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CCITT

G.765

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THE INTERNATIONAL
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CONSULTATIVE COMMITTEE

GENERAL ASPECTS OF DIGITAL TRANSMISSION SYSTEMS;

TERMINAL EQUIPMENTS

PACKET CIRCUIT MULTIPLICATION EQUIPMENT

Recommendation G.765

FOREWORD

The CCITT (the International Telegraph and Telephone Consultative Committee) is a permanent organ of the International Telecommunication Union (ITU). CCITT is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The Plenary Assembly of CCITT which meets every four years, establishes the topics for study and approves Recommendations prepared by its Study Groups. The approval of Recommendations by the members of CCITT between Plenary Assemblies is covered by the procedure laid down in CCITT Resolution No. 2 (Melbourne, 1988).

Recommendation G.765 was prepared by Study Group XV and was approved under the Resolution No. 2 procedure on the 1st of September 1992.

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CCITT NOTES

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

2) A list of abbreviations used in this Recommendation can be found in Annex A.

PACKET CIRCUIT MULTIPLICATION EQUIPMENT

(1992)

1 General considerations of packet circuit multiplication equipment

This Recommendation is intended as a base document for the specification and interconnection of packet circuit multiplication equipment (PCME) and packet circuit multiplication systems (PCMS) from various manufacturers.

PCME provides for the compression and packetization of several types of traffic. A PCME converts speech, voiceband data, facsimile, channel-associated (i.e. in-band) signalling, common channel signalling, video and digital data information from primary rate channel formats or synchronous digital hierarchy (SDH) level 1 formats to link access procedure D-channel (LAPD)-like frame format. The LAPD-like link layer protocol is used with unacknowledged operation to limit delay in the network. The LAPD-like frames are transported as packet streams in a wideband packet network over a full or fractional primary channel, or an SDH virtual tributary.

Wideband packet technology, as used herein, refers to packet systems requiring transmission channels capable of supporting rates above 64 kbit/s up to 150 Mbit/s. Application-specific protocol at layers 3 and above are used to transport the various types of traffic. A functional representation of a PCME node is shown in Figure 1/G.765.

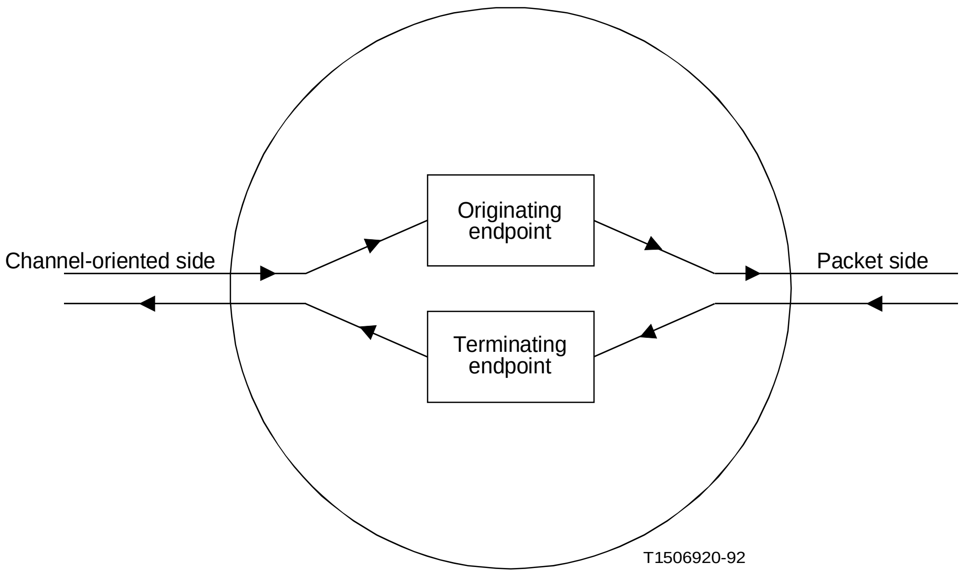


FIGURE 1/G.765

Endpoint node

On the channel-oriented (full-rate) side, 1544 kbit/s and/or 2048 kbit/s or SDH synchronous transport module (STM)-1 interfaces are provided. A time slot interconnect function can connect any time slot or group of time slots to the proper processing function as required to packetize the incoming channel-oriented traffic. A frame cross-connect function transfers the layer 2 produced by the processing functions to the appropriate packetized side interface. On the packetized side, 1544 kbit/s and/or 2048 kbit/s or SDH STM-1 interfaces are provided to carry the bit-serial packet streams.

PCME allows networking in both the circuit and packet domains, offers bandwidth on demand, and achieves graceful degradation of voice quality during congestion. A reference model for a PCME network is shown in Figure 2/G.765.

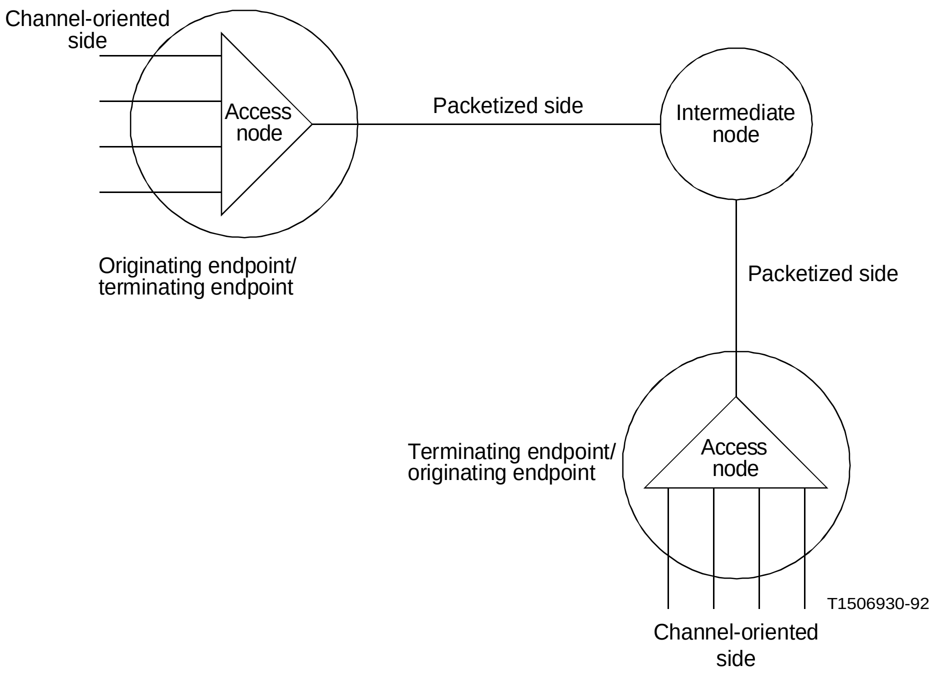


FIGURE 2/G.765

Reference Model for a PCME network

1.1 *Speech processing*

For speech traffic, the input speech samples may be coded at the originating endpoint of the access node before packetization by one of several coding methods. The stream of coded speech is transformed into packets with the format specified in Recommendation G.764. The samples are collected over a period of 16 ms and divided into blocks, as defined in Recommendation G.764. The blocks are arranged to facilitate block dropping, as explained below.

Periods of activity and inactivity are respectively called “bursts” and “gaps”. It is not necessary to transmit packets during gaps and silent intervals may be removed.

The terminating endpoint at the far side reconstructs a continuous stream of speech from the incoming packets using the information in the packet header: the time stamp (TS) value and the sequence number. The time stamp field stores the value of the total accumulated variable delay that a packet has experienced. Each node adds to the time stamp value, the time it took to serve the packet using its local clock as a reference.

Build-out procedures compensate for the variable delay that packets may experience within the network. These procedures apply for the first packet of a voiceband spurt, for all signalling packets and for the first packet after a missing packet is detected. When any of the above packets arrive within the time stamp value less than the value of the build-out, they are stored for the following duration:

Time before play-out = Build-out – Time stamp value

If they arrive with a time stamp value that exceeds the build-out, they are discarded. Other packets are placed in the play-out queue in the order of their arrival and are played without interruption after the preceding packet (see § 5.3.3.2 of Recommendation G.764).

The value of the build-out is a trade-off between accepting excessively large delay and have a large number of discarded packets (see § 3.3, Note 2).

The voice packet header contains information about the level of noise that was measured by the originating endpoint. The terminating endpoint uses this information to play out a matching noise level.

PCME has the additional ability of dropping blocks from a speech packet as a congestion control mechanism. The *n*th block consists of the *n*th bit from each sample collected during the sampling interval. The packet header indicates the number of droppable blocks contained in the packet. Congested nodes may use this information to drop the least significant block from packets to abate the congested state.

In general, the speech processing functions include echo cancellation, speech detection, signal classification, embedded adaptive differential pulse code modulation (ADPCM) coding, speech packetization, speech depacketization, variable rate ADPCM decoding, and noise fill. Echo cancellation will normally be required because the speech packet length is 16 ms. Speech detection and noise fill improve transmission efficiency by allowing the transmission of speech packets only when speech signals are present. Signal classification provides for the detection of voiceband data signals and the estimation of their speed, so that an appropriate coding algorithm can be chosen. Speech packetization and depacketization provide for the proper time stamping and delay build-out of packets within a talk spurt, so that gaps do not occur. These processes also control the effects of missing or excessively delayed packets.

1.2 *Channel-associated signalling*

The signalling associated with each voiceband connection is conveyed in signalling packets. Signalling packets are sent separately on a different logical channel.

A signalling transition is defined for channel-associated signalling as a change in state of the A bit for 2-state signalling. A- and/or B-bit in 4-state signalling, or the A-, B-, C-, and/or D-bit for 16-state signalling. The channel-associated signalling process detects changes in the state of A, AB, and ABCD signalling, and creates packets to convey the changed state to the distant PCME (see § 11.2).

1.3 *Common channel signalling*

Common channel signalling may be physically or logically out of band.

1.3.1 *Common channel signalling (out-of-band physical)*

The signalling associated with each incoming connection is transported on a separate physical channel as defined in Recommendation G.704. The signalling information is conveyed in signalling frames flowing on a separate logical address (see § 11.3).

1.3.2 *Common channel signalling (out-of-band logical)*

The signalling associated with each incoming connection is transported via a separate logical channel, as in some of the additional packet mode protocol bearer services. In this case, the PCME shall frame relay the information over a separate logical channel.

1.4 *Digital data*

Digital data can be transported by using any of the following:

1) a digital circuit emulation (DICE) protocol for the transport of special circuits in a bit transparent manner;

2) a high-level data-link control (HDLC) specific procedure;

3) an LAPD specific procedure;

4) a V.120 specific procedure.

Interconnection with digital data on 64 kbit/s clear channels may involve ways to increase the compression gain, such as removing HDLC flags and/or network idle codes.

1.5 *Facsimile*

For group 3 facsimile transport, the V.21 handshake signals may be transported as voiceband data in voice packets defined in Recommendation G.764. The coded page information is demodulated to extract the baseband signals, which are transmitted in the facsimile frames described in § 12.

There are three types of facsimile frames:

1) facsimile capability indication frames;

2) spurt header frames that contain modem control information;

3) facsimile page information frames that contain the T.4 coded image information UN unscrambled format.

The PCME at the terminating end recombines the facsimile frames to reconstruct the original facsimile signal.

1.6 *Video transport*

Recommendation H.221 defines how video, audio signals of Recommendation H.261 at the rate of 64 kbit/s or less, and various data rates are framed, then submultiplexed, and combined with audiovisual control and indication signals for transmission over the multiple B, multiple H0, H11 or H12 channels. In particular, the "information transfer rate command" defined in Recommendation H.221 allows the transmitting terminal to vary the number of B or H0 channels carrying the combined audiovisual information at 20 ms intervals. Thus, if the format of Recommendation H.221 is converted to a packetized version, variable rate video could be transmitted over the wideband packetized system so as to improve video quality during motion without requiring the continuous allocation of the peak bit rate.

Recommendation H.261 specifies coding of video for visual telephony and video teleconferencing. Recommendation H.261 can encode video at rates suitable for operation over one or six B (64 kbit/s) channels, one to five H0 (384 kbit/s), or an H11 (1536 kbit/s) or H12 (1920 kbit/s) channel. The actual source coding rate can be controlled to accommodate fixed bit-rate transmission with suitable transmit buffering and coding control feedback. Alternatively, the source coding rate of the video signal can be allowed to vary with picture complexity and motion if a variable rate transmission facility is available.

The video processing frames on the H.221 signal contain the bit rate allocation signal of the H.221 framing format. These frames constitute one or more packets each of 20 ms of H.221 signal.

2 Interfaces

2.1 *1544 kbit/s interfaces*

2.1.1 *Physical interface*

The physical interface conforms to the specifications in § 2 of Recommendation G.703.

2.1.2 *Frame structure*

The basic frame structure is shown in § 2.1 of Recommendation G.704. The characteristics of the frame structure carrying channels at various bit rates in 1544 kbit/s is given in § 3 of Recommendation G.704.

2.2 *2048 kbit/s interface*

2.2.1 *Physical interface*

The physical interface conforms to the specifications in § 6 of Recommendation G.703.

2.2.2 *Frame structure*

The basic frame structure is shown in § 2.3 of Recommendation G.704. The characteristics of the frame structure carrying channels at various bit rates in 2048 kbit/s is given in § 5 of Recommendation G.704. Bit 1 of the frame can be used in accordance with § 2.3.3 of Recommendation G.704 for a cycle redundancy check (CRC) procedure.

2.3 *SDH STM-1*

SDH STM-1 may be supported. The primary level signals shall be mapped as virtual containers (VCs) (VC-11 for 1544 kbit/s or VC-12 for 2048 kbit/s) into an STM-1 (155 520 kbit/s) as described in Recommendation G.709. The electrical interface characteristics for STM-1 shall conform to § 12 of Recommendation G.703.

2.4 *Channel-oriented side interconnection with the packetized side*

By service Administration, it shall be possible to treat any time slot, or contiguous group of time slots, on the channel-oriented interface as a single circuit, and to connect that circuit to functions that provide packetization for:

1) speech and voiceband data;

2) signalling;

3) facsimile;

4) video;

5) data.

2.5 *Packetized-side interconnection*

It shall be possible to direct any flow of packets on a channel-oriented side circuit to any packet stream on the packetized side.

Any packet stream from the packetized side may be interconnected to any other packet stream to achieve a packet cross-connect function.

3 Voice-band processing

3.1 *Echo cancellation*

An echo canceller shall be available for each speech and voiceband data circuit. The echo canceller shall conform to the requirements of Recommendation G.165.

As an objective, the echo canceller processing range may be a per-circuit administerable parameter.

3.2 *Signal classification*

The PCME shall provide for signal classification as a per-circuit administerable parameter. For example, the PCME may include an automatic signal classifier to classify the voiceband signal as:

1) voiceband data at 7200 bit/s or higher rates;

2) voiceband data at less than 4800 bit/s;

3) voiceband data at 1200 to 2400 bit/s;

4) voiceband data at less than 1200 bit/s;

5) speech.

3.3 *Speech packetization*

Speech packetization shall be done according to Recommendation G.764. As an example in a representative application, voiceband data at rates exceeding 9600 bit/s shall be carried in pulse-code modulation (PCM). Voiceband data at rates greater than 7200 bit/s and less than or equal to 9600 bit/s shall be encoded using the 40 kbit/s fixed rate algorithm of Recommendation G.726. Voiceband data at 1200 to 4800 bit/s shall be encoded using the 32 kbit/s fixed rate algorithm of Recommendation G.726. Voiceband data at less than 1200 bit/s shall be encoded as for speech, using the 24 kbit/s fixed rate algorithm of Recommendation G.726.

Decoding shall be done using the algorithm indicated in Recommendation G.764 header.

Note 1 – In a national network, the time stamp (TS) and the build-out procedures of Recommendation G.764 may be replaced by a fixed-delay for the first packet. The fixed additional delay for the first packet of a speech burst shall be administerable to accommodate transit times through networks or through interconnection nodes not implementing TS updating. At the originating endpoint, the TS will be set to zero. In an intermediate node, the TS field will not be updated. However, the build-out procedure will be used always on network-network and user-network interfaces.

Note 2 – To meet the allowable transmission delay given in Recommendation G.114, the build-out shall be selected such that the total delay (propagation + build-out) shall not exceed the 400 ms allowance for voice traffic. The build-out should not exceed 70 ms in normal conditions.

3.3.1 *ADPCM/PCM transcoding*

A specific incoming channel may be defined by administration to correspond to information containing μ-law or A-law voiceband samples.

3.3.2 *PCM operation*

Recommendation G.764 specifies that the ADPCM coder on both sides shall be reset at the beginning of every speech burst. This is the case when all samples for a speech burst are coded with the same ADPCM algorithm specified in the coding type (CT) field. However, Recommendation G.764 does not specify the action of the ADPCM coders when the part of the traffic is coded according to Recommendation G.711.

When an originating PCME transports the incoming channel-oriented traffic in PCM format, it shall arrange the PCM coded speech as described in Recommendation G.764. The resultant voice packets shall have the format described in Figure 2/G.764, and shall be transmitted on the packetized side of the endpoint.

The ADPCM encoder at the originating endpoint shall operate on the incoming PCM signal using the 40 kbit/s fixed rate ADPCM algorithm of Recommendation G.726, even though its ADPCM output is not transmitted. The ADPCM codec at the terminating endpoint shall operate as an encoder in an identical manner as the ADPCM codec of the originating endpoint, and its ADPCM output shall not be transmitted. Thus, when there are no line errors, the state variables of both ADPCM coders that are described in Tables 6/G.726 and 7/G.727 shall be identical for both endpoints. Furthermore, both ADPCM codecs shall be tracking the input PCM signal and would be ready to switch to their respective normal operations without introducing adaptation gaps.

When the originating endpoint PCME begins coding the incoming traffic, using the ADPCM algorithm indicated in the coding type field of the packet header, the ADPCM coded speech shall be arranged as described in Figure 7/G.764 and then transmitted in voice packets with the formats shown in Figure 2/G.764. At the terminating endpoint, the ADPCM codec shall decode the speech, using the ADPCM algorithm indicated in the coding type field to reconstruct the original signal, and then convert it to PCM, as indicated in Recommendations G.726 and G.727. In the case of the embedded ADPCM algorithms of Recommendation G.727, the decoder at the terminating endpoint shall also use the information coded in the block dropping indicator field to select the decoding algorithm to use.

4 Video processing

The PCME shall implement packetization of fixed-rate and variable-rate video for teleconferencing and videotelephony. The specific procedures are for further study.

5 Interface with cellular speech packetization networks

This item is for further study.

6 Digital data interface

The PCME shall be equipped to receive, packetize and transmit the following digital data traffic arriving on the channel-oriented side as:

1) special traffic, using the DICE protocol and the virtual data link capability (VDLC) for bit transparent transport;

2) asynchronous and synchronous traffic, using V.120;

3) digital data traffic, using frame relay or link access procedure for frame mode bearer services (LAPF).

In some national applications, the PCME shall be equipped to receive, packetize and transmit digital data from the channel-oriented side to operate at either 56 or 64 kbit/s, or at the subrates of 2400, 4800 or 9600 bit/s. The polarity of the data bit polarity can be either normal or inverted, as determined by Administration.

As an objective, the PCME may be equipped to packetize and transmit digital data systems for other national applications.

As an objective, the PCME may be equipped to receive, packetize and transmit digital data from groups of time slots on the channel-oriented side at rates of $n \times 64$ kbit/s. The method of packetization in this case is for further study.

7 Digital circuit emulation (DICE) protocol

The digital circuit emulation (DICE) protocol may be used to transport digital data that arrive on the channel-oriented side. DICE builds upon the same physical, link and packet layers of Recommendation G.764 to increase efficiency of use of available bandwidth by:

1) eliminating the redundant transmission of terminal and network idle codes, thereby releasing bandwidth for utilization; and

2) eliminating the transmission of redundant copies from subrate channels.

The DICE protocol consists of a physical layer, a link layer, a packet layer and a high layer. Subsections 7.1, 7.2 and 7.3 describe the physical, link and packet layers by referring to the description in Recommendation G.764. Subsection 7.4 describes DICE procedures for the high, packet and link layers of the originating endpoint. Subsection 7.5 describes the procedures at the intermediate nodes, while § 7.6 describes the procedures at the terminating endpoint.

7.1 *Physical layer*

The physical layer is the same as for Recommendation G.764 (see § 3.1 of Recommendation G.764).

7.2 *Link layer*

The link layer is the same as described in § 3.2 of Recommendation G.764. In particular, the address field is the same as described in § 3.2.1 of Recommendation G.764. Figure 3/G.765 depicts the format of a DICE frame. The control field of the unnumbered information (UI) frame is described in Recommendation Q.921/I.441. The control field of the unnumbered information with header (UIH) frame is described in § 3.2.3.2 of Recommendation G.764.

7.3 *Packet layer*

The packet layer procedures apply to the information transfer phase only. Call control procedures are outside the scope of this Recommendation.

There are two types of DICE packets: DICE information packets and DICE idle update packets. DICE idle update packets update the idle code that the terminating endpoint should play to the channel-oriented side in the absence of information packets. Both packets have the format shown in Figure 3/G.765 except that idle update packets shall have zero-length DICE information field and shall have the sequence number (SEQ) set to 0.

7.3.1 *Protocol discriminator (PD)*

The format and encoding of the protocol discriminator (PD) field are the same as the voice packet format (see § 3.3.1.1 of Recommendation G.764).

7.3.2 *Block dropping indicator (BDI)*

The format of the block dropping indicator (BDI) field is the same as in the voice packet (see § 3.3.1.2 of Recommendation G.764). Because the DICE packets are not block droppable, both the C-subfield and the M-subfield are set to 0.

7.3.3 *Time stamp (TS)*

The format of the TS field is the same as the voice packet format (see § 3.3.1.3 of Recommendation G.764).

7.3.4 *M-bit*

The more (M) bit shall always be set to 1 (see § 3.3.1.5 of Recommendation G.764).

7.3.5 *Sub-class field (SC)*

The sub-class (SC) field is used to indicate that the packet is a digital data packet. The SC field is coded as 11 for digital data.

7.3.6 *Control bit (C)*

The control (C) bit is set by the originating end to indicate whether the last bit to arrive for each octet has been removed. In some national applications, this bit is called the control bit and is used for synchronization, status and remote testing on the channel-oriented side. C is set to 0 if the control bit is removed, otherwise C is set to 1.

<table>
<tr><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th></th></tr>
<tr><td colspan="6">Address (upper subfield)</td><td>0</td><td>0</td><td>Octet 1</td></tr>
<tr><td colspan="7">Address (lower subfield)</td><td>1</td><td>Octet 2</td></tr>
<tr><td colspan="8">Control field</td><td>Octet 3</td></tr>
<tr><td colspan="8">Protocol discriminator (PD)</td><td></td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td><td>Octet 4</td></tr>
<tr><td colspan="8">Block dropping indicator (BDI)</td><td>Octet 5</td></tr>
<tr><td>R</td><td>R</td><td>0</td><td>0</td><td>R</td><td>R</td><td>0</td><td>0</td><td></td></tr>
<tr><td colspan="8">Time stamp (TS)</td><td>Octet 6</td></tr>
<tr><td>M
1</td><td colspan="2">SC
1 1</td><td>C</td><td colspan="4">IBT</td><td>Octet 7</td></tr>
<tr><td colspan="4">Sequence number</td><td>EQ
1</td><td colspan="3">BILO</td><td>Octet 8</td></tr>
<tr><td colspan="8">DICE information field</td><td></td></tr>
<tr><td colspan="8">Check sequence
2 octets</td><td></td></tr>
</table>

R Reserved for future use and set to 0

FIGURE 3/G.765

DICE frame format

7.3.7 *Idle background type (IBT)*

The idle background type (IBT) indicates the type of idle code that has been removed from the original data stream by the originating endpoint. An idle code is a sequence that indicates that no data are being sent on the channel-oriented side. The type of idle codes to be recognized is determined by service administration.

In the absence of packets to be played out, the IBT value of the last received packet shall be used to determine the idle codes to be played out on the channel-oriented side.

The terminal idle code is the all 1 octet. For 64 kbit/s, the terminal idle code may be inverted to the all 0 octet. The network idle code depends on whether the channel-oriented circuit is used in a point-to-point connection or in a multipoint connection. In a multipoint connection, two idle codes are possible: 1111 1111 or 1111 1110. Table 1/G.765 shows the relation between the idle code and the coding of the IBT field at the originating endpoint.

TABLE 1/G.765

Correspondence between the channel-oriented idle code and the IBT field at the originating endpoint

Bit rate (kbit/s)	Idle code		IBT		
	Bit pattern	Meaning	Point-to-point	Multipoint	
	Bit 1 ... Bit 8			Option 1	Option 2
64	0000 0000 1111 1111 1111 1110	Normal	1000 1111 1110	1000 1111 1110	1000 1111 1111
56	1111 1111 1111 1110	Normal	1111 1110	1111 1110	1111 1111
	X001 1110 X001 1000 X001 1010 X000 0000	Failure	1101 1100 1010 1000	1110 1110 1110 1110	1111 1111 1111 1111
Subrate	0111 1111 0111 1110	Normal	1111 1110	1111 1110	1111 1111
	0001 1110 0001 1000 0001 1010 0000 0000	Failure	1101 1100 1010 1000	1110 1110 1110 1110	1111 1111 1111 1111
All rates		No idle	0111	1110	1111

Note – X may be 0 or 1.

The first bit of the idle code arriving on the channel-oriented side is the leftmost bit of the idle code pattern. It is represented as bit 1 in Table 1/G.765 and is the most significant bit of the idle code bit pattern. In some national networks, bit 1 is called the “subrate framing bit” while bit 8 is called the “control bit”.

The failure network idle codes are defined in Table 2/G.765.

TABLE 2/G.765

Failure network idle codes

Code	Meaning
Bit 1 ... Bit 8	
X001 1110	Abnormal station code
X001 1010	Multiplexer out of sync
X001 1000	Unassigned multiplexer channel
X000 0000	Zero code suppression

The abnormal station code indicates one of the following:

1) a failure in the user's subrate or 56 kbit/s equipment;

2) a failure in the local loop in the direction of transmission towards the network;

3) removal of the far-end equipment.

The multiplexer out of sync and unassigned multiplexer channel codes indicate failure within the network. The "No idle" IBT represents the case of a user that is not subscribed to any of the corresponding idle codes.

The initial value of the IBT field is 1111 (decimal 15). The IBT value is updated as indicated in § 7.4.3.1.

At the terminating endpoint, the IBT field is translated into a bit pattern on the channel-oriented side, as indicated in Table 3/G.765. In this table, options 1 and 2 of the multipoint connections have been combined.

TABLE 3/G.765

Correspondence between the IBT field and the channel-oriented idle code at the terminating endpoint

Bit rate (kbit/s)	Meaning normal	IBT code point-to-point	Channel-oriented bit pattern	IBT code multipoint	Channel-oriented bit pattern
			Bit 1 ... Bit 8		Bit 1 ... Bit 8
64	Normal	1000	0000 0000	1000	0000 0000
		1111	1111 1111	1111	1111 1111
		1110	1111 1110	1110	1111 1110
56	Normal	1111	1111 1111	1111	1111 1111
		1110	1111 1110	1110	1111 1110
	Failure	1101	1001 1110	1111	1111 1111
		1100	1001 1000	1111	1111 1111
		1010	1001 1010	1110	1111 1110
		1000	1000 0000	1110	1111 1110
Subrate	Normal	1111	0111 1111	1111	1111 1111
		1110	0111 1110	1110	1111 1110
	Failure	1101	0001 1110	1111	1111 1111
		1100	0001 1000	1110	1111 1110
		1010	0001 1010	1111	1111 1111
		1000	0000 0000	1110	1111 1110
All rates	No idle	0111	0010 0001	1110	1111 1110
				1111	1111 1111

Note – X may be 0 or 1.

The first bit to be played out on the channel-oriented side is the leftmost bit for idle code bit patterns. It is represented as bit 1 in Table 3/G.765 and is the most significant bit of the idle code bit pattern. In some national networks, bit 1 is called the "subrate framing bit" while bit 8 is called the "control bit".

7.3.8 *Sequence number (SEQ)*

The format of the SEQ field for the DICE packet is the same as for the voice packet (see § 3.3.1.6 of Recommendation G.764).

7.3.9 *Delay equalization bit*

The delay equalization (EQ) bit is set by the originating endpoint to enable or disable the build-out delay procedures at the terminating endpoint. When the EQ bit is set to 1, build-out procedures are enabled; otherwise, they are disabled. It is always set to 1 for DICE.

7.3.10 *Bits in last octet (BILO)*

LAPD specifies that frames should be octet-aligned, and therefore, the last octet of information shall be padded if necessary by a number of 1's to ensure this alignment. The bits in last octet (BILO) field contains the number of usable bits in the last information octet (i.e. that are valid data bits) to separate them from those that have been padded to the last octet. The valid BILO values are given in Table 4/G.765.

TABLE 4/G.765

BILO field format

Bit number 321	Number of valid bits in last octet	Number of added 1's to last octet
001	1	7
010	2	6
011	3	5
100	4	4
101	5	3
110	6	2
111	7	1
000	8	0

7.3.11 *DICE information field*

The number of octets in the information field shall be dependent on the bit rate of the incoming channel-oriented circuit. Recommendation G.764 specifies that the maximum size for the information field is 482 octets. To carry the traffic for certain national applications, the maximum number of octets in the DICE information field, NMAX, that constitute the information field, shall be set by service administration as a multiple of 7. This protects against the non-synchronization between the data bits and the corresponding control bit if the control bits are not removed and some packets are lost. The following values of NMAX (shown in Table 5/G.765) correspond to a packetization period of about 20 ms, which is the packetization interval for non-voice packets such as facsimile and video.

TABLE 5/G.765

Size of the DICE information field

Bit rate (bit/s)	NMAX in octets
2 400	7
4 800	14
9 600	28
56 000	133
64 000	133

The octets of the DICE information field are transmitted in ascending numerical order. Inside an octet, bits are transmitted in an increasing order, i.e. bit 1 is transmitted first (see Figure 3/G.765). Therefore, the bits shall be arranged in the DICE information field so that the first bit to be transmitted on the packet side is the first arriving bit on the channel-oriented side. As explained in § 7.3.7, in some national applications, the first bit of an octet to arrive on the channel-oriented side is called the "subrate framing bit", while the last bit is called the "control bit". Arithmetically, bit 1 is the most significant bit of an octet from the channel-oriented side while bit 8 is the least significant bit of an octet on the packetized side.

7.4 *DICE originating endpoint procedures*

7.4.1 *Preprocessing*

The preprocessor shall operate on the bit stream arriving from the channel-oriented side. Subrate traffic consists of CMAX duplicated copies of the user traffic. CMAX is 1 for 56 kbit/s, 5 for 9600 bit/s, 10 for 4800 bit/s and 20 for 2400 bit/s. The preprocessor shall retain only one copy of the subrate information and shall drop the redundant copies. It shall send this copy to the idle code detector.

7.4.2 *Operation of the idle code detector*

The idle code detector shall monitor the pre-processed traffic to determine if it contains idle codes or user data.

If an idle code is present, it shall discriminate between the non-failure idle codes (e.g. terminal idle or normal network idle) or failure codes. The patterns for the various idle codes are specified in Table 1/G.765.

When the detector detects the arrival of an idle code, it shall proceed as follows:

1) For a normal idle code, it shall start two counters, IDLE_LAT_CNT and NORM_IDLE_CNT, to count the number of idle codes and the normal idle codes received, respectively.

2) For a failure idle code, it shall start the counters, IDLE_LAT_CNT and FAIL_IDLE_CNT, to count the number of idle codes and failure idle codes received, respectively.

Subsequently, if the same idle code continues to arrive on the channel-oriented side, the idle code detector shall increment the counter IDLE_LAT_CNT. Depending on the type of idle code, either NORM_IDLE_CNT or FAIL_IDLE_CNT shall be incremented.

If a data octet arrives on the channel-oriented side, the counters IDLE_LAT_CNT and either NORM_IDLE_CNT or FAIL_IDLE_CNT (depending on the case) shall be reset to 0.

If a new idle code arrives, the counters IDLE_LAT_CNT, NORM_IDLE_CNT and FAIL_IDLE_CNT shall be reset to 0 and shall be updated to reflect the new idle code.

A protocol parameter, denoted as IDLE_LAT_MAX, controls the update of the system variable IBT_IDLE. When the same idle code (whether normal or failure) arrives consecutively for IDLE_LAT_MAX times, the idle code detector shall update the value of the system variable IBT_IDLE according to Table 1/G.765.

The value of IDLE_LAT_MAX can range from 2 to 15. It shall be selected to minimize the probability that data octets with bit errors are not interpreted erroneously as idle codes.

Even if NORM_IDLE_CNT and FAIL_IDLE_CNT have not reached their respective maximum, the idle latency counter IDLE_LAT_CNT may attain its maximum value IDLE_LAT_MAX. In this case, the idle code detector entity shall update the value of the IBT_IDLE system variable to correspond to the new idle code, as defined in Table 1/G.765.

If the idle code detector receives the same pattern of a non-failure (normal) idle code for NORM_IDLE_MAX times, it shall stop the parallel-to-serial converter until the idle pattern changes or user data arrive. It shall reset the NORM_IDLE_CNT and the IDLE_LAT_CNT counters.

Similarly, if the idle code detector receives the same pattern of a failure idle code for FAIL_IDLE_MAX times, it shall stop the parallel-to-serial converter until the idle code pattern changes or user data arrive. It shall reset the FAIL_IDLE_CNT and the IDLE_LAT_CNT counters.

To allow the change of value of the IBT_IDLE system variable before the parallel-to-serial converter switches its state from active to one of the IDLE states, the following relation shall be satisfied:

$$\text{IDLE\_LAT\_MAX} \leq \text{NORM\_IDLE\_MAX} \ll \text{FAIL\_IDLE\_MAX}.$$

This relation is based on previous experience with some national circuits.

7.4.3 *Operation of the parallel-to-serial converter*

The parallel-to-serial converter shall convert the retained octet into a serial bit stream supplied to the data detector. The serialization shall be done in the order of increasing bit numbers, i.e. from bit 1 to bit 8, with the bit numbering done according to the nomenclature of the channel-oriented pattern of Table 1/G.765. This is also the order of bit arrival on the channel-oriented side. As previously explained in § 7.3.7, in some national networks the first bit of an arriving octet is called the “subrate framing bit” while the last bit is called the “control bit”.

For subrate traffic (bit rates less than 56 kbit/s), the parallel-to-serial converter shall remove the first bit of an octet (the “subrate framing” bit). If the circuit is provisioned for a multipoint configuration, it shall also remove the last bit of each octet (the “control” bit) for non-64 kbit/s channels. If the circuit is not provisioned for multipoint operation, the parallel-to-serial converter shall remove the “control” bit if this is specified by service provisioning. Whenever the control bit is removed, it shall set the variable C to 0; otherwise, it shall set it to 1.

Operation of the parallel-to-serial converter is under the control of the idle code detector. Thus the originating endpoint parallel-to-series converter has three global states: the ACTIVE state, the IDLE_NORMAL state and the IDLE_FAILURE state. The transitions among the various states are depicted in Figure 4/G.765.

Note – The actual time required to start the transition from the ACTIVE state to either the IDLE_NORMAL or IDLE_FAILURE state depends on the incoming subrate traffic.

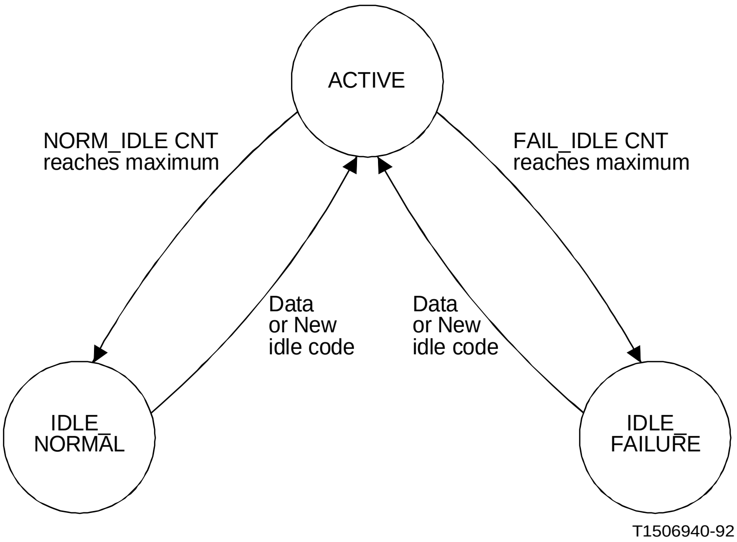


FIGURE 4/G.765
Global DICE state transitions at the parallel-to-serial converter of the originating endpoint

The parallel-to-serial converter shall remain in the active state as long as the idle code detector has not signalled that the same pattern of idle code has arrived consecutively for a specified number of times. This number is a protocol parameter defined by service administration and is denoted as NORM_IDLE_MAX for non-failure (normal) codes and as FAIL_IDLE_MAX for failure codes.

When the parallel-to-serial converter changes its state from ACTIVE to one of the IDLE states, it shall send a message to the data collector so that the latter may cease collecting data. When the state changes from IDLE to ACTIVE, the parallel-to-serial converter informs the data collector to start collecting data.

Note that there is no direct transition between the IDLE_FAILURE and IDLE_NORMAL states, but that such a transition is mediated by the ACTIVE state.

7.4.4 *Operation of the data collector*

The data detector shall peel the successive data bits from the incoming bit stream and shall arrange them in successive octets so that they can be put in the DICE information field in a way that preserves the order of transmission on each side. It shall take the bits in the order of their arrival and then stack them in the DICE information field, shown in Figure 3/G.765, starting from bit 1, to bit 8 of each octet. When an octet is formed, it shall signal to the high layer entity that a DICE data octet is available.

If the parallel-to-serial converter signals to the data collector to stop collecting additional data, the data collector shall complete the current octet by putting 1’s in the higher order bits. When all bits of the octet have been formed, it shall signal to the high layer entity that the last DICE octet is being sent and shall indicate to the high layer entity the number of valid bits in the last octet.

7.4.5 *High layer procedures*

The high layer can be in one of two states, the PACKETIZE state and the IDLE state.

7.4.5.1 *Procedures in the IDLE state*

In the DICE state, the high layer entity of the originating endpoint shall cease packetization. If the circuit is provisioned to send idle update packets, the high layer entity shall restart the timer T_IDLE whenever it expires and then shall send the PL-DICE-IDLE request (C, IBT) primitive to the packet layer to request the transmission of an idle update packet. T_IDLE determines the period between the successive transmission of idle update packets.

The idle update packet updates the idle code octet that the terminating endpoint at the far side should play on its channel-oriented side in the absence of information packets. If the data collector indicates that it has started to collect new data arriving on the channel-oriented side, the high layer entity shall stop the T_IDLE timer and shall move back to the PACKETIZE state.

7.4.5.2 *Procedures in the PACKETIZE state*

In this state, the high layer entity shall operate on an octet-by-octet basis to collect up to NMAX octets of information bits and shall construct the information field of a DICE frame. Thus, a DICE data spurt begins when the high layer entity enters the PACKETIZE state and ends when the high layer entity moves into the IDLE state.

The high layer entity shall update the value of the send sequence variable (SSEQ) and shall then inform the layer 3 of the originating endpoint to transmit a packet using the PL-DICE-DATA request (SSEQ, BILO, C, IBT) primitive. The value of SSEQ is 0 for the first packet of each DICE data spurt. Subsequent SSEQ numbers are from 1 to 15 with a rollover to 1. The value of C is set to 1 for 64 kbit/s, or as indicated above for other rates. As long as the data collector has not informed that it is not sending the last octet, the BILO field shall always be set to 0. Finally, the value of the IBT field shall correspond to the current value of the IBT system variable, as defined in § 9.4.3.1.

The high layer entity shall continue to packetize the incoming channel-oriented traffic until the data collector has informed it that it was sending the last octet of user data. The high layer entity shall then stop packetization and shall use the number of valid data bits in the last octet communicated by the data collector to select the value of the system variable BILO that represents the number of valid data bits as shown in Table 4/G.765. It shall then request from the layer 3 entity to send the current packet in a DICE frame even if the size of its information field is less than NMAX octets using the primitive PL-DICE-DATA request (SSEQ, BILO, C, IBT). The value of IBT in this primitive shall be equal to the current value of the system variable IBT_IDLE.

It shall start the timer T_IDLE and then move to the IDLE state.

NMAX is the maximum size of the DICE information field in octets. Therefore, if the value of NMAX is less than NORM_IDLE_MAX (or FAIL_IDLE_MAX), the high layer entity shall form several DICE information frames with idle code patterns.

7.4.6 *Layer 3 procedures for the originating endpoint*

When the high layer entity informs the layer 3 entity to start packet transmission using the PL-DICE-DATA request (SSEQ, BILO, C, IBT), the layer 3 entity shall start the timer TVDELAY and insert the values of BILO, C, and IBT in their respective fields. The value of SEQ in the packet is set to be that of SSEQ.

If the high layer entity indicates to the layer 3 entity to send idle update packets using the PL-DICE-IDLE request (C, IBT) primitive, the layer 3 entity shall set the SEQ to 0 and the C and IBT fields to their respective values indicated in the primitive. The layer 3 entity shall set the value of the BILO field to zero.

The layer 3 entity shall await the arrival of the DL-L1-READY indication primitive from layer 2. Upon receipt of this primitive, layer 3 shall stop the timer TVDELAY and its value shall be copied to the TS field. The value of the TS shall not exceed 200 ms and its resolution is 1 ms. If the variable delay exceeds 200 ms, the value shall be set to 200 ms.

The layer 3 entity shall pass the DICE packet to the layer 2 entity for transport using the DL-UNIT-H-DATA request primitive (if the control field is UIH) or the DL-UNIT-DATA request (if the control field is UI).

7.4.6.1 *DICE link layer procedures*

The link layer procedures are the same as those defined in §§ 4.2.1 and 4.2.2 of Recommendation G.764.

7.5 *Immediate node procedures*

Upon receipt of the DL-PVP-H-DATA indication primitive, if the UIH frame is used (or the DL-PVP-DATA indication if the UI frame is used), the layer 3 entity shall start timer TVDELAY. The layer 3 entity shall examine the value encoded in the PD field. If this value matches that for packetized voice protocol (PVP), the packet shall be buffered until the layer 3 entity receives the primitive DL-L1-READY indication from layer 2. Upon receipt of this primitive, the variable delay timer TVDELAY is stopped and its value shall be used to update the packet′s TS field. The resolution of TVDELAY is 1 ms. The value of TS field shall not exceed 200 ms.

The layer 3 entity shall then pass the information to layer 2 via the DL-PVP-H-DATA request primitive for a UIH frame or a DL-PVP-DATA request primitive for a UI frame.

7.6 *DICE terminating endpoint procedures*

7.6.1 *DICE link layer procedures*

The link layer procedures are the same as specified in §§ 4.2.1 and 4.2.2 of Recommendation G.764.

7.6.2 *Layer 3 procedures*

Upon receipt of the DL-UNIT-H-DATA indication primitive from layer 2 for a UIH frame (or DL-UNIT-DATA indication for a UI frame), the layer 3 entity at the terminating endpoint shall examine the value encoded in the PD field. If this value matches that for PVP, the layer 3 entity shall proceed as below. Otherwise, it shall drop the packet. The layer 3 entity shall examine the value coded in the SC field. If this value is decimal 3, the layer 3 entity shall proceed as below. Otherwise, it shall drop the packet.

When the high layer entity requests the play-out of data using the PL-DICE-DATA request primitive, the packet layer shall check its queue.

If the queue is empty, the packet layer shall send PL-DICE-IDLE indication (C, IBT) to the higher layer entity with IBT = IBT_LAST. IBT_LAST is a system variable that contains the value of the IBT field in the last received packet.

If a packet is on the queue, the packet layer shall invoke the build-out procedures of § 5.3.3.2 of Recommendation G.764. In all cases, when RSEQ is incremented, it shall be incremented in the range of 1 to 15 with a rollover to 1. Also, the value of the system variable IBT_LAST shall be updated to contain the value of the IBT field in the received packet if and only if this IBT value corresponds to an idle code defined in Table 1/G.765.

If the packet has a sequence number of 0, the packet layer shall invoke the build-out procedures of § 5.3.3.2 of Recommendation G.764. At the scheduled play-out time, the packet layer shall send to the higher layer entity either the PL-DICE-DATA indication (BILO, C, IBT) primitive or the PL-DICE-IDLE indication (C, IBT) primitive, depending on whether the packet is a DICE information packet or a DICE idle update packet. In the case of an information packet, it shall set RSEQ to 1.

If the packet has a sequence number > 0 and arrives in sequence, the packet layer shall send to the higher layer entity the PL-DICE-DATA indication (BILO, C, IBT) primitive, and shall increment RSEQ.

If the packet arrives out-of-sequence with a non-zero sequence number, the packet shall be retained for the interval of (BUILDOUT – time stamp) ms.

At the scheduled play-out time, the packet layer shall inform the higher layer entity with the PL-DICE-DATA indication (BILO, C, IBT) primitive in the case of a DICE information packet and increment RSEQ, or with the PL-DICE-IDLE indication (C, IBT) primitive for an update packet and set RSEQ to 0.

7.6.3 *High layer entity procedures*

The high layer entity at the terminating end shall request from the packet layer whether all data have been played out on the channel-oriented side.

The high layer entity will take each packet and then rearrange the DICE information field in a serial fashion. The serialization of the bits of each octet shall be performed in ascending order from bit 1 to bit 8, with the bit numbering done according to the numbering convention of Figure 3/G.765. The high layer entity shall remove (8-BILO) 1’s from the end of the data stream.

7.6.4 *Procedures of the serial-to-parallel converter*

The serial-to-parallel converter shall multiplex the serial bit stream arriving from the higher layer entity with specific bits it generates, and reorganize the multiplexed stream into a parallel format according to Tables 1/G.765 and 3/G.765.

7.6.4.1 *Procedures for bit rates below 56 kbit/s*

The serial-to-parallel converter shall fill the remaining position of the current octet, if any, with ones. It shall then retrieve the octet representing the idle code bit pattern that corresponds to the value stored in the system variable IBT_LAST, using Table 1/G.765, and send it to the channel-oriented side.

For subrate operation, the serial-to-parallel converter shall reinsert the “subrate framing” bit (the first bit of an octet to be sent on the channel-oriented side), the “control” bit (the last bit to be sent) into the bit stream if C is 0 in each octet that it forms. The serial-to-parallel converter shall transmit CMAX consecutive copies of each octet.

7.6.4.2 *Procedures at 56 kbit/s*

The serial-to-parallel converter shall fill the remaining position of the current octet, if any, with ones. It shall then retrieve the octet representing the idle code bit pattern that corresponds to the value stored in the system variable IBT_LAST, using Table 1/G.765, and send it to the channel-oriented side.

For 56 kbit/s operation, the serial-to-parallel converter shall reinsert the “subrate framing” bit (the first bit of an octet to be sent on the channel-oriented side), the “control” bit (the last bit to be sent) into the bitstream if C is 0, and shall transmit one copy of each octet that it forms.

7.6.4.3 *Procedures at 64 kbit/s*

The serial-to-parallel converter shall then retrieve the octet representing the idle code bit pattern that corresponds to the value stored in the system variable IBT_LAST, using Table 1/G.765, and send it to the channel-oriented side.

For 64 kbit/s operation, the serial-to-parallel converter shall transmit one copy of each octet that it forms.

7.7 *Systems variables*

7.7.1 *Send sequence state variable*

See § 7.1 of Recommendation G.764.

7.7.2 *Receive sequence state variable*

See § 7.2 of Recommendation G.764.

7.7.3 *IBT_IDLE*

At the originating endpoint, IBT_IDLE stores the value that corresponds to the most recent idle code arriving on the channel-oriented side that has caused the IDLE_LAT_CNT to reach is threshold of IDLE_LAT_MAX.

7.7.4 *IBT_LAST*

At the terminating endpoint, IBT_LAST stores the value of the IBT in the last received packet.

7.7.5 *T_IDLE*

T_IDLE is the idle update timer. T_IDLE determines the period between the successive transmission of idle update packets. Its value is set to 60 seconds.

7.7.6 *TVDELAY*

This timer is used to measure the variable queueing delay that a packet experiences in a node that is used to update the TS field of a voiceband packet.

7.8 *Protocol parameters*

7.8.1 *Build-out delay*

See § 8.1 of Recommendation G.764.

7.8.2 *CMAX*

CMAX is the number of duplicate copies of the subrate user traffic. Its value is 1 for 56 kbit/s, 5 for 9600 bit/s, 10 for 4800 bit/s and 20 for 2400 bit/s.

7.8.3 *FAIL_IDLE_MAX*

FAIL_IDLE_MAX defines the maximum number of consecutive identical failure idle octets that can arrive at the channel-oriented side before the high layer entity enters the idle failure state and stop packetization. For point-to-point connections, the number is one of the values 2, 3, 6, 12, 15, 30, 60 and 500. The default value is 500. For multipoint connections, the value is set to 2 and cannot be changed.

7.8.4 *IDLE_LAT_MAX*

IDLE_LAT_MAX defines the maximum number of consecutive identical idle octets that can arrive on the channel-oriented side before updating the value of the IBT_IDLE system variable. This prevents the erroneous resetting of IBT_IDLE due to bit errors. The value of IDLE_LAT_MAX ranges from 2 to 15. The default value is 2.

7.8.5 *NMAX*

NMAX defines the maximum number of octets in the DICE information field of a DICE packet (see § 7.3.11).

7.8.6 *NORM_IDLE_MAX*

NORM_IDLE_MAX defines the maximum number of consecutive identical normal (non-failure) idle octets that can arrive on the channel-oriented side before the high layer entity enters the idle normal state. For point-to-point connections, the allowable values are 2, 3, 6, 12, 15, 30, 60 and 500. The default value is 3 to allow for the transmission of two consecutive idle codes on the secondary channel. The value of 6 corresponds to 4.8 kbit/s lines provisioned at 9.6 kbit/s. The value of 12 corresponds to 2.4 kbit/s lines provisioned at 9.6 kbit/s. The values of 15, 30 and 60 correspond respectively to 9.6 kbit/s, 4.8 kbit/s and 2.4 kbit/s lines provisioned at 56 kbit/s. For multipoint connections, the value is set to 2 and cannot be changed.

7.9 *Summary of primitives*

7.9.1 *Primitives for the interfaces between layers 2 and 3*

The primitives for the interfaces between layers 2 and 3 have the same definition as in § 9 of Recommendation G.764.

7.9.1.1 *DL-LI-READY indication*

See § 9.1.1 of Recommendation G.764.

7.9.1.2 *DL-UNIT-DATA request*

See § 9.1.2 of Recommendation G.764.

7.9.1.3 *DL-UNIT-DATA indication*

See § 9.1.3 of Recommendation G.764.

7.9.1.4 *DL-UNIT-H-DATA request*

See § 9.1.4 of Recommendation G.764.

7.9.1.5 *DL-UNIT-H-DATA indication*

See § 9.1.5 of Recommendation G.764.

7.9.1.6 *DL-PVP-H-DATA indication*

See § 9.1.6 of Recommendation G.764.

7.9.1.7 *DL-PVP-DATA indication*

See § 9.1.7 of Recommendation G.764.

7.9.1.8 *DL-PVP-H-DATA request*

See § 9.1.8 of Recommendation G.764.

7.9.1.9 *DL-PVP-DATA request*

See § 9.1.9 of Recommendation G.764.

7.9.2 *Primitives for the interface between layer 3 and the higher layer entity*

7.9.2.1 *PL-DICE-DATA request (SSEQ, BILO, C, IBT)*

The PL-DICE-DATA request (SSEQ, BILO, C, IBT) primitive is used by the originating endpoint high layer entity to request the layer 3 entity to transmit DICE information packets. SSEQ is 0 for the first packet of a DICE data spurt. Subsequent primitives have the SSEQ numbers 1 to 15 with a rollover to 1. The value of BILO is set to 0 for 64 kbit/s and to its appropriate value for the other rates. The value of C is set to 1 for 64 kbit/s and to 0 for other bit rates. Finally, the value of the IBT corresponds to current idle code, as defined in § 7.4.3.

7.9.2.2 *PL-DICE-DATA indication (BILO, C, IBT)*

PL-DICE-DATA indication (BILO, C, IBT) primitive is used by the packet layer of the terminating endpoint to indicate to its high layer entity the arrival of a DICE information packet with the parameter BILO, C and IBT.

7.9.2.3 *PL-DICE-IDLE request (C, IBT)*

PL-DICE-IDLE request (C, IBT) primitive is used by the originating endpoint high layer entity to request to the layer 3 entity to transmit an idle update packet. The value of C is set to 1 for 64 kbit/s, and to 0 for other rates. The value of the IBT corresponds to the current idle code, as defined in § 7.4.3.

7.9.2.4 *PL-DICE-IDLE indication (C, IBT)*

PL-DICE-IDLE indication (C, IBT) primitive is used by the packet layer of the terminating endpoint to indicate to its high layer entity the arrival of a DICE idle update packet.

8 Virtual data link capability (VDLC protocol)

The VDLC protocol may be used to transport digital data that arrive on the channel-oriented side. VDLC builds upon the same physical, link and packet layers of Recommendation G.764 and extends DICE to cover the bit-oriented procedures of HDLC. Thus, VDLC removes specific bits, idle codes and HDLC flags arriving from the channel-oriented traffic. VDLC allows frame partitioning and rejoining, and the inversion of the polarity of the bit stream. In place of lost information packets, VDLC allows a provisionable number of HDLC flags to be played out on the channel-oriented side.

The reception, packetization and transport of DSO-B multiplexed subrates, 56 kbit/s with error correction on two 64 kbit/s time slots, and 19 200 bit/s are for further study.

Subsections 8.1, 8.2 and 8.3 describe the physical, link and packet layers by referring to the description of Recommendation G.764, § 8.4 describes VDLC procedures for the high, packet and link layers of the originating endpoint. Subsection 8.5 describes the procedures at the intermediate nodes, while § 8.6 describes the procedures at the terminating endpoint.

8.1 *Physical layer*

The physical layer is the same for Recommendation G.764 (see § 3.1 of the same Recommendation).

8.2 *Link layer*

The link layer is the same for DICE (see § 7.2).

8.3 *Packet layer*

The packet layer procedures apply to the information transfer phase only. Call control procedures are outside the scope of this Recommendation.

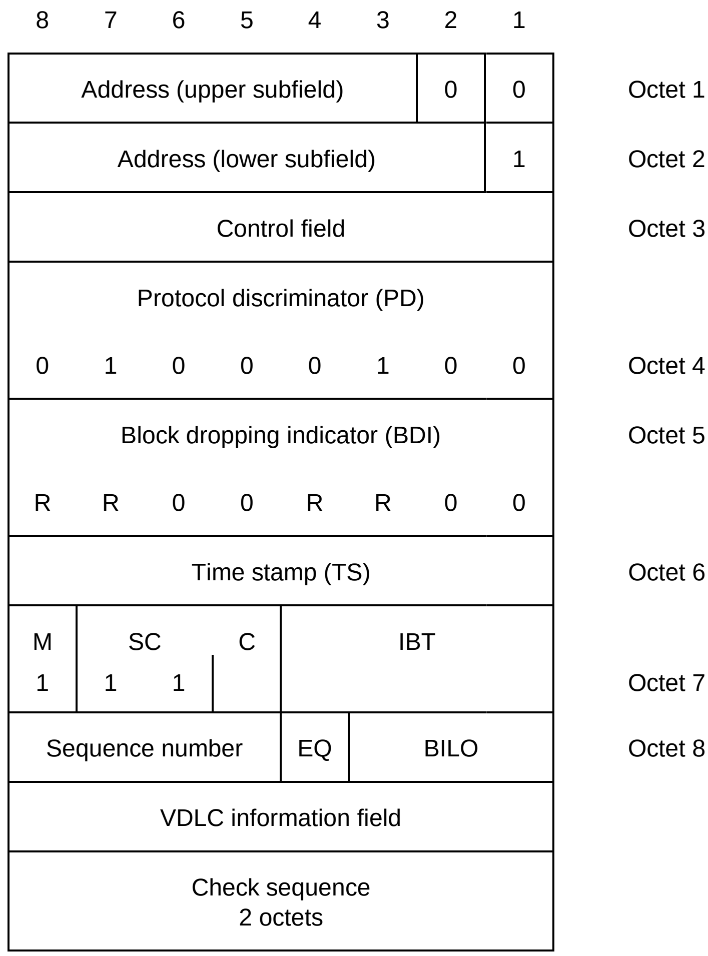
VDLC packets are of the format shown in Figure 5/G.765. There are three types of VDLC packets:

1) VDLC information packets;

2) VDLC update packets;

3) VDLC flag packets.

VDLC update packets have zero-length information field; a SEQ value of 0 and an EQ value of 0. They update the bit pattern that the terminating endpoint should play to the channel-oriented side in the absence of information packets. VDLC flag packets contain HDLC flags in their VDLC information field.



M M-Bit

R Reserved for future use and set to 0

FIGURE 5/G.765

VDLC frame format

8.3.1 *Protocol discriminator (PD)*

Same as for DICE (see § 7.3.1).

8.3.2 *Block dropping indicator (BDI)*

Same for DICE (see § 7.3.2).

8.3.3 *Time stamp (TS)*

Same as for DICE (see § 7.3.3).

8.3.4 *M-bit*

Same as for DICE (see § 7.3.4).

8.3.5 *Sub-class field (SC)*

Same as for DICE (§ 7.3.5).

8.3.6 *Control bit (C)*

The control (C) bit is set by the originating endpoint to indicate whether the last bit to arrive for each octet has been removed. In some national applications, this bit is called the "control bit" and is used for synchronization, status and remote testing on the channel-oriented side. C is set to 0 if the control bit is removed; otherwise C is set to 1. For non-64 kbit/s channels, C shall be set to 0, because the control bit is always removed.

8.3.7 *Idle background type (IBT)*

As in DICE, the IBT indicates the type of idle code that has been removed from the original data stream by the originating endpoint. In addition, VDLC defines three new entries that are used to indicate to the terminating endpoint what action to take in case of HDLC frames. The type of codes to be recognized is determined by service administration.

In addition to the IBT codes described in Table 1/G.765, VDLC uses the IBT coding types of Table 6/G.765 at the originating endpoint for point-to-point and multipoint connections.

TABLE 6/G.765

Meaning of the additional coding types at the originating endpoint

Bit rate (kbit/s)	Meaning	IBT code
All	Complete HDLC frame in VDLC frame	0000
	Partitioned HDLC frame (last)	0000
	Paratitioned HDLC frame (not last)	0001
	VDLC frame contains HDLC flags (flag packet)	0010
	VDLC frame contains an update packet in the FLAG_IDLE state	0010

The initial value of the IBT field is 1111. This value shall be updated according to the traffic characteristics, as indicated in § 8.4.1.

At the terminating endpoint, the IBT coding types shown in Table 7/G.765 are used for both point-to-point and multipoint connections, in addition to those already listed in Table 3/G.765.

8.3.8 *Sequence number*

Same as for DICE (see § 7.3.8).

8.3.9 *Delay equalization bit*

The EQ bit is set by the originating endpoint to enable or to disable the build-out delay procedures at the terminating endpoint. When EQ is set to 1, build-out procedures are enabled; otherwise, they are disabled. The originating endpoint shall set EQ to 0 except for the following cases, where EQ is set to 1:

1) the first VDLC packet that contains a partial HDLC frame of user information when frame partitioning and rejoining is done;

2) subsequent packets that contain partial HDLC frame information, with the exception of the last packet.

TABLE 7/G.765

Meaning of the additional coding types at the terminating endpoint

Bit rate (kbit/s)	IBT code	Meaning
All	0000	Stuff bits for transparency and append an HDLC flag
	0001	Stuff bits for transparency and no HDLC flag appended
	0010	No bit stuffing (VDLC flag packet and VDLC update packet)

8.3.10 *Bits in last octet*

The BILO field contains the number of bits in the last information octet that are valid data bits.

8.3.11 *VDLC information field*

The minimum length of a frame arriving on the channel-oriented side is 4 octets between HDLC flags. Smaller frames shall be dropped at the originating endpoint.

The size for the VDLC information field, VMAX, shall not exceed 482 octets, as required by Recommendation G.764. However, a smaller size can be selected by service administration, according to Table 5/G.765.

If the size of an HDLC frame on the channel-oriented side exceeds VMAX octets, the frame shall either be dropped or shall be broken into consecutive VDLC frames, depending on operator's provisioning.

The octets of the VDLC information field are transmitted in ascending numerical order. Inside an octet, bits are transmitted in an increasing order, i.e. bit 1 is transmitted first (see Figure 5/G.765). Therefore, the bits shall be arranged in the VDLC information field so that the first bit to be transmitted on the packet side is the first arriving bit on the channel-oriented side. As explained in § 7.3.7, in some national applications, the first bit of an octet to arrive from the channel-oriented side is called the "subrate framing bit", while the last bit is called the "control bit". Arithmetically, bit 1 is the most significant bit of an octet on the channel-oriented side while bit 8 is the least significant bit of an octet on the packetized side.

8.4 *VDLC procedures at the originating endpoint*

The channel-oriented bit stream is first treated according to § 8.4.1. Two high layer entity processors monitor the pre-processed bit stream. The idle code detector, whose action is described in § 8.4.2, operates on the preprocessed traffic. The parallel-to-serial conversion of the traffic is the function of the parallel-to-serial converter, which is described in § 8.4.3. The HDLC detector operates on the serial bit stream, as shown in § 8.4.4.

8.4.1 *Preprocessing*

The subrate traffic consists of CMAX duplicated copies of the user traffic. CMAX is 1 for 56 kbit/s, 5 for 9600 bit/s, 10 for 4800 bit/s and 20 for 2400 bit/s, and the subrate framing pattern consists of CMAX bits. For traffic at rates less than 56 kbit/s, the preprocessor shall retain one copy of the subrate information and remove the redundant octets.

8.4.2 *Operation of the idle code detector*

The idle code detector operates on the pre-processed traffic to distinguish idle codes from other octets. Idle codes are defined by service administration, as indicated in Table 1/G.765.

When the idle code detector detects an idle code specified by service administration, it shall start counter IDLE_LAT_CNT to count the number of idle codes received. If the same idle code continues to arrive on the channel-oriented side, the counter IDLE_LAT_CNT shall be incremented for each newly arrived octet.

If the idle detector detects a non-idle octet, it shall reset the counter IDLE_LAT_CNT.

If the idle code detector detects a new idle, it shall set the counter IDLE_LAT_CNT to 1 and shall increment it as the octets of the new idle code continue to arrive.

If the IDLE_LAT_CNT counter reaches the value of IDLE_LAT_MAX, it shall send a message to the high layer entity to signal that the threshold IDLE_LAT_MAX has been reached and to inform it of the corresponding idle code.

If the IDLE_LAT_CNT counter reaches the value of VDLC_IDLE_MAX, it shall send a message to the high layer entity to signal that the threshold VDLC_IDLE_MAX has been reached and to inform it for the corresponding idle code.

The values of IDLE_LAT_MAX and VDLC_IDLE_MAX shall be set by service provisioning.

8.4.3 *Operation of the parallel-to-serial converter*

The parallel-to-serial converter shall convert the retained octet into a serial bit stream supplied to the HDLC detector. The serialization shall be done in the order of increasing bit numbers, i.e. from bit 1 to bit 8, with the bit numbering done according to the nomenclature of the channel-oriented pattern of Table 1/G.765. This is also the order of bit arrival on the channel-oriented side. As previously explained in § 7.3.7, in some national applications, the first bit of an arriving octet is called the "subrate framing bit" while the last bit is called the "control bit".

The parallel-to-serial converter shall remove the first bit of an octet (the "subrate framing" bit) for subrate traffic at rates of less than 56 kbit/s. It shall also remove the last bit of an octet (the "control" bit) for non-64 kbit/s channels. If so provisioned by service administration, it shall invert the remaining bits.

8.4.4 *Operation of the HDLC detector*

The HDLC detector operates on serial bit stream to determine if the traffic contains an HDLC flag, an abort (at least seven consecutive 1's) or user data.

HDLC octets are not necessarily octet-aligned with the octets on the channel-oriented side. For example, in some applications, the HDLC detector may require the examination of up to three octets of channel-oriented traffic to recognize the presence of an HDLC flag.

The HDLC detector shall peel the successive data bits from the incoming bit stream and shall arrange them in successive octets so that they can be put in the VDLC information field in a way that preserves the order of transmission on each side. It shall take the bits in the order of their arrival and shall stack them in the VDLC information field (shown in Figure 5/G.765), starting from bit 1 to bit 8 of each octet. It shall remove the bits stuffed for transparency from the data stream. When an octet is formed, it shall signal to the high layer entity than an HDLC data octet is available. Also, it shall signal to the high layer entity to drop the data bits collected between two flags, if these data bits are not octet aligned.

8.4.5 *High layer procedures*

The high layer entity can be in one of six global states: The AWAIT state, the PACKETIZE state, the IDLE state, the FLAG_IDLE state, the FLAG_WAIT state and the ABORT state. The initial state of the high layer entity is the IDLE state. A simplified state transition diagram of the high layer entity is shown in Figure 6/G.765.

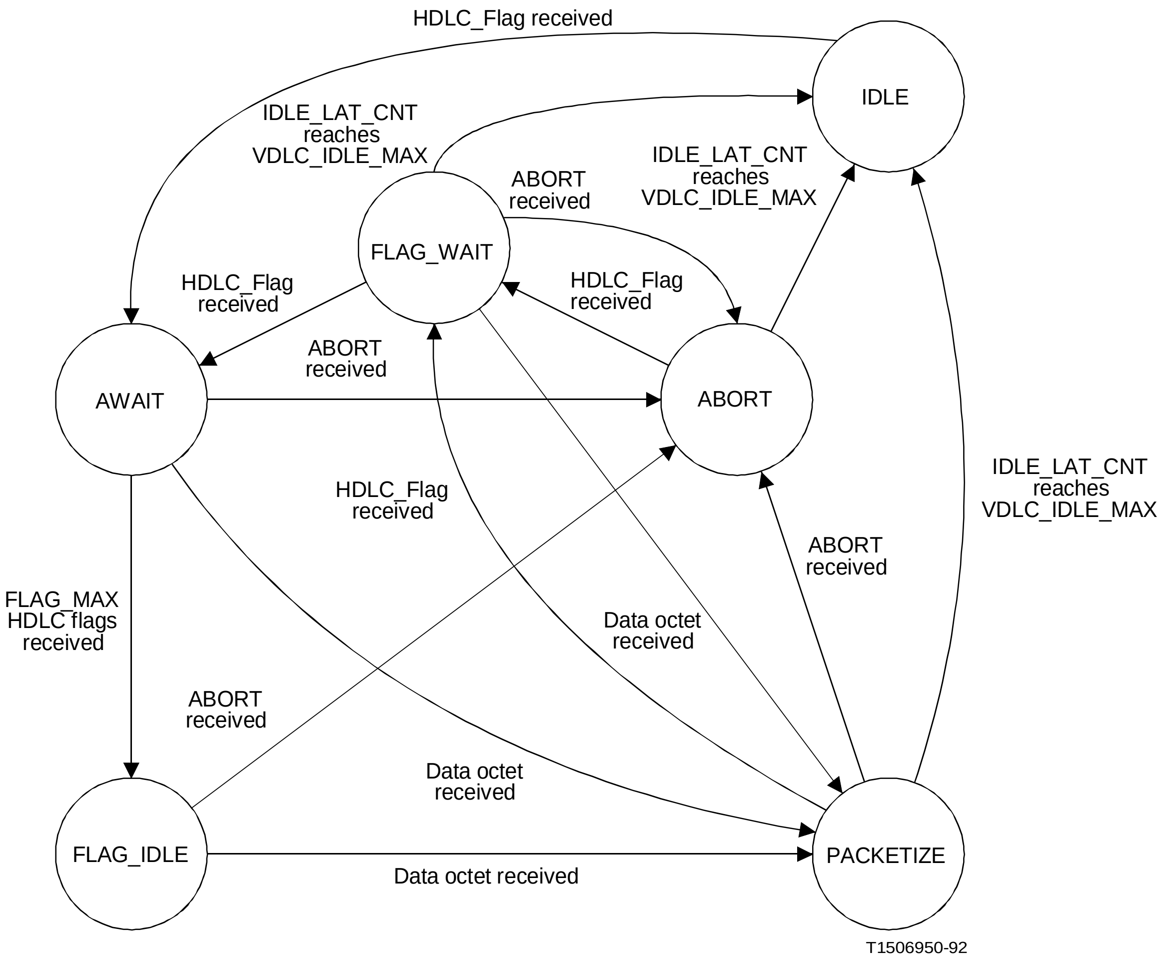


FIGURE 6/G.765
Global VDLC state transitions at the high layer entity of the originating endpoint

The system variable, timers and counters used in the following description are:

1) IBT_IDLE, which corresponds to the most recent idle code that has caused the idle latency counter IDLE_LAT_CNT of the originating endpoint to reach one of the two thresholds, IDLE_LAT_MAX or VDLC_IDLE_MAX. The initial value of IBT_IDLE is 1111 (15 decimal).

2) IBT_LAST, which stores the value of the IBT in the last received packet at the terminating endpoint. The initial value of IBT_LAST is 1111 (15 decimal).

3) IDLE_LAT_CNT, which is the idle latency counter for idle codes before updating IBT_IDLE.

4) NFLAG, which is the flag latency counter for HDLC flags. NFLAG counts the number of times that HDLC flags have been received consecutively.

5) RSEQ, the receive sequence number variable, gives the SEQ of the next packet to be received. It is updated by incrementing the previous RSEQ from 1 to 15 with a rollover to 1.

6) SSEQ, the send sequence number variable, gives the SEQ of the next packet to be sent. It is updated by incrementing the previous SSEQ from 1 to 15 with a rollover to 1.

7) T_IDLE, which is a timer that determines the period between the successive transmission of update packets.

8) VDLC_IDLE_CNT, which is the idle latency counter for the number of idle codes before the high layer entity enters the IDLE state.

8.4.5.1 *Procedures in the IDLE state*

Upon entering this state, the high layer entity of the originating endpoint shall cease packetization of the incoming channel-oriented traffic. It shall restart the timer T_IDLE whenever it expires and then shall send the PL-VDLC-IDLE request (IBT) primitive to the packet layer to transmit a VDLC update packet. IBT has the value stored in the system variable IBT_IDLE. (The layer 3 entity shall set the SEQ to 0 and the EQ to 0 in the packet header, as explained in § 8.4.6.)

If a message arrives from the idle detector indicating that the IDLE_LAT_CNT counter has reached its threshold IDLE_LAT_MAX, the high layer entity shall update the value of IBT_IDLE to correspond to the idle code in question. It shall restart the timer T_IDLE and shall send the PL-VDLC-IDLE request (IBT) primitive to the packet layer to transmit VDLC update packet with the IBT equal to the new value of the IBT_IDLE system variable.

If the HDLC detector indicates the reception of an HDLC flag, the high layer shall stop the timer T_IDLE. It shall reset the flag counter NFLAG to 0 and the SSEQ to 0 and shall move to the AWAIT state.

8.4.5.2 *Procedures during the AWAIT state*

In the AWAIT state, the high layer entity shall increment NFLAG whenever the HDLC detector indicates that an HDLC flag has arrived on the channel-oriented side.

If the value of NFLAG becomes FLAG_MAX, the high layer entity shall put NFLAG HDLC flags in the VDLC information field. If shall then request the transmission of a VDLC packet using the primitive PL-VDLC-FLAG request (SSEQ). SSEQ is incremented within the range 1 to 15 with a rollover to 1. The packet layer shall set IBT to 0010 and EQ to 1. It shall leave the AWAIT state and enter the FLAG_IDLE state. FLAG_MAX is selected by service administration.

If the HDLC detector indicates the reception of an abort, the high layer entity shall put NFLAG HDLC flags in the VDLC information field. It shall request the transmission of a VDLC flag packet using the primitive PL-VDLC-FLAG request (SSEQ). The high layer entity shall then move to the ABORT state.

If the HDLC detector indicates the reception of HDLC data, the high layer entity shall put NFLAG HDLC flags in the VDLC information field. It shall then request the transmission of a VDLC flag packet using the primitive PL-VDLC-FLAG request (SSEQ). The high layer entity shall put the data octet in the first octet of the information field and then move to the PACKETIZE state.

8.4.5.3 *Procedures during the PACKETIZE state*

The high layer entity shall remain in the PACKETIZE state as long as:

– the idle code detector has not indicated that the counter IDLE_LAT_CNT has reached VDLC_IDLE_MAX; and

– the HDLC detector has not indicated that it has received an HDLC flag or an abort.

In the PACKETIZE state, the high layer entity shall operate on an octet-by-octet basis to collect up to VMAX octets of information bits and shall construct the information field of a VDLC frame.

The high layer entity shall continue preparing the VDLC information field until either the HDLC detector has detected a new HDLC flag or an abort, or the idle code detector has indicated that the IDLE_LAT_CNT has reached its threshold VDLC_IDLE_MAX.

If the HDLC detector indicates reception of a new flag, the subsequent action is as follows:

1) If the VDLC information field contains fewer than four octets, the VDLC packet shall be dropped and the high layer entity shall move to the FLAG_WAIT state.

2) If the HDLC detector signals that the VDLC information field is not octet aligned, the high layer entity shall drop the packet and shall move to the FLAG_WAIT state.

3) If the VDLC information field is ≤ VMAX, the high layer entity shall send the primitive PL-VDLC-DATA request (SSEQ, IBT, EQ) with IBT = 0000 and EQ = 0 to the packet layer. It shall increment the SSEQ within the range 1 to 15 with a rollover to 1 and shall go to the FLAG_WAIT state.

4) If the VDLC information field is larger than VMAX octets, then depending upon the provisioning, the incoming HDLC frames shall either be partitioned into successive VDLC frames or shall be dropped. SSEQ shall not be updated if the frame is dropped. In both cases, the high layer entity shall then move to the FLAG_WAIT state.

If an HDLC frame is partitioned, the high layer entity shall set the SSEQ to 0 and shall send the primitive PL-VDLC-DATA request (SSEQ, IBT, EQ) with SSEQ = 0, IBT = 0001, and EQ = 1 for first frame. For subsequent VDLC frames, it shall set IBT to 0001, and EQ to 1. The high layer entity shall increment the SSEQ with a rollover to 1 after sending each primitive. The value of EQ = 1 ensures that the terminating endpoint builds-out the VDLC frame before play-out. The value of IBT = 0001 ensures that the terminating endpoint does not append flags. The last packet shall have the IBT = 0000 and EQ = 0 to add flags after play-out and avoid the build-out procedures and improve the overall end-to-end delay.

If a message arrives from the idle detector to indicate that the value of VDLC_IDLE_MAX has been reached, the high layer entity shall update the value of the system variable IBT_IDLE to correspond to the idle code in question. It shall send the PL-VDLC-IDLE request (IBT) primitive to the packet layer to request the transmission of an update packet with IBT equal to the new value of system variable IBT_IDLE. (The layer 3 entity shall set the value to EQ to 0 and SEQ to 0.) It shall start the timer T_IDLE and then move to the IDLE state.

If the HDLC detector indicates that an abort has arrived, the high layer entity shall drop the current packet without updating SSEQ, and shall move to the ABORT state.

8.4.5.4 *Procedures in the FLAG_IDLE state*

The high layer entity shall restart the timer T_IDLE whenever it expires and then shall send the PL-VDLC-IDLE request (IBT) primitive to the packet layer to transmit a VDLC update packet with IBT = 0010. The packet layer shall set EQ to 0 and SEQ to 0 in the packet header.

The high layer shall stop the timer T_IDLE if the HDLC detector indicates reception of a data octet. The high layer entity shall set the SSEQ to zero; it shall put the data octet in the first octet of the information field and then shall move to the PACKETIZE state.

If the HDLC detector indicates reception of an abort, the high layer entity shall stop the timer T_IDLE and shall move to the ABORT state.

8.4.6 *Procedures in the ABORT state*

In the ABORT state, the high layer entity shall cease packetization.

When the idle code detector indicates that the counter IDLE_LAT_CNT has reached the threshold VDLC_IDLE_MAX, the high layer entity shall update the IBT_IDLE system variable to correspond to the idle code in question. It shall send the PL-VDLC-IDLE request (IBT) primitive to the packet layer to request the transmission of an update packet, with IBT equal to the new value of system variable IBT_IDLE. (The layer 3 entity shall set EQ to 0 and SEQ to 0.) It shall start the timer T_IDLE and then move to the IDLE state.

If the HDLC detector indicates reception of an HDLC flag, the high layer entity shall move to the FLAG_WAIT state.

8.4.7 *Procedures in the FLAG_WAIT state*

In this state, the high layer entity shall cease packetization.

When the idle code detector indicates that the counter IDLE_LAT_CNT has reached the threshold VDLC_IDLE_MAX, the high layer entity shall update the IBT_IDLE system variable to correspond to the idle code in question. It shall send the PL-VDLC-IDLE request (IBT) primitive to the packet layer to request the transmission of an update packet, with IBT equal to the new value of system variable IBT_IDLE. (The layer 3 entity shall set EQ to 0 and SEQ to 0.) It shall start timer T_IDLE and then move to the IDLE state.

The high layer entity shall set the flag counter NFLAG to 1 and shall move to the AWAIT state if the HDLC detector indicates reception of an HDLC flag.

If the HDLC detector indicates reception of an abort, the high layer entity shall put the data octet in the first octet of the information field and then shall move to the ABORT state. SSEQ shall not be updated.

If the HDLC detector indicates reception of an octet of data, the high layer entity shall put the data octet in the first octet of the information field and then move to the PACKETIZE state.

8.4.8 *Layer 3 procedures for the originating endpoint*

When the high layer entity informs the layer 3 entity to transmit a packet using the PL-VDLC-DATA request (SSEQ, IBT, EQ) the layer 3 entity shall start the timer TVDELAY and insert the values of IBT and EQ in their respective fields. The SEQ shall be set equal to the value of the SSEQ.

If the high layer entity indicates to the layer 3 entity to send update packets using the PL-VDLC-IDLE request (IBT) primitive, the layer 3 entity shall start the timer TVDELAY and set the IBT field to the value indicated in the primitive. It shall set the SEQ to 0, the BILO to 0000 and the EQ to 0.

If the high layer entity indicates to the layer 3 entity to send flag packets using the PL-VDLC-FLAG request (SSEQ) primitive, the layer 3 entity shall start the timer TVDELAY and set the SEQ field to the value indicated by SSEQ in the primitive. It shall set the EQ to 0, the BILO to 0000 and the IBT to 0010.

The layer 3 entity shall await the arrival of the DL-L1-READY indication primitive from layer 2. Upon receipt of this primitive, layer 3 shall stop the timer TVDELAY and its value shall be copied to the TS field. The value of the TS shall not exceed 200 ms. If the variable delay exceeds 200 ms, the value if set to 200 ms.

The layer 3 entity shall pass the VDLC packet to the layer 2 entity for transport using the DL-UNIT-H-DATA request primitive (if the control field is UIH) or the DL-UNIT-DATA request (if the control field is UI).

8.4.8.1 *VDLC link layer procedures*

The link layer procedures are the same as those defined in §§ 4.2.1 and 4.2.2 of Recommendation G.764.

8.5 *Intermediate node procedures*

Same as for DICE (see § 7.5).

8.6 *VDLC terminating endpoint procedures*

8.6.1 *VDLC link layer procedures*

The link layer procedures are the same as specified in §§ 4.2.3 and 4.2.4 of Recommendation G.764.

8.6.2 *Layer 3 procedures*

Upon receipt of the DL-UNIT-H-DATA indication primitive from layer 2 for a UIH frame (or DL-UNIT-DATA indication for a UI frame), the layer 3 entity at the terminating endpoint shall examine the value encoded in the PD field. If this value matches that for PVP, the layer 3 entity shall proceed as below. Otherwise, it shall drop the packet. The layer 3 entity shall examine the value coded in the SC field. If this value is decimal 3, the layer 3 entity shall proceed as below. Otherwise, it shall drop the packet.

When the high layer entity requests the play-out of data using the PL-VDLC-DATA request primitive, the packet layer shall check its queue.

If the queue is empty, the packet layer shall send PL-VDLC-IDLE indication (IBT) to the high layer entity.

If a packet is on the queue, the packet layer shall proceed according to the value of the EQ field. If EQ is = 0, no build-out procedures shall be invoked; if EQ is = 1, the build-out procedures of § 5.3.3.2 of Recommendation G.764 shall be invoked. In all cases, when RSEQ is incremented, it shall be incremented in the range of 1 to 15 with a rollover to 1. Also, the value of the system variable IBT_LAST shall be updated to contain the value of the IBT field in the received packet if and only if this IBT value corresponds to an idle code defined in Table 1/G.765.

8.6.2.1 *Procedures without build-out*

When a packet arrives in sequence with a non-zero sequence number, the packet layer shall play it immediately. The packet layer shall inform the high layer entity with the PL-VDLC-DATA indication (IBT) primitive and increment the value of RSEQ.

If the packet arrives in sequence and has a sequence number of 0, the packet layer shall inform the high layer entity with the PL-VDLC-DATA indication (IBT) primitive, and set RSEQ to 1 if the packet is a VDLC information packet, or with a PL-VDLC-IDLE indication (IBT) for an update packet.

If the packet arrives out-of-sequence and has a sequence number > 0, the packet layer shall examine the value of the IBT field. If the value of the IBT field is either 0 or 1, the packet layer shall send the PL-VDLC-FLAGS indication primitive to the higher layer entity. Otherwise, it shall send the PL-VDLC-ONE-FLAG indication primitive.

The packet layer shall inform the high layer entity with the PL-VDLC-DATA indication (IBT) primitive and increment RSEQ if the packet is a VDLC information packet, or with a PL_VDLC-IDLE indication (IBT) and set RSEQ to 0 for an update packet.

8.6.2.2 *Procedures with build-out*

If the packet has a sequence number of 0, the packet layer shall invoke the build-out procedures of § 5.3.3.2 of Recommendation G.764. At the scheduled playout-time, the packet layer shall send to the higher layer entity either the PL-VDLC-DATA indication primitive or the PL-VDLC-IDLE indication (IBT) primitive, depending on whether the packet is a VDLC information packet or a VDLC update packet. In the case of an information packet, it shall set RSEQ to 1.

If the packet has a sequence number > 0 and arrives in sequence, the packet layer shall send to the higher layer entity the PL-VDLC-DATA indication primitive, and shall increment RSEQ.

If the packet arrives out-of-sequence with a non-zero sequence number, the packet layer shall examine the value of the IBT field. If the value of the IBT field is either 0 or 1, the packet layer shall send the PL-VDLC-FLAGS indication primitive to the higher layer entity. Otherwise, it shall send the PL-VDLC-ONE-FLAG indication primitive. The packet layer shall then schedule the packet for playout according to the build-out procedures of § 5.3.3.2 of Recommendation G.764. Thus, the packet shall be retained for the interval of (BUILDOUT – Time Stamp) ms.

At the scheduled play-out time, the packet layer shall inform the higher layer entity with the PL-VDLC-DATA indication (IBT) primitive in the case of a VDLC information packet and increment RSEQ, or with the PL-VDLC-IDLE indication (IBT) primitive for an update packet and set RSEQ to 0.

8.6.3 *High layer entity procedures*

The high layer entity at the terminating endpoint shall request from the packet layer whenever all data have been played out on the channel-oriented side.

The high layer entity will take each packet and then rearrange the VDLC information field in a serial fashion. The serialization of the bits of each octet shall be performed in ascending order from bit 1 to bit 8, with the bit numbering done according to the numbering convention of Figure 5/G.765.

The high layer entity shall also inform the serial-to-parallel converter whether to operate in the IDLE mode or in the HDLC mode.

8.6.3.1 *Procedures after receiving PL-VDLC-ONE-FLAG indication*

The high layer entity shall inform the serial-to-parallel converter to operate in the HDLC mode. It shall then send the bit pattern representing one HDLC flag to the serial-to-parallel converter.

8.6.3.2 *Procedures after receiving PL-VDLC-FLAGS indication*

The high layer entity shall inform the serial-to-parallel converter to operate in the HDLC mode. It shall then send the bit pattern representing FLAG_MIN HDLC flags to the serial-to-parallel converter.

8.6.3.3 *Procedures after receiving PL-VDLC-IDLE indication (IBT)*

The action depends on whether the IBT code corresponds to the values in Tables 1/G.765 and 3/G.765, or in Tables G.6/G.765 and 7/G.765.

If IBT > 2, the high layer entity shall put the serial-to-parallel converter in the IDLE mode.

If IBT ≤ 2, the high layer entity shall put the serial-to-parallel converter into the HDLC mode and shall send to it the bit pattern representing one HDLC flag in a serial fashion.

8.6.3.4 *Procedures after receiving PL-VDLC-DATA indication (IBT)*

The high layer entity shall put the serial-to-parallel converter into the HDLC mode. Subsequent actions depend on whether the IBT code corresponds to the values in Tables 1/G.765 and 3/G.765, or in Tables 6/G.765 and 7/G.765.

1) If IBT = 0, the high layer entity shall send the VDLC information field serially to the serial-to-parallel converter. The serialization of each octet shall be done in the order of increasing bit number, as shown in Figure 5/G.765. For data transparency, it shall insert a 0 after each sequence of five consecutive ones in the data stream. After pumping out the data bits, the high layer entity shall send the bit pattern of an HDLC flag serially. It shall then request additional data from the packet layer, using the PL-VDLC-DATA indication.

2) If IBT = 1, the high layer entity shall send the VDLC information field serially to the serial-to-parallel converter. The serialization of each octet shall be done in the order of increasing bit number, as shown in Figure 5/G.765. For data transparency, it shall insert a 0 after each sequence of five consecutive ones in the data stream. After pumping out the data bits, the high layer entity shall request additional data from the packet layer, using the PL-VDLC-DATA indication.

3) If IBT = 2, the high layer entity shall send the VDLC information field serially to the serial-to-parallel converter. The serialization of each octet shall be done in the order of increasing bit number, as shown in Figure 5/G.765. After pumping out the data bits, the high layer entity shall request additional data from the packet layer, using the PL-VDLC-DATA indication.

If the IBT value is different than 0, 1 or 2 the high layer entity shall indicate an error to the management entity.

8.6.4 *Procedures of the serial-to-parallel converter*

The serial-to-parallel converter shall multiplex the serial bit stream arriving from the higher layer entity with specific bits it generates, and reorganize the multiplexed stream into a parallel format according to Tables 1/G.765 and 3/G.765.

The serial-to-parallel converter has two modes of operation: the HDLC mode of operation and the idle mode of operation. The high layer entity determines the mode of operation of the serial-to-parallel converter, as described in § 8.6.3. The procedures used in each mode depends on the speed, as described below.

8.6.4.1 *Procedures of bit rates below 56 kbit/s*

1) In the HDLC mode, the serial-to-parallel converter shall put the incoming serial bits in the bit positions 2 through 7 of each octet that it shall form. In each octet, it shall set the values of bits 1 and 8 to 1. Bit 1 is the first bit of an octet to be transmitted on the channel-oriented side, and bit 8 is the last bit to be transmitted. Arithmetically, bit 1 is the most significant bit of an octet on the channel-oriented side, while bit 8 is the least significant bit. As explained in § 7.3.7, in some national applications, the first bit of an octet on the channel-oriented side is called the "subrate framing bit", while the last bit is called the "control bit". The nomenclature of the number of the bits of the channel-oriented pattern is as shown in Tables 1/G.765 and 3/G.765.

   The serial-to-parallel converter shall transmit CMAX consecutive copies of each octet that it forms.

2) In the IDLE mode of operation, the serial-to-parallel converter shall fill the remaining position of the current octet, if any, with ones. It shall then retrieve the octet representing the idle pattern that corresponds to the value stored in the system variable IBT_LAST, using Table 1/G.765, and send it to the channel-oriented side.

   The serial-to-parallel converter shall transmit CMAX consecutive copies of each octet that it forms.

8.6.4.2 *Procedures at 56 kbit/s*

1) In the HDLC mode, the serial-to-parallel converter shall put the incoming serial bits in the bit positions 1 through 7 of each octet that it shall form. In each octet, it shall set the values of bit 8 to 1. Bit 8 is the first bit of an octet to be transmitted on the channel-oriented side. Arithmetically, bit 8 is the least significant bit of an octet on the channel-oriented side. As explained in § 7.3.7, in some national applications, the last bit of an octet on the channel-oriented side is called the "control bit". The nomenclature of the number of the bits of the channel-oriented pattern is as shown in Tables 1/G.765 and 3/G.765.

2) In the IDLE mode of operation, the serial-to-parallel converter shall fill the remaining position of the current octet, if any, with ones. It shall then retrieve the octet representing the idle pattern that corresponds to the value stored in the system variable IBT_LAST, using Table 1/G.765, and send it to the channel-oriented side.

   For 56-kbit/s operation, the serial-to-parallel converter shall transmit one copy of each octet that it forms.

8.6.4.3 *Procedures at 64 kbit/s*

1) In the HDLC mode, the serial-to-parallel converter shall put the incoming serial bits in the bit positions 1 through 8 of each octet that it shall form. Bit 1 is the first bit of an octet to be transmitted on the channel-oriented side, and bit 8 is the last bit to be transmitted. Arithmetically, bit 1 is the most significant bit of an octet on the channel-oriented side, while bit 8 is the least significant bit. The nomenclature of the number of the bits of the channel-oriented pattern is as shown in Tables 1/G.765 and 3/G.765.

2) In the IDLE mode of operation, the serial-to-parallel converter shall fill the remaining position of the current octet, if any, with ones. It shall then retrieve the octet representing the idle pattern that corresponds to the value stored in the system variable IBT_LAST, using Table 1/G.765, and send it to the channel-oriented side.

   For 64-kbit/s operation, the serial-to-parallel converter shall transmit one copy of each octet that it forms.

8.7 *System variables*

8.7.1 *IBT_IDLE*

At the originating endpoint, the IBT_IDLE system variable corresponds to the most recent idle code that has caused the idle latency counter IDLE_LAT_CNT of the originating endpoint to reach one of the two thresholds, IDLE_LAT_MAX or VDLC_IDLE_MAX. The initial value of IBT_IDLE is 1111 (15 decimal).

8.7.2 *IBT_LAST*

At the terminating endpoint, IBT_LAST stores the value of the IBT in the last received packet. The initial value of IBT_LAST is 1111 (15 decimal).

8.7.3 *Send sequence state variable*

See § 7.1 in Recommendation G.764.

8.7.4 *Receive sequence state variable*

See § 7.2 of Recommendation G.764.

8.7.5 *T_IDLE*

Same as § 7.7.5 for DICE.

8.7.6 *TVDELAY*

Same as § 7.7.6 for DICE.

8.8 *Protocol parameters*

8.8.1 *Build-out delay*

See § 8.1 in Recommendation G.764.

8.8.2 *CMAX*

CMAX is the number of duplicate copies of the subrate user traffic. Its value is 1 for 56 kbit/s, 5 for 9600 bit/s, 10 for 4800 bit/s, and 20 for 2400 bit/s.

8.8.3 *FLAG_MAX*

FLAG_MAX is the maximum size of a VDLC flag packet.

8.8.4 *FLAG_MIN*

FLAG_MIN is the number of HDLC flags that must be played on the channel-oriented side instead of a lost packet. The value of FLAG_MIN may be set to 1, 2, 16 or 32. The default value is 1. It is recommended that FLAG_MIN = FLAG_MAX.

8.8.5 *IDLE_LAT_MAX*

IDLE_LAT_MAX is the maximum number of times the same idle octet must be received consecutively on the channel-oriented side before the IBT_IDLE system variable can be changed. Its default value is 2.

8.8.6 *VDLC_IDLE_MAX*

VDLC_IDLE_MAX is the maximum number of times that the same idle octet must be received consecutively on the channel-oriented side before the high layer entity moves to the IDLE state. The value of VDLC_IDLE_MAX is set to 8.

8.8.7 *VMAX*

VMAX defines the maximum number of octets that shall be collected from the channel-oriented side to form a VDLC frame. The value of VMAX is determined by service administration, and shall be less than or equal to 482 octets.

8.9 *Summary of primitives*

8.9.1 *Primitives for the interfaces between layers 2 and 3*

The primitives for the interfaces between layers 2 and 3 have the same definition as in § 9 of Recommendation G.764 and § 7.9.1 for DICE.

8.9.1.1 *DI-LI-READY indication*

See § 9.1.1 of Recommendation G.764.

8.9.1.2 *DL-UNIT-DATA request*

See § 9.1.2 of Recommendation G.764.

8.9.1.3 *DL-UNIT-DATA indication*

See § 9.1.3 of Recommendation G.764.

8.9.1.4 *DL-UNIT-H-DATA request*

See § 9.1.4 of Recommendation G.764.

8.9.1.5 *DL-UNIT-H-DATA indication*

See § 9.1.5 of Recommendation G.764.

8.9.1.6 *DL-PVP-H-DATA indication*

See § 9.1.6 of Recommendation G.764.

8.9.1.7 *DL-PVP-DATA indication*

See § 9.1.7 of Recommendation G.764.

8.9.1.8 *DL-PVP-H-DATA request*

See § 9.1.8 of Recommendation G.764.

8.9.1.9 *DL-PVP-DATA request*

See § 9.1.9 of Recommendation G.764.

8.9.2 *Primitives for the interface between layer 3 and the higher level entity*

8.9.2.1 *PL-VDLC-DATA indication*

The PL-VDLC-DATA indication primitive is used by the packet layer of the terminating endpoint to indicate to the high layer entity the arrival of VDLC information packet.

8.9.2.2 *PL-VDLC-DATA request*

The PL-VDLC-DATA request primitive is used by the high layer entity of the terminating endpoint to request data from the layer 3 entity.

8.9.2.3 *PL-VDLC-DATA request (SSEQ, IBT, EQ)*

The PL-VDLC-DATA request (SSEQ, IBT, EQ) primitive is used by the originating endpoint high layer entity to indicate to the layer 3 entity to transmit VDLC information packets with the corresponding values of IBT and EQ and with the sequence number SEQ = SSEQ. The value of C is set to 0 in the packet.

8.9.2.4 *PL-VDLC-FLAGS indication*

The PL-VDLC-FLAGS indication primitive indicates to the high layer entity of the terminating endpoint to play FLAG_MIN HDLC flags to replace a lost packet.

8.9.2.5 *PL-VDLC-FLAG request (SSEQ)*

The PL-VDLC-FLAG request (SSEQ) primitive is used by the originating endpoint high layer entity to indicate to the layer 3 entity to transmit VDLC flag packets with the sequence number SEQ = SSEQ. The layer 3 entity sets IBT to 0010 and EQ to 0 and C to 0.

8.9.2.6 *PL-VDLC-IDLE indication (IBT)*

The PL-VDLC-IDLE indication (IBT) primitive is used by the packet layer of the terminating endpoint to indicate to the high layer entity the arrival of VDLC update packet with the IBT value indicated in the primitive.

8.9.2.7 *PL-VDLC-IDLE request (IBT)*

The PL-VDLC-IDLE request (IBT) primitive is used to update the idle code that the far end should play at the channel-oriented side. The value of the IBT corresponds to the value of the IBT_IDLE system variable.

8.9.2.8 *PL-VDLC-ONE-FLAG indication*

The PL-VDLC-ONE-FLAG indication primitive indicates to the high layer entity of the originating endpoint to play one HDLC flag to replace a lost packet.

9 Interface with LAPD

If the digital data protocol is native LAPD, then the LAPD frame relay option can be used. For primary rate applications that require code restrictions to maintain one's density, bit inversion is necessary so that bit stuffing and bit inversion prevent the all 0 octet and satisfy the one's density requirements of restricted transmission facilities.

10 Interface with V.120

Recommendation V.120 may be used to rate adapt and submultiplex lower speed data into higher speed data. Two situations may apply:

1) the digital data on a channel-oriented circuit may be formatted using a synchronous HDLC-like protocol;

2) the digital data may be asynchronous.

10.1 *V.120 frame format*

The Recommendation V.120 specifies the packetization of data into LAPD-like frames. It includes three modes of operation:

1) an asynchronous mode;

2) a synchronous mode, which envelopes HDLC frames and achieves data compression by removing redundant flags that would normally be transmitted on fixed sub-rate circuits to fill the time between frames;

3) a bit-transparent mode.

In frame relay networks, Recommendation V.120 restricts the modes to the asynchronous and the synchronous modes.

The V.120 frame format is similar to the layer 2 frame format specified in Recommendation G.764. It consists of an HDLC flag, address octets (default is 2), control octets (HDLC format), optional V.120 header octets to communicate terminal status and controls, information octets, frame check sequence (FCS) octets and a HDLC flag.

In the asynchronous mode, no segmentation capability is provided for, therefore, octet 3 of the V.120 frame will have the form:

X	X	X	X	X	X	1	1

X = 1 or 0

In this case, therefore, this pattern will be different from the PD of PVP.

In the synchronous mode, a segmentation capability is provided and the segmentation bits (bits 1 and 2) may be either 0 or 1. Bit 1 is set to 1 to indicate that the frame contains the final portion of the message. Bit 2 is set to 1 to indicate that the frame is the first one in a series of messages. Both are set for a message corresponding to a single frame.

Bits 3 and 4 are used for error indication. Both are set to 1 when the data terminal equipment overruns the V.120 terminal adaptor. Therefore, octet 3 takes the following form:

X	X	X	X	1	1	X	X

X = 1 or 0

Bit 3 is set to 1 when the message is aborted. Also, bit 1 is set to 1 to indicate the end of segmentation. Accordingly, octet 3 becomes:

X	X	X	X	0	1	0	1

X = 1 or 0

In either case, the V.120 header does not coincide with the PVP protocol discriminator.

10.1.1 *V.120 asynchronous mode operation*

The PCME shall implement a V.120 synchronous mode operation, as defined in Recommendation V.120, § 3.3.1, for use in asynchronous applications.

10.2 *V.120 synchronous mode operation*

The PCME shall implement V.120 synchronous mode operation, as defined in Recommendation V.120, § 3.4.1, for use when service administration indicates that the data is formatted using HDLC protocols, in inverted polarity. The logical addresses for V.120 shall be established by service administration, and the V.120 signalling frames and procedures shall not be used.

10.3 *V.42 and V.42 bis*

The use of V.42 and V.42 *bis* for error control data compression is for further study.

11 Signalling transport

11.1 *General*

The following sections address the transport of signalling information arriving at the channel-oriented side of a PCME node on 1544 kbit/s and 2048 kbit/s primary multiplex rate systems. The two types of signalling information addressed are:

1) channel-associated signalling;

2) common channel signalling.

Refer to § 3 of Recommendation G.704 regarding the signalling methods for the 1544 kbit/s interface and to § 5 of Recommendation G.704 regarding the signalling methods for 2048 kbit/s interfaces.

Signalling information arriving in designated signalling channels shall be packetized and transported over a packet connection separate from that of packetized speech or voiceband data in accord with § 4 of Recommendation G.764. Signalling tones in voice channels that arrive at PCM sampled tones shall be packetized and transported over a packet connection as packetized voiceband signals. (See § 11.2.1.)

11.2 *Channel-associated signalling*

The PCME shall support the transport of channel-associated signalling. By service administration, a voice circuit shall be identifiable as having 2-state (A), 4-state (AB), or 16-state (ABCD) in-band signalling, or non of these. When signals are transported as PCM sampled analogue signalling tones, they should be transported in voiceband signal packets. Originating endpoint PCME nodes shall transport signalling information arriving on the channel-oriented side according to either the 1544 kbit/s or the 2048 kbit/s primary multiplex rate.

11.2.1 *PCM sampled analogue signalling tones*

In systems in which signalling information is transferred as a 64 kbit/s PCM sampled analogue tone, the originating endpoint PCME node shall interpret the PCM signal arriving on its channel-oriented side as a voiceband signal, which it shall packetize using UIH voice frames, as defined in § 3.3.1 of Recommendation G.764. It shall then transmit those frames to the terminating endpoint PCME node, which shall transfer the data from the voice frames to its channel-oriented side, in accordance with Recommendation G.764.

11.2.2 *2-, 4-, and 16-state channel-associated signalling*

Signalling information in the form of 2-, 4-, or 16-state channel-associated signalling on the channel-oriented side of a PCME node shall be transported on the packetized side using UI signalling frames, as specified in § 3.3.2 of Recommendation G.764. The signalling packets shall be carried via a logical address different from the logical address for speech or voiceband data. The system parameters required to control the transport of this signalling information are TSIG_REF and TSIG_KA, which are defined in § 8 of Recommendation G.764.

When an originating or terminating endpoint node is provisioned, signalling bits on the channel-oriented side unused by a signalling system should be mapped to specific values, as noted in Recommendation G.704.

11.2.2.1 *1544 kbit/s signalling*

For the 1544 kbit/s primary multiplex rate described in Recommendation G.733, either a 12-frame or 24-frame multiframe format is present on the channel-oriented side. The allocation of signalling bits for the channel-oriented side is described in § 3.1 of Recommendation G.704.

For 2-state signalling, the A-bit shall be mapped directly to the A-bit field of the G.764 signalling frame. The B-bit, C- and D-bits of the G.764 signalling packet shall be mapped to that B =€A, C = A and D = B. Signalling frames on the packet side of the originating endpoint shall be generated only when transitions of the A-bit occur on the channel-oriented side of the originating endpoint, or when TSIG_REF expires. The terminating endpoint node shall pass the A-bit only from the packet side to the channel-oriented side interface. The B-, C- and D-bits shall be ignored. They shall not be used for testing or maintenance purposes.

For 4-state signalling, the PCME originating endpoint shall accept the A- and B-bits, and shall map them into the A- and B-bit fields in the UI signalling frame, as specified in G.764. The unused C and D bits on the channel-oriented side shall be ignored. The C and D bit fields in the signalling frame should be set with C = A and D = B. Transition of either the A- or B-bit on the channel-oriented side, or the expiration of TSIG_REF, shall cause a signalling frame to be generated on the packet side of the originating endpoint. The terminating endpoint node shall pass the A- and B-bits only to the channel-oriented side interface.

For 16-state signalling, the originating endpoint node shall map the channel-oriented side ABCD bits directly to the ABCD bit field of the signalling frame. Transition of any one or more of the ABCD bits on the channel-oriented side of the originating endpoint, or expiration of TSIG_REF, shall cause a G.764 signalling frame to be generated. The terminating endpoint node shall pass the ABCD bit field from the signalling frame to the terminating endpoint channel-oriented side directly.

11.2.2.2 *2048 kbit/s signalling*

The 2048 kbit/s primary multiplex rate, described in Recommendation G.732, supports channel-associated signalling as specified in Recommendation G.704. The arrangement of the 64 kbit/s channel time slot 16 provides signalling channels designated *a*, *b*, *c* and *d*.

When 2-state signalling is used, only transitions of the *a* bit on the channel-oriented side of the originating endpoint, or expiration of TSIG_REF, shall cause a G.764 signalling frame to be generated and *a* to be mapped to the A-bit field on the packet side. As per § 5.1.3.2.2 of Recommendation G.704, one option is to set the unused *b*, *c* and *d* signalling bits on the channel-oriented side to the values *b* = 1, *c* =€0, and *d* = 1. Therefore, the B, C and D bits of the G.764 signalling packet should be set to B = 1, C = 0, and D = 1. The user may specify other values as well, such as:

1) each bit is not changed;

2) each bit is set to 0;

3) each bit is set to 1;

4) each bit is inverted to ensure end-to-end signalling compatibility.

The terminating endpoint shall transfer the *a*-, *b*-, *c*- and *d*-bits from the packet side to the channel-oriented side. It is the user's responsibility to ensure end-to end signalling compatibility.

When 4-state signalling is used, transitions of either the *a*- or *b*-bit on the channel-oriented side of the originating endpoint, or expiration of TSIG_REF, shall generate G.764 signalling packets with A = *a* and B = *b*. As per G.704, one option is to map the C- and D-bit fields in the signalling frame to C = 0 and D = 1. The user may specify other values as above. The terminating endpoint shall transfer the *a*-, *b*-, *c*- and *d*-bits from the packet side to the channel-oriented side. The C- and D-bits shall be ignored. They shall not be used for testing or maintenance purposes.

For 16-state signalling, the originating endpoint node shall accept from the channel-oriented side and map to the signalling frame the *a*-bit to A, *b* to B, *c* to C, and *d* to D-bit field. When the full 16 states are provisioned, a change in state of the *a*-, *b*-, *c*- or *d*-bit on the channel-oriented side, or the expiration of TSIG_REF, shall generate a G.764 signalling frame on the packet side. The terminating endpoint shall transfer the *a*-, *b*-, *c*- and *d*-bits from the packet side to the channel-oriented side.

11.2.3 *Interface between 2-, 4-, and 16-state signalling*

When different signalling formats (2-, 4-, or 16-state signalling) in the same primary rate multiplex are provisioned on the channel-oriented sides of a PCME network, translation from one signalling format to the other shall be accomplished on the channel-oriented side of either endpoint so that the PCME network interfaces the same signalling format at both endpoints. The associations shall be set as indicated in §§ 11.2.2.1 and 11.2.2.2. It is the user's responsibility to ensure end-to-end signalling compatibility.

11.2.4 *Interface between 1544 kbit/s and 2048 kbit/s primary rate signalling systems*

In the case where 1544 kbit/s and 2048 kbit/s primary rate channel-associated signalling systems are connected via a PCME network, translation of signalling from one format to the other, including bit inversion, shall be accomplished at the channel-oriented side of the 2048 kbit/s interface. The associations shall be set as indicated in §§ 11.2.2.1 and 11.2.2.2. It is the user's responsibility to ensure end-to-end signalling compatibility.

11.2.5 *Trunk conditioning for channel-associated signalling*

In the presence of facility and maintenance alarms, the PCME node shall be able to recognize alarms affecting the channel-oriented and packet side of the originating and terminating endpoints. In national networks, the user may provision the trunk conditioning action to be taken for the affected channels on the channel-oriented side.

The procedures taken by a PCME node when a RED, YELLOW, alarm indication signal (AIS), or out of frame (OOF) alarm is established or cleared on the channel-oriented or packet side are described in § 6 of Recommendation G.764.

11.2.6 *Support of present channel-associated signalling systems*

11.2.6.1 *Signalling system R1*

The PCME network shall support the R1 signalling system defined in Recommendation Q.310. Signalling information includes line signalling for line or supervisory signals and register signalling for address signals, all of which are addressed in the following sections.

11.2.6.1.1 *2600 Hz line signalling*

When analogue circuits are cascaded with PCM systems, a 2600 Hz line signalling tone, as described in Recommendation Q.311, is coded and transferred in the PCM line system as a 64 kbit/s PCM sampled tone. This shall be carried in the PCME network as voiceband signals in the manner specified in § 11.2.1.

11.2.6.1.2 *PCM line signalling*

In digital PCM systems, R1 signalling provides for individual channel PCM line signalling in the 1544 kbit/s primary multiplex rate (see Recommendation Q.314). The PCM line signalling is provided in a 12-frame multiframe using 4-state signalling in which the same signalling information is sent on both the A and B signalling channels. The PCME network shall carry this signalling information in the manner specified for 4-state signalling in § 11.2.2.1.

11.2.6.1.3 *Register signalling*

Register signalling uses pulses of two-out-of-six multifrequency in-band tones, as specified in Recommendation Q.315. Appearing on PCM systems as PCM sampled tones, these pulses shall be transported over the PCME network in the manner specified in § 11.2.1.

11.2.6.2 *Signalling system R2*

Signalling system R2, defined in Recommendation Q.400, includes analogue and digital versions of line signalling, and interregister signalling for address signals. The PCME network shall support the transport of system R2 signalling information, as specified in the following sections.

11.2.6.2.1 *Line signalling – Analogue version*

The analogue version of line signalling (Recommendations Q.411, Q.412 and Q.414) uses a 3825 Hz out of band tone for signalling link-by-link. If not first converted to the digital version of line signalling, the 3825 Hz tone will arrive on the channel-oriented side of a PCME node as a 64 kbit/s PCM sampled tone. This tone shall be transported in the manner specified in § 11.2.1.

11.2.6.2.2 *Line signalling – Digital version*

The digital version of line signalling for system R2 is transmitted link-by-link using 4-state signalling (two signalling channels) in each direction, as described in Recommendation Q.421. The PCME network shall transport this signalling information in the manner specified for 4-state signalling in § 11.2.2.2.

11.2.6.2.3 *Interregister signalling*

System R2 interregister signalling is performed end-to-end (or by end-to-end sections) using multifrequency two-out-of-six in-band tones in a compelled signalling procedure. When a relatively long period may elapse between reception of the last digit and detection of the condition of the called subscriber's line, such as when a satellite link is included, fully compelled signalling may be suspended by using pulsed backward signals (see Recommendation Q.442). Appearing as PCM sampled tones on the channel-oriented side of a PCME node, these continuous or pulsed tones shall be transported in the manner of § 11.2.1.

11.2.6.3 *Signalling System No. 5*

Line signalling for Signalling System No. 5 (SS5) is accomplished link-by-link using 2400 Hz and 2600 Hz tones transmitted individually or in combination, as specified in Recommendations Q.140 and Q.141. Register signalling for SS5, specified in Recommendation Q.151, is accomplished link-by-link using *en bloc* multifrequency pulsed combinations of two-out-of-six in-band tones.

The PCME node shall support the transport of analogue SS5 signal tones as 64 kbit/s PCM sampled tones, as specified in § 11.2.1.

11.3 *Common channel signalling*

11.3.1 *Common channel signalling (out-of-band physical)*

Prevalent types of common channel signalling systems include Signalling System No. 6 (SS6) and Signalling System No. 7 (SS7).

11.3.1.1 *Common channel signalling for 1544 kbit/s primary multiplex rate*

As provided in Recommendation G.704, for both 24-frame and 12-frame multiframes, one octet time slot is used to provide common channel signalling at a rate of 64 kbit/s. In the case of a 12-frame multiframe, the S-bits (the first bit of even numbered frames) may be arranged to carry common channel signalling at a rate of 4 kbit/s or a submultiple of this rate. These channels are capable of transporting SS6 information. SS7 is optimized for 56 kbit/s or 64 kbit/s digital channels, but is also suitable for operation at lower speeds.

11.3.1.2 *Common channel signalling for 2048 kbit/s primary multiplex rate*

As provided in Recommendation G.704, channel time slot 16 may be used for common channel signalling up to a rate of 64 kbit/s to transport both SS6 and SS7. The method of obtaining signal alignment will form part of the particular common channel signalling specification.

11.3.1.3 *Interface for signalling between 1544 kbit/s and 2048 kbit/s primary rates*

A PCME network transporting common channel signalling information between 1544 kbit/s and 2048 kbit/s primary multiplex rate systems shall carry that information transparently on the packet stream. Details are for further study.

11.3.1.4 *Support of present common channel signalling systems*

11.3.1.4.1 *Signalling System No. 6 (SS6)*

The transport of SS6 is left for further study.

11.3.1.4.2 *Signalling System No. 7 (SS7)*

SS7 is optimized for operation on 56 or 64 kbit/s channels. It is suitable for use on point-to-point links and provides error detection and correction for each individual signalling link.

A network of PCMEs shall support transport of the SS7 signal units that are carried on the signalling links comprising of SS7 network.

Signal units arrive on the channel-oriented side of the PCME endpoint in the basic formats given in § 2 of Recommendation Q.703. Each signal unit uses opening and closing HDLC flags consisting of single octets with the bit pattern 01111110. The originating endpoint of the SS7 signalling link uses HDLC bit stuffing procedures to preclude imitation of the flag code.

SS7 signal units arriving at the channel-oriented side of an originating endpoint shall be transported on the packet side using the VDLC frame format and procedures given in § 8.

The maximum length of a SS7 signalling unit is 280 octets in North America (§ 4, Chapter T1.111.3 of ANSI T1.111-1988) and 70 octets for international networks (§ 4 of Recommendation Q.703). These lengths are well within the maximum length requirement of a G.764 information field. If it is desired that SS7 signal units be transported entirely within single VDLC frames, the maximum length VMAX of the VDLC frame information field shall be provisioned large enough to accommodate the appropriate maximum SS7 signal unit lengths. In this case the EQ bit (bit 4 of octet 8) and the M-bit (bit 8 of octet 7) shall be set to 0.

For the purpose of congestion control, SS7 traffic is categorized as administrative traffic. VDLC frames transporting such traffic over the PCME network shall be so marked using the logical address assignment. See § 11.6 for congestion control procedures.

11.3.2 *Common channel signalling (out-of-band logical)*

For further study.

11.4 *International reserved signalling bits*

The use of international reserved signalling bits (S_i bits in Table 1a/G.704) is to be defined.

11.5 *National reserved signalling bits*

The use of the spare bits reserved for national use (S_n bits in Table 1a/G.704) is to be defined.

11.6 *Procedures*

The procedures to convey per-call requests and dynamic load control are to be defined.

12 Facsimile demodulation and compression protocol

The facsimile demodulation and compression protocol (FADCOMP) describes procedures to compress group (G3) facsimile traffic by PCME, Group 3 facsimile traffic includes two types of information transfer:

a) call control information; and

b) image data.

The call control information flows in both directions while the transfer of image data is unidirectional. The image data include the T.30 training check (TCF).

FADCOMP procedures specify that:

1) end-to-end capability indication procedures shall follow facsimile call set-up;

2) the handshake and call control information shall flow on a logical link provisioned for voice, following the procedures described in Recommendation G.764;

3) if the indication procedures show that both PCME endpoints are compatible, the originating (or demodulating) endpoint shall extract the baseband image signal and transmit it at its baseband rate. The terminating (or remodulating) endpoint shall regenerate the sampled voiceband signal of the image data.

4) if the indication procedures show that both ends are not compatible, the image traffic shall continue to proceed on the voice path.

The facsimile demodulation and compression protocol is a T.30 protocol analysis approach. It relies on a continuous analysis of the T.30 protocol exchanges from both directions to determine the call parameters, the demodulating and the remodulating sides, and to follow the progress of the facsimile call. As such, this protocol specification only supports facsimile equipment complying with specific T.30 group 3 (G3).

Figure 7/G.765 shows the various protocol layers and peer-to-peer entities involved with FADCOMP. The protocol uses the same physical and link layers as Recommendation G.764, and builds upon the packet layer of Recommendation G.764 using two new layers; the modulation layer and the call state layer.

While this Recommendation provides detailed procedures for V.29 and V.27 *ter* based facsimile calls, it does not preclude other modulation methods (e.g. V.17). Detailed procedures for these other methods are left for further study.

The organization of this Recommendation is as follows: §§ 12.1, 12.2 and 12.3 describe the formats of the physical, link and packet layers, in part by referring to the description of Recommendation G.764. Subsection 12.4 describes the call-state layer, whose operation is the same for both endpoints. Subsection 12.5 describes the protocol procedures at the originating (demodulating) endpoint. Subsection 12.6 describes the procedures at the intermediate nodes, while subsection 12.7 describes the procedures at the terminating (remodulating) endpoint. Subsection 12.8 summarizes the system variables and protocol parameters. Subsection 12.9 lists the interface primitives used in this protocol.

12.1 *Physical layer*

The physical layer is the same as for Recommendation G.764 (see § 3.1 of the same Recommendation).

12.2 *Link layer*

The link layer is the same as for Recommendation G.764. In particular, the address field is the same as described in § 3.2.1 of Recommendation G.764.

There are three types of facsimile frames:

1) facsimile capability indication frames;

2) facsimile spurt header frames; and

3) facsimile page information frames.

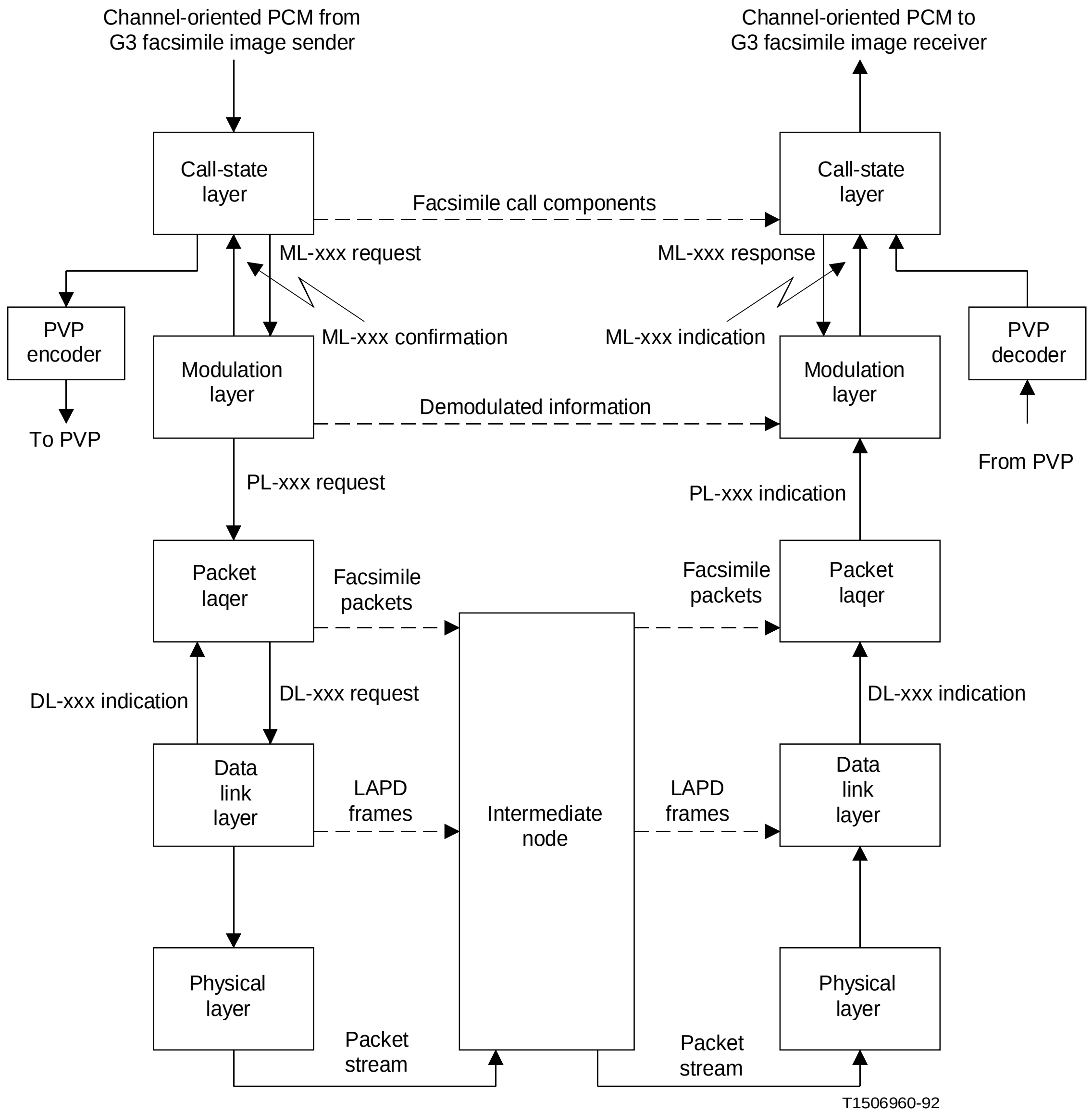


FIGURE 7/G.765

Facsimile protocol layer model

All frames flow on the same virtual circuit, which is the same virtual circuit used for the voiceband path that carries the G.764 frames of the permanent virtual connection. Figure 8/G.765 depicts the format of a facsimile capability indication frame, Figure 9/G.765 depicts the format of a facsimile spurt header frame, and Figure 10/G.765 describes the format of a facsimile page information frame. The facsimile capability indication and spurt header frames may be either a UI frame or a UIH frame. The facsimile page information is a UIH frame. The control field of the UI frame is described in Recommendation Q.921/I.441. The control field of the UIH frame is described in § 3.2.3.2 of Recommendation G.764.

12.3 *Packet layer*

The following fields are common to all packet types.

12.3.1 *Protocol discriminator (PD)*

Same as for Recommendation G.764 (see § 3.3.2.1 of the same Recommendation).

8	7	6	5	4	3	2	1	
Address (upper subfield)						0	0	Octet 1
Address (lower subfield)							1	Octet 2
Control field (UI or UIH)								Octet 3
Protocol discriminator								Octet 4
0	1	0	0	0	1	0	0	
Block dropping indicator (BDI)								Octet 5
R	R	0	0	R	R	0	0	
Time stamp (TS)								Octet 6
M	SC		DMC			Type		Octet 7
0	0	1	0	0	0	1	0	
Sequence number				EQ	BILO			Octet 8
0	0	0	0	1	0	0	0	
V.27		V.29		V.17				Octet 9
2.4	4.8	7.2	9.6	7.2	9.6	12	14.4	
V.33								Octet 10
12	14.4	R	R	R	R	R	R	
Check sequence 2 octets								

Reserved for future use and set to 0

FIGURE 8/G.765

Facsimile capability indication frame

12.3.2 *Block dropping indicator (BDI)*

Same as for DICE (see § 7.3.2 of this Recommendation).

12.3.3 *Time stamp (TS)*

Same as for DICE (see § 7.3.3 of this Recommendation).

8	7	6	5	4	3	2	1	
Address (upper subfield)						0	0	Octet 1
Address (lower subfield)							1	Octet 2
Control field (UI or UIH)								Octet 3
Protocol discriminator (PD)								Octet 4
0	1	0	0	0	1	0	0	
Block dropping indicator (BDI)								Octet 5
R	R	0	0	R	R	0	0	
Time stamp (TS)								Octet 6
M	SC		DMC			Type		Octet 7
0	0	1	0	0	0	0	0	
Sequence number				EQ	BILO			Octet 8
0	0	0	0	1	0	0	0	
Action				R	R	R	R	Octet 9
Check sequence 2 octets								

Reserved for future use and set to 0

FIGURE 9/G.765

Facsimile spurt header frame

12.3.4 *M-bit*

The M-bit is set to 0, except for page information packets. In this case, the M-bit is set to 1 for all page information packets, except for the last packet of a page spurt, where it is set to 0.

12.3.5 *Sub-class field (SC)*

The sub-class (SC) field is used to indicate that the packet is a digital modem packet. The SC field is coded as 01.

<table>
<tr><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th><th></th></tr>
<tr><td colspan="6">Address (upper subfield)</td><td>0</td><td>0</td><td>Octet 1</td></tr>
<tr><td colspan="7">Address (lower subfield)</td><td>1</td><td>Octet 2</td></tr>
<tr><td colspan="8">Control field (UIH)</td><td>Octet 3</td></tr>
<tr><td colspan="8">Protocol discriminator (PD)</td><td rowspan="2">Octet 4</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>0</td><td>1</td><td>0</td><td>0</td></tr>
<tr><td colspan="8">Block dropping indicator (BDI)</td><td rowspan="2">Octet 5</td></tr>
<tr><td>R</td><td>R</td><td>0</td><td>0</td><td>R</td><td>R</td><td>0</td><td>0</td></tr>
<tr><td colspan="8">Time stamp (TS)</td><td>Octet 6</td></tr>
<tr><td>M</td><td colspan="2">SC
0 1</td><td colspan="3">DMC
0 0 0</td><td colspan="2">Type
0 1</td><td>Octet 7</td></tr>
<tr><td colspan="4">Sequence number</td><td>EQ
1</td><td colspan="3">BILO</td><td>Octet 8</td></tr>
<tr><td colspan="8">Facsimile page information field</td><td></td></tr>
<tr><td colspan="8">Check sequence
2 octets</td><td></td></tr>
<tr><td colspan="8">Reserved for future use and set to 0</td><td></td></tr>
</table>

FIGURE 10/G.765

Facsimile page information frame format

12.3.6 *Digital modem class (DMC)*

The digital modem class (DMC) field indicates the type of digital modem used for digital modem packets (SC = 01). The codes indicated in Table 8/G.765 are currently used.

TABLE 8/G.765

Digital modem class field codes

Code	Meaning
000	Facsimile
001	Reserved for future use
010	Reserved for future use
011	Reserved for future use
100	Reserved for future use
101	Reserved for future use
110	Reserved for future use
111	Prohibited

Undefined codes are reserved for future use.

12.3.7 *Type*

The type field is used to identify the type of packet for a given digital modem class. For DMC = 000, the types indicated in Table 9/G.765 are used:

TABLE 9/G.765

Type field codes

Code	Meaning
00	Spurt header packet
01	Page information packet
10	Capability indication packet
11	Reserved for future use

As explained in § 12.3.11, the information field of the capability indication and of the spurt header frames (octet 9) contain information that is not available in the V.21 component of the group 3 facsimile call.

Page information frames contain demodulated facsimile page information.

12.3.8 *Sequence number*

Same as for DICE (se § 7.3.8).

12.3.9 *Delay equalization bit*

Same as for DICE (see § 7.3.9).

12.3.10 *Bits in last octet (BILO)*

This field indicates the valid number of bits in the last octet of a facsimile page information frame. For V.29 and V.27 *ter* modulation signals, the definition of its values are as per Table 10/G.765.

TABLE 10/G.765

BILO definitions for V.29 and V.27 *ter*

Code	Meaning
000	Information field has even number of symbols
100	Information field has odd number of symbols

For spurt header and capability indication frames, the BILO field is set to zero.

12.3.11 *Packet information field*

The information carried in the packet information field depends on the packet type, as indicated in the following subsections.

12.3.11.1 *Facsimile capability indication packets*

Referring to Figure 8/G.765, octets 9 and 10 of a facsimile capability indication packet contains the following fields.

12.3.11.1.1 *V.27*

Bits 8 and 7 of octet 9 make up the V.27 field. These bits are set to 1 to indicate that the V.27 *ter* modulation scheme is supported at 2.4 kbit/s and 4.8 kbit/s, respectively. Otherwise, they are set to 0.

12.3.11.1.2 *V.29*

Bits 6 and 5 of octet 9 make up the V.29 field. These bits are set to 1 to indicate that the V.29 modulation scheme is supported at 7.2 kbit/s and 9.6 kbit/s, respectively. Otherwise, they are set to 0.

12.3.11.1.3 *V.17*

Bits 4 through 1 of octet 9 make up the V.17 field. These bits are set to 1 to indicate that the V.17 modulation scheme is supported at 7.2 kbit/s, 9.6 kbit/s, 12 kbit/s, and 14.4 kbit/s, respectively. Otherwise, they are set to 0.

12.3.11.1.4 *V.33*

Bits 8 and 7 of octet 10 make up the V.33 field. These bits are set to 1 to indicate that the V.33 modulation scheme is supported at 12 kbit/s and 14.4 kbit/s, respectively. Otherwise, they are set to 0.

12.3.11.2 *Spurt header packets*

Referring to Figure 9/G.765, octet 9 of spurt header packets contains the following fields.

12.3.11.2.1 *Action*

This field contains the action that the terminating endpoint should perform when the facsimile spurt header packet arrives. See Table 11/G.765.

The exact response of some of the actions (e.g. generate training sequence) depends on the modulation method of the facsimile call. Modulation techniques other than V.29 and V.27 *ter* may require different actions. This issue is for further study. Undefined codes are reserved and are left for further study.

12.3.11.3 *Page information packets*

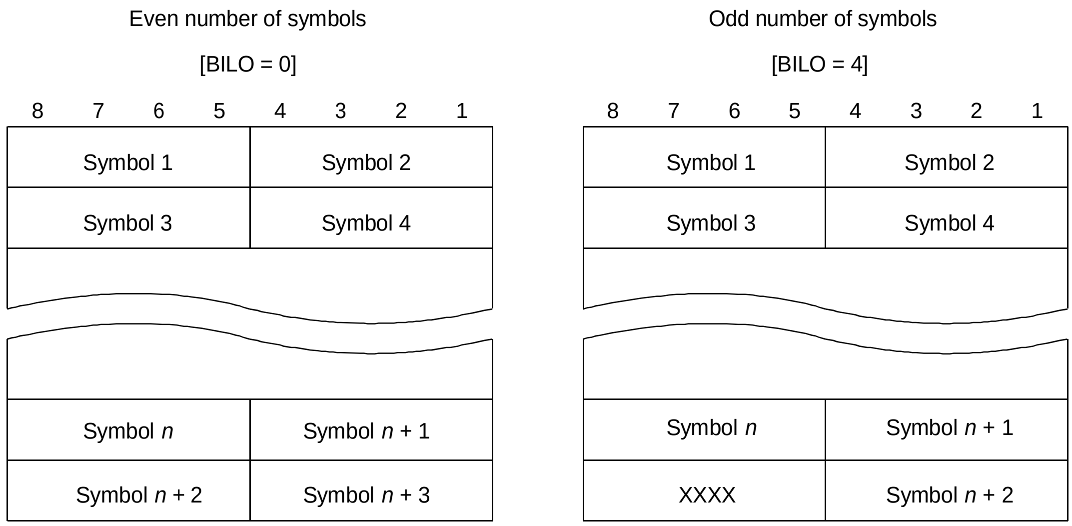
The format of page information packets is shown in Figure 10/G.765. In these packets, the facsimile page information field contains the demodulated information. The facsimile page information field shall not exceed 482 octets, as required by Recommendation G.764. The actual size depends on the modulation characteristics.

TABLE 11/G.765

Action field codes

Code	Meaning
0001	Generate a training sequence
0010	Abort
0011	Start generating a 1700 Hz echo protection tone (EPT)
0100	Start generating a 1800 Hz echo protection tone (EPT)
0101	Stop generating EPT tone
1111	Do nothing

Figure 11/G.765 shows the arrangement of the V.29 and V.27 *ter* symbols in the facsimile page information field.



Symbol definitions

Modulation method	Speed	Symbol format
V.29	9600 7200	Q4 Q3 Q2 Q1 0 Q4 Q3 Q2
V.27 *ter*	4800 2400	0 T3 T2 T1 0 0 D2 D1

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Note 1 – Q defined as per Recommendation V.29.

Note 2 – T defined as tribits as per Recommendation V.27 *ter*. T1 is the left column of Table 1/V.27 *ter*.

Note 3 – D defined as dibits as per Recommendation V.27 *ter*. D1 is the left column of Table 2/V.27 *ter*.

Note 4 – Q, T and D as shown after unscrambling.

Note 5 – X are “don't care”.

FIGURE 11/G.765

Information field for V.29 and V.27 *ter* demodulated packets

12.4 *Call state layer procedures*

The call state layer is the T.30 protocol messages to recognize the beginning of a facsimile call and determines the role of the endpoints for the call (transmitting/demodulating or receiving/remodulating). It also routes the PCM channel-oriented traffic to either the PVP path or the FADCOMP path, and selects the output of either the PVP procedure or FADCOMP remodulation to produce the PCM output. Thus, a single call-state layer connects to both the terminating and originating endpoints of a PCME node.

While each of the lower layers has distinct originating and terminating roles, the role of the call-state layer dynamically changes. Initially, the call-state layer is waiting for a facsimile call to arrive and its role is in the reset mode. At the very beginning of a facsimile call, the call-state layer does not know which endpoint will be the originating (demodulating) endpoint and which will be the terminating (remodulating) endpoint. Furthermore, the call-state layer may reverse its role later as the facsimile call progresses.

The service primitives exchanged with both the originating and terminating modulation layers are based on the role that the call-state layer plays. When the role of the call-state layer is reset, the call-state layer does not exchange primitives with either the originating or terminating modulation layers. Instead, PCM data is routed to and from PVP.

When the call-state layer has the role of a demodulator, it sends and receives primitives to/from the originating endpoint modulation layer, and receives facsimile capability primitives from the terminating endpoint modulation layer. Depending on the phase of the call, the information arriving from the channel-oriented side is sent to the packetized side either through the voice path or through the demodulation path. Information arriving from the packetized side is sent to the channel-oriented side via the voice path.

When the call-state layer has the role of a remodulator, it sends and receives primitives to/from the terminating endpoint modulation layer, and sends the facsimile capability primitives to the originating endpoint modulation layer. Information from the packetized side is sent to the channel-oriented side either via PVP or through the remodulator, depending on the state of the call. Information from the channel-oriented side is sent to the packetized side via PVP.

12.4.1 *Model of the call-state layer*

Figure 12/G.765, a block diagram model of the call-state layer, helps explain the above points. The following subsections describe the individual elements.

12.4.1.1 *DEMUX*

This block shall route the traffic arriving from the channel-oriented side to either the PVP coder input (PVP) or the modulation layer demodulator input (FADCOMP). This block also has capability to inhibit information transfer (OFF), thus providing echo suppression when the call-state layer is in the remodulation role. The control signal (PVP, FADCOMP, OFF) is the near-end path select variable generated by the state machine.

12.4.1.2 *MUX*

This block is responsible for selecting the appropriate source for information for the channel-oriented side, either the PVP decoder output (PVP) or the modulation layer modulator output (FADCOMP). The control signal (PVP, FADCOMP) is the far-end path select variable generated by the state machine.

It is required that MUX have a special fail-safe mechanism to handle the exception case where the terminating end is expecting to remodulate but the originating end is not demodulating. This mechanism is as follows: when the far-end path select is set to FADCOMP, and a PVP packet arrives (which is not normally expected), the resulting PVP decoder output is the source of the channel-oriented information.

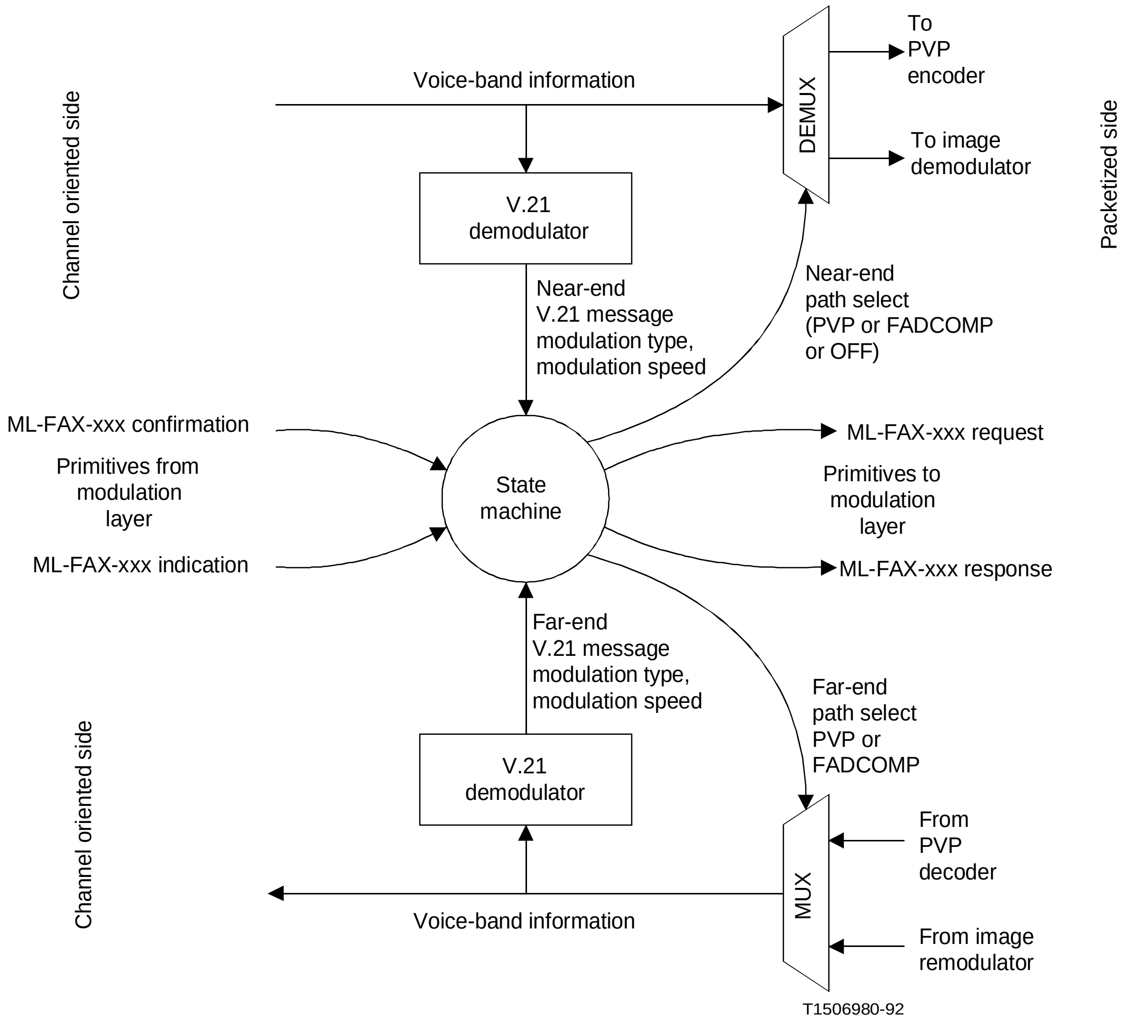


FIGURE 12/G.765

Call-state layer functional model

12.4.1.3 *V.21 demodulators*

There is one V.21 demodulator for each PCM direction, monitoring the PCM signal for that direction. Each V.21 demodulator is responsible for recognizing the presence of a V.21 modulated signal, extracting legal message frames, and extracting any modem speed and type information that is contained within the message frames. Part of the processing includes normal HDLC operations, such as bit-unstuffing and CRC-16 checking. If such operations yield invalid HDLC frames, the message is ignored. The type of message frame and any associated speed or type information is sent to the state machine. Only signalling with 300 bit/s modulation speed is supported. Facsimile calls with 2400 bit/s signalling shall be processed entirely via PVP.

Recommendation T.30 specifies messages that contain modem type and speed information. It is required that the V.21 demodulator extract speed and modem type information from these T.30 messages. However, facsimile calls between machines made by the same manufacturer may have this information embedded in the non-standard facilities T.30 messages. Currently, the extraction of modem speed and type from these non-standard facilities messages is not specified and is left for further study.

12.4.1.4 *State machine*

The state machine uses message types, modem type and speed indications, and primitives from the originating and terminating modulation layers to track the state of a facsimile call. It sets the near-end and far-end path select variables and issues primitives to the originating and terminating modulation layers. Subsection 12.4.2 contains an exact description of the state machine.

12.4.2 *Description of the state machine*

Figures 13/G.765 through 23/G.765 show the state transitions in the state machine in response to V.21 messages and primitives from the modulation layer. The state machine, as described in this section, assumes that both ends have identical resources and that the resources needed are always available. Recovery actions when the resources are not available or are not compatible are left for further study.

While *fax capability* primitives have been incorporated into the modulation layer and below, the details of the response of the state machine to these primitives are under study. The general flow is as follows: the remodulating PCME endpoint sends a capability indication frame to the demodulating endpoint after it sees a T.30 digital identification signal (DIS) V.21 frame. The demodulating PCME endpoint uses this information, knowledge of its own capabilities, and modulation type and speed information obtained from subsequent V.21 messages to determine whether to demodulate or send the page information through PVP. The fail-safe mechanism in DEMUX allows the remodulating PCME endpoint to properly transport the page information to the receiving facsimile equipment in either case.

As indicated in § 12.4.1.3, the V.21 demodulators will determine the modulation type and speed of all G3 standard-protocol facsimile calls, including Recommendations V.29, V.27 *ter*, V.33, and V.17. Currently, only Recommendations V.29 and V.27 *ter* are covered by this protocol. Other modulation types are left for further study and currently undemodulated.

In Figures 13/G.765 through 23/G.765, the following nomenclature should be observed in addition to the abbreviations listed in Annex A:

a) V.21 messages are noted by capitalized abbreviations, such as non-standard set-up (NSS) or digital transmit command (DTC).

b) V.21 messages prefixed by a hyphen are messages with the FINAL bit set and are therefore “final frames”. As defined in § 5.3.5 of Recommendation T.30, a final frame is the last frame transmitted prior to an expected response from the distant station. In the text itself, it is assumed that all V.21 messages are final frames, unless explicity stated.

c) V.21 messages are shown as coming from the near-end (channel-oriented side) or the far-end (packetized side).

d) For ease of reference, the state labels contain two parts:

   – a prefix “t” or “r”, representing a transmitting/demodulating or receiving/remodulating endpoint;

   – a state identifier consisting of a letter and a number, the letter identifies a state and the number defines a sub-state within that state.

The state machine is described in four parts:

1) global actions that occur in most states;

2) the initial state, which is common to both demodulating and remodulating endpoints (state a1);

3) a set of states that are followed by the demodulating (transmitting) endpoint (states t.a1 through t.g3);

4) a set of states that are followed by the remodulating (receiving) endpoint (states r.a1 through r.g3).

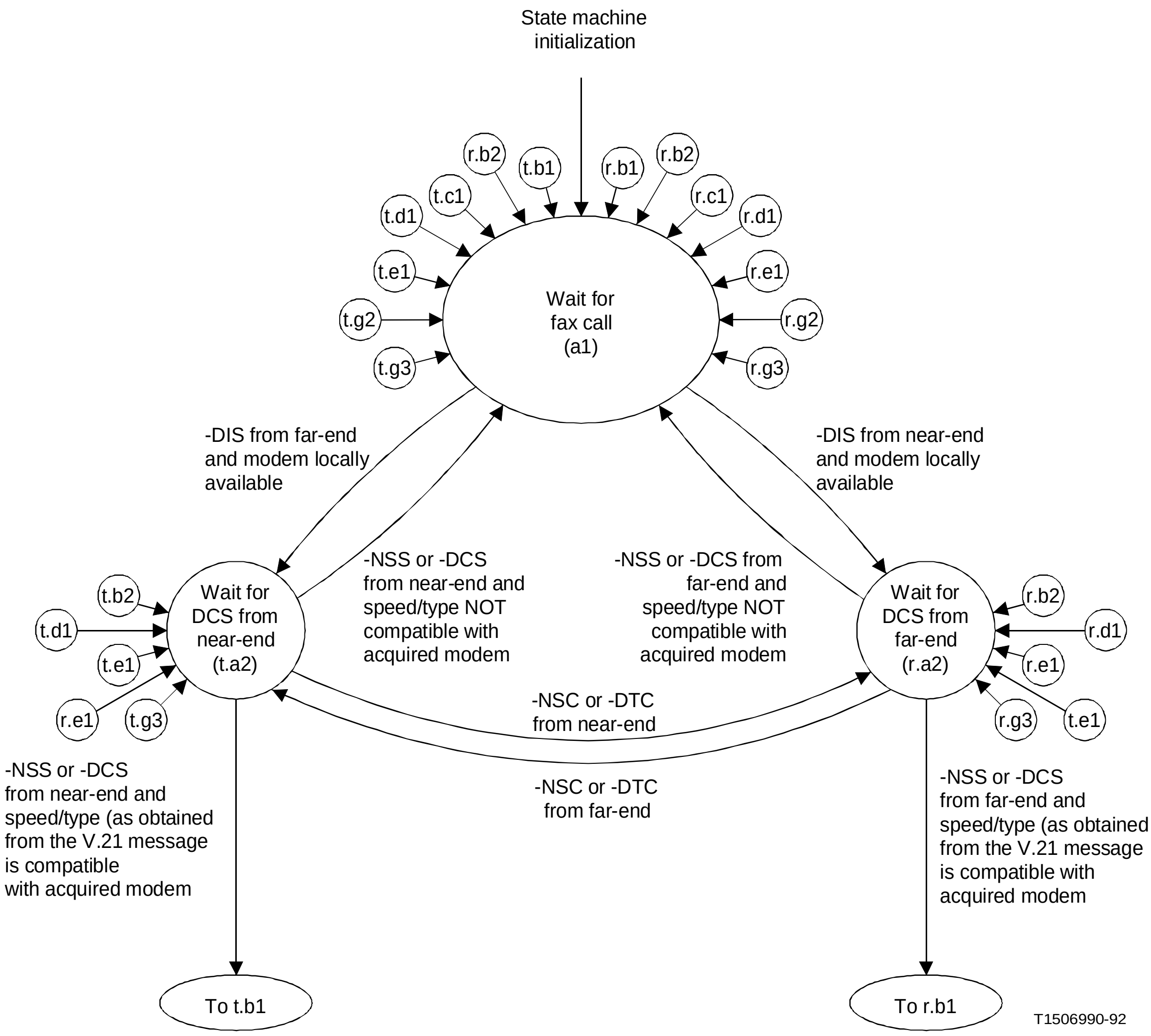


FIGURE 13/G.765

Call-state layer state machine (a)

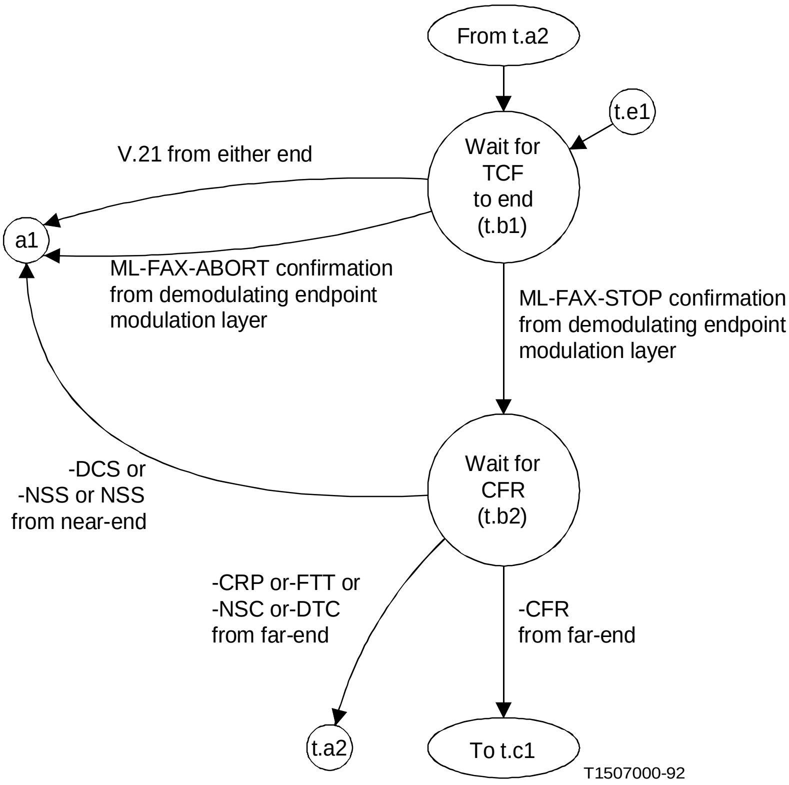


FIGURE 14/G.765

Call-state layer state machine (state t.b)

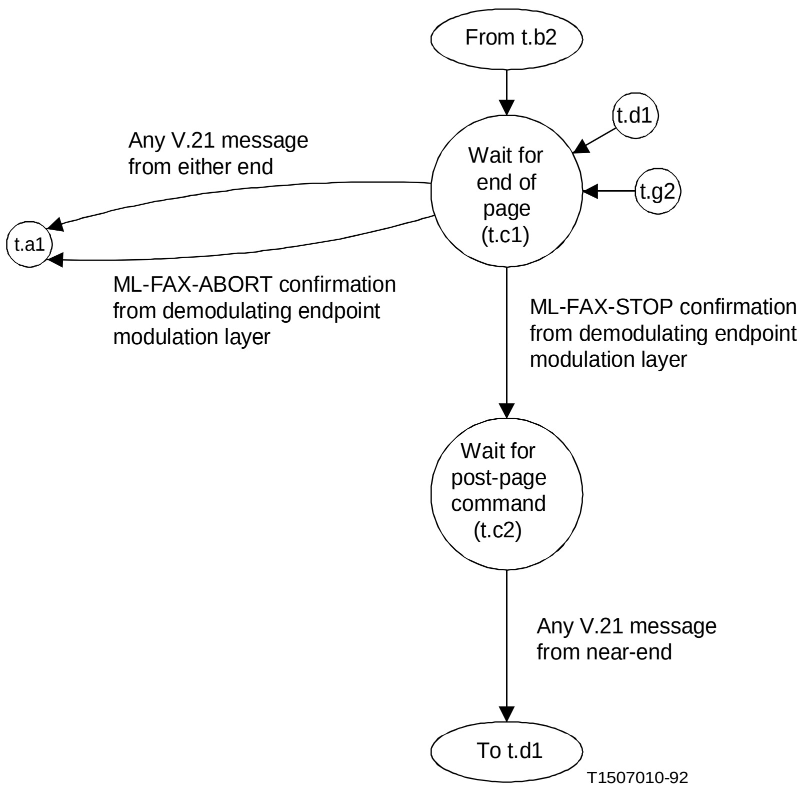


FIGURE 15/G.765

Call-state layer state machine (state t.c)

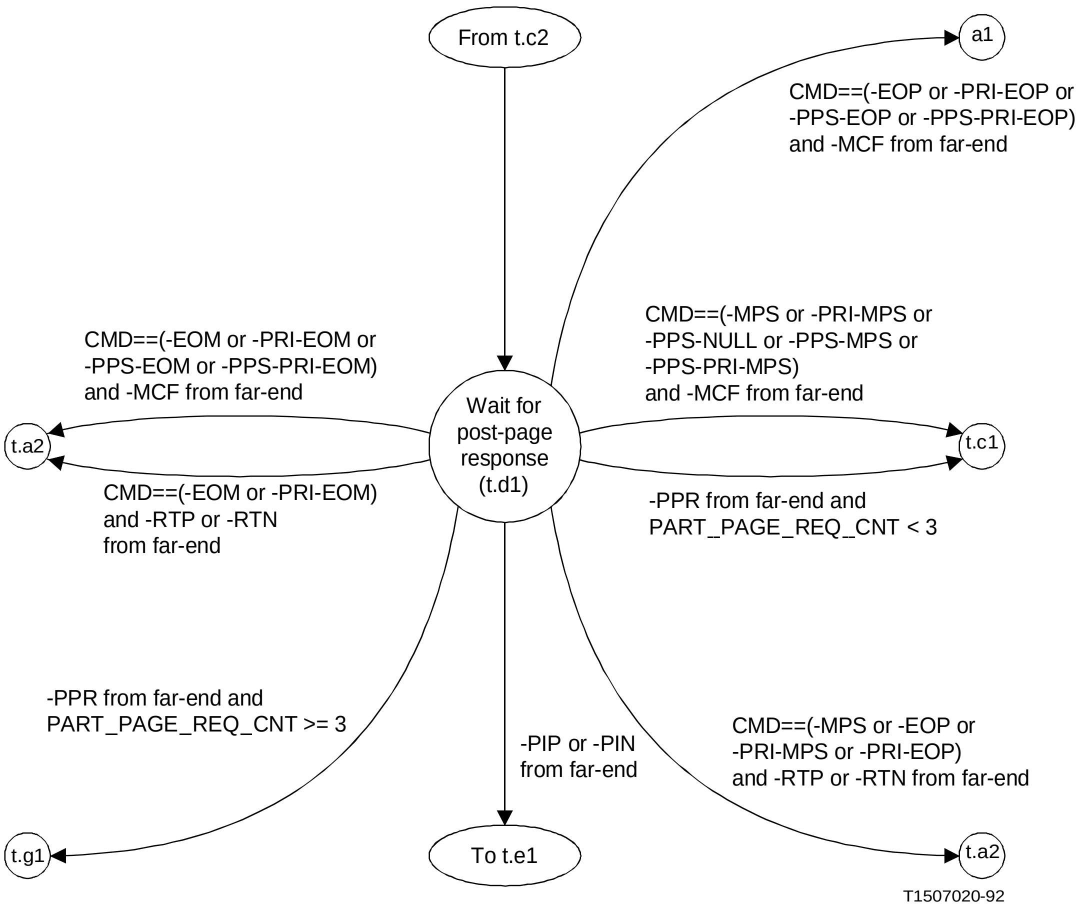


FIGURE 16/G.765

Call-state layer state machine (state t.d)

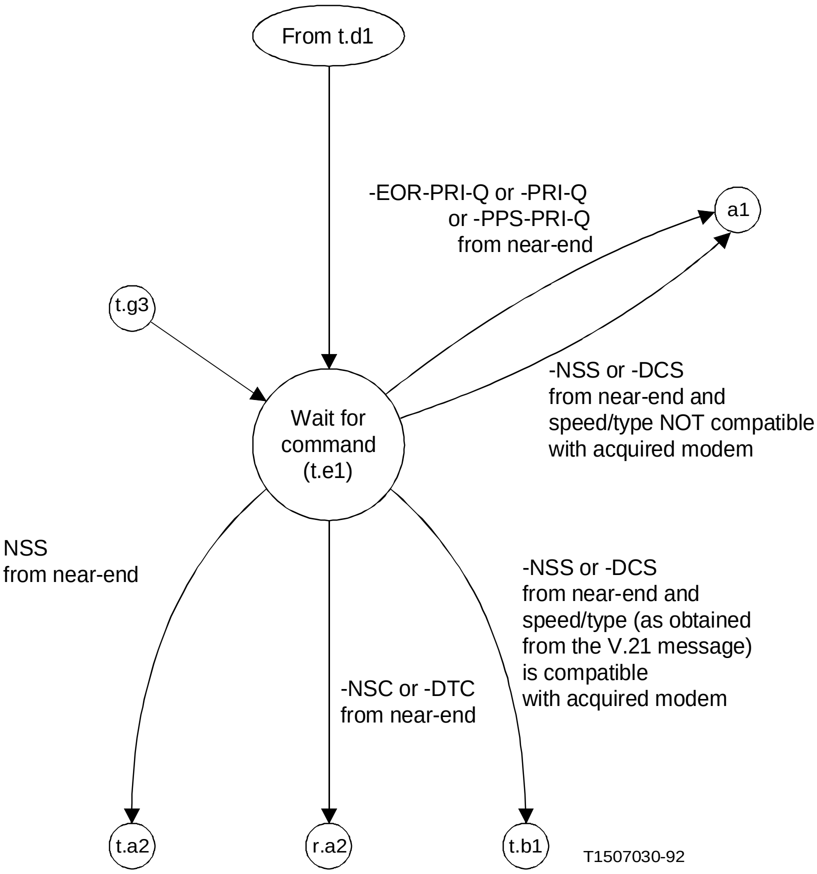


FIGURE 17/G.765

Call-state layer state machine (state t.e)

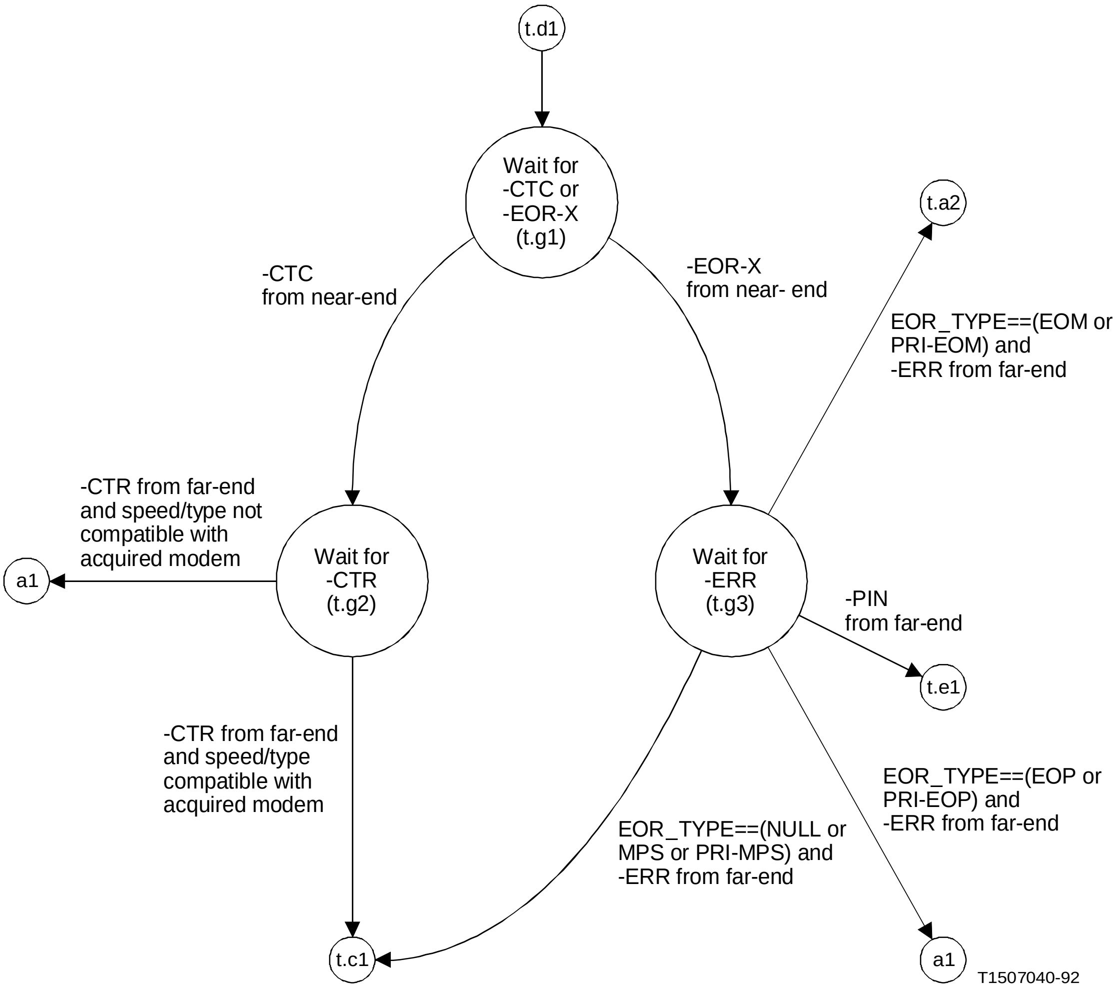


FIGURE 18/G.765

Call-state layer state machine (state t.g)

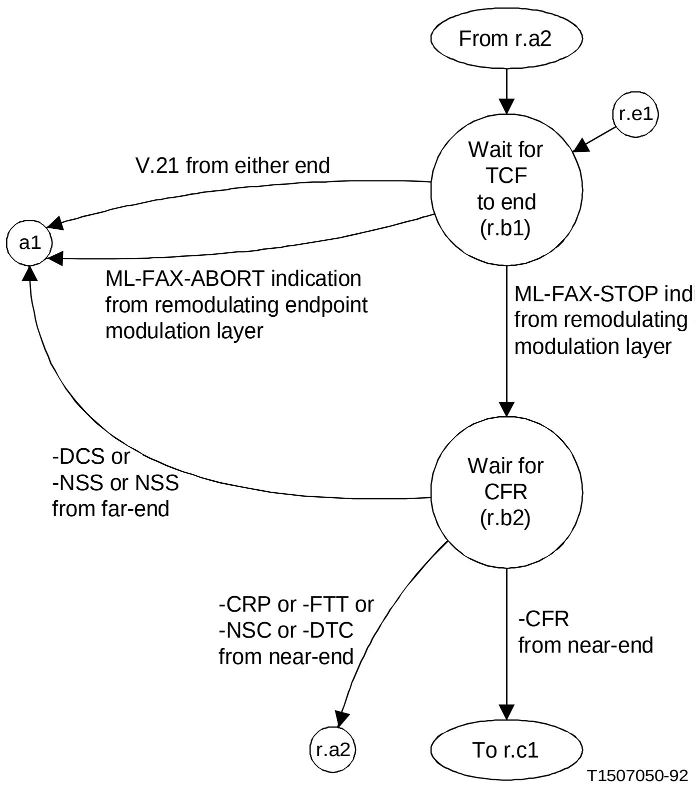


FIGURE 19/G.765

Call-state layer state machine (state r.b)

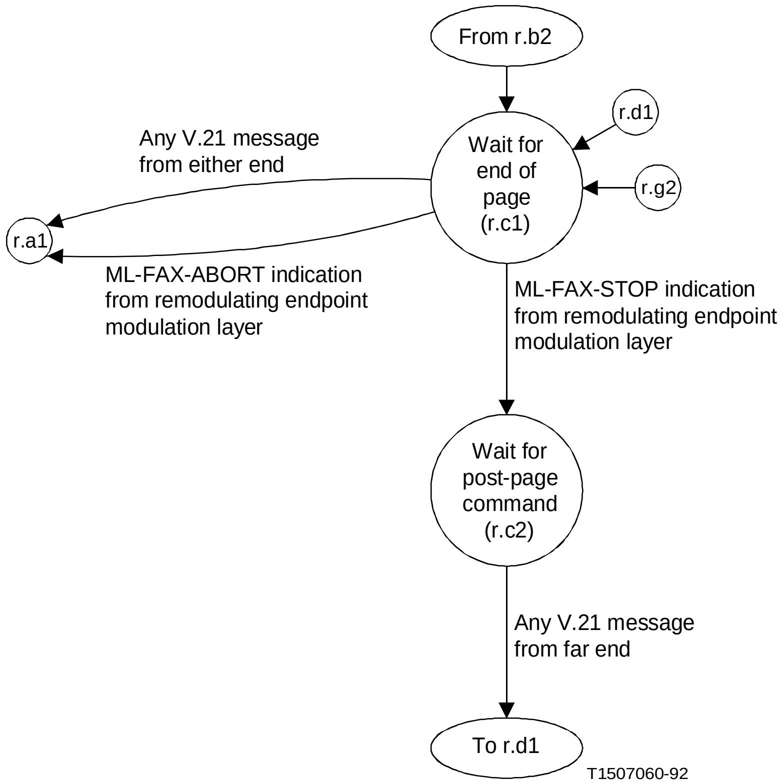


FIGURE 20/G.765

Call-state layer state machine (state r.c)

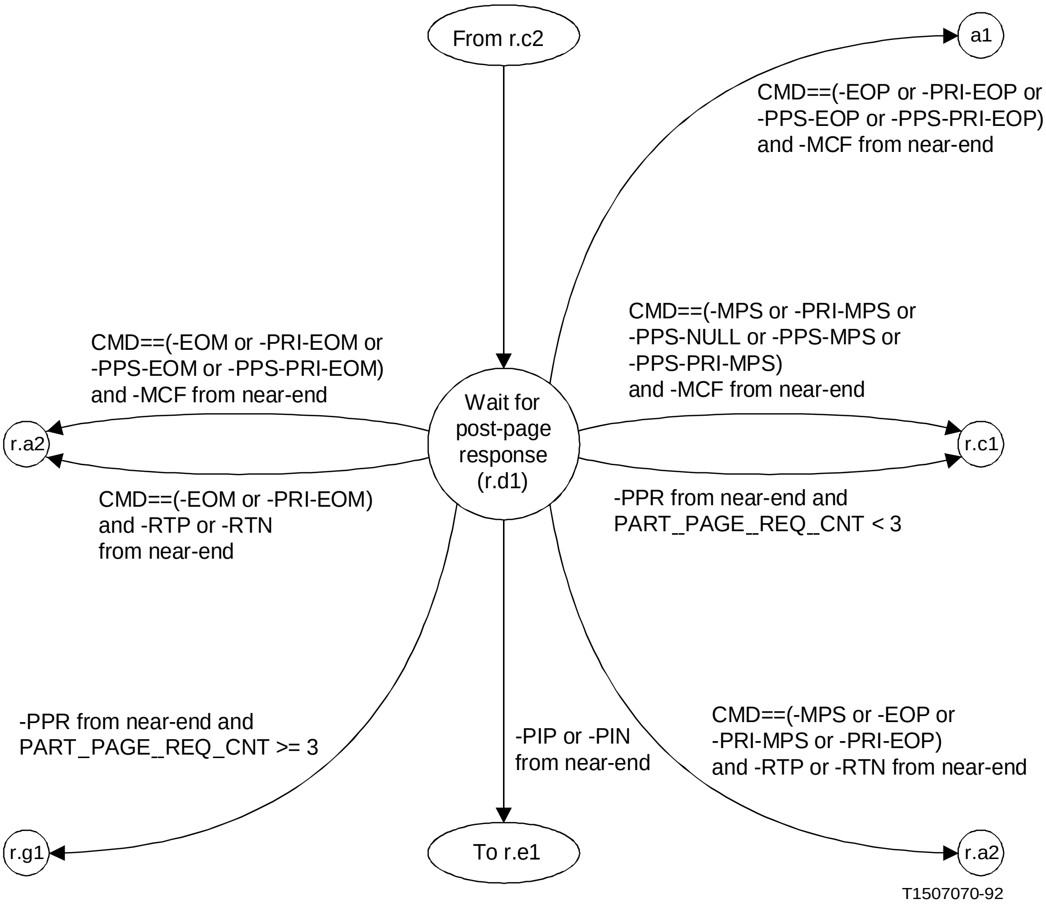


FIGURE 21/G.765

Call-state layer state machine (state r.d)

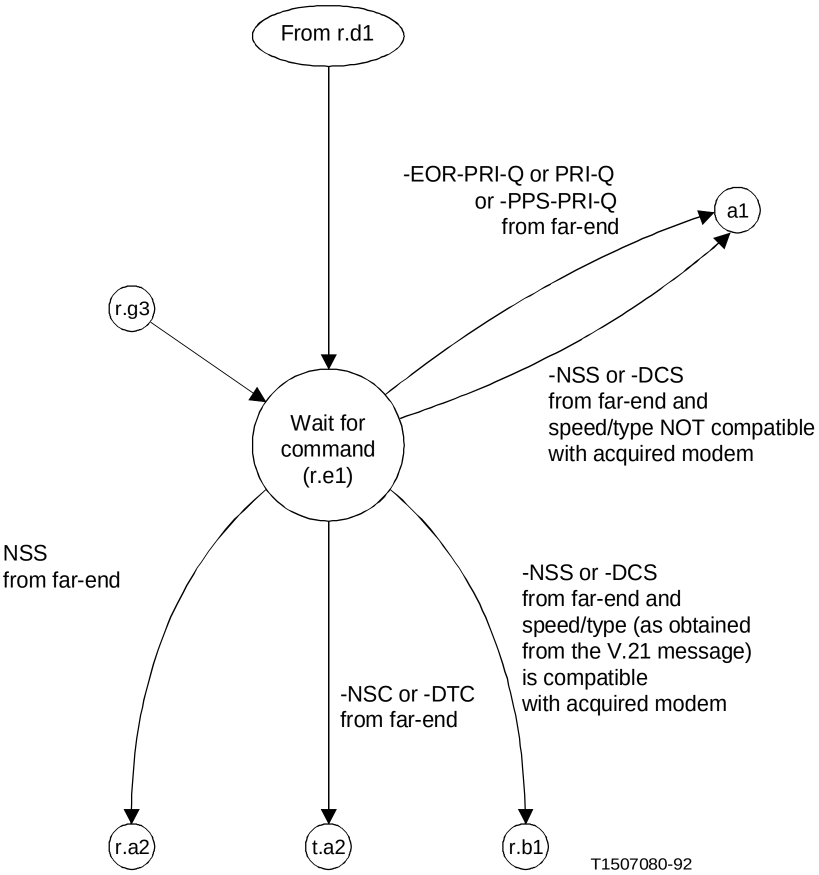


FIGURE 22/G.765
Call-state layer state machine (state r.e)

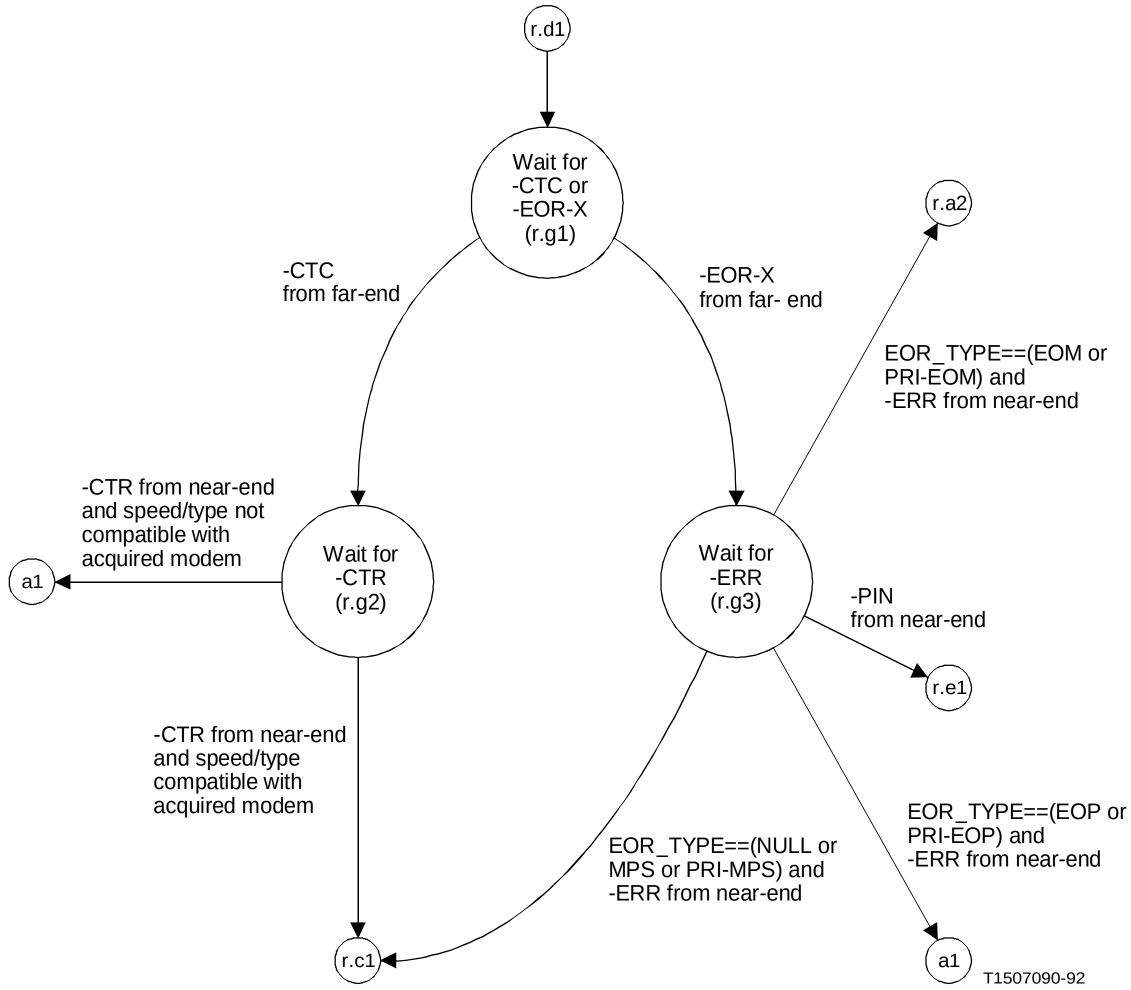


FIGURE 23/G.765
Call-state layer state machine (state r.g)

12.4.2.1 *Global actions*

All states, other than a1, t.b1, t.c1, r.b1, and r.c1, have an associated timer that is set when the state is entered. If a T.30 message is not received before the timer expires, the state machine shall release all resources and transition to the WAIT_FOR_FAX state (a1). This is a fail-safe mechanism; the value of the timer for each state is under study.

While in all states, other than a1, t.b1, t.c1, r.b1, and r.c1, if a final disconnect (DCN) or DIS T.30 message is received from either side, the state machine shall release all resources and transition to the WAIT_FOR_FAX call state (a1).

12.4.2.2 *Actions in the initial state*

In the initial state, WAIT_FOR_FAX (a1), both the multiplexer and demultiplexer are in the PVP position so that the traffic follows the rules specified in Recommendation G.764. The state machine shall observe the traffic to detect the presence of the T.30 digital identification signal (DIS). If this signal arrives, then:

1) If the signal arrives from the channel-oriented (near-end) side, the state machine shall check that the remodulating resources are available. If they are available, it allocates the necessary resources. It then assumes the remodulating (receiving) endpoint role and moves to the WAIT_FOR_DCS_FROM_FAR_END state (r.a2).

2) If the signal arrives from the packetized (far-end) side, the state machine shall check that the demodulator resources are available. If they are available, it allocates these resources. It then assumes the demodulating (transmit) endpoint role and moves to the WAIT_FOR_DCS_FROM_NEAR_END state (t.a2).

12.4.2.3 *Actions in the demodulating endpoint states*

12.4.2.3.1 *Actions in the WAIT_FOR_DCS_FROM_NEAR_END state*

In the WAIT_FOR_DCS_FROM_NEAR_END state (t.a2), each endpoint shall check whether traffic coded according to the modulation type and speed that have been provided by the corresponding V.21 demodulator can be demodulated with the available resource. This information is extracted either from the digital command signal (DCS) of Recommendation T.30 or from the information embedded in the non-standard set-up (NSS), both arriving from the V.21 demodulator of the channel-oriented side. If compatibility has been verified, then the state machine shall

1) store the modem speed and type in the system variables ORIG_SPEED and ORIG_TYPE, respectively;

2) put the demultiplexer in the FADCOMP position to route the information from the channel-oriented side to FADCOMP. The call-state layer shall send the ML-FAX-START request (ORIG_SPEED,ORIG_TYPE) primitive to the modulation layer of its corresponding originating endpoint.

The call-state layer shall set the system variable PART_PAGE_REQ_CNT to 0 and shall move to the WAIT_FOR_TCF_TO_END state (t.b1).

If the modulation type and speed as extracted from the T.30 message is not compatible with the PCME's resources, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL state (a1).

If a non-standard facilities command (NSC) or DTC T.30 message is received from the channel-oriented side, the machine changes its role to that of a remodulating endpoint and moves to the WAIT_FOR_DCS_FROM_FAR_END state (r.a2).

12.4.2.3.2 *Actions in the WAIT_FOR_TCF_TO_END state (t.b1)*

In this state, the call-state layer shall wait for the primitives from the corresponding modulation layer. If either V.21 demodulator indicates that V.21 message is coming, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall send the ML-FAX-STOP request to indicate to the modulation layer of the demodulating endpoint to return to the OFF state. It shall release all resources and return to the WAIT_FOR_FAX_CALL state (a1).

If the ML-FAX-STOP confirmation primitive arrives from the modulation layer of the originating endpoint, the call-state layer shall put both the multiplexer and the Demultiplexer in the PVP mode. It shall then move to the WAIT_FOR_CFR (t.b2) state.

If the ML-FAX-ABORT confirmation arrives from the modulation layer of the originating endpoint, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall release all resources and return to the WAIT_FOR_FAX_CALL (a1) state.

12.4.2.3.3 *WAIT_FOR_CFR state (t.b2)*

If either DCS or NSS signals arrives from the channel-oriented side, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall release all resources and return to the WAIT_FOR_FAX (a1) state.

If the confirmation to receive (CFR) arrives from the packetized side, the state machine shall put the demultiplexer in the FADCOMP position to route the information from the channel-oriented side through FADCOMP. The call-state layer shall send the ML-FAX-START request (ORIG_SPEED,ORIG_TYPE) primitive to the modulation layer of its corresponding originating endpoint. The state machine shall then move to WAIT_FOR_PAGE_END (t.c1) state.

If the V.21 demodulator indicates the arrival of any of the following messages from the packetized side, the state machine shall return to the WAIT_FOR_DCS_FROM_NEAR END (t.a2) state: command repeat (CRP), failure to train (FTT), Non-standard facilities command (NSC), or digital transmit command (DTC).

12.4.2.3.4 *WAIT_FOR_END_OF_PAGE state (t.c1)*

In this state, the call-state layer shall wait for the primitives from the corresponding modulation layer. If either V.21 demodulator indicates that V.21 message is coming, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall send the ML-FAX-STOP request to indicate to the modulation layer of the demodulating endpoint to return to the OFF state. It shall release all resources and return to the WAIT_FOR_FAX_CALL (a1) state.

If the ML-FAX-STOP confirmation primitive arrives from the modulation layer of the originating endpoint, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall then move to the WAIT_FOR_POST_PAGE_CMD (t.c2) state.

If the ML-FAX-ABORT confirmation arrives from the modulation layer of the originating endpoint, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall release all resources and return to the WAIT_FOR_FAX_CALL (a1) state.

12.4.2.3.5 *WAIT_FOR_POST_PAGE_COMMAND state (t.c2)*

In this state, the state machine is awaiting a V.21 message from the channel-oriented side. This message will be called subsequently the “post-page command.” Upon receipt of the post-page command, the state machine moves to the WAIT_FOR_POST_PAGE_RESPONSE state (t.d1).

12.4.2.3.6 *WAIT_FOR_POST_PAGE_RESPONSE state (t.d1)*

In this state, the state machine is awaiting specific messages from the packetized side, which represent the response to the previously received post-page command. The combination of the command and response determine the actions.

12.4.2.3.6.1 *End of procedure*

The end of procedure is indicated by one of the following post-page commands: end of procedure (EOP), procedure interrupt-EOP (PRI-EOP), [procedure interrupt (PRI)], partial page signal-EOP (PPS-EOP) [partial page signal (PPS)], and PPS.PRI-EOP. If the post-page response is message confirmation (MCF), the state Machine releases all allocated resources and returns to the WAIT_FOR_FAX_CALL (a1) state.

12.4.2.3.6.2 *End of message*

The end of message is indicated by one of two combinations:

1) One of the following commands: end of message (EOM), Procedure Interrupt-EOM (PRI-EOM), Partial Page Signal-EOM (PPS-EOM), and PPS-PRI-EOM, along with the Message Confirmation (MCF) response.

2) One of the following commands: end of message (EOM) or procedure interrupt-EOM (PRI-EOM), along with one of the following responses: retrain positive (RTP) or retrain negative (RTN).

In either case, the state machine moves to the WAIT_FOR_DCS_FROM_NEAR_END state (t.a2).

12.4.2.3.6.3 *Multiple page*

The multiple page case is indicated by one of two combinations :

1) One of the following commands: multipage signal (MPS), procedure interrupt-MPS (PRI-MPS), partial page signal-MPS (PPS-MPS), PPS-PRI-MPS, PPS-Null, along with the message confirmation (MCF) response. In this case, the PART_PAGE_REQ_CNT variable is reset to 0.

2) The response is a partial page request (PPR) while the partial page received count PART_PAGE_REQ_CNT is less than 3. The post-page command is irrelevant. In this case, the PART_PAGE_REQ_CNT variable is incremented.

Additional actions are as follows:

1) put the demutiplexer in the FADCOMP position to route the information from the channel-oriented side through FADCOMP;

2) send the ML-FAX-START request (ORIG_SPEED,ORIG_TYPE) primitive to the modulation layer of its corresponding originating endpoint;

3) move to the WAIT_FOR_END_OF_PAGE state (t.c1).

12.4.2.3.6.4 *Partial page request*

This is the case when the response PPR is detected while the PART_PAGE_REQ_CNT has reached the limit of 3, regardless of the post-page command. The PART_PAGE_REQ_CNT variable is reset to 0 and the state changes to the WAIT_FOR_CTC_OR_EOR-X state (t.g1)

12.4.2.3.6.5 *Procedure to retrain*

This is the case when one of the following commands is detected: multipage signal (MPS), end of procedure (EOP), procedure interrupt-MPS (PRI-MPS), procedure interrupt-EOP(PRI-EOP), along with either retrain negative (RTN) or retrain positive (RTP). In this case, the state changes to the WAIT_FOR_DCS_FROM_NEAR_END state (t.a2).

12.4.2.3.6.6 *Procedure interrupt*

This is the case when the response is either procedure interrupt negative (PIN) or procedure interrupt positive (PIP), regardless of the post-page command. The state changes to the WAIT_FOR_CMD State (t.e1).

12.4.2.3.7 *WAIT_FOR_CMD state (t.e1)*

If the V.21 demodulator indicates the arrival of a "non-final" non-standard setup (NSS) from the channel-oriented side, the state machine shall return to the WAIT_FOR_DCS_FROM_NEAR_END state (t.a2).

If the V.21 demodulator indicates the arrival of either the non-standard facilities command (NSC) or the digital transmit command (DTC) from the channel-oriented side, the state machine shall switch the role of the node to a remodulating node and shall move to the WAIT_FOR_DCS_FROM_FAR_END state (r.a2).

If the V.21 demodulator indicates the arrival of either the non-standard setup (NSS) or the digital command signal (DCS) from the channel-oriented side, and the modulation type and speed extracted from the V.21 information are compatible with the allocated modem, the state machine shall

1) store the modem speed and type in the system variables ORIG_SPEED and ORIG_TYPE, respectively;

2) put the demutiplexer in the FADCOMP position to route the information from the channel-oriented side through FADCOMP;

3) send the ML-FAX-START request (ORIG_SPEED,ORIG_TYPE) primitive to the modulation layer of its corresponding originating endpoint;

4) set PART_PAGE_REQ_CNT to 0;

5) move to the WAIT_FOR_TCF_TO_END state (t.b1).

If the V.21 demodulator indicates the arrival of either the non-standard setup (NSS) or the digital command signal (DCS) from the channel-oriented side, and the modulation type and speed extracted from the V.21 information are not compatible with the allocated modem, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL (a1) state.

If the V.21 demodulator indicates the arrival of EOR-PRI-Q, PRI-Q or PPS-PRI-Q from the channel-oriented side, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL (a1) state. As defined in § A.7.1 of Recommendation T.30, PRI-Q is a general term referring to either PRI-EOM, PRI-MPS or PRI-EOP post message command. These commands are used in the optional T.4 error correction mode. PPS-PRI-Q could be either PPS-PRI-EOM, PPS-PRI-MPS or PPS-PRI-EOP post message command.

12.4.2.3.8 *WAIT_FOR_CTC_OR_EOR-X state (t.g1)*

If the V.21 demodulator indicates the arrival of the continue to correct (CTC) from the channel-oriented side, the state machine shall set the speed to ORIG_SPEED and modulation type to ORIG_TYPE as extracted by the V.21 demodulator, and shall move to the WAIT_FOR_CTR state (t.g2).

If the V.21 demodulator indicates the arrival of EOR-X signal [end of retransmission (EOR)] from the channel-oriented side, where X is either Q or PRI-Q, it shall move to the WAIT_FOR_ERR state (t.g3). As defined in § A.7.1 of Recommendation T.30, EOR-Q represents either the post-message command EOR-EOM, EOR-MPS, EOR-EOP or EOR-Null. EOR-PRI-Q represents either EOR-PRI-EOM, EOR-PRI-MPS or EOR-PRI-EOP. X is referred to as “EOR TYPE” subsequently.

12.4.2.3.9 *WAIT_FOR_CTR state (t.g2)*

If the V.21 demodulator indicates the arrival of the response to continue to correct (CTR) from the packetized side, and the speed and modulation type are compatible with the allocated modem, the state machine shall

1) store the modem speed and type in the system variables ORIG_SPEED and ORIG_TYPE, respectively;

2) put the demultiplexer in the FADCOMP position to route the information from the channel-oriented side through FADCOMP;

3) send the ML-FAX-START request (ORIG_SPEED,ORIG_TYPE) primitive to the modulation layer of its corresponding originating endpoint;

4) set PART_PAGE_REQ_CNT to 0;

5) move to the WAIT_FOR_END_OF_PAGE state (t.c1).

If the V.21 demodulator indicates the arrival of the response to continue to correct (CTR) from the packetized side, and the modulation type and speed extracted from the V.21 information are not compatible with the allocate modems, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL state (a1).

12.4.2.3.10 *WAIT_FOR_ERR state (t.g3)*

If the V.21 demodulator indicates the arrival of a response to end of retransmission (ERR) from the packetized side and the EOR type as set in state t.g1 is either EOM or PRI-EOM, the state machine shall move to WAIT_FOR_DCS_FROM_NEAR_END state (t.a2).

If the terminating endpoint V.21 demodulator indicates the arrival of a response to end of retransmission (ERR) from the packetized side and the EOR type as set in state t.g1 is either Null, MPS or PRI-MPS, the state machine shall

1) set the demultiplexer to FADCOMP;

2) send the primitive ML-FAX-START request (ORIG_SPEED,ORIG_TYPE) to the modulation layer of the originating endpoint;

3) move to the WAIT_FOR_END_OF_PAGE state (t.c1).

If the V.21 demodulator indicates the arrival of a procedure interrupt negative (PIN) from the packetized side, the state machine shall return to the WAIT_FOR_CMD state (t.e1).

If the V.21 demodulator indicates the arrival of response for end of retransmission (ERR) from the packetized side and the EOR type as set in state t.g1 is either EOP or PRI-EOP, the state machine shall set the multiplexer and demutiplexer to PVP, release all allocated resources and then move to the WAIT_FOR_FAX_CALL state (a1).

12.4.2.4 *Actions in the remodulating endpoint states*

12.4.2.4.1 *Actions in the WAIT_FOR_DCS_FROM_FAR_END state (r.a2)*

Each endpoint shall check whether traffic coded according to the modulation type and speed that have been provided by the corresponding V.21 demodulator can be remodulated with the available resource. This information is extracted either from the digital command signal (DCS) of T.30 or from the information embedded in the non-standard set-up (NSS) from the V.21 demodulator of the packetized side. If compatibility has been verified, then the state machine shall

1) store the modem type and speed in the system variables TERM_SPEED and TERM_TYPE, respectively;

2) put the multiplexer in the FADCOMP position to route the information from the packetized side through FADCOMP. The demultiplexer is put in the OFF position to prevent echo of the regenerated signal from returning to the channel-oriented side. The call-state layer shall send the ML-FAX-START response (TERM_SPEED,TERM_TYPE) primitive to the modulation layer of its corresponding terminating endpoint.

The call-state layer shall set the system variable PART_PAGE_REQ_CNT to 0 and shall move to the WAIT_FOR_TCF_TO_END state (r.b1).

If the modulation type and speed as extracted from the T.30 message is not compatible with the PCME's resources, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL state (a1).

If an NSC or DTC T.30 message is received from the packetized side, the machine changes its role to that of a demodulating endpoint and moves to the WAIT_FOR_DCS_FROM_NEAR_END state (t.a2).

12.4.2.4.2 *Actions in the WAIT_FOR_TCF_TO_END state (r.b1)*

In this state, the call-state layer shall wait for the primitives from the corresponding modulation layer. If either V.21 demodulator indicates that V.21 is coming, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall send the ML-FAX-STOP response to indicate to the modulation layer of the remodulating endpoint to return to the OFF state. It shall release all resources and return to the WAIT_FOR_FAX_CALL state (a1).

If the ML-FAX-STOP indication primitive arrives from the modulation layer of the terminating endpoint, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall then move to the WAIT_FOR_CFR (r.b2) state.

If the ML-FAX-ABORT indication arrives from the modulation layer of the terminating endpoint, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall release all resources and return to the WAIT_FOR_FAX state.

12.4.2.4.3 *WAIT_FOR_CFR state (r.b2)*

If either DCS or NSS signals arrives from the packetized side, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall release all resources and return to the WAIT_FOR_FAX_CALL (a1) state.

If the confirmation to receive (CFR) arrives from the channel-oriented side, the state machine shall put the multiplexer in the FADCOMP position to route the information from the packetized side through FADCOMP. The demultiplexer shall be put in the OFF position to prevent echo of the regenerated signal from the channel-oriented side.

The call-state layer shall send the ML-FAX-START response (TERM_SPEED,TERM_TYPE) primitive to the modulation layer of its corresponding terminating endpoint.

The state machine shall then move to the WAIT_FOR_PAGE_END (r.c1) state.

If the V.21 demodulator indicates the arrival of any of the following messages from the channel-oriented side, the state machine shall return to the WAIT_FOR_DCS_FROM_FAR_END (r.a2) state: command repeat (CRP), failure to train (FTT), non-standard facilities command (NSC), or digital transmit command (DTC).

12.4.2.4.4 *WAIT_FOR_END_OF_PAGE state (r. c1)*

In this state, the call-state layer shall wait for the primitives from the corresponding modulation layer. If either V.21 demodulator indicates that V.21 is coming, the call-state layer shall put both the multiplexer and the demutiplexer in the PVP mode. It shall send the ML-FAX-STOP response to indicate to the modulation layer of the terminating endpoint to return to the OFF state. It shall release all resources and return to the WAIT_FOR_FAX_CALL (a1) state.

If the ML-FAX-STOP indication primitive arrives from the modulation layer of the terminating endpoint, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall then move to the WAIT_FOR_POST_PAGE_COMMAND (r.c2) state.

If the ML-FAX-ABORT indication arrives from the modulation layer of the terminating endpoint, the call-state layer shall put both the multiplexer and the demultiplexer in the PVP mode. It shall release all resources and return to the WAIT_FOR_FAX_CALL (a1) state.

12.4.2.4.5 *WAIT_FOR_POST_PAGE_COMMAND state (r.c2)*

In this state, the state machine is awaiting a V.21 message from the packetized side. This message will be called subsequently the "post-page command." Upon receipt of the post-page command, the state machine moves to the_WAIT_FOR_POST_PAGE_RESPONSE state (r.d1).

12.4.2.4.6 *WAIT_FOR_POST_PAGE_RESPONSE state (r.d1)*

In this state, the state machine is awaiting specific messages from the channel-oriented side, which represent the response to the previously received post-page command. The combination of the command and response determines the actions.

12.4.2.4.6.1 *End of procedure*

The end of procedure is indicated by one of the following post-page commands: end of procedure (EOP), procedure interrupt-EOP (PRI-EOP), partial page signal-EOP (PPS-EOP), and PPS-PRI-EOP. If the post-page response is Message Confirmation (MCF), the state machine releases all allocated resources and returns to the WAIT_FOR_FAX_CALL (a1) state.

12.4.2.4.6.2 *End of message*

The end of message is indicated by one of two combinations:

1) One of the following commands: end of message (EOM), procedure interrupt-EOM (PRI-EOM), partial page signal-EOM (PPS-EOM), and PPS-PRI-EOM, along with the message confirmation (MCF) response.

2) One of the following commands: end of message (EOM) or procedure interrupt-EOM (PRI-EOM), along with one of the following responses: retrain positive (RTP) or retrain negative (RTN).

In either case, the state machine moves to the WAIT_FOR_DCS_FROM_FAR_END state (r.a2).

12.4.2.4.6.3 *Multiple page*

The multiple page case is indicated by one of two combinations:

a) One of the following commands: multipage signal (MPS), procedure interrupt-MPS (PRI-MPS), partial page signal-MPS (PPS-MPS), PPS-PRI-MPS, PPS-Null, along with the message confirmation (MCF) response. In this case, the PART_PAGE_REQ_CNT variable is reset to 0.

b) The response is a partial page request (PPR) while the partial page received count PART_PAGE_REQ_CNT is less than 3. The post-page command is irrelevant. In this case, the PART_PAGE_REQ_CNT variable is incremented.

Additional actions are as follows:

1) put the multiplexer in the FADCOMP position to route the information from the packetized side through FADCOMP;

2) put the demultiplexer in the OFF position to prevent echo of the regenerated signal from the channel-oriented side;

3) send the ML-FAX-START response (TERM_SPEED,TERM_TYPE) primitive to the modulation layer of its corresponding terminating endpoint;

4) move to WAIT_FOR_END_OF_PAGE state (r.c1).

12.4.2.4.6.4 *Partial page request*

This is the case when the response PPR is detected while the PART_PAGE_REQ_CNT has reached the limit of 3, regardless of the post-page command. The PART_PAGE_REQ_CNT variable is reset to 0 and the state changes to the WAIT_FOR_CTC_OR_EOR_X state (r.g1).

12.4.2.4.6.5 *Procedure to retrain*

This is the case when one of the following commands is detected: multipage signal (MPS), end of procedure (EOP), procedure interrupt-MPS (PRI-MPS), procedure interrupt-EOP (PRI-EOP), along with either retrain negative (RTN) or retrain positive (RTP). In this case, the state changes to the WAIT_FOR_DCS_FROM_FAR_END state (ra2).

12.4.2.4.6.6 *Procedure interrupt*

This is the case when the response is either procedure interrupt negative (PIN) or procedure interrupt positive (PIP), regardless of the post-page command. The state changes to WAIT_FOR_CMD state (r.el).

12.4.2.4.6.7 *WAIT_FOR_CMD state (r.el)*

If the V.21 demodulator indicates the arrival of the "non-final" non-standard setup (NSS) from the packetized side, the state machine shall return to the WAIT_FOR_DCS_FROM_FAR_END state (r.a2).

If the V.21 demodulator indicates the arrival of either the non-standard facilities command (NSC) or the digital transmit command (DTC) from the packetized side, the state machine shall switch the role of the node to a demodulating node and shall move to The WAIT_FOR_DCS_FROM_NEAR_END state (ta2).

If the V.21 demodulator indicates the arrival of either the non-standard setup (NSS) or the digital signal command (DCS) from the packetized side, and the modulation type and speed as extracted from The V.21 information are compatible with the allocated resources, the state machine shall

1) store the modem speed and type in the system variables TERM_SPEED and TERM_TYPE, respectively;

2) put the multiplexer in the FADCONP position to route the information from the packetized side through FADCONP;

3) put the demultiplexer in the OFF position to prevent echo of the regenerated signal from the channel-oriented side;

4) send the ML_FAX_START_RESPONSE(TERM_SPEED,TERM_TYPE) primitive to the modulation layer of its corresponding terminating endpoint;

5) set PART_PAGE_REQ_CNT to 0;

6) move to the WAIT_FOR_TCF_TO_END state (r.bl).

If the V.21 demodulator indicates the arrival of either the non-standard setup (NSS) or the digital command signal (DCS) from the packetized side, and the modulation type and speed extracted from the V.21 information are not compatible with the allocate modems, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL state (al).

If the V.21 demodulator indicates the arrival of EOR-PRI-Q or PRI-Q or PPS-PRI-Q from the packetized side, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL state (a1). As defined in A.7.1 of Recommendation T.30, PRI-Q is a general term referring to either PRI-EOM, PRI-MPS or PRI-EOP post message command. These commands are used in the optional T.4 error correction mode. PPS-PRI-Q could be either PPS-PRI-EOM, PPS-PRI-MPS or PPS-PRI-EOP post message command.

12.4.2.4.7 *WAIT_FOR_CTC_OR_EOR_X state (r.gl)*

If the V.21 demodulator indicates the arrival of the continue to correct (CTC) from the packetized side, the state machine shall set the speed to TERM_SPEED and the modulation type to TERM_TYPE as extracted by the V.21 demodulator, and shall move to the WAIT_FOR_CTR state (r.g2).

If the V.21 demodulator indicates the arrival of EOR signal from the packetized side, where X is either Q or PRI-Q, it shall move to the WAIT_FOR_ERR (r.g3) state. As defined in A.7.1 of Recommendation T.30, EOR-Q indicates either EOR-EOM, EOR-MPS, EOR-EOP or EOR-Null post-message command. EOR-PRI-Q indicates either EOR-PRI-EOM, EOR-PRI-MPS or EOR-PRI-EOP. X is referred to as “EOR type” subsequently.

12.4.2.4.8 *WAIT_FOR_CTR state (r.g2)*

If the V.21 demodulator indicates the arrival of the response to continue to correct (CTR) from the channel-oriented side, and the modulation type and speed as extracted from the V.21 information are compatible with the allocated resources, the state machine shall

1) store the modem speed and type in the system variables TERM_SPEED and TERM_TYPE, respectively;
2) put the multiplexer in the FADCOMP position to route the information from the packetized side through FADCOMP;
3) put the demultiplexer in the OFF position to prevent echo of the regenerated signal from the channel-oriented side;
4) send the ML-FAX-START response (TERM_SPEED,TERM_TYPE) primitive to the modulation layer corresponding terminating endpoint;
5) set PART_PAGE_REQ_CNT to 0;
6) move to the WAIT_FOR_END_OF_PAGE state (r.c1).

If the V.21 demodulator indicates the arrival of the response to continue to correct (CTR) from the channel-oriented side, and the modulation type and speed extracted from the V.21 information are not compatible with the allocate modems, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL (al) state.

12.4.2.4.9 *WAIT_FOR_ERR state (r.g3)*

If the V.21 demodulator indicates the arrival of a response to end of retransmission (ERR) from the channel-oriented side and the EOR type as set in state r.g1 is either EOM or PRI-EOM, the state machine shall move to the WAIT_FOR_DCS_FROM_FAR_END state (r.a2).

If the V.21 demodulator indicates the arrival of a response to end of retransmission (ERR) from the channel-oriented side, and the EOR_TYPE as set in state r.gl is either null or MPS or PRI-MPS, the state machine shall

1) set the multiplexer to FADCOMP;
2) set the demultiplexer to OFF;
3) send the primitive ML_FAX_START response (TERM_SPEED,TERM_TYPE) to the modulation layer of the terminating endpoint;
4) move to the WAIT_FOR_END_OF_PAGE state (r.c1).

If the V.21 demodulator indicates the arrival of a response to end of retransmission (ERR) from the channel-oriented side, and the EOR type as set in state r.g1 is either EOP or PRI-EOP, all resources are released and the state machine moves back to the WAIT_FOR_FAX_CALL state (al).

If the V.21 demodulator indicates the arrival of a procedure interrupt negative (PIN) from the channel-oriented side, the state machine shall return to the WAIT_FOR_CMD state (r.e1).

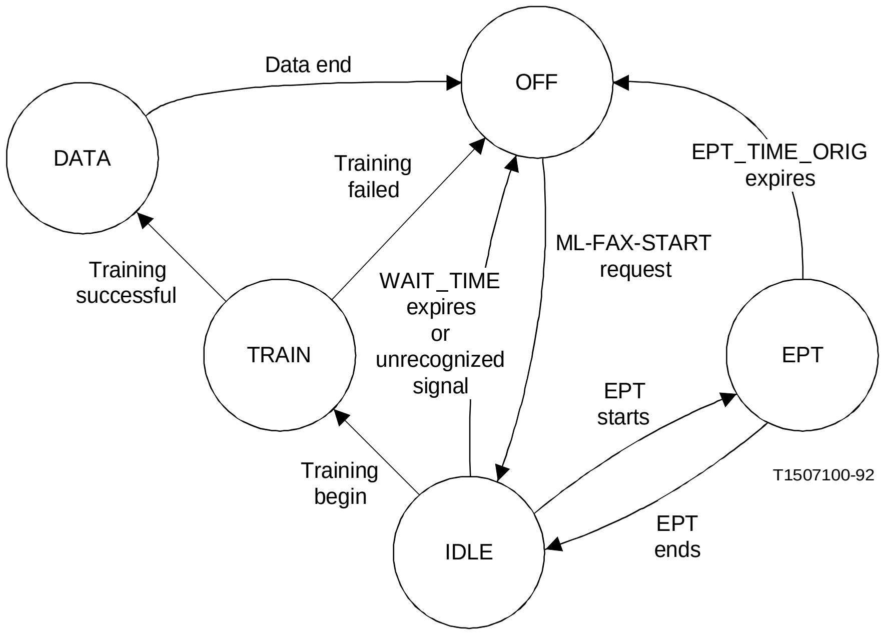
12.5 *Facsimile originating (demodulating) endpoint procedures*

12.5.1 *Modulation layer procedures at the originating endpoint*

This layer shall demodulate the 64 kbit/s facsimile page data and extract the baseband data. It has the additional function of detecting echo protection tones and training sequences.

The finite state machine, shown in Figure 24/G.765, depicts the operation of the modulation layer.

State transitions occur after reception of request primitives from the call-state timer expiration or upon arrival of specific signals from the channel-oriented side.



Note – For simplitiy, the transition from any state to the OFF state due to the ML-FAX-STOP request primitive is not shown.

FIGURE 24/G.765

Global states of the originating end modulation layer finite state machine

12.5.1.1 *OFF state*

This is the initial state of the modulation layer at the originating endpoint.

While in this state, if a ML-FAX-CAPABILITY request (capabilities) primitive is received from the call state layer, the modulation layer shall send the PL-CAPABILITY request (capabilities) primitive to the packet layer.

When the ML-FAX-START request (TYPE,SPEED) arrives from the call-state layer, the modulation layer shall place the TYPE and speed parameters into the ML_ORIG_TYPE and ML_ORIG_SPEED system variables. Then the state machine transitions to the IDLE state.

12.5.1.2 *IDLE state*

Upon entering the IDLE state, the modulation layer shall restart the WAIT_TIME timer. This timer measures the time that the originating end modulation layer shall wait for a signal (either an EPT tone or facsimile page modulation signal). The default value is 3 seconds. Other values are for further study.

The action of the modulation layer shall be as follows:

1) If an echo protection tone (EPT) is detected, the modulation layer shall send the PL-FAX-SPURT-HEADER request (ACTION) primitive to the layer 3 entity, where ACTION is set to 1700 Hz EPT start or 1800 Hz EPT start, depending on the frequency of the tone. The modulation layer state machine shall stop the WAIT_TIME timer and then transition to the EPT state.

2) If a training sequence for modem type ML_ORIG_TYPE at speed ML_ORIG_SPEED is detected, the modulation layer sends the PL-FAX-SPURT-HEADER request (ACTION) primitive to the layer 3 entity where ACTION is set to generate a training sequence. The modulation layer state machine shall stop the WAIT_TIME timer and then transition to the TRAIN state;

3) If the timer WAIT_TIME expires, then the modulation layer shall send the ML-FAX-ABORT confirmation primitive to the call-state layer. It shall also send the PL-FAX-SPURT-HEADER request (ACTION) primitive to the layer 3 entity, where ACTION is set to *abort*. The modulation layer state machine shall then move to the OFF state.

4) If the ML-FAX-STOP request primitive arrives from the call-state layer, the modulation layer shall move to the OFF state.

12.5.1.3 *EPT state*

Upon entering the EPT state, the modulation layer shall restart the EPT_TIME_ORIG timer. The default value for this timer is 500 ms.

In the EPT state, the modulation layer shall await the end of the EPT tone in the voiceband signal. When the end of EPT energy is declared, the modulation layer shall send the PL-FAX-SPURT-HEADER request (ACTION) to the layer 3 entity, where ACTION is set to *EPT stop*. The modulation layer shall then move back to the IDLE state.

If the timer EPT_TIME_ORIG expires, then the modulation layer shall send the PL-FAX-SPURT-HEADER request (ACTION) primitive to the layer 3 entity, where ACTION is set to *abort*. It shall send the ML-FAX-ABORT confirmation primitive to the call-state layer. The modulation layer state machine shall then move to the OFF state.

If the ML-FAX-STOP request primitive arrives from the call-state layer, the modulation layer shall move to the OFF state.

12.5.1.4 *TRAIN state*

In the TRAIN state, the modulation layer shall synchronize to the incoming modulated signal and shall await the end of the training sequence.

If the training sequence completes and the modulation layer was able to train according to modem type ML_ORIG_TYPE and speed ML_ORIG_SPEED, the modulation layer shall send the PL-FAX-DATA-START request primitive to the layer 3 entity, informing it that demodulated bits are about to arrive. The modulation layer state machine shall then move to the DATA state.

If the ML-FAX-STOP request primitive arrives from the call-state layer, the modulation layer shall move to the OFF state.

If the modulation layer detects an error in the training sequence or it is unable to train, it shall send the PL-FAX-SPURT-HEADER request (ACTION) primitive to the layer 3 entity, where ACTION is set to *abort*. It shall also send the ML-FAX-ABORT confirmation primitive to the call-state layer. The modulation layer state machine shall then move to the OFF state.

12.5.1.5 *DATA state*

In the DATA state, the modulation layer shall demodulate the voiceband signal according to ML-ORIG-TYPE and ML_ORIG_SPEED and unscramble the bits. The unscrambled bits are given to the packet layer grouped by symbols. For example, if ML_ORIG_TYPE is V.29, the demodulation shall be done according to Recommendation V.29, including the unscrambling operation of Appendix II of Recommendation V.29. The output of this demodulator that is given to the packet layer shall consist of a series of unscrambled symbols containing unscrambled bits Ql through Q4, for 9600 bit/s and Q2 through Q4 for 7200 bit/s (see §§ 2.2.1 and 2.2.2 of Recommendation V.29), arranged as shown in Figure 11/G.765, for the two speeds 9600 bit/s and 7200 bit/s. Similar actions are taken for Recommendation V.27 *ter*.

When the carrier terminates, the modulation layer shall send the PL-FAX-DATA-STOP request primitive to the layer 3 entity and the ML-FAX-STOP confirmation primitive to the call-state layer. The modulation layer state machine shall then move to the OFF state.

If the signal can no longer be demodulated, the modulation layer shall send the PL-FAX-SPURT-HEADER-request (ACTION) primitive to the layer 3 entity, where ACTION is set to *abort*. It shall send the ML-FAX-ABORT-confirmation primitive to the call-state layer. It shall then move to the OFF state.

If the ML-FAX-STOP request primitive arrives from the call-state layer, the modulation layer shall move to the OFF state.

12.5.2 *Packet layer procedures at the originating endpoint*

The function of this layer is to generate packets in response to request primitives.

12.5.2.1 *Receipt of the PL-FAX-SPURT-HEADER request primitive*

When the modulation layer informs the layer 3 entity to send a spurt header packet using the PL-FAX-SPURT-HEADER request (ACTION) primitive, the layer 3 entity shall start a timer TVDELAY associated with that packet and shall format a facsimile spurt header frame (see Figure 9/G.765) with the *ACTION* field set according to the parameters. Then, the remaining procedures, described in § 12.5.2.5, are followed.

12.5.2.2 *Receipt of the PL-FAX-CAPABILITY request primitive*

When the modulation layer informs the layer 3 entity to send a capability packet using the PL-FAX-CAPABILITY request (capabilities) primitive, the layer 3 entity shall start a timer TVDELAY associated with that packet and shall format a facsimile Capability Indicator frame (see Figure 8/G.765) with the V.27, V.29, V.33 and V.17 fields set according to the capabilities parameter. Then, the remaining procedures, described in § 12.5.2.5, are followed.

12.5.2.3 *Receipt of the PL-FAX-DATA-START request primitive*

When the modulation layer informs the layer 3 entity to start packetizing data using the PL-FAX-DATA-START request primitive, the layer 3 entity shall begin segmenting and buffering packets using the symbols supplied by the modulation layer. Each packet is of the format given in Figure 10/G.765, which shows the facsimile page information frame format. The M-bit shall be set to 1. For the first packet, the SEQ field shall be set to 1; for subsequent packets, SEQ shall be incremented to 15 with a rollover to 1.

The symbols from the modulation layer shall be placed into the packet according to Figure 11/G.765. The information field of the packet shall contain the number of symbols arriving in 20 ms, nominally 48, 32 and 24 for V.29 (9.6 kbit/s and 7.2 kbit/s), 4.8 kbit/s V.27 *ter*, and 2.4 kbit/s V.27 *ter*, respectively. These correspond to 24, 16, and 12 octets of information most of the time, although, due to the lack of synchronization between the facsimile machine and the PCME, the information field can occasionally be one octet longer. The last packet of a page may contain fewer symbols since the number of symbols on a page does not need to be a factor of the number received in 20 ms. The last octet of a packet may contain less than two symbols, in which case the BILO field shall be set to indicate the number of bits that are not to be considered. For example, for V.29 and V.27 *ter*, the BILO field is set to either 0 or 4, depending on whether the number of symbols in the packet is even or odd, respectively. In the latter case, the value of the four most significant bits in the last octet of the information field shall not be considered.

After each packet is formed, the packet layer shall start a timer TVDELAY that is associated with that packet. Then, the remaining procedures, noted in § 12.5.2.5, shall be followed.

The packetization process shall be continued until the PL-FAX-DATA-STOP request primitive is received.

12.5.2.4 *Receipt of the PL-FAX-DATA-STOP request primitive*

When the modulation layer informs the layer 3 entity to stop packetizing data using the PL-FAX-DATA-STOP request primitive, the layer 3 entity shall finish the packet it is in the process of forming until all the bits are used up. The remaining procedures are identical to those for the previous facsimile page information packets, except that the M-bit is set to 0.

12.5.2.5 *Time stamping procedures*

Packets shall be buffered on a first-in/first-out (FIFO) basis. Upon receipt of the DL-L1-READY indication primitive from the link layer, the layer 3 entity shall stop the TVDELAY timer associated with the packet at the head of the FIFO queue and shall copy its value (in ms) to the TIME STAMP field. The value of the TIME STAMP field is clamped at 200. The packet shall be delivered to the link layer via either the DL-UNIT-H-DATA request or DL-UNIT-DATA request primitives.

12.5.3 *Link layer procedures at the originating endpoint*

The link layer procedures are the same as those defined in §§ 4.2.1 and 4.2.2 of Recomendation G.764.

12.6 *Intermediate node procedures*

Same as for DICE (see 7.5).

12.7 *Facsimile procedures at the terminating (remodulating) endpoint*

12.7.1 *Link layer procedures at the terminating endpoint*

The Link Layer procedures are the same as specified in §§ 4.2.3 and 4.2.4 of of Recommendation G.764.

12.7.2 *Packet layer procedures at the terminating endpoint*

The function of the packet layer is to reassemble the baseband facsimile image data and can control information from the received packets.

12.7.2.1 *Common procedures*

Upon receipt of the DL-UNIT-H-DATA indication or DL-UNIT-DATA indication from the link layer, the layer 3 entity shall examine the values encoded in the PD, SC, and DMC fields.

If the PD value matches that for PVP, the layer 3 entity shall proceed according to the value of the SC field; otherwise the packet is dropped.

If the value of the SC field is 00, the value for voice and voiceband data, the layer 3 entity shall follow the procedures described in § 5 of Recommendation G.764.

If the value of the SC field is 11, the value of digital data, the layer 3 entity shall follow the procedures in either § 7.6.2 for DICE or in § 8.6.2 for VDLC.

If the value of the SC field is 01, the value for the digital modem class, and the DMC value is the value for facsimile, the layer 3 entity shall proceed as described below. Actions for other values of DMC are for further study.

Procedures of the case of SC = 10 are left for further study.

12.7.2.2 *Build-out delay*

The build-out delay procedures are the same as for § 5.3.3.2 of Recommendation G.764, except that at playout time, the action depends on the packet type as indicated by the type field. Specific actions are described as the following subsection.

The build-out delay system variable has the same definition as for PVP, but its value must be chosen so as to preserve the gap width between the facsimile call components. The build-out delay for facsimile depends on:

1) the build-out delay for the voice path;

2) the processing time (including ADPCM encoding and decoding) at both the originating and terminating endpoints for the V.21 call control signals;

3) The processing time (including signal detection and demodulation times) at both the originating and terminating endpoints for the training sequence spurt header packet.

Thus, there are separate build-out delay parameters, one for the voice path and the second for the facsimile demodulation path. Both these parameters indicate the end-to-end delay from packetization to depacketization, but do *not* include signal processing times (item 2 above for voice path, and item 3 for facsimile demodulation) or transmission propagation time (a function of the transmission facilities). The total end-to-end delay includes build-out, processing, and transmission propagation times. To preserve gap widths, the total end-to-end must be the same for both paths, i.e.

voice_build-out + voice_processing_time = fax_build-out + facsimile_processing_time

The propagation time is not included because it is the same on both sides of the equation. The processing times are implementation dependent. Either the voice build-out delay or the facsimile demodulation build-out delay shall be set by service administration and the other build-out delay may be derived as expected above.

12.7.2.3 *Actions as determined by type field*

At playout time, as determined in the previous subsection, one of the following actions are taken.

12.7.2.3.1 *Spurt header packet (Type=00)*

Type=00 indicates a spurt header packet. The layer 3 entity shall send the PL-FAX-SPURT-HEADER indication (ACTION) to the modulation layer, where ACTION is set to the value encoded in the ACTION field of the arriving packet.

12.7.2.3.2 *Page information packet (Type=0l)*

Type = 0l indicates a page information packet

1) If the SEQ is > 0 and the M-bit is set to 1, then the layer 3 entity shall inform the modulation layer that a page information packet has arrived via the PL-FAX-DATA indication primitive. It shall remove the symbols from the facsimile page information field, as per Figure 11/G.765, in sequential order, and shall buffer them. The last octet of the information field shall be treated according to the BILO field. The contents of the buffer shall be sent to the modulation layer a symbol at a time as needed by the modulation layer.

2) If the SEQ field is > 0 and of the value the M-bit is 0, the layer 3 entity shall remove the symbols in the facsimile page information field and shall add them to the buffer, the contents of which are sent to the modulation layer. When the buffer is emptied, the layer 3 entity shall send the PL-FAX-DATA-STOP indication primitive to the modulation layer.

3) If SEQ = 0, the corresponding build-out procedures described in § 5.3.3.2 of Recommendation G.764 shall be followed.

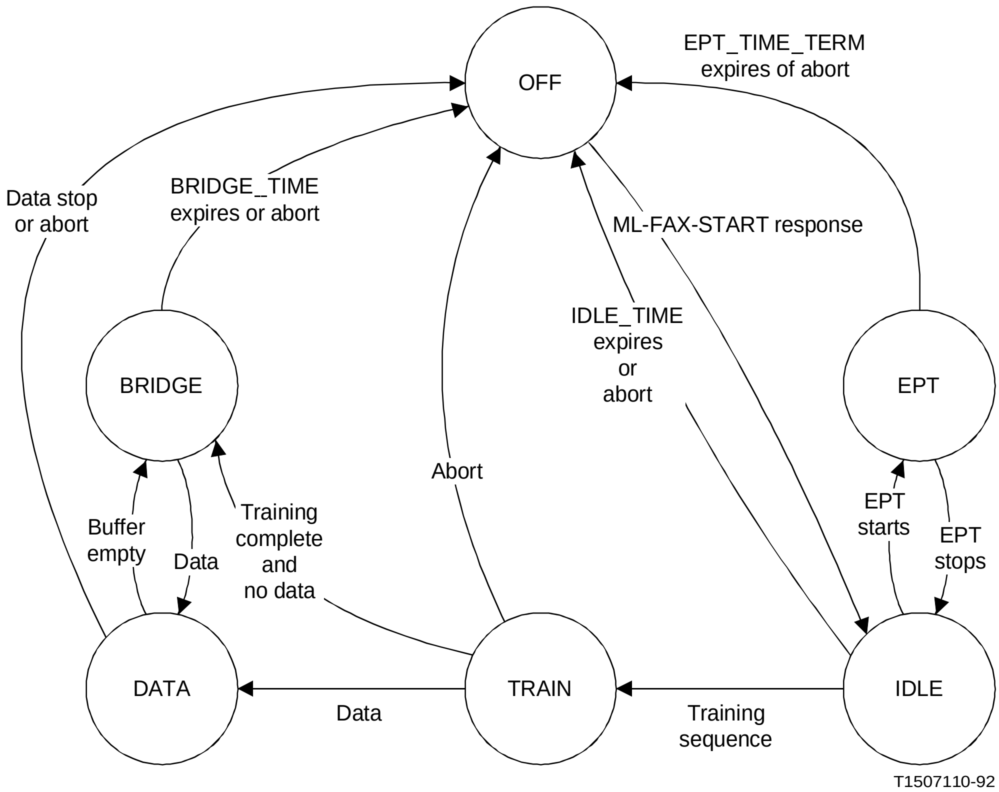
12.7.2.3.3 *Capability indication packet* (*Type = 10*)

Type=10 indicates a capability indication packet. The layer 3 entity shall send the PL-FAX-CAPABILITY indication (capabilities) to the modulation layer, where capabilities are set according to the V.27, V.29, V.33 and V.17 fields of the arriving packet.

12.7.3 *Modulation layer procedures at the terminating endpoint*

This layer shall reconstruct the original carrier and EPT signals for the facsimile page Figure 25/G.765 contains a state diagram of this layer.

For all states, if the modulation layer receives a ML-FAX-STOP response primitive from the call-state layer, it shall go to the OFF state and stop any remaining timer.



Note – For simplicity, the transition from all states to the OFF state due to reception of the ML-FAX-STOP response primitive or of some spurt header packets.

FIGURE 25/G.765

Global states of the terminating end modulation layer terminating end finite state machine

12.7.3.1 *OFF state*

This is the initial state of the modulation layer.

While in this state, if the modulation layer receives a PL-FAX-CAPABILITIES indication (capabilities) primitive from the packet layer, it sends a ML-FAX-CAPABILITIES indication (capabilities) primitive to the call-state layer.

When the modulation layer receives the ML-FAX-START response (TYPE,SPEED) primitive from the call-state layer, the modulation layer shall place the TYPE and SPEED parameters into the ML_TERM_TYPE and ML_TERM_SPEED system variables. It then moves to the IDLE state.

12.7.3.2 *IDLE state*

As soon as it enters this state, the modulation layer shall start the IDLE_TIME timer. The default value for this timer is 3 seconds. Other values are for further study.

In this state, the modulation layer shall wait for the layer 3 entity to indicate receipt of a facsimile spurt header packet, at which time the modulation layer shall stop the IDLE_TIME timer.

If the modulation layer receives the PL-FAX-SPURT-HEADER indication (ACTION) primitive from the layer 3 entity, then:

1) If ACTION is set to 1700 Hz, EPT start or 1800 Hz EPT start, then the modulation layer shall take the following actions:
   - set system variable ML_TERM_EPT_FREQ to indicate 1700 Hz or 1800 Hz, depending on the ACTION parameter;
   - move to the EPT state.
2) If ACTION is set to training sequence, then the modulation layer shall move to the TRAIN state.
3) if ACTION is set to Abort, the modulation layer shall
   - send the ML-FAX-ABORT indication primitive to the call-state layer;
   - move to the OFF state.

If the IDLE_TIME timer expires, the modulation layer shall send the ML-FAX-ABORT indication primitive to the call-state layer, and then return to the OFF state.

12.7.3.3 *EPT state*

Upon entering the EPT state, the modulation layer shall

1) start the timer EPT_TIME_TERM. This timer measures the time that the terminating end modulation layer remains in the EPT state generating an EPT tone. The default value of the timer is 500 ms;
2) begin generating the PCM samples that correspond to an echo protection tone of a frequency corresponding to the ML_TERM_EPT_FREQ system variable. The tone signal power shall meet the specifications of Recommendation V.2.

If the modulation layer receives the PL-FAX-SPURT-HEADER indication (ACTION) primitive from the layer 3 entity with ACTION set to *EPT stop*, the modulation layer shall terminate the generation of the EPT tone, shall stop the EPT_TIME_TERM timer and shall move to the IDLE state.

If the modulation layer receives the PL-FAX-SPURT-HEADER indication (ACTION) primitive from the layer 3 entity with ACTION set to *abort*, the modulation layer shall

a) terminate the generation of the EPT tone and stop the EPT_TIME_TERM timer;
b) send the ML_FAX_ABORT indication primitive to the call-state layer;
c) move to the OFF state.

After expiration of the timer EPT_TIME_TERM, the modulation layer shall

1) terminate the generation of the EPT tone;
2) send the ML-FAX-ABORT indication primitive to the call-state layer;
3) move to the OFF state.

12.7.3.4 *TRAIN state*

Upon entering the TRAIN state, the modulation layer shall begin generating the PCM samples that correspond to a training sequence specified for modem type ML_TERM_TYPE and speed ML_TERM_SPEED by the corresponding Recommendations.

While the training sequence is being generated, if the modulation layer receives the PL-FAX-SPURT-HEADER indication (ACTION) primitive from the layer 3, entity the modulation layer shall

1) terminate the generation of the training sequence;
2) send the ML-FAX-ABORT indication primitive to the call-state layer;
3) move to the OFF state

While the training sequence is being generated, if the modulation layer receives the PL-FAX-DATA indication primitive, the modulation layer shall

a) complete the generation of the full training sequence;
b) move to the DATA state.

If the regenerated training sequence ends before the layer receives the PL-FAX-DATA indication primitive, the modulation layer shall move to the BRIDGE state.

12.7.3.5 *DATA state*

In the DATA state, the modulation layer shall continue generating PCM samples representing a modulated signal of modem type ML_TERM_TYPE and modem speed ML_TERM_SPEED system variables.

Upon entering the DATA state, the modulation layer shall obtain a symbol from the layer 3 entity and modulate it in the earliest available signal time to preserve the continuity with the training sequence.

In the case of V.29 at 9600 bits/s, the modulation layer shall scramble and modulate the unscrambled Q1 through Q4 bits of a symbol (see Figure 11/G.765) as per the Recommendation V.29. For V.29 at 7200 bits/s, the modulation layer shall scramble and modulate the unscrambled Q2 through Q4 bits of a symbol, as per Recommendation V.29. Note that at this speed, Ql is 0 by definition. For V.27 *ter* at 4800 bits/s or 2400 bits/s, the modulation layer shall scramble and modulate the unscrambled Tl through T3 and Dl through D2 bits, respectively, from each symbol, according to Recommendation V.27 *ter*.

If the PL-FAX-DATA-STOP indication primitive arrives from the layer 3 entity, the following actions are taken:

1) modulate any remaining symbols;
2) terminate the generation of the carrier;
3) send the ML-FAX-STOP indication primitive to the call-state layer;
4) move to the OFF state.

If the modulation layer receives the PL-FAX-SPURT-HEADER indication (ACTION) primitive from the layer 3 entity with ACTION set to *abort*, the modulation layer shall

a) terminate generation of the carrier;
b) send the ML-FAX-ABORT indication primitive to the call-state layer;
c) move to the OFF state.

If all the available symbols have been demodulated (i.e. the buffer is empty) and the PL-FAX-DATA-STOP indication has not arrived, the modulation layer shall move to the BRIDGE state.

12.7.3.6 *BRIDGE state*

Upon entering the BRIDGE state, timer BRIDGE_TIME shall be started. This timer measures the time that the terminating end modulation layer remains in the BRIDGE state, keeping the modem carrier alive while recovering from lost facsimile page information packets. The default value is 45 ms.

While in the BRIDGE state, the modulation layer shall continue to generate a modulation signal of modem type ML_TERM_TYPE and modem speed ML_TERM_SPEED system variables while awaiting data to arrive. The pattern of symbols to be modulated shall correspond to the encoding of the all zeros symbol.

If the PL-FAX-DATA indication primitive arrives from the layer 3 entity, then the modulation layer state shall move to the DATA state.

If the modulation layer receives the PL-FAX-SPURT-HEADER indication (ACTION) primitive from the layer 3 entity with ACTION set to *abort*, the modulation layer shall

1) terminate generation of the carrier;
2) send the ML-FAX-ABORT indication primitive to the call-state layer;
3) move to the OFF state.

If timer BRIDGE_TIME expires, the following actions shall be taken:

a) terminate generation of the carrier;
b) send the ML-FAX-ABORT indication to the call-state layer;
c) move to the OFF state.

The value of the BRIDGE_TIME timer should be set as large as possible, taking into account the uncertainty due to time stamping. Its value should not violate the T.30 constraint that the minimum gap length between two components of a facsimile call is 55 ms. The default value is 45 ms. Other values are for further study.

12.8 *System variables and protocol parameters*

12.8.1 *Variables*

The variables listed below are used by the FADCOMP protocol. They are in addition to those defined in Recommendation G.764.

12.8.1.1 *ML_ORIG_SPEED*

This is the modem speed (e.g. 9600 bits/s) that was determined by the originating end call-state layer and is used by the originating end modulation layer.

12.8.1.2 *ML_ORIG_TYPE*

This is the modem type (e.g. V.29) that was determined by the originating end call-state layer and is used by the originating end modulation layer.

12.8.1.3 *ML_TERM_EPT_FREQ*

This is the frequency (1700 Hz, 1800 Hz) of the EPT that the modulation layer generates.

12.8.1.4 *ML_TERM_SPEED*

This is the modem speed (e.g., 9600 bits/second) as determined by the terminating end call-state layer and used by the terminating end modulation layer.

12.8.1.5 *ML_TERM_TYPE*

This is the modem type (e.g. V.29) as determined by the terminating end call-state layer and used by the terminating end modulation layer.

12.8.1.6 *ORIG_SPEED*

This is the speed of the modulation as extracted from T.30 messages by the call-state layer in its demodulator role.

12.8.1.7 *ORIG_TYPE*

This is the type of the modulation as extracted from T.30 messages by the call-state layer in its demodulator role.

12.8.1.8 *TERM_SPEED*

This is the speed of the modulation as extracted from the T.30 messages by the call-state layer in its remodulator role.

12.8.1.9 *TERM_TYPE*

This is the type of the modulation as extracted from the T.30 messages by the call-state layer in its remodulator role.

12.8.2 *Timers*

The following timers are used by the FADCOMP protocol in addition to those used in Recommendation G.764.

12.8.2.1 BRIDGE_TIME

This timer measures the time that the terminating end modulation layer remains in the BRIDGE state, keeping the modem carrier alive while recovering from lost facsimile page information packets. The default value is 45 ms.

12.8.2.2 *EPT_TIME_ORIG*

This timer measures the time that the originating end modulation layer remains in the EPT state. The default value is 500 ms.

12.8.2.3 EPT_TIME_TERM

This timer measures the time that the terminating end modulation layer remains in the EPT state generating an EPT tone. The default value is 500 ms.

12.8.2.4 *IDLE_TIME*

This timer measures the time that the terminating end modulation layer can remain in the IDLE state. The default value is 3 seconds.

12.8.2.5 *TVDELAY*

This timer is used to measure the variable queuing delay in a node that a packet encounters. It is used to update the TS field of a facsimile packet.

12.8.2.6 *WAIT_TIME*

This timer measures the time that the originating end modulation layer shall wait for a signal (either an EPT tone or facsimile page modulation signal) while its in the idle state. The default value is 3 seconds.

12.9 *Summary of primitives*

12.9.1 *Primitives for the interfaces between link and packet layers*

The primitives for the interfaces between the link and packet layers have the same definition in § 9 of Recommendation G.764 and in § 7.9.1 for DICE.

12.9.1.1 *DL-LI-READY indication*

See § 9.1.1 of Recommendation G.764.

12 9.1.2 *DL-UNIT-DATA request*

See § 9.1.2 of Recommendation G.764.

12.9.1.3 *DL-UNIT-DATA indication*

See § 9.1.3 of Recommendation G.764.

12.9.1.4 *DL-UNIT-H-DATA request*

See § 9.1.4 of Recommendation G.764.

12.1.9.1.5 *DL-UNIT-H-DATA indication*

See § 9.1.5 of Recommendation G.764.

12.9.2 *Primitives for the interface between packet and modulation layers*

12.9.2.1 *PL-FAX-CAPABILITY indication (CAPABILITIES)*

This primitive is used by the terminating endpoint packet layer of the endpoint whose call-state layer role is that of a demodulator to indicate to the modulation layer that a capability indication packet has arrived for the modulation layer to transmit up to the call-state layer.

12.9.2.2 *PL-FAX-CAPABILITY request (CAPABILITIES)*

This primitive is used by the modulation layer of the originating endpoint whose call-state layer role is that of a remodulator to indicate to the layer 3 entity that a capability indication packet is to be formed.

12.9.2.3 *PL-FAX-DATA indication*

This primitive is used by the packet layer of the terminating endpoint to indicate to the modulation layer that a page information packet, that is not the last packet of a page spurt, has arrived.

12.9.2.4 *PL-FAX-DATA-START request*

This primitive is used by the modulation layer of the originating endpoint to indicate to the layer 3 entity that demodulated symbols are to be segmented into packets.

12.9.2.5 *PL-FAX-DATA-STOP indication*

This primitive is used by the layer 3 entity of the terminating endpoint to indicate to the modulation layer that the last page information packet of a page spurt has arrived and all its symbols have been read out of the buffer by the Modulation Layer.

12.9.2.6 *PL-FAX-DATA-STOP request*

This primitive is used by the modulation layer of the originating endpoint to indicate to the layer 3 entity that there are no more demodulated symbols to segment into packets.

12.9.2.7 *PL-FAX-SPURT-HEADER indication (ACTION)*

This primitive is used by the layer 3 entity of the terminating endpoint to indicate to the modulation layer an action to be executed regarding the EPT tone or the training sequence.

12.9.2.8 *PL-FAX-SPURT-HEADER request (ACTION)*

This primitive is used by the modulation layer of the originating endpoint to indicate to the layer 3 entity that a packet indicating the given action is to be formed.

12.9.3 *Primitives for the interface between the modulation and call-state layers*

12.9.3.1 *ML-FAX-ABORT confirmation*

This primitive is used by the modulation layer of the originating endpoint to confirm to the call-state layer that the facsimile page spurt has been aborted.

12.9.3.2 *ML-FAX-ABORT indication*

This primitive is used by the modulation layer of the terminating endpoint to inform the call-state layer that the facsimile remodulation has been aborted.

12.9.3.3 *ML-FAX-CAPABILITY indication (CAPABILITIES)*

This primitive is used by the modulation layer of the terminating endpoint whose call-state layer is in the demodulator role to indicate to the call-state layer the remodulation capabilities of the far-end PCME.

12.9.3.4 *ML-FAX-CAPABILITY request (CAPABILITIES)*

This primitive is used by the call-state layer, when it is in the remodulator role, to indicate to the originating endpoint of the modulation layer the originating endpoint's remodulation capabilities.

12.9.3.5 *ML-FAX-START request (TYPE,SPEED)*

This primitive is used by the call-state layer of the originating endpoint to indicate to the modulation layer that a facsimile page spurt should be demodulated, using the given modem TYPE and SPEED.

12.9.3.6 *ML-FAX-START response (TYPE,SPEED)*

This primitive is used by the call-state layer of the terminating endpoint to indicate to the modulation layer that a facsimile page spurt should be remodulated, using the given modem TYPE and SPEED.

12.9.3.7 *ML-FAX-STOP confirmation*

This primitive is used by the modulation layer of the originating endpoint to confirm to the call-state layer that the facsimile page spurt has ended.

12.9.3.8 *ML-FAX-STOP indication*

This primitive is used by the modulation layer of the terminating endpoint to indicate to the call-state layer that the facsimile page spurt has ended.

12.9.3.9 *ML-FAX-STOP request*

This primitive is used by the call-state layer of the originating endpoint to indicate to the modulation layer that the facsimile page spurt has been interrupted and that the modulation layer should return to the OFF state.

12.9.3.10 ML-FAX-STOP response

This primitive is used by the call-state layer of the terminating endpoint to indicate to the modulation layer that the facsimile page spurt has been interrupted and that the modulation layer should return to the OFF sate.

13. Testing of the link

13.1 *Overview*

The test procedures consists of a compelled exchange identification (XID) frames to allow the verification of the data link layer connection.

There are two types of test procedures:

a) end-to-end tests where only edge nodes of the network shall process the frame;

b) sectionalization tests, where each node of the path shall process the frame.

When the XID command frame with the test packet in its information field arrives at a node that must respond, the node shall respond with the indicated XID response frame. The sending node shall receive the XID response within a certain time limit T_{test} from sending the XID command. If the response is not received before T_{test} expires, the test is declared to be a failure.

Failure of the test indicates the occurrence of one or more of the following conditions:

1) link not established (physically and/or logically);

2) errors in processing;

3) lost command or response due to network congestion.

The procedures allow for testing of all circuits irrespective of the type of traffic that they carry (voice, voiceband data, facsimile, video, digital data). This provides the capability of locating link failures in a wideband packet network and/or of ensuring the integrity of a permanent virtual circuit path before actual traffic is allowed to flow.

The procedures allow for the testing for both two-way and one-way circuits. In each case, the XID frame that contains the test packet is sent with the same address used for the user's traffic. For a two-way circuit, the response XID frame returns on the user's address. For a one-way circuit, the response XID frame flows on the management channel whose address is 8191 (the thirteen bits of the address are all set to 1).

13.2 *Frame description*

Figure 26/G.765 illustrates the format of the XID frame used for link testing. The following subsections describe the functional fields for the XID command for testing of two-way and one-way permanent virtual circuits (PVCs).

Octet	Bits 8	7	6	5	4	3	2	1	Field name
1							C/R	0	Address octet 1
2								1	Address octet 2
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	1	Format identifiier (131)
5	1 1	1 1	1 1	1 1	1 1	1 1	0 1	1 0	Group identifier (253) Group identifier (254)
6	X	X	X	X	X	X	X	X	Group length octet 1
7	X	X	X	X	X	X	X	X	Group length octet 2
8									DLCI value octet 1
9									DLCI value octet 2
10	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	Responding node address (36 octets)
46									FCS octet 1
47									FCS octet 2

FIGURE 26/G.765

XID command/response frame for testing permanent virtual circuits
X = 0 or 1

13.2.1 *Address octets*

Octets 1 and 2 represent the address field for a default two octet address. The first octet includes the address extension bit, the command/response (C/R) bit and the 6-bit upper subfield of the address. The second octet includes the 7-bit lower subfield of the address (including the two address bits taken for congestion control, the discard eligibility flag bit) and the address extension bit The C/R bit is set to 0 for a command and to 1 for a response. For all types of PVCs, the command is sent using the same data link connection identifier (DLCI) used for the user's traffic. The response is sent on the user's DLCI for two-way PVCs and on DLCI = 8191 for all other PVCs (a one-way PVC, broadcast PVCs, concentrated PVCs).

13.2.2 *Control field*

Octet 3 contains the control field for the XID frame.

13.2.3 *Format identifier field*

Octet 4 contains the format identifier field. The format identifier field is a fixed length of one octet. Its value is 131 decimal.

13.2.4 *Group identifier field*

Octet 5 contains the group identifier field. This field identifies the function of the XID information field. The value of this field is selected to distinguish the various uses of the XID frame with the same value for format identifier, decimal 131. The group identifier field is selected to be 253 for end-to-end testing to indicate the frame is to be processed by the edge nodes only. The value is set to 254 for a sectionalization test, i.e. that all nodes in the path must process the frame.

13.2.5 *Group length field*

Octets 6 and 7 contain the group length field. This 16-bit field codes the "length" in octets of the remainder of this message, excluding FCS and closing flag. The length is coded in decimal format.

13.2.6 *DLCI value field*

Octets 8 and 9 contain the values of the DLCI, including the bits for congestion control and discard eligibility. This field is useful when XID responses for non two-way permanent virtual circuits are sent on the management DLCI of 8191.

13.2.7 *Responding node address*

The responding node address is a field of up to 36 octets starting from octet 10 that contains an ASCII address for the node.

13.2.8 *FCS Field*

The last two octets of the message are for the FCS field.

13.3 *Procedures*

The test procedures are initiated by a command entered by the network personnel. Upon receipt of this command, the PCME shall send an XID command frame with a test packet as specified above. It shall start a timer T_{test}, the value of which can be one of the following: 3, 6, 10, 20, 30, 40, 60, 90 and 120 seconds.

Depending on the value of the group identifier (GI) field, the XID command frame with the test packet shall be processed either by each node in the network or by the edge nodes only. For end-to-end testing (GI = 253), the terminating endpoint (the edge node) shall loop the XID command frame with the test packet and send it back to the originating endpoint. For sectionalization testing (GI = 254), each intermediate node, as well as the terminating endpoint, shall loop back the XID frame as well.

The responses are displayed to the user.

Note – In the case of a voice connection with channel associated signalling, the XID frame tests the logical connection for voice only. Testing of the associated signalling logical connection is obtained through the procedures of Recommendation G.764, in particular through the timer TSIG_KA (see § 6.4 of Recommendation G.764).

The value of the timer TSIG_KA ranges from 1.5 seconds to 90 seconds, depending on the value of the timer TSIG_REF, as given in Table 12/G.765 (see §§ 8.2 and 8.3 of Recommendation G.764):

Therefore, T_{test} shall be at least equal to the value of TSIG_KA. For the default value of TSIG_KA = 25 seconds, T_{test} shall be at least 30 seconds.

In an end-to-end test, if the timer T_{test} expires before an XID response frame is received, the test is declared to be a failure.

TABLE 12/G.765

Values of TSIG_KA

TSIG_REF	TSIG_KA
1	1.5 2.5 3.5 4.5
5	7.5 12.5 17.5 22.5
10	15 25 35 45
20	30 50 70 90

In a sectionalization test, if no response arrives before timer T_{test} expires, the test is declared to be a failure. The responses from the responding nodes are displayed to the user. If all nodes in the path respond, and the responses arrive before timer T_{test} expires, the test is declared to be a success.

14 Permanent virtual circuit restoration

14.1 *Overview*

The purpose is to provide the PCME with a mechanism for PVC restoration after detection of a fault in transmission paths associated with a network node. The PVC restoration procedures involve a backup after the failure and a switchback after the fault is repaired. The XID response frame is used with the format specified below and is sent in the backward path for each direction of the connection. Figure 27/G.765 shows how this is done for a two-way connection. In a one-way connection, only one XID frame will be launched.

Two approaches are considered: end-to-end notification (method 1) and consolidated PVC restoration notification (method 2).

14.1.1 *End-to-end notification (method 1)*

This method is restricted to two-way connections. In this approach, a PVC restoration/switchback request is generated for each failed PVC that has a backup PVC after a facility alarm has occurred or has been cleared. This individual fault indication message shall be generated by the node that terminates the failed facility. The messages are transmitted towards the endpoints, and each message includes the identity of each virtual circuit on the associated network facilities affected by the failure. At each node, the frames are relayed through the network and their DLCI is translated to the appropriate address toward the next node. At each endpoint node, the virtual circuits are switched to alternate virtual circuits on one or more different physical facilities.

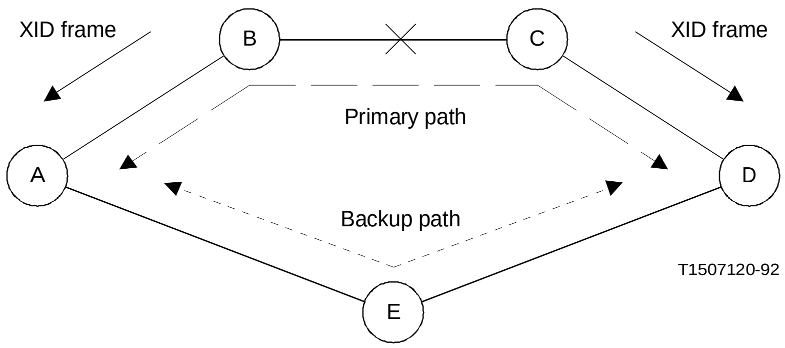


FIGURE 27/G.765
Diagram for PVC restoration and switchback in a two-way connection

14.1.2 *Consolidated PVC restoration notification (method 2)*

A consolidated PVC restoration notification is a PVC restoration/switchback message that carries information related to multiple DLCIs up to the limit of the LAPD information field length of 260 octets.

In the case where many DLCIs are affected, more than one message may be generated, although the total number of generated frames is much less than in the first case. Furthermore, this approach is more general since it can be used for all types of PVCs while the first method is restricted to two-way PVCs. In this approach, every intermediate node is required to terminate the message and do further processing.

14.2 *Frame description*

Figures 28/G.765 and 29/G.765 illustrate the format of the XID frame for the PVC backup/switchback procedure for methods I and 2, respectively. The following subsections describe the functional fields of the XID frames used.

Octet	Bits 8	7	6	5	4	3	2	1	Field name
1							C/R	0	Address octet 1
2								1	Address octet 2
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	1	Format identifier (131)
5	1	1	1	1	0	0	1	1	Group identifier backup (243)
	1	1	1	1	0	0	0	1	Group identifier switchback (241)
6									FCS octet 1
7									FCS octet 2

FIGURE 28/G.765

XID response frame for PVC backup/switchback (method 1)

Octet	8	7	6	5	4	3	2	1	Field name
1	1	1	1	1	1	1	C/R	0	Address octet 1
2	1	1	1	1	1	1	1	1	Address octet 2
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	1	Format identifier (131)
5	1 1	1 1	1 1	1 1	0 0	0 0	1 0	0 0	Group identifier backup (242) Group identifier switchback (240)
6									Group length octet 1
7									Group length octet 1
8 9	–	–	–	–	–	–	–	–	DLCI value octet 1 (1st DLCI) DLCI value octet 2 (1st DLCI)
	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	
$7 + (2n - 1)$ $7 + 2n$ a)	–	–	–	–	–	–	–	–	DLCI value octet 1 (*n*th DLCI) DLCI value octet 2 (*n*th DLCI)
$7 + 2n + 1$									FCS octet 1
$7 + 2(n + 1)$									FCS octet 2

a) Total length shall not exceed 256 octets.

FIGURE 29/G.765

XID response frame for PVC backup/switchback (method 2)

14.2.1 *Address octets*

Octets 1 and 2 represent the address field for a default two octet address. The first octet includes the C/R bit and the 6-bit upper subfield of the address. The second octet includes the 7-bit lower subfield of the address (including the two address bits taken for congestion control, the discard eligibility flag bit) and the address extension bit. The C/R bit is set to I to indicate that the XID used is a response. In method 1, the DLCI used is that of the primary PVC path, while in method 2, the DLCI is set to 8191.

14.2.2 *Control field*

Octet 3 contains the control field for the XID frame.

14.2.3 *Format identifier field*

Octet 4 contains the format identifier field. The value of 131 decimal is used for wideband packet applications.

14.2.4 *Group identifier field*

Octet 5 contains the group identifier field. This field identifies the function of the XID information field. The value of this field is selected to distinguish the various uses of the XID frame with the same value for format identifier, decimal 131. The group identifier field is selected as follows:

1) For method 1, it is set to 243 for restoration through backup, and to 241 for switchback. This means that the frame shall be processed by the edge nodes only.

2) For method 2, the value shall be set to 242 for restoration through backup and to 240 for switchback. This means that all nodes in the path shall process the frame by updating the list of DLCIs in the information field of the XID frame and updating the group length field accordingly. It is also possible in this case that the arriving XID frame may be split into several XID frames, if the new DLCIs correspond to virtual circuits that have different physical links.

Note 1 – Method 2 may facilitate future internetworking with frame relay networks defined in Recommendation Q.922.

Note 2 – In method 2, the use of the same DLCI for all links of a PVC (i.e. on an end-to-end basis) may alleviate the computational load.

14.2.5 *Group length field*

In Figure 29/G.765, octets 6 and 7 contain the group length field. This 16-bit field describes the "length" of the octets in the remainder of this message, excluding FCS and closing flag.

14.2.6 *DLCI value field*

In Figure 29/G.765, octet(s) 8 and onward present the DLCI values that identify logical links that shall be backed up or switched back. For this field, the first octet shall represent the first octet of DLCI. The next octet shall represent the second octet of the DLCI.

14.2.7 FCS field

The last two octets of the message are for the FCS field. They are octets 6 and 7 in Figure 28/G.765, and octets (7 + 2n + l) and [7 + 2(n + l)] in Figure 29/G.765.

14.3 *Procedures*

14.3.1 *Backup*

After detecting a fault in the transmission path, a node shall identify the affected PVCs with backups that terminate at that node and shall generate an XID response frame to indicate that a fault has affected these PVCS. In method 1, the notification message is sent in the backward direction, using the primary path DLCI with the GI = 243 (decimal). In method 2, the message is sent on DLCI = 8191 and GI = 242 (decimal) in the backward direction.

The format of the XID frames used is given above. The XID frame is an XID response frame, i.e. with the C/R bit set to 1.

When it receives such a message, any network node shall determine whether it terminates the affected virtual circuits. If it does, then:

1) In method 1, it shall initiate the switching to the backup links.

2) In method 2, it shall remove its DLCI from the DLCI list and translate the remaining DLCIs to the new values that correspond to the same PVCs on the outgoing physical link(s). The arriving XID frame may be split, if necessary, into one or more XID frames, each having the format of Figure 31/G.765, depending on the association of the virtual circuits with the physical links.

If the network node does not terminate the affected virtual circuit, then:

a) In method 1, the node shall only translate the layer 2 address to that which is associated with the virtual circuit on the outgoing physical link.

b) In method 2, the translation shall be performed on all DLCIs in the information field of the XID frame. It is also possible in this case that the arriving XID frame may be split into several XID frames, if the new DLCIs correspond to virtual circuits that have different physical links.

14.3.2 *PVC integrity check*

In Method 2, the end-to-end integrity of the PVC may be checked before the switchback. This is done after the alarm in the transmission path associated with a given PVC has been cleared. This integrity check is done by launching an XID command on the management link (DLCI = 8191) and with the group identifier = 239. The format of the command is given in Figure 30/G.765. The node awaits for XID responses for each PVC and records the corresponding DLCIs. The format of response, given in Figure 3 1/G.765, shows how the responding DLCI is recorded in the XID response frame. The responding DLCIs, if any, are then used in the switchback procedures.

Octet	Bits								Field name
	8	7	6	5	4	3	2	1	
1	1	1	1	1	1	1	0	0	Address octet 1
2	1	1	1	1	1	1	1	1	Address octet 2
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	1	Format identifier (131)
5	1	1	1	0	1	1	1	1	Group identifier PVC integrity check (239)
6									Group length octet 1
7									Group length octet 2
8 9	–	–	–	–	–	–	–	–	DLCI value octet 1 (1st DLCI) DLCI value octet 2 (1st DLCI)
	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	
7 + (2*n* – 1) 7 + 2*n* a)	–	–	–	–	–	–	–	–	DLCI value octet 1 (*n*th DLCI) DLCI value octet 2 (*n*th DLCI)
7 + 2*n* + 1									FCS octet 1
7 + 2 (*n* + 1)									FCS octet 2

a) Total length shall not exceed 256 octets.

FIGURE 30/G.765

XID command frame for PVC integrity check

Octet	Bits								Field name
	8	7	6	5	4	3	2	1	
1	1	1	1	1	1	1	1	0	Address octet 1
2	1	1	1	1	1	1	1	1	Address octet 2
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	1	Format identifier (131)
5	1	1	1	0	1	1	1	1	Group identifier PVC integrity check (239)
6	–	–	–	–	–	–	–	–	DLCI value octet 1 (1st DLCI)
7									DLCI value octet 2 (1st DLCI)
8									FCS octet 1
9									FCS octet 2

FIGURE 31/G.765

XID response frame for PVC integrity check

14.3.3 *Switchback*

14.3.3.1 *Without integrity check*

After the alarm in the transmission path associated with a given PVC has been cleared, that node shall generate an XID response as a fault clearance indication message and transmit it on all the physical links associated with the other network nodes that have at least one virtual circuit affected by the failure. The GI is set to decimal 241 in method 1 and 240 in method 2.

The XID response can take one of the two formats displayed above.

When it receives such a message, any network node shall determine whether it terminates the affected virtual circuits. If it does, then:

1) In method 1, it shall initiate the switching back to the original links.

2) In method 2, it shall remove its DLCI from the DLCI list and translate the remaining DLCIs to the new values that correspond to the same PVCs on the outgoing physical link(s). The arriving XID frame may be split, if necessary, into one or more XID frames, depending on the association of the virtual circuits with the physical links.

If the network node does not terminate the affected virtual circuit, it shall relay the XID. In method 1, the node shall translate the layer 2 address to that associated with the virtual circuit on the outgoing physical link. In method 2, the translation shall be performed on all the DLCIs in the information field of the XID frame with the possible splitting of the arriving XID frame into one or more XID frames, depending on the association of the virtual circuits with the physical links.

14.3.3.2 *With integrity check*

This applies to method 2 only. If an integrity check is used, the switchback is initiated as above but only for the DLCIs that have responded to the XID command frame for PVC integrity checking.

15 *Packet stream backup*

15.1 *Overview*

The packet stream restoration feature allows the PCME to backup the traffic from a failed packet stream on a preprovisioned backup packet stream. A packet stream is a collection of logical links multiplexed together onto one physical channel between two endpoints of the wideband packet network. The two streams provisioned as backup-pair act as primary and secondary transmission paths for traffic on either stream. In normal conditions, i.e. no facility failures, the traffic is routed on each primary stream so that the two streams are carrying their normal share of traffic. When the facility corresponding to either packet stream fails, the traffic is switched to the backup stream.

Both nodes terminating a packet stream need to activate backup/switchback action on that stream. For this purpose, node-to-node communication is required between the two end PCMEs. This is achieved via an XID message with GI field set to 245 for initiating the backup and 247 for initiating the switchback message. The XID messages shall be transmitted on the primary stream, and, after receiving the message, the PCME node shall activate or deactivate the backup action for the failed stream.

15.2 *Frame description*

Figure 32/G.765 illustrates the format of the XID frame for the packet stream backup/switchback procedures. The following subsections describe the functional fields for the XID response.

Octet	Bits 8	7	6	5	4	3	2	1	Field name
1							C/R	0	Address octet 1
2								1	Address octet 2
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	1	Format identifier (131)
5	1 1	1 1	1 1	1 1	0 0	1 1	0 1	1 1	Group identifier for backup (245) Group identifier for switchback (247)
6									FCS octet 1
7									FCS octet 2

FIGURE 32/G.765

XID response frame for packet stream backup/switchback

15.2.1 *Address octets*

Octets 2 and 3 represent the address field for a default two octet address. The first octet includes the C/R bit and the 6-bit upper subfield of the address. The second octet includes the 7-bit lower subfield of the address (including the two address bits taken for congestion control, the discard eligibility indicator bit) and the address extension bit The C/R bit is set to 1 to indicate that the XID used is a response. The DLCI used is any DLCI on the backup packet stream.

15.2.2 *Control field*

Octet 3 contains the control field for the XID frame.

15.2.3 *Format identifier field*

Octet 4 contains the format identifier field. The value of 131 decimal is proposed to be used for wideband packet applications.

15.2.4 *Group identifier field*

Octet 5 contains the group identifier field. This field identifies the function of the XID information field. The value of this field is selected to distinguish the various uses of the XID frame with the same value for format identifier, decimal 131. The group identifier field is 245 for backup, and 247 for switchback. This means that the frame shall be processed by the edge nodes only.

15.2.5 *FCS field*

The last two octets of the message are for the FCS field.

15.3 *Procedures*

15.3.1 *Backup*

The node that detects a fault in the transmission path associated with a given packet stream shall generate an XID response frame to indicate that a fault has affected this packet stream. The notification message is sent on any DLCI with GI set to decimal 245.

The XID response takes the format displayed above.

When it receives such a message, any network node shall determine whether it terminates the affected packet stream. If it does, then it shall initiate the switching to the backup packet stream.

If the network node does not terminate the affected virtual circuit, the node shall only translate the layer 2 address to that which is associated with the packet stream on the outgoing physical link.

15.3.2 *Switchback*

After the alarm in the transmission path associated with a given packet stream has been cleared, that node shall generate an XID response frame as a fault clearance indication message and transmit it on the physical link associated with the backup packet stream. The DLCI is any DLCI of the packet stream and the GI is set to decimal 247. The format of the XID response is given in Figure 32/G.765.

When it receives such a message, any network node shall determine whether it terminates the affected virtual circuits. If it does, then it shall initiate the switching back to the original packet stream.

If the network node does not terminate the affected packet stream, it shall translate the layer 2 address to that associated with the packet stream on the outgoing physical link.

16 Generation of the alarm indication signal

The AIS is transmitted downstream of a transmission facility to indicate an upstream failure and prevent the propagation of the alarm to other downstream network equipment. Therefore, a node shall declare an AIS on a facility, if and only if, the following conditions are true:

1) all channels (24 or 30 depending on the interface) are packetized on one packet stream;

2) the primary path for this packet stream has failed and either there is no backup path or the backup path has also failed;

3) there are no PVC backup connections for any of the channels (24 or 30).

17 Data collection

17.1 *Transmission facilities monitoring*

Each PCME should monitor each of the incoming and outgoing digital links for the following conditions and parameters, and store separate cumulative counts of each type of events as required by users: bit error ratio (BER), errored seconds (ES) and severely errored seconds (SES). Default and user provisionable thresholds for these performance measures are available for major and minor alarms. The user can display the current values upon request.

When a threshold is exceeded, the corresponding major or minor alarm occurs. Trunk processing operations minimize effects of errors following major or minor alarms. This results in the removal of the affected trunks from service and making them appear "busy" to other network elements. An alarm indication signal (AIS) should be sent.

Trunk processing consists of sending a data word and two different signalling words on each affected incoming full-rate 64 kbit/s channel. The first signalling word is sent during the first 2500 ms after detection of a failure condition. Transmission of the second signalling word continues for the remainder of the failure condition.

Other counters are for slips, out-of-frame errors and change of frame alignment CRC-6 counter, bipolar violations.

The PCME shall count in an hourly summary, for each circuit or packet connection:

1) The number of layer 2 frames sent and received on each circuit or packet connection;

2) The number of user information segments sent and received on each circuit or packet connection, where the length of a user information segment is a system administerable parameter;

3) The number of speech bit blocks dropped;

4) The number of speech, voiceband data, video, or V.120 data frames dropped due to congestion.

The hourly summaries shall be available by request over the operations, administration, and maintenance (OAM) interface, and they shall be kept for at least three days and until erased by command.

17.2 *Traffic statistics*

The PCME shall monitor and store records of the various parameters needed to evaluate the traffic handling performance.

17.2.1 *Voice-band statistics*

To be defined.

17.2.2 *Digital data statistics*

To be defined.

17.2.3 *Facsimile statistics*

To be defined.

17.2.4 *Video statistics*

To be defined.

17.3 *Maintenance report*

To be defined according to the guidelines of monitoring of error performance (Recommendation G.821).

18 Congestion control

Congestion control techniques can be functionally divided into several aspects:

1) load measurement;

2) network reaction after detection of congestion;

3) notification messages sent to the users; and

4) user reactions.

The notification procedure must be flexible enough to fit the different traffic types that could be carried in a wideband packet network. Subsection 18.1 describes the anticipated different traffic categories in future frame relay networks. Subsection 18.2 presents the topological model on which this mechanism is based. Subsection 18.3 presents the consolidated link layer management congestion message for congestion control. Subsection 18.4 contains procedures that build upon this framework, taking into account different traffic categories. The network and user action are described in further detail.

Throughout the discussion, it is assumed that network congestion is an exceptional situation that requires prompt action. It is also assumed that receipt of the congestion notification by end user equipment does not create an error condition, although user's response is optional. It is assumed that the consolidated link layer management message will be sent between two nodes that have a common understanding of the LAPD address size. For the purpose of illustration, the default address shown is the default size of two octets. The communication of the message between two subnetworks that employ different address sizes is an item for further study.

18.1 *Traffic categories in wideband packet networks*

Potential traffic categories in a wideband packet network can be classified on the basis of their sensitivities at the user level to loss and to delay variation, as follows:

1) *Type A:* Administrative traffic, such as signalling and management traffic.

2) *Type B:* Loss sensitive/delay variation tolerant traffic, such as asynchronous and synchronous data transfer.

3) *Type C:* Loss sensitive/delay variation sensitive traffic, such as facsimile and continuous bit rate or isochronous data and video.

4) *Type D:* Loss tolerant/delay variation sensitive traffic, which includes packetized voice and embedded coded video.

5) *Type E:* Loss tolerant/delay variation tolerant traffic, such as telemetry traffic.

There are several ways to distinguish among the various classes and sub-classes of traffic. One way is to use a protocol identifier to separate delay sensitive for delay tolerant traffic (time stamping is needed to process delay sensitive traffic and to avoid delay variations between successive packets of the same traffic burst). Another way is to use different DLCI assignments as the "marking" agent The use of DLCI may be on an individual or group basis. Furthermore, the DLCI space may be segmented with each range corresponding to a type of traffic. At a third level, the use of the sub-class field can be used to distinguish various types of packets for the same DLCI (e.g. voiceband, facsimile or digital data).

Note – For the purpose of internetworking with frame relay networks, as defined in Recommendation Q.922, the use of DLCI as the distinguishing factor is appropriate. However, the exact method for internetworking is left for further study.

The following subsections highlight the main characteristics of each traffic type.

18.1.1 *Type A: Administrative traffic*

Type A traffic includes the “control” and “management” traffic that would flow across a frame relay network, such as signalling and layer management traffic. This type of traffic flow can be characterized as having the following properties:

1) very essential to the operation of a communications network;

2) packet loss should be avoided as much as possible;

3) packets of information must be delivered in a timely fashion (i.e. with minimum delay).

Examples of this type of information stream are the Q.931 signalling messages used for the purpose of negotiation of the services desired from the serving subnetwork, together with identification of facilities requested. Other examples include management-messages for layer management (e.g. LAPD broadcast messages used in terminal endpoint identifier (TEl) assignment) as well as for the transport of OSI network management protocols.

Because administrative traffic is always present in a network, all nodes in a communication subnetwork will transport at least two forms of traffic.

18.1.2 *Type B: Loss sensitive/delay variation tolerant traffic*

Type B traffic describes the transport of data information that has a non-continuous or bursty presentation of information at the access point to the network.

Examples of such traffic include:

a) asynchronous data traffic from an asynchronous terminal to a host computer; and

b) bulk transfer data traffic.

This type of traffic can be characterized as having the following properties:

1) packet loss should be kept as low as possible. This is because the consequences of packet loss may be severe, e.g. session re-establishment;

2) information is tolerant of delay. Information presented at the ingress node of a network may be queued and presented to the egress node in an asynchronous fashion;

3) delay must be kept to a defined limit. However, this delay may exceed that of types A, C, and D.

This type of traffic could use the discard eligibility indicator defined in Recommendation Q.922 to differentiate the presentation of traffic that exceeds the negotiated range.

18.1.3 *Type C: Loss sensitive/delay variation sensitive traffic*

Type C traffic describes the transport of data information that has a continuous presentation of information at the access point to the network. This includes, for example, the support of facsimile and continuous bit rate or isochronous data and video.

This type of traffic can be characterized as having the following properties:

1) packet loss should be kept as low as possible. The consequences of packet loss could be severe (e.g. session re-establishment);

2) delay variation must be minimal to preserve the quality of the played back information;

3) information is presented to the ingress network node/terminal adaptor as an uninterrupted bit stream and must be played out continuously at the egress node/terminal adaptor.

This type of traffic requires that all nodes of a subnetwork, together with end points must conform to the negotiated traffic rate determined at subscription time.

18.1.4 *Type D: Loss tolerant/delay variation sensitive traffic*

Type D traffic includes information that may be arranged such that the same packet contains blocks of different levels of significance. Under congestion, the packet size may be reduced by shedding less significant blocks. Here, the main objective is to deliver information (even with some information loss) and variations in packet arrival at the terminating end must be limited. This is clear in the case of embedded coding of voice and video (continuous bit rate video is discussed in § 18.1.3). Another example may correspond to data with advanced forward error correction methods. All blocks will be delivered as long as the delivery delay is acceptable. Otherwise, “less significant” blocks are dropped. The notion of “droppable” blocks infers that delivery is only necessary if the transit delay is under some threshold. Note that procedures for handling this form of traffic are described in Recommendation G.764.

This type of traffic can be characterized as having the following properties:

1) partial information has more value than no information (i.e. some blocks of a packet may be dropped or some packets may be lost or dropped);

2) packets of information must be delivered in sequence and at regular intervals (i.e. with minimum delay variation).

18.1.5 *Type E: Loss tolerant/delay variation tolerant traffic*

Type E traffic includes information that arrives infrequently to the access point of a network. It also includes frames that the network node has marked as “discardable.” It is not required that all frames be delivered and delay is tolerated. Examples of this type of traffic include telemetry traffic.

This type of traffic can be characterized as having the following properties:

1) partial information has more value than no information (i.e. some packets may be lost or dropped);

2) packets of information must be delivered in sequence but the delivery interval may be irregular (i.e. tolerant of delivery delay variation).

18.1.6 *Explicit congestion notification*

A frame relay node will support two or more traffic types concurrently. Therefore, properly designed network nodes will have the ability to distinguish traffic by service categories and to take appropriate action in the event of congestion. If needed, the distinction of traffic types may be through several means such as the use of the DLCI assignment.

18.2 *Topological model*

The topological model used in this proposal is shown in Figure 33/G.765. Node Y is the node under congestion; it has generated an explicit congestion notification message. Node X is in the backward direction from the congested node, and node Z is in the forward direction. UNI is the user-network interface.

There are two independent algorithms used when congestion is declared. The network algorithm is used to protect network resources and/or to maintain with high probability the negotiated quality of service and/or bandwidth. This algorithm affects both the end user traffic and the network administration traffic.

The second type of algorithm is the end user algorithm, which controls the offered load from the end user.

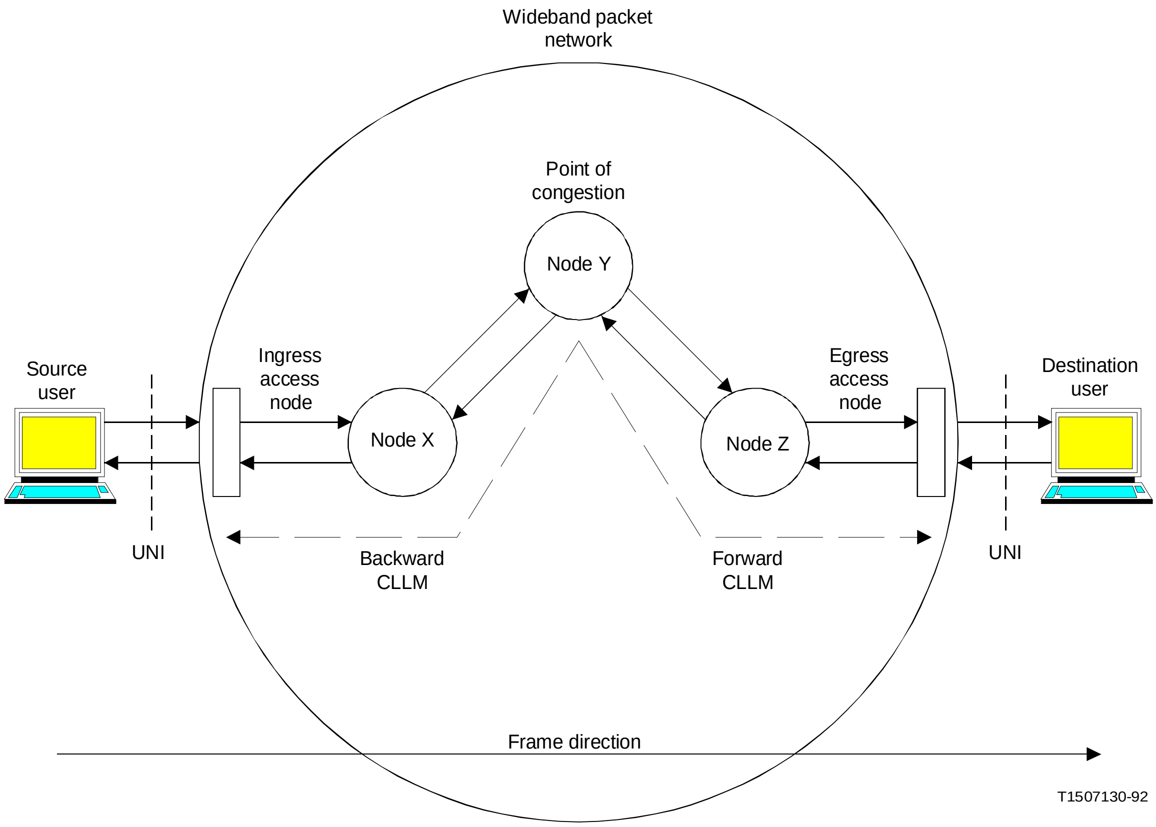


FIGURE 33/G.765
Wideband packet network topology

18.3 *Action of the congested node*

When a wideband packet node becomes severely congested, it determines the DLCIs of all permanent logical links connected to the congested resource and then sends a notification using one or more consolidated link layer management messages. The purpose of the consolidated link layer management message is

a) to inform the edge nodes of the network of the current state of the congestion (i.e. congestion is getting worse, is staying the same, or is decreasing); and/or

b) to notify the source that negotiated traffic ranges have been exceeded.

The congested node may also drop frames that have been identified as "discardable," according to the procedures of Recommendation Q.922.

The edge node may take action to reduce network congestion such as blocking additional call establishment Estimation of the network state is network-dependent

The three congestion states of a node are: Normal, Moderate Congestion, and Maximum Congestion.

1) In the Nominal state, there is no congestion.

2) In the Moderate Congestion state, the node has reached a level of congestion in which the end user and network administration traffic has increased to a point greater than the available network resources. The node and/or network is not in danger of collapse, but it cannot maintain the agreed upon quality of service and/or bandwidth.

3) In the Maximum Congestion state, the node and/or network is in danger of collapse and immediate traffic reduction is required.

The network node determines the current congestion states and its action depends on the past congestion state:

i) If the Congestion state is Normal, and the previous Congestion state was Normal, then no message is generated.

ii) If the previous Congestion state was Nominal, and a change of state has occurred, then the appropriate state transition message is generated. The node generates messages every T_{cong} seconds to update the congestion level information. The minimum value of T_{cong} is 10 seconds; other values are for further study. Once the node has returned to the Normal state, the message generation is terminated.

18.3.1 *Transition messages*

The following six state transition messages are used:

1) *Congestion increasing* – The level of congestion has increased to a moderate congestion level from the Normal state. The congestion is not, however, increasing fast enough to bring down the network.

2) *Congestion clearing* – The level of congestion has reduced since the last measurement and/or message. The congestion has disappeared, and the state has changed from Moderate to Normal.

3) *Sustained congestion* – The level of congestion has not changed since the last measurement and/or message. This message can be generated when the node is either in the moderate congestion state or in the maximum congestion state.

4) *Critical congestion* – The level of congestion has increased since the last measurement and/or message. The level of congestion indicates that the network is in danger of collapse and requires immediate action.

5) *Congestion abating* – The level of congestion has decreased since the last measurement and/or message. The congestion has not cleared, and the Congestion state has changed from Maximum Congestion to Moderate Congestion.

6) *Critical congestion clearing* – The level of congestion has decreased considerably since the last measurement and/or message and the state has changed from Maximum Congestion to Normal.

The state transition diagram is shown in Figure 34/G.765.

The consolidated link layer management message lists all the DLCIs that correspond to the congested packet stream(s). These DLCIs will correspond to sources that are currently active and those that are not. The purpose is to prevent those sources that are not active from becoming active and hence increasing congestion. This is particularly needed for bursty traffic such as traffic types B and D.

It may be necessary to send more than one consolidated link layer management message to notify all the logical links whose DLCIs are associated with the congested packet stream(s).

Further actions, if any, depend on the type of traffic, as expected below.

a) *Type A traffic* – No further action is needed.

b) *Type B traffic* – If there is a congestion, then a notification is sent. If the congestion persists, frames marked as discardable are dropped.

c) *Type C traffic* – If the node experiences congestion, the network node shall inform the edge node to block additional calls.

d) *Type D traffic* – If the node experiences congestion, the network node may reduce the coding rate for voice or data. If the congestion persists, the network node identifies the channels that may be inactivated and then generates a message in the backward direction to block additional call establishment.

   Furthermore, other messages may be used as well. For example, a G.764 signalling packet with the normal/alarm bit set to 1 may be used as explicit congestion notification in the forward direction for channels that have channel-associated signalling and that have trunk conditioning as an administered option.

e) *Type E traffic* – If the node experiences congestion, a notification is sent. If the congestion persists, then frames marked as discardable are dropped.

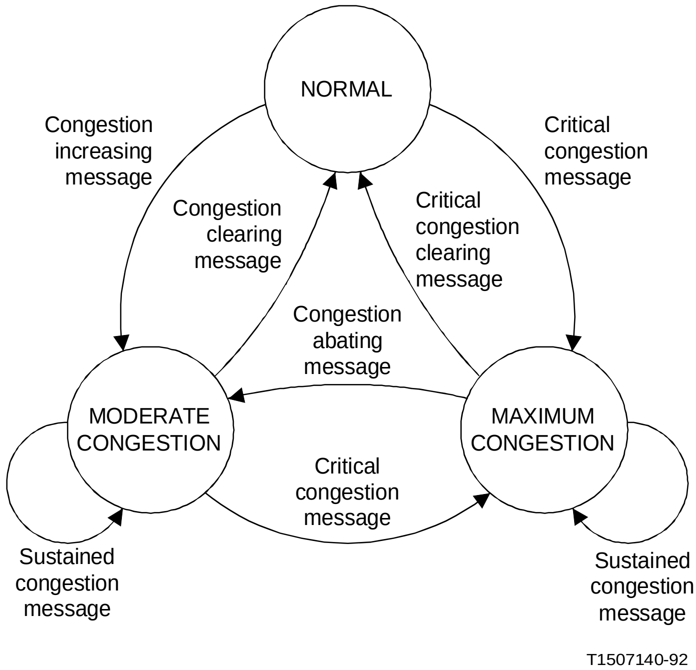


FIGURE 34/G.765

State transitions of a congested wideband packet node

18.4 *Network node response to CLLM*

Network nodes can react in different ways to the consolidated link layer management message congestion (CLLM).

18.4.1 *Network ingress node reaction*

After receiving a consolidated link layer management message, a network node interprets the list of congested DLCIs and then translates it to outgoing DLCIs. Because the outgoing DLCIs may not always be on the same packet stream or access facility, multiple outgoing messages may be generated in the backward direction in response to a single incoming message. However, a single message will contain several DLCIs from the same packet stream. At the edge of the network, the access channels are made to appear “busy” (“trunk conditioning”) for some or all of the calls so that no further traffic is routed to these congested access channels. This will reduce adding to the congestion level. A second action would be to prevent the establishment of all new calls, which would eventually reduce the congestion level for that access channel.

If the node interfaces with an international switching centre (ISC), the ISC procedures of Recommendation Q.50 shall be followed

18.4.2 *Operation of wideband packet network node in the presence of congestion*

The actions refer to two aspects:

1) treatment of the traffic; and

2) generation of CLLMs.

18.4.2.1 *Traffic treatment*

Once an explicit notification of congestion has been made, the network node will examine the incoming traffic and may serve different categories of traffic with different priorities of processing attention. For example, if the speech is coded according to the embedded ADPCM algorithms of Recommendation G.727, one or several blocks containing the least significant bits may be dropped. The node may also drop frames that have been marked as discardable. Once the congestion has been eliminated, the network node may once again resume serving all traffic.

18.4.2.2 *Message generation*

The network node determines the current congestion states and its action depends on the past congestion state:

1) If the Congestion state is Normal, and the previous Congestion state was Normal, then no message is generated.

2) If the previous state was Normal, and a change of state has occurred, then the appropriate state transition message is generated. The node generates messages every T_{cong} seconds to update the congestion level information. Once the node has returned to the Normal state, the message generation is terminated.

In general, CLLM messages are sent from the point of congestion and terminated at the edge nodes. However, in the case of connections to frame relay networks and terminals, the edge node may pass the CLLM onwards across the network to network interface or the user to network interface.

Note – The use of the same DLCI for all links of a permanent virtual circuit (i.e. on an end-to-end basis) may alleviate the computational load.

18.5 *End-user's response to the CLLM*

The end-user's equipment response is optional; however, receipt of the congestion notification by end user equipment shall not create an error condition.

The following proposal presents different ways that end-user equipment can react to congestion notification by a wideband packet network.

No action should be taken for types A, D and E traffic.

18.5.1 *Type B traffic*

18.5.1.1 *End-user's action*

1) *Congestion Increasing* – The end user should reduce the offered load (to the next step if possible). Since the node is in the Moderate Congestion state, the service is only degraded. The end user should, therefore, be allowed to implement an algorithm that will reduce the offered load, but this can increase the service quality to some of the end user traffic, while reducing or degrading further other end user traffic. These ideas set the stage for the bandwidth enforcement or dynamic change of coding algorithms feature.

2) *Congestion clearing* – The end user should allow the offered load to increase to return service quality to the negotiated value for all traffic. The end user may, however, implement the return following an algorithm that protects the network against "flip-flop" between the Normal and Moderate Congestion states.

3) *Sustained congestion* – The end user may either keep the offered load at the current reduced rate, or further reduce the offered load to force the node into the Normal state.

4) *Critical congestion* – Since the level of congestion has increased considerably so that the network is in danger, the end user must reduce the offered load so that the node is at least forced back to the moderately Congested state (this action will protect the network against the situation in which an end user algorithm has not been altered to take into account network growth, and so a "faulty" end user algorithm cannot fail to bring runaway congestion under control).

5) *Congestion abating* – The return to the Moderate Congestion state will also allow the end user to adjust the offered load. The end user may increase the offered load, or re-implement the algorithms used when the Congestion Increasing message is received.

6) *Critical congestion clearing* – The end user should allow the offered load to increase, to return service quality to the negotiated value for all traffic. The end user may, however, implement the return following an algorithm that protects the network against "flip-flop" between the Nominal and Critical Congestion states.

18.5.1.2 *Load reduction*

Reduction of the end user's information transfer rate should be guided by the following guidelines:

1) the end user adjustment of offered load should be rate based (to distinguish from window based mechanisms);

2) some lower bound on rate reduction is to be established to achieve fairness among end users;

3) rate reduction steps should not be too drastic to eliminate big fluctuations in throughput;

4) reduction in response to implicit notification should depend on whether or not an explicit notification has been received.

For example, upon the reception of the first CLLM, the user should reduce its offered load to the negotiated committed information rate (CIR). If the operating point is at or below this level, no reduction is required. This will achieve some fairness among users operating at different load levels and contributing differently to congestion. When a second CLLM is received the user shall reduce its offered load to 75% of negotiated CIR. If a third CLLM is received, the user shall reduce its offered load to 50% of the CIR. No further reduction is required in response to explicit notification messages. This avoids penalizing complying users, thus achieving some degree of fairness.

If the user can operate at the new reduced rate without receiving any type of congestion notification (explicit or implicit), the user is allowed to raise the offered load to 75% of the CIR. If operation at the new increased load is possible without receiving a congestion notification, the user can increase the rate again. The first increase is to 75% of CIR. The second increase brings the offered load to the negotiated CIR. The rate can then be increased to the original offered load.

An implicit notification received following an explicit one should be interpreted as an indication of severe congestion, and the rate should be reduced to 50% of CIR level, irrespective of the current offered load. An implicit notification not preceded by an explicit one is likely to have been caused by bit errors and requires more moderate reduction in offered load.

18.5.2 *Type C traffic*

Upon the reception of a congestion notification, the access point shall check that the presentation of data to the ingress node of the network is at the subscription rate. A continued violation of this subscription rate will lead to overflow conditions in the serving network. The resolution of this error event remains for further study. A second action would be to prevent the establishment of new calls.

18.6 Frame format for the consolidated layer management congestion message

Figure 35/G.765 illustrates the format of this CLLM frame.

18.6.1 *Address octets*

Octets 1 and 2 represent the address field for a default two octet address. The first octet includes the C/R bit and the 6-bit upper subfield of the address. The second octet includes the 5-bit lower subfield of the address, the two address bits taken for congestion control and the address extension bit. The consolidated layer management congestion message is sent over DLCI = 8191 to ensure compatibility with the D-channel.

18.6.2 *Control field*

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

18.6.3 *Format identifier field*

Octet 4 contains the format identifier field (decimal 131).

Octet	8	7	6	5	4	3	2	1	Field name
1	1	1	1	1	1	1	C/R	0	Address octet 1
2	1	1	1	1	1	1	1	1	Address octet 2
3	1	0	1	0	1	1	1	1	XID control field
4	1	0	0	0	0	0	1	1	Format identifier (131)
5	1	1	1	1	1	0	1	0	Group identifier (250)
6									Group length octet 1
7									Group length octet 2
8									Cause identifier value
9	0	0	0	0	0	0	0	1	Parameter identifier = 1 (Network identifier)
10	0	0	0	0	0	0	1	0	Parameter length = 2
11 12	–	–	–	–	–	–	–	–	Network identifier value
13	0	0	0	0	0	0	1	0	Parameter identifier = 2 (DLCI identifier)
14									Parameter length
15 16	–	–	–	–	–	–	–	–	DLCI value octet 1 (1st DLCI) DLCI value octet 2 (1st DLCI)
	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	.. .. ..	
$14 + (2n - 1)$ $14 + 2n$ [a]	–	–	–	–	–	–	–	–	DLCI value octet 1 (*n*th DLCI) DLCI value octet 2 (*n*th DLCI)
$14 + 2n + 1$									FCS octet 1
$14 + 2(n + 1)$									FCS octet 2

[a] Maximum number of octets is 260.

FIGURE 35/G.765

Consolidated layer management congestion message

18.6.4 *Group identifier field*

Octet 5 contains the group identifier field (decimal 250).

18.6.5 *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 this message, excluding FCS and closing flag. For compatibility with D-channel applications, the maximum length is set to 260.

18.6.6 *Cause identifier value*

Octet 8 contains the cause identifier, which identifies the following causes:

1) *Congestion increasing* – The level of congestion has increased to a moderate congestion level from the Normal state. The congestion is not, however, increasing fast enough to bring down the network.

2) *Congestion clearing* – The level of congestion has reduced since the last measurement and/or message. The congestion has disappeared, and the state has changed from Moderate to Normal.

3) *Sustained congestion* – The level of congestion has not changed since the last measurement and/or message. This message can be generated when the node is in either the Moderate Congestion state or in the Maximum Congestion state.

4) *Critical congestion* – The level of congestion has increased considerably since the last measurement and/or message. The level of congestion indicates that the network is in danger of collapse and requires immediate action.

5) *Congestion abating* – The level of congestion has decreased since the last measurement and/or message. The congestion has not ceased and the Congestion state has changed from Maximum Congestion to Moderate Congestion.

6) *Critical congestion clearing* – The level of congestion has decreased considerably since the last measurement and/or message and the state has changed from Maximum Congestion to Normal.

The codes for the cause field are shown in Table 13/G.765.

TABLE 13/G.765

Cause field codes

Bits								Field name
8	7	6	5	4	3	2	1	
0	0	0	0	0	0	1	0	Congestion increasing
0	0	0	0	0	0	1	1	Congestion clearing
0	0	0	0	0	1	0	0	Sustained congestion
0	0	0	0	0	1	1	0	Critical congestion
0	0	0	0	0	1	1	1	Critical congestion clearing
0	0	0	0	1	0	0	0	Congestion abating

18.6.7 *Parameter field for network identifier*

Octet 9 contains the parameter identifier field for the network identifier. When the parameter identifier field is set to 1, then the following octets of this parameter contain the network identifier.

18.6.8 *Parameter length field*

Octet 10 contains the length of the network identifier length field. In Figure 35/G.765, the value shown is decimal 2; however, other values may be chosen.

18.6.9 *Network identifier value field*

In Figure 35/G.765, octets 11 through 12 contain the value of the network identifier that identifies the network that originated the congestion message. The network identifier shall follow the rules in § 5 of Recommendation E. 164.

18.6.10 *Parameter field for DLCI identifier*

Octet 13 contains the parameter identifier field for the DLCI identifier. If the DLCI identifier field is missing, then the frame shall be ignored. When the parameter identifier field is set to 2, then the following octets of this parameter contain the DLCI(s) of the frame relay links that are congested.

18.6.11 *Parameter length field for DLCI identifier*

Octet 14 contains the total length in octets of the DLCI(s) being reported. For example, if (*n*) DLCIs are being reported and they have lengths of two octets each, then the octet size is (*n*) times (2).

18.6.12 *Parameter value field for DLCI(s)*

The following octets present the DLCI values that identify the logical links that have encountered a congested state. In Figure 35/G.765, these values are in octets 15 and up. For this field, the first octet contains the first octet of the address field, while the second octet contains the second octet of the address field.

18.6.13 *FCS field*

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

18.7 *User notification message*

The same format is used at the network-network interface and the user-network interface. The notification of the user terminal equipment of the presence of congestion (by the edge network node) will require a user notification message. This message could be of the same format as the consolidated link layer management message. However, the list of DLCIs would not necessarily be the same.

18.8 *Actions in special cases*

Typical PVCs are usually two-way connections. Therefore, the DLCI for the transmit and receive directions usually will be the same value.

In some cases, the DLCI in one direction may be different than the DLCI for the reverse direction, such as in broadcast circuits as applied to the multidestinational configuration of satellite connections.

1) In this case, the node receives a congestion message, may determine the origin of the message, and then reduce the part of the traffic that is going to the congested node only.

2) In packet/circuit broadcast or concentration applications, there will be mapping of two or more DLCIs to a single 64 kbit/s channel. If an ingress node receives a congestion message, the end user on the access side of the ingress node shall be informed. In these situations, the ingress node may either:

   – disable packetization for all logical channel and/or 64 kbit/s circuits transmitting to the network; or

   – disable packetization for a subset of the affected connections. The subset shall include all traffic destined for the congested node.

3) In a concentration application, there will be mapping of two or more logical channels to a single logical channel, or two or more circuits on a logical channel, or two or more logical channels on a circuit. When an intermediate node is congested or has received a congestion message, it shall generate congestion messages for all permanent virtual paths through the node.

Note that a packet stream backup may cause the bandwidth to be shared between two packet streams. The situation, however, may cause congestion.

It may not be fair to the users of one packet stream to experience some degradation of service due to the congestion caused by backing up other users. To avoid this, the node may have the ability to distinguish between the DLCIs of both packet streams so that the source of the DLCIs can be distinguished.

In the event of a Congestion state being declared, the node may be able to reduce traffic of a backed up packets stream first, instead of reducing the traffic of both packet streams simultaneously. Note that the node may be able reduce the non-backed up traffic first, if there is a hierarchy of traffic importance.

18.9 *Variable bandwidth links*

In a variant of the topological model described in § 18.2, one or more of the communication channels between the nodes may provide bandwidth on demand by physical expansion of the channel capacity, e.g. satellite links using load-adaptive time division multiple access (TDMA). In this case, an additional congestion relief action is possible by increasing the channel capacity of one or more channels serving the node, subject to availability. This topic is for further study.

19 Dynamic load control

The interface of a packet circuit multiplication equipment with a switch is defined in Recommendation Q.50. Actions taken between PCME are for further study.

20 Interface with Q.922 frame relay networks

Internetworking with frame relay networks defined in Recommendation Q.922 is for further study.

21 Synchronization

The PCME shall be integrated into the synchronization hierarchy as described and specified in Recommendations G.811 and G.812. In the case of SDH interfaces, Recommendation G.815 shall apply.

Note that while the channel-oriented side interfaces and the packetization/depacketization functions must operate synchronously, the packetized-side interfaces can each operate asynchronously, since layer 2 interframe fill can be adjusted to compensate for individual rate differences.

22 Glossary

22.1 **adaptive differential pulse code modulation (ADPCM)**

ADPCM algorithms are compression algorithms that achieve bit rate reduction through the use of adaptive prediction and adaptive quantization.

22.2 **block**

A block is a specific group of octets within a voice packet that is made up of bits of the same significance.

22.3 **block dropping**

Block dropping is a process by which one or more of the less significant bits of all the samples stored in a packet are dropped to alleviate congestion.

22.4 **block dropping indicator (BDI)**

The block dropping indicator (BDI) is the field of the voice packet header that indicates the number of blocks that have been dropped and the maximum number that can be dropped.

22.5 **build-out delay**

Build-out delay is the maximum variable transmission and processing delay that is permitted in a wideband network.

22.6 bursts

Bursts are periods of high energy content signals present in the access channel of a wideband network.

22.7 check sequence (CS)

The check sequence is a 16-bit sequence in the last two octets of a frame (excluding flags) that offers a cyclic redundancy check (CRC). The CRC is derived over either the header in unnumbered information with header check (UIH) format frames or over the entire packet frame for unnumbered information (UI) frames (excluding flags).

22.8 coding type (CT) field

The coding type field of a voice/voiceband data packet is a 5-bit sequence in the packet header that indicates the method of coding speech samples used at the originating endpoint before packetization.

22.9 congestion

Congestion is the condition that exists in a network if the bandwidth needed for the instantaneous traffic exceeds the bandwidth available in the network.

22.10 data link connection identifier (DLCI)

The DLCI is a 13-bit field that defines the destination address of a frame on a physical-link-by-physical-link basis.

22.11 digital circuit emulation (DICE) protocol

The DICE protocol is a wideband protocol used to transport digital data that arrive on the channel-oriented side through a specific format containing idle codes and repetition of user's data.

22.12 digital speech interpolation

Digital speech interpolation is a process that takes advantage of inactive periods of a conversation to insert speech from other conversations and to remove silent periods.

22.13 embedded adaptive differential pulse code modulation (embedded ADPCM)

Embedded ADPCM algorithms are ADPCM algorithms that quantize the difference between the input and the estimated signal into core bits and enhancement bits.

22.14 frame check sequence (FCS)

The frame check sequence is a 16-bit cyclic redundancy check sequence that is derived over an entire packet frame (excluding flags) of a UI format packet.

22.15 gap

A gap is a period of low energy content signals present of a digital speech interpolation device.

22.16 **header check sequence (HCS)**

The header check sequence is a 16-bit cyclic redundancy check that is derived from the first 8 octets (excluding flags) of a UIH format packet.

22.17 **idle code**

An idle code is a special sequence that indicates that no data are being sent on the channel-oriented side.

22.18 **more (M) bit**

The M-bit is a bit used to indicate that more packets in sequence are to be expected by the terminating endpoint.

22.19 **originating endpoint**

The originating endpoint of a wideband packet node is the point that receives channel-oriented traffic, packetizes it and sends it into the wideband packet network.

22.20 **packetized circuit multiplication equipment (PCME)**

A packet circuit multiplication equipment is a general class of equipment that compresses and integrates voice, voiceband data, digital data, signalling, image, facsimile and network control into packets of common formats at the wideband range of bit rates greater than 64 kbit/s and less than the broadband rates of 150 Mbit/s.

22.21 **packet circuit multiplication system**

A packet circuit multiplication system is a telecommunications network comprising two or more PCMC nodes.

22.22 **packet header**

The packet header consists of octets 4 to 8 (inclusive) of the frame (flags excluded from the octet numbers).

22.23 **packetization interval**

The packetization interval is the duration of the channellized traffic that has been packetized.

22.24 **packet stream**

A packet stream is a collection of logical links multiplexed together onto one physical channel between two endpoints of the wideband packet network.

22.25 **protocol discriminator (PD) field**

The PD field is the first octet of the packet header that identifies the protocol used to transport the frame.

22.26 **scheduled play-out time**

The scheduled play-out time is the frame at which a received packet is to be played out.

22.27 **sequence number (SEQ)**

The sequence number SEQ of a packet is a field of the packet header that is used by the terminating endpoint to determine if the packets arrive in sequence.

22.28 **signalling transition**

A signalling transition of channel-associated signalling is a change in state of the A-bit for 2-state signalling, A- and/or B-bit in 4-state signalling, or the A-, B-, C-, and/or D-bit for 16-state signalling.

22.29 **terminating endpoint**

The terminating endpoint of a wideband packet node is the part of the node that receives packetized traffic, depacketizes it and then plays it back as channel-oriented traffic.

22.30 **time stamp (TS)**

The time stamp is a field that records the cumulative variable queuing delay experienced by a packet in transversing the network with a resolution of 1 ms.

22.31 **unnumbered information (UI) frame**

A Ul frame is a frame used to transfer unacknowledged information between two link layer entities. The format and encoding are the same as specified in Recommendation Q.921/I.441. The CRC is derived over the entire frame.

22.32 **unnumbered information with header check (UIH) frame**

The UIH frame is similar to the UI frame except that the CRC sequence is derived over the frame and packet headers (the first 8 octets excluding flags) rather than over the entire frame.

22.33 **virtual data link capability (VDLC) protocol**

The VDLC protocol is a wideband protocol that is used to transport digital data packets arriving from the channel-oriented side in HDLC frames.

ANNEX A

(to Recommendation G.765)

Alphabetical list of abbreviations used in this Recommendation

ADPCM	Adaptive differential pulse code modulation
AIS	Alarm indication signal
BDI	Block dropping indicator
BER	Bit error ratio
BILO	Bits in last octet
C/R	Command/response
CFR	Confirmation to receive
CIR	Committed information rate
CLLM	Consolidated link layer management message
CRC	Cyclic redundancy check
CRP	Command repeat
CT	Coding type

CTC	Continue to correct
CTR	Response to continue to correct
DCN	Disconnect
DCS	Digital command signal
DICE	Digital circuit emulation
DIS	Digital identification signal
DLCI	Data link connection identifier
DMC	Digital modem class
DTC	Digital transmit command
EOM	End of message
EOP	End of procedure
EOR	End of retransmission
EPT	Echo protection tone
EQ	Equalization
ERR	Response to end of retransmission
ES	Errored second
FADCOMP	Facsimile demodulation and compression protocol
FCS	Frame check sequence
FIFO	First-in first-out
FTT	Failure to train
GI	Group identifier
HDLC	High-level data-link control
IBT	Idle background type
ISC	International switching centre
LAPF	Link access procedure for frame mode bearer service
LAPD	Link access procedure D-channel
MCF	Message confirmation
MOS	Mean opinion score
MPS	Multipage signal
NSC	Non-standard facilities command
NSS	Non-standard set-up
OAM	Operations, administration, and maintenance
OOF	Out of frame
PCM	Pulse-code modulation
PCME	Packet circuit multiplication equipment

PCMS	Packet circuit multiplication system
PD	Protocol discriminator
PIN	Procedure interrupt negative
PIP	Procedure interrupt positive
PPR	Partial page request
PPS	Partial page signal
PRI	Procedure interrupt
PVC	Permanent virtual circuit
PVP	Packetized voice protocol
RTN	Retrain negative
RTP	Retrain positive
SC	Sub-class
SDH	Synchronous digital hierarchy
SEQ	Sequence number
SES	Severely errored second
SS5	Signalling system No. 5
SS6	Signalling system No. 6
SS7	Signalling system No. 7
STM	Synchronous transport module
TCF	Training check
TDMA	Time division multiple access
TEI	Terminal endpoint identifier
TS	Time stamp
Ul	Unnumbered information
UIH	Unnumbered information with header
UNI	User-network interface
VC	Virtual container
VDLC	Virtual data link capability
XID	Exchange identification

Supplement No. 1

PERFORMANCE CONSIDERATIONS

The implementation of the G.765 speech processing algorithms is not specified unless it is required for interworking. This allows improvements as the state of the art advances. These algorithms have a significant impact on the perceived performance of a PCME.

Specifying performance or specifying the impact of these algorithms on performance is a very complex subject. It is also outside the scope of G.765.

However, it might be desirable to give some guidance to implementors of G.765. This might also be useful (for test purposes) to administrations using PCME.

This supplement is not part of the Recommendation and is included for guidance only. It gives one particular organization views on performance guidelines for signal classification, speech detection, packet loss recovery procedures, and noise fill.

1 Signal classification errors

The signal classifier shall not classify voiceband data at a lower rate than the actual rate or as speech more than five times per thousand calls.

The signal classifier shall not classify voiceband data at a higher rate than the actual rate or as speech more than 50 times per thousand calls.

The combination of the signal classifier and speech coder shall operate such than the initial training of voiceband modems operates at the same error rate as for the entire call.

2 Speech Detection

The packet circuit multiplication equipment (PCME) shall incorporate a speech detector to eliminate silent intervals and stop packetization.

The speech detector shall operate such that the speech activity measured by packet flow does not exceed the actual speech activity by more than 5%. For example, if the actual speech activity is 38%, then the speech activity measured at the packet interface shall be less than 43%.

The mean opinion score (MOS) measured when silence elimination is activated, but without bit dropping or packet loss, shall not drop more than 0.3 below the MOS without silence elimination under normal operating conditions (e.g. absence of background noise).

3 Packet Loss

Speech packets may be lost due to errors in transmission or to queue underflow or overflow at the terminating end. The PCME shall include means to minimize these effects so that under nominal channel transmission performance and nominal load conditions the MOS for 1% speech packet loss is not worse than the normal MOS by more than 0.3.

A number of fill-in strategies can close the gaps in the talk spurt

1) replace the discarded packets with samples of zero-amplitude values or with background noise;

2) repeat the most recent packet;

3) reconstruct the lost packet by sample interpolation using the samples that are in the arrived packets;.

4) use speech segments from the last received packets to replace the missing speech segments.

Although silence substitution or noise interpolation is easy to implement, it can degrade the subjective quality of voice. Packet repetition has less stringent requirements on memory space and processing power. The repetition algorithm may vary if speech is classified in several classes. For example, the last pitch waveform may be repeated for voice segments, while the last packet may be used otherwise.

4 Noise Fill

Noise shall be filled in to replace the silent intervals eliminated from the talk spurt at the originating end.

The noise shall be white and within 1 dB of the value in the noise field of the last received G.764 packet. It shall be free of buzzes, tones or other audible clues to regularity.