Octet 256, then the checked frame is considered error-free. If they are different, then the checked frame is considered in error.

NOTE - As described in 6.2, CRC calculation for 56 kbit/s bearer channels is performed after insertion of an 8th bit set to 1 at the end of each septet.

6.4.2 Consequent Actions

6.4.2.1 Enabling and Disabling the CRC Procedures

An endpoint **shall** indicate that CRC procedures are being used by starting the CRC Encoding process on the transmitting end, thereby not transmitting the CRC bits as all 1's. If an endpoint supports the CRC procedure on this channel, it **shall** enable the CRC Decoding process when it receives a CRC Octet with the CRC bits set to a value other than all 1's; otherwise, it **shall** transmit the E bit set to 0 and CRC set to all 1's.

An endpoint **shall** indicate that CRC Encoding procedures are being disabled by setting all CRC bits to binary 1 and setting the E bit to 0. An endpoint **shall** disable the Decoding process when it receives three CRC octets with CRC set to all 1's and an E bit set to 0.

The above procedure can induce a short period of CRC errors while the endpoints start and stop CRC procedures. The actions taken in the following two subclauses should take this into account.

This procedure allows an endpoint to enable the CRC procedures on a channel by channel basis.

6.4.2.2 Action on Bit E

The E bit of the CRC octet is set to 1 in the transmitting direction when a CRC error is detected in the receive direction (see 6.4.1.3). Otherwise, it is set to zero.

6.4.2.3 Monitoring for Error Performance

The quality of the received 56/64 kbit/s channel can be monitored by counting the number of CRC frames in error within a period of one second. The quality of the transmitted 56/64 kbit/s channel can be monitored by counting the number of received E bits set to 1.

The threshold for declaring a channel out of service is left for further study and is implementation dependent.

7 Description of the Information Channel

The information channel is used to communicate control information between two endpoints. In all modes, the Information Channel occupies the entire bandwidth of the Master Channel during initial parameter negotiation. In modes 2 and 3, the Information Channel occupies octet 128 of the Channel Aggregation Frame in all bearer channels during delay equalization and throughout the duration of the call. In mode 1, the Information Channel occupies octet 128 of the Channel Aggregation Frame in all bearer channels only during the initial delay equalization. In mode 0, the Information Channel is not present after initial parameter negotiation.

7.1 Information Channel Frame

Information channel frames are framed with a unique ALIGNment pattern (01111111) in the first octet. In addition, the first bit (b1) of the subsequent octets is set to one. Figure 5 shows the structure of the Information Channel (IC) frame. IC octets only contain seven bits of information so that a common structure can be used for 56 and 64 kbit/s bearer channels. In Figure 5, bit 8 of each octet is depicted as having the value 1. For 64 kbit/s bearer channels, bit 8 is set to 1. For 56 kbit/s bearer channels provided via 64 kbit/s facilities, bit 8 is used for network signaling and is set to 1 for off-hook. For the case of 56 kbit/s baseband bearer channels, bit 8 is not present and an overhead "octet" transmitted over the bearer channel contains only 7 bits. 6.2 describes procedures for using 56 kbit/s bearer channels.

	b1	b2	b3	b4	b5	b6	b7	b8
	ALIGN							
Octet 1	0	1	1	1	1	1	1	1
2	1	Channel ID						1
3	1	Group ID						1
4	1	Operating Mode			Res			1
5	1	RMULT						1
6	1	SUBMULT			BCR	Res	MFG	1
7	1	RI	RL Req	RL Ind	REV			1
8	1	Subaddress						1
9	1	Transfer Flag						1
10	1	1	1	Digit - 1				1
11	1	1	1	Digit - 2				1
12	1	1	1	Digit - 3				1
13	1	1	1	Digit - 4				1
14	1	1	1	Digit - 5				1
15	1	1	1	Digit - 6				1
16	1	1	1	Digit - 7				1

Figure 5 - Information Channel Frame

NOTE 1 - Annex D provides details of the additional capability to be used when phone numbers longer than 7 digits are required.

ALIGN: Alignment octet (Octet 1, Bits 1-8)

The alignment octet provides a framing mechanism for the Information channel frame. It takes a constant value of "01111111".

NOTE 2 - For 56 kbit/s baseband bearer channels, only the first seven bits of the ALIGN octet are transmitted (i.e., 0111111).

CID: Channel identifier (Octet 2, Bits 2-7)

When simultaneously dialing N calls, the network delay in call setup for each call might not be uniform. Hence the incoming call arrival sequence at the Answering Endpoint cannot be assumed to be equal to the call setup sequence at the Calling Endpoint. The CID identifies each individual channel in the transmit direction for each side of the connection and is used to sequence the time slots in proper order at the receiving end. In each endpoint, the CID value transmitted in each channel is independent of the CID value received from the other endpoint. The Calling and Answering endpoint **shall** assign CID = 1 to the initial channel and **shall** assign CID in sequential ascending order corresponding to the relative order of the remaining channels. A value of 0 in the CID field indicates negotiation of parameters.

The CID is a 6-bit binary encoded number in the range $0 \leq \text{CID} \leq 63$.

GID: Group identifier (Octet 3, Bits 2-7)

The call Group Identifier is used to identify the group of bearer channels associated with a particular call. The value of this parameter **shall** be agreed upon by both ends at the time of establishing the master channel. The GID negotiated on the master channel **shall** be used in all subsequent bearer channels for this call. The GID is assigned by the Answering Endpoint and is unique to this call at the Answering Endpoint. The Calling Endpoint uses a combination of the GID and a local identifier to uniquely identify a call. The value of 0 is reserved to indicate an unknown GID during parameter negotiation and channel initiation.

This field contains a binary encoded number in the range $0 \leq \text{GID} \leq 63$

MODE: Operating mode (Octet 4, Bits 2-4)

This field indicates the mode of operation desired for this call. The four modes of operation are described in 6.1 of this International Standard.

Bits	
<u>2 3 4</u>	
0 0 0	operating Mode 0
0 0 1	operating Mode 1
0 1 0	operating Mode 2
0 1 1	operating Mode 3
1 0 0	Reserved
1 0 1	Reserved
1 1 0	Reserved
1 1 1	Reserved for negotiation.

NOTE 3 - There is no coding for the Transparent Mode because in the Transparent Mode there is no Information Channel.

Res: Reserved (Octet 4, Bits 5-7):

These bits are reserved and **shall** be set to 1 on transmission and **shall** be ignored on receipt.

RMULT: Rate Multiplier (Octet 5, Bits 2-7)

The Rate Multiplier field RMULT together with the Subrate Multiplier field SUBMULT contains information that uniquely defines the application rate for a given call. The application rate is determined from these fields in slightly different ways depending on the Operating Mode given in the MODE field of the Information Message (Octet 4, Bits 2-4). See 7.1.1 for details.

RMULT takes a value in the range $0 \leq \text{RMULT} \leq 63$.

SUBMULT: Subrate Multiplier (Octet 6, Bits 2 - 4):

The Rate Multiplier field RMULT together with the Subrate Multiplier field SUBMULT contains information that uniquely defines the application rate for a given call. For Modes 0, 1 and 2, the SUBMULT field **shall** be set to all binary ones on transmit and ignored on receipt. See 7.1.1 for details.

For Mode 3, SUBMULT takes a value in the range $0 \leq \text{SUBMULT} \leq 6$ for BCR = 56 kbit/s and $0 \leq \text{SUBMULT} \leq 7$ for 64 kbit/s

BCR: Bearer Channel Rate (Octet 6, Bit 5)

This field indicates the data rate to use when determining how to use the bearer channel. A 56 kbit/s BCR means that the channels used are based on 56 kbit/s multiples and a 64 kbit/s BCR means that the channels used are based on 64 kbit/s multiples.

This field takes the following values

<u>Bit 5</u>	
1	64 kbit/s base
0	56 kbit/s base

Res: Reserved (Octet 6, Bit 6):

This bit is reserved and **shall** be set to 1 on transmission and **shall** be ignored on receipt.

MFG: Manufacturing ID Flag (Octet 6, Bit 7):

When this bit is set to 1, the Digits field contains a 7 binary encoded digit Manufacturer's ID. Annex C contains the Manufacturer ID assignments. When this bit is set to 0, the Digits field does not contain the Manufacturers ID and is used according to other procedures.

The Manufacturer's ID is exchanged between equipment at call initialization time. Equipment can use the ID to identify the equipment on the other end of the connection. Manufacturers can use this information to identify their own equipment on the other end of the connection in order to add proprietary extensions to the protocol.

RI: Remote indicator (Octet 7, Bit 2)

The RI field indicates that delay equalization has been accomplished.

Bit 2

- 1 call is delay equalized
- 0 call is not delay equalized.

RL REQ: Remote loopback Request (Octet 7, Bit 3)

This bit is used to request that the remote endpoint loop back toward the local endpoint. The receipt of an RL REQ bit set to one indicates a request to enable remote loopback. RL REQ set to zero indicates a request to disable remote loopback. **When remote loopback is not requested, this bit shall be set to 0.**

Bit 3

- 1 request for remote loopback
- 0 turn off remote loopback.

RL IND: Remote Loopback Indication (Octet 7, Bit 4)

This bit is used to indicate to the remote endpoint that the local endpoint is looping the delay equalized payload from all channels back to the remote endpoint. This bit is used as a response to the receipt of RL REQ = 1 or to indicate an unsolicited loopback. **When not in loopback, this bit shall be set to 0.**

Bit 4

- 1 Sending endpoint is in loopback state
- 0 Sending endpoint is not in loopback state.

REV: REVision level (Octet 7, Bits 5-7)

This field can be used to check version compatibility between the local and far end units. If this field is not used it **shall** be set to all binary ones on the transmitting end and ignored on the receiving end. All endpoints developed to Issue 1 of this International Standard **shall** use a Revision Level of 0.

This is a binary encoded number in the range $0 \leq \text{REV} \leq 7$.

If one CAU transmits a higher value of REV than the other CAU then only those procedures defined for the lower value of REV shall be used by both CAUs.

Subaddress: Subaddress (Octet 8, Bits 2-7)

This field is used to indicate the subaddress of a call. It takes a value in the range from 0 to 63. A value of 0 indicates that the subaddress is not used.

A CAU may be capable of handling multiple simultaneous calls; the subaddress provides a means of distinguishing an individual call amongst the multiple calls that may exist.

XFLAG: Transfer Flag (Octet 9, Bits 2-7)

When CID = 0, the transfer flag is used during initial parameter negotiation for signaling the transmission of additional phone numbers (7 digits each) to the calling unit. During Channel Deletion procedures, the XFLAG field is used to identify the channel to be deleted.

See 8.1 for description of the phone number transfer procedures and 8.3 for channel deletion procedures.

This field is binary encoded and takes values in the range $0 \leq \text{XFLAG} \leq 63$

When CID is not equal to 0, this field and bits 2-7 of octets 10 - 16 can be used for User Information transfer and are not defined in this International Standard.

DIGITS: Phone Number Dial Digits (Octets 10 - 16, Bits 4-7)

When CID = 0 and MFG = 0 the Digits fields are used for phone number negotiation during initial parameter negotiation. There are seven Digits fields, each containing a number from the list below. When sending less than 7 digits, the endpoint **shall** left justify the number (i.e., if there are M digits, then these digits fill the first M Digits fields) and **shall** fill the unused Digits fields with the EON value.

See 8.1 and 8.2 for phone number delivery procedures.

When CID is not equal to 0, the XFLAG field and bits 2-7 of octets 10 - 16 can be used for User Information transfer and are not defined in this International Standard.

When CID = 0 and MFG = 1, the Digits field contains a binary encoded 7 digit number specifying the Manufacturer's ID of the manufacturer of the transmitting endpoint.

Bits	Digits
4 5 6 7	
0 0 0 0	0
0 0 0 1	1
0 0 1 0	2
0 0 1 1	3
0 1 0 0	4
0 1 0 1	5
0 1 1 0	6
0 1 1 1	7
1 0 0 0	8
1 0 0 1	9
1 0 1 0	*
1 0 1 1	#
1 1 0 0	EON
1 1 0 1	Reserved
1 1 1 0	Cause Indicator
1 1 1 1	PAD

Cause: Cause Codes (Octets 10 and 11, Bits 2 - 7)

When the first digits field has the value "1110", it indicates that the following field is a Cause Value. The Cause Value is a binary encoded value in the range $0 \leq \text{Cause} \leq 63$. The following cause codes have been defined:

Value	Meaning
0	Reserved
1	No resource available
2	Channel error rate exceeded threshold
3	Normal Clearing
4	Bandwidth addition request
5	Mode not supported
6	Rate not supported
7	Information Channel framing lost
8	FAW framing lost
9	Delay Equalization unsuccessful
10	Unknown command/protocol error
11	Temporary failure, in recovery
12	Failure, no recovery
13	Bandwidth deletion request

Cause Codes 14 - 63 are reserved for further study.

Cause Codes can be used whenever negotiations take place (i.e., CID = 0 in the master channel), and Manufacturer's ID and Phone Numbers are not being transferred. Also Cause Codes can be transmitted by forcing an "Add a Channel" or "Delete a Channel" procedure with no change in the RMULT or SUBMULT field.

NOTE - ISDN subaddresses may be included in the digits field.

7.1.1 Rate Multiplier and Subrate Multiplier Calculation and Operation

Given the Bearer Channel Rate (56 or 64 kbit/s), the Application Data Rate can be derived from the RMULT and SUBMULT values or the RMULT and SUBMULT values can be derived from the application data rate (A) as follows: In the following equations, all data rates are in bits/second.

Mode 0, 1:

$$\text{E1. } A = \text{RMULT} \cdot \text{BCR}$$

$$\text{E2. } \text{RMULT} = \frac{A}{\text{BCR}}$$

Mode 2:

$$E3. \quad A = RMULT * BCR * \left(\frac{63}{64} \right)$$

$$E4. \quad RMULT = \frac{(A * 64)}{(BCR * 63)}$$

Mode 3:

$$E5. \quad A = (RMULT * BCR) + (SUBMULT * 8000)$$

$$E6. \quad RMULT = \left\lfloor \frac{A}{BCR} \right\rfloor \text{ (rounded down to the next lowest integer)}$$

$$E7. \quad SUBMULT = \frac{(A - (RMULT * BCR))}{8000}$$

NOTE- The SUBMULT field only has meaning in Mode 3. This is because Modes 0, 1 and 2 only support rates that are multiples of the bearer rate (in Mode 2, multiples of 63/64 of the bearer rate.). Mode 3 supports application data rates of any multiple of 8 kbit/s; therefore, the SUBMULT field is required to specify the application data rate with an 8 kbit/s granularity. In Modes 0, 1 and 2 the SUBMULT field **shall** be set to all ones on transmission and ignored on receipt.

Let EBR (Effective Bearer Rate) represent the effective bandwidth per network channel available for the transfer of application data. EBR is defined as the Bearer Channel Rate (BCR) minus the bandwidth required to transfer the Channel Aggregation overhead octets.

Mode 0, 1:

$$E8. \quad EBR = BCR, \text{ since the Channel Aggregation overhead octets are removed before application data is transferred over the channel.}$$

Modes 2 and 3:

$$E9. \quad EBR = \left(\frac{63}{64} \right) * BCR, \text{ since every 64th octet of a network channel is required for the transfer of overhead octets.}$$

The number of network channels (N) required to complete the call is then determined directly based on application data rate and effective bearer rate:

Modes 0, 1, 2 and 3:

$$E10. \quad N = \left\lceil \frac{A}{EBR} \right\rceil \text{ rounded up to the nearest integer.}$$

From the above equations it follows that for Modes 0, 1 and 2 the number of channels N required for a given call is equal to the Rate Multiplier RMULT. Only in Mode 3 is it necessary to explicitly calculate N. In the case of Mode 3, N can be calculated from RMULT and SUBMULT by substituting equation E5 for A to get

$$E11. \quad N = \frac{RMULT * BCR + SUBMULT * 8000}{EBR}$$

Equation E11 must be used on the receiving end of a parameter negotiation frame to determine the number of channels.

7.1.1.1 Distribution of Application Data Across the Channel Aggregation Frame

In Modes 0, 1 and 2 the application data rate is only allowed to be integer multiples of the effective bearer channel rate (EBR). In Mode 0 and 1, EBR is the same as the bearer channel rate BCR (i.e., $EBR = BCR = 56$

or 64 kbit/s). In Mode 2 EBR is BCR scaled by 63/64 (i.e., $EBR = BCR * (63/64) = 55.125 \text{ kbit/s}$ ($BCR = 56 \text{ kbit/s}$) or 63 kbit/s ($BCR = 64 \text{ kbit/s}$)). In Modes 1 and 2 all available bandwidth is used by data (Mode 1) or data and overhead (Mode 2).

In Mode 3 the application data rate (A) is allowed to be an integer multiple of 8 kbit/s. To support this granularity in the application data rate, only a portion of the available bandwidth in the Nth network channel is used. In Mode 3, two parameters (L and M) are calculated based on application rate and bearer channel rate. These parameters define the number of bits within the Nth channel that carry application data.

The parameter L specifies the number of octets in each 64 octet segment (bounded by overhead octets) in the Nth channel that contain application data. Transmission of the L octets in the Nth channel begins (N-1) octets before the overhead octet. The parameter M specifies the number of bits in the last octet of each L octet cluster that contains application data. For example, if M is calculated to be 3, then the most significant three bits are filled with application data and the last 5 bits are forced to ones as shown below.

b1	b2	b3	b4	b5	b6	b7	b8
D1	D2	D3	1	1	1	1	1

NOTE - All unused bit locations in the Nth channel **shall** be set to all ones.

For example, for $BCR = 56 \text{ kbit/s}$, $N = 4$, $L = 22$ and $M = 2$ (Application Data Rate of 184 kbit/s, $RMULT = 3$, $SUBMULT = 2$), application data is disbursed in the Nth channel such that $N - 1$ application data octets are transmitted before an overhead octet (e.g., FAW) and the remaining application data octets are transmitted after the overhead octet (e.g., FAW). In this case the output is shown in Figure 6. The first column represents time (e.g., DS1 frames). Columns 2 - 5 contain the four channels used in the call. Column 6 contains the number of octets (in that DS1 frame) that contain data. For example, in the first DS1 frame, one octet is used for FAW and (N-1) octets are used for user data. This example shows data starting at the FAW overhead octet of the first channel instead of the first octet of the frame. In the Nth channel, three octets before the overhead octet are used for data and $L - 3 (= 19)$ octets after the overhead octet are used for user data. An X in the Nth channel indicates that these octets are set to 1 and do not contain User Data. A D indicates a data octet and D2 indicates a data octet containing two data bits.

This pattern repeats itself around every overhead octet.

	<u>CID=1</u>	<u>CID=2</u>	<u>CID=3</u>	<u>CID=4</u>	<u># of Octets with Data</u>
1	FAW	D	D	D	N-1
2	D	FAW	D	D	N-1
3	D	D	FAW	D	N-1
4	D	D	D	FAW	N-1
5	D	D	D	D	N
6	D	D	D	D	N
7	D	D	D	D	N
8	D	D	D	D	N
.	.	.	.	.	.
.	.	.	.	.	.
22	D	D	D	D	N
23	D	D	D	D2	N
24	D	D	D	X	N-1
.	.	.	.	.	.
.	.	.	.	.	.
64	D	D	D	X	N-1
65	IC	D	D	D	N-1
66	D	IC	D	D	N-1
67	D	D	IC	D	N-1
68	D	D	D	IC	N-1
69	D	D	D	D	N
70	D	D	D	D	N
.	.	.	.	.	.
.	.	.	.	.	.

Figure 6 - Distribution of Application Data Across the Channel Aggregation Frame

7.1.1.2 Calculation of Parameters L and M

This subclause is used only for Mode 3.

In order to calculate L and M, the total number of application data bits that need to be transferred in the Nth channel (#BITS(N)) must first be determined. Let REM(N) be defined as the remainder of the application data rate A divided by the effective bearer channel rate EBR (EBR = (63/64) * BCR), except when the remainder = 0.

$$\text{E12. } \text{REM}(N) = \text{remainder} \left[\frac{A}{\text{EBR}} \right] \text{ except that if remainder} = 0, \text{ then } \text{REM}(N) = 1$$

Since there are 252 octets per Channel Aggregation frame that can contain data,

$$\text{E13. } \# \text{BITS}(N) = \text{REM}(N) * 252 * (7 + \text{BASE}),$$

where BASE is defined to be 1 if the bearer channel rate (BCR) is 64 kbit/s and 0 if the BCR is 56 kbits. The quantity (7 + BASE) is the number of allowed application data bits per octet.

L is then calculated as follows:

$$\text{E14. } L = \frac{\# \text{BITS}(N)}{(4 * (7 + \text{BASE}))} \text{ rounded up to the nearest integer.}$$

NOTE - The factor of 4 in the divisor is required since the data in the Nth channel is placed in the Channel Aggregation frame in four separate blocks of L octets.

M is then calculated based on L and #BITS(N). If $(L * (7 + \text{BASE})) = \frac{\# \text{BITS}(N)}{4}$ exactly (i.e., no rounding is required to determine L) then,

M = (7+BASE), i.e., the Lth octet contains no unused bit fields;

otherwise,

$$M = \frac{\#BITS(N)}{4} - ((L - 1) * (7 + BASE))$$

The table in Annex B shows the values of M and L for application rates of all multiples of 8000 bit/s that can be supported in Mode 3 on up to 24 bearer channels. The values are shown for bearer channel rates of 56 and 64 kbit/s. In addition, for each rate the appropriate values for the Rate Multiplier RMULT and the Subrate Multiplier SUBMULT are given as well as the number of required network channels N necessary to place the call.

7.2 Information Channel (IC) Synchronization

Except for the initial channel parameter negotiation, an endpoint **shall** establish overall frame alignment prior to establishment of Information Channel synchronization. For initial channel parameter negotiation, the Information channel uses the entire bandwidth of the master channel.

The ALIGN octet is used to determine IC synchronization.

IC Synchronization Detection

An endpoint **shall** declare IC synchronization when it detects the following sequence:

Detection of the ALIGN pattern.

Detection of Bit 1 = 1 of the next octet.

Detection of a second ALIGN pattern in the next correct position (16 octets after the initial ALIGN pattern).

Loss of IC Synchronization

An endpoint **shall** declare the loss of IC synchronization when it receives three consecutive incorrect ALIGN octets.

In Modes 2 and 3, the endpoint continuously monitors the ALIGN pattern to determine if Information Channel synchronization has been lost. Modes 0 and 1 only use the ALIGN pattern and the Information Channel during call setup.

The endpoint **shall** start the IC synchronization detection procedure immediately once it detects loss of IC frame synchronization or achieves multiframe synchronization.

7.3 Transmission and Recognition of an Information Channel Frame

Once a connection has been established, an endpoint transmits the Information Message continuously in the Information Channel (see Clause 8). When this International Standard refers to "sending" an Information Message, it means the endpoint starts transmitting the new values in the Information Channel Frame. Please note that for initial parameter negotiation in the master channel, the Information Message is transmitted and received using the entire bandwidth of the master channel and does not use the Information Channel of the multiframe structure until after parameter negotiation is complete.

Once Information Channel Synchronization has been achieved, the endpoint can transmit and receive Information Messages in the Information Channel. Since these frames are transmitted continuously, the receiving endpoint has to monitor the received frames for a change in value. Also, since there is no CRC or checksum on the IC Frame, the receiving endpoint should not be sensitive to instantaneous changes in state. When this International Standard refers to "receiving" an Information Message, it means that the endpoint has detected a valid change in values of the Information Channel Frame. The method for determining a valid change in values is implementation dependent, but it is recommended that the receiver check several Information Channel Frames in succession before declaring a change in values (i.e., 2 out of 3 majority voting).

When transmitting Information Channel messages, the following constraints **shall** be followed:

- When transmitting messages with CID=0, the same Information Channel message **shall** be transmitted in all channels (including Channel ID = 0).
- The same values of the GID, MODE, RMULT, SUBMULT, BCR, RI, RL REQ, RL IND fields **shall** be transmitted in all channels when CID is not equal to 0. This means that when a value changes in one channel, it changes in all channels.

The rest of this International Standard refers to a valid (debounced) Information Channel Frame as an Information Message.

8 Procedures

8.1 Call Setup

8.1.1 Initial Channel Setup

This subclause describes the interactions between Calling and Answering Endpoints in order to establish a call. It is structured in sequence order.

The initial call setup procedure begins with the connection of the first channel in the $n \times 56/64$ kbit/s call. This channel is referred to as the "master" channel. The parameter negotiation process is performed over this channel. Neither Endpoint **shall** make any additional call requests until the entire negotiation process has been completed.

Calling Endpoint

Once the Calling Endpoint receives an indication that the master channel is connected, and following selection of ISO/IEC aggregation at point (3) of Figure 2 if applicable, it **shall** begin the negotiation process by repeatedly transmitting the Information Message (using the entire bandwidth of the master channel) with the Channel Identifier (CID) set to 0 and **shall** start TCinit and TCnull (if implemented - See 9.2). (A CID of 0 is used as the negotiation flag). The Calling Endpoint also **shall** include the parameter values desired for the call (i.e., Mode, RMULT, SUBMULT, MFG, BCR, and Revision). The Group Identifier (GID) **shall** be set to 0. The Remote Indicator bit and the Remote Loopback bits **shall** be set to 0. In the first message, the Calling Endpoint can send its Manufacturer's ID by setting the MFG Flag to 1 and including the ID in the Digits field. In the initial message, XFLAG **shall** be set to all binary 1's. If the Calling Endpoint does not send its Manufacturer's ID then the MFG Flag **shall** be set to 0 and the Digits field **shall** be set to all 1's.

If the Calling Endpoint supports subaddressing, it includes the subaddress in the Subaddress field. If the Calling Endpoint does not support subaddressing or if the Calling Endpoint does not request a subaddress, it sets the Subaddress field to all binary 0's.

Answering Endpoint

Upon receipt of an incoming call and indication that the channel is connected, and following selection of ISO/IEC aggregation at point (3) in Figure 2 if applicable, the Answering Endpoint **shall** transmit all 1's on the channel, start TAnull and start searching for multiframe or Information Channel alignment (i.e., Frame Alignment Word or ALIGNment octet).

NOTE - If the Answering Endpoint detects Frame Alignment, then the incoming call is an additional channel of an existing call. If the Answering Endpoint detects Information Channel Alignment without detecting overall Frame Alignment, then the incoming call is the master channel of a new call. See 8.1.2 for a description of additional channel setup. If TAnull expires, the Answering Endpoint defaults to Transparent Mode (see 9.1). Additional transparent channels are treated separately using initial channel setup procedures.

Once the Answering Endpoint detects a valid Information message, at point (2) in Figure 2 if applicable, it **shall** consider the channel to be the master channel of a new call and **shall** stop TAnull. If multiframe is detected, the Answering Endpoint **shall** stop TAnull, **shall** treat it as an additional channel for an existing call and **shall** use the Group Identifier to identify the existing call (see 8.1.2).

For the master channel of a new call, if the Answering Endpoint accepts the requested parameters, it **shall** return the same values as were received and start TAinit. If the Answering Endpoint does not accept the requested parameters, it **shall** either return RMULT and SUBMULT = 0 (disconnect request) with a valid Mode value and start TAdisc or return a different set of parameters (parameter negotiation) and start TAinit. The Answering Endpoint **shall** assign a Group Identifier to the call and return it in the GID field. This identifier identifies this call uniquely among calls received by this Answering Endpoint. The XFLAG field **shall** be set to all 1's.

If the Answering Endpoint chooses to return a Manufacturer's ID, it **shall** set the MFG Flag to 1, include the ID in the Digits field and send the message back with the other parameters as the first response to the Calling Endpoint. If the Answering Endpoint does not return a Manufacturer's ID, it **shall** transmit MFG set to 0 and the Digits fields set to all 1's.

If the Answering Endpoint does not support Subaddressing, it returns all binary 0's in the Subaddress field and ignores the incoming Subaddress field. If the Answering Endpoint does support subaddressing, it looks at the incoming Subaddress field to get the subaddress. If this subaddress is acceptable, it returns the same subaddress. If it is unacceptable, it **shall** either disconnect the call (using negotiation) or return a different subaddress. If the Answering Endpoint receives a subaddress of decimal 0, then it **shall** either return a subaddress of decimal 0 or return the subaddress assigned to the call.

Calling Endpoint

The Calling Endpoint **shall** detect the response from the Answering Endpoint, at point (2) in Figure 1bis if applicable, when it receives an Information Message with CID=0 and the MODE field containing a valid value (i.e., "000", "001", "010", "011"). At this point, the Calling Endpoint **shall** stop timer TCnull (if implemented - see 8.2). The Calling Endpoint **shall** either accept the parameter values requested by the Answering Endpoint or initiate disconnect procedures. If the MFG field is set to 1, the Manufacturer's ID is contained in the Digits field. If the MFG field is set to 0, the Calling Endpoint **shall** ignore the Digits field. In either case, the Calling Endpoint **shall** ignore the XFLAG field. If it decides to proceed, it **shall** initiate the transfer of phone numbers .

If the Calling Endpoint does not use the Subaddress field, it **shall** ignore the contents of that field. Otherwise, it can use the contents of the Subaddress field to determine the subaddress assigned to the call by the Answering Endpoint.

The Calling Endpoint **shall** request the initial phone number by sending the Answering Endpoint an Information Message with CID=0 and the transfer flag (XFLAG) set to Decimal 1 and the Digits field set to all 1's. The Calling Endpoint **shall** set the rest of the parameters to the negotiated values.

Answering Endpoint

After transmitting the initialization response, when the Answering Endpoint receives a message with XFLAG set to decimal 1, the Answering Endpoint **shall** return the first number by setting the XFLAG field to decimal 1 and placing the phone number in the Digits field. If the phone number to be used is greater than 7 digits in length (e.g., international calls), the Answering Endpoint **shall** return the last (rightmost) 7 digits. If the phone number to be used is less than 7 digits in length (e.g., 5 digit private numbers), the Answering Endpoint **shall** place the digits in the first M Digit fields where M is the number of digits. The Answering Endpoint **shall** fill the last 7 - M Digit fields with the EON character (bit pattern "1 1 0 0").

Calling Endpoint

When the Answering Endpoint returns M digits, the Calling Endpoint replaces the last M digits of the original phone number with the M digits received from the Answering Endpoint. If M = 0 (all Digits fields contain the EON character), the Calling Endpoint uses the original phone number.

The Calling Endpoint **shall** request the additional phone number by sending the Answering Endpoint an Information Message with CID=0 and the transfer flag (XFLAG) incremented by 1 indicating acceptance of the first number and readiness to receive the next phone number. The Digits field **shall** be set to all 1's. The Calling Endpoint **shall** set the rest of the parameters to the negotiated values. If the number of channels is N, the Calling Endpoint **shall** request N-1 phone numbers.

Answering Endpoint

When the Answering Endpoint receives an Information Message with CID=0 and the XFLAG field incremented by 1, it **shall** transmit the next phone number in the Digits field, and the received XFLAG in the XFLAG field.

If the Answering Endpoint only supports one phone number, it **shall** return the EON character in all the Digits fields for each phone number request received from the Calling Endpoint.

Calling Endpoint

The Calling Endpoint **shall** use the phone numbers received from the Answering Endpoint in the same proportion as were received from the Answering Endpoint. For example, if the Answering Endpoint returns EON for all phone numbers, the Calling Endpoint uses the original phone number for all channels. If the Answering Endpoint returns a different phone number for each channel, the Calling Endpoint uses a different phone number for each additional channel. If the Answering Endpoint has two phone numbers A and B and returns phone number A twice and phone number B three times, the Calling Endpoint **shall** use phone number A for two channels and phone number B for three channels.

The complete list of phone numbers is passed in this manner until the Calling Endpoint receives the last number. The Calling Endpoint **shall** indicate the conclusion of the negotiation process by transmitting an Information message with the channel identifier (CID) set to 1 and parameters set to negotiated values.

Answering Endpoint

When the Answering Endpoint receives an Information Message with CID set to 1, it **shall** transmit its Information Message with the channel identifier (CID) set to 1 and the other parameters set to the negotiated values. This indicates to the Calling Endpoint that the Answering Endpoint is ready to accept establishment of additional channels. The Answering Endpoint also **shall** stop TAinit and start TAadd01.

Calling Endpoint

When the Calling Endpoint receives an Information Message with CID=1, it **shall** stop TCinit, start TCadd01 and initiate the connection of the remaining channels in the call. Parallel dialing is optional but recommended to reduce call setup times. However, it should be noted that there may be a requirement in some networks to insert a programmable delay between consecutive additional channel setup attempts. For Modes 1, 2 and 3, the Calling Endpoint also **shall** start transmitting the multiframe structure in the master channel (immediately after receiving CID=1 from the Answering Endpoint) with the Alignment (A) bit in the CRC octet set to zero, the E bit set to 0 and the CRC4 bits set to 1. It also **shall** send all ones in the data octets. The Calling Endpoint also **shall** start searching for overall frame alignment in the master channel and start TCfa. The Calling Endpoint **shall** transmit the following field values in the Information Message:

CID: Set to 1.

RI, RL REQ and RL IND: Set to 0. These value can change subsequently due to achievement of Delay Equalization or Remote Loopback operation.

MFG ID: Set to 0.

Group Identifier: The GID assigned to this call by the Answering Endpoint.

XFLAG: Information subchannel.

Digit Fields: Information subchannel.

Other parameters: Set to negotiated values.

For Mode 0, the Calling Endpoint **shall** cut the channel through to the Application.

Answering Endpoint

After the Answering Endpoint has transmitted an Information Message with CID=1, it **shall** wait until loss of Information Message Alignment. At this point, for Modes 1, 2 and 3, the Answering Endpoint starts to transmit the multiframe structure. When the Answering Endpoint detects loss of Information Message Alignment, for Modes 1, 2 and 3, it **shall** start transmitting the multiframe structure in the master channel with the Alignment (A) bit in the CRC octet set to zero, the E bit set to 0 and the CRC4 bits set to 1. It also **shall** send all ones in the data octets. Once the Answering Endpoint starts transmitting the multiframe structure, it **shall** start searching for overall frame alignment in the master channel and start TAfa. The Answering Endpoint **shall** transmit the following field values in the Information Message in the Information Channel:

CID: Set to 1.

RI, RL REQ and RL IND: Set to 0. These value can change subsequently due to achievement of Delay Equalization or Remote Loopback operation.

Group Identifier: The GID assigned to this call by the Answering Endpoint.

MFG Flag: Set to 0.

XFLAG: Information subchannel.

Digit Fields: Information subchannel.

Other parameters: Set to negotiated values.

For Mode 0, after detecting loss of Information Channel Alignment, the Answering Unit stops sending Information Frames and cuts through the Application.

For Modes 1, 2 and 3, when each end detects Frame Alignment, it **shall** set the A bit to 1 in the transmit direction and start the CRC4 procedures (if implemented). It also starts searching for IC Frame Synchronization.

For Modes 1, 2 and 3, when each end detects frame alignment and detects the A bit set to 1 in the reverse direction it also **shall** stop Timers TAfa and TCfa.

REV: REVision level (Octet 7, Bits 5-7)

This field can be used to check version compatibility between the local and far end units. If this field is not used it **shall** be set to all binary ones on the transmitting end and ignored on the receiving end. All endpoints developed to the main body of Issue 1 of this International Standard **shall** use a Revision Level of 0. Annex D defines the additions necessary to make this into a Revision 1 product which caters for extended digit fields.

This is a binary encoded number in the range $0 \leq \text{REV} \leq 7$.

If one CAU transmits a higher value of REV than the other CAU then only those procedures defined for the lower value of REV shall be used by both CAUs.

8.1.2 Additional Channel Setup

For Mode 0, no framing is done on the additional channels; therefore, DEQ Control is not used and no procedures are defined other than setting up the additional channels (Call Control responsibility) and cutting the channels through to the Application as they are connected. When all channels are connected, Timer Txadd01 is stopped.

For Modes 1, 2 and 3, for each additional channel, when each connection is established the Calling Endpoint **shall** begin transmitting the multiframe structure with the Alignment (A) bit in the CRC octet set to zero, the E bit set to 0 and the CRC4 bits set to 1. It also **shall** send all ones in the data octets. The Calling Endpoint starts the TCfa timer.

Upon connection, the Calling Endpoint **shall** send the Information message repeatedly in the Information Channel. The Information message **shall** contain the following field values:

Channel Identifier: Channel Identifier assigned to this channel by the Calling Endpoint.

RI, RL REQ and RL IND: Set to 0.

Group Identifier: The GID assigned to this call by the Answering Endpoint.

XFLAG: Information subchannel.

Digit Fields: Information subchannel.

Other parameters: Set to negotiated values.

The Calling Endpoint **shall** assign the Channel Identifier sequentially beginning with 1 (master channel).