GA27-3287-1

Systems

IBM Implementation of X.21 Interface General Information Manual

Second Edition (October 1981)

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Preface

This manual describes the CCITT recommendation X.21 interface to public data networks (PDNs) as implemented by IBM. It includes (1) a brief overview of X.21, (2) information on X.21 functional, mechanical, and electrical characteristics, and (3) information on the operation of X.21 using both circuit-switched and leased-circuit networks.

This manual can assist customers, communications suppliers, and engineers in selecting or designing equipment to attach to a PDN using an X.21 interface. Before you use this manual, you should have a good understanding of telecommunications.

This manual is divided into four chapters and two appendixes as follows:

- Chapter 1 contains general information on the X.21 interface.
- Chapter 2 provides basic information on the functional, mechanical, and electrical characteristics of the X.21 interface.
- Chapter 3 provides information on the interface states defined by CCITT recommendation X.21.
- Chapter 4 describes the operation of the X.21 interface using a circuit-switched network and a leased-circuit network.
- Appendix A describes DTE time-limits and DCE time-outs for the X.21 interface.
- Appendix B contains a list of abbreviations and a glossary of terms.

An index follows the appendixes.

Related Publications

This manual contains references to other publications for the convenience of those readers who want additional information. These publications are:

- Electronic Industries Association (EIA). *Electrical Characteristics of Balanced Voltage Digital Interface Circuits.* EIA Standard RS-422-A, December 1979, available from:

  EIA Engineering Department
  Standards Sales Office
  2001 Eye Street, N.W.
  Washington, D.C. 20006, U.S.A.

- International Organization for Standardization (ISO). *Data Communications - 15-Pin DTE/DCE Interface Connector and Pin Assignments.* International Standard (IS) 4903, 1979, available from:

  American National Standards Institute Inc.
  1430 Broadway
  New York, N.Y. 10018, U.S.A.

- The following publications available from the International Telegraph and Telephone Consultative Committee (CCITT):
  - International Telegraph and Telephone Consultative Committee (CCITT), Data Transmission over the Telephone Network, Seventh Plenary Assembly, Yellow Book, Volume VIII.1, International Telecommunications Union, 1981, for Recommendations V.3, V.4, and V.11.
  - International Telegraph and Telephone Consultative Committee (CCITT), Data Communications Networks, Seventh Plenary Assembly, Yellow Book, Volume VIII.2, International Telecommunications Union, 1981, for Recommendations X.2, X.4, X.21, X.24, and X.27.
  - International Telegraph and Telephone Consultative Committee (CCITT), Data Communication Networks, Seventh Plenary, Yellow Book, Volume VIII.3, International Telecommunications Union, 1981, for Recommendation X.96.

The CCITT Yellow Books are available from:

International Telecommunications Union (UIT)
Geneva, Switzerland.
or
United Nations Bookstore
United Nations Plaza
New York, New York 10017, U.S.A.
or
The National Technical Information Service,
U.S. Department of Commerce
Springfield, Virginia 22161, U.S.A.

Industry Standards Reflected in this Manual

The implementation of the X.21 interface described in this manual is designed according to the specifications of the following industry standards and recommendations as understood and interpreted by IBM as of August 1980:

- Electronic Industries Association (EIA) Standard RS-422-A
- International Telegraph and Telephone Consultative Committee (CCITT) recommendations: V series and X series.
- International Organization for Standardization (ISO) International Standard (IS) 4903.

Contents

Figures

Chapter 1. Introduction

Note: Before attempting to use this manual, review the Preface at the front of the manual. The Preface (1) explains the purpose of the manual, (2) identifies the intended user, and (3) indicates the prior knowledge needed by the user.

The CCITT recommendation X.21 defines a general-purpose interface between terminals and the new, synchronous, public data networks (PDNs) that provide circuit-switched and leased-circuit services for data communications. Recommendation X.21 covers:

- Methods for attaching data terminal equipment (DTE) to data circuit-terminating equipment (DCE)
- Procedures for link control
- Methods for data transfer
- Services for circuit-switched and leased-circuit networks

IBM Implementation of X.21—Statement of Direction

IBM encourages the use of international standards as the basis for interfaces to public data networks that provide circuit-switched and leased-circuit services. IBM continues to participate in and contribute to international standards efforts to develop and enhance these interfaces. Services with interfaces based on CCITT recommendation X.21 provide users with new alternatives for data transmission. These new alternatives supplement the functions provided by IBM's System Network Architecture, and should be made available to IBM customers.

IBM's objective is to enable selected products to be attached to data networks with an X.21 interface. The announcement of an X.21 attachment capability supporting additional products or functions will be based on IBM's technical and business judgment in addressing the requirements of its customers. As with most standards, CCITT recommendation X.21 is not a specification but is more adequately defined as a design guide. Therefore, this manual provides information on IBM's implementation of CCITT recommendation X.21.

Network, as used in this manual, refers to a public data network. For additional definitions of network, refer to the glossary at the end of this manual.

Network Attachment

Recommendation X.21 defines six interchange circuits and one 15-pin connector for the interface between data terminal equipment (DTE) and data circuit-terminating equipment (DCE) for synchronous operation on public data networks. See Figure 1-1.

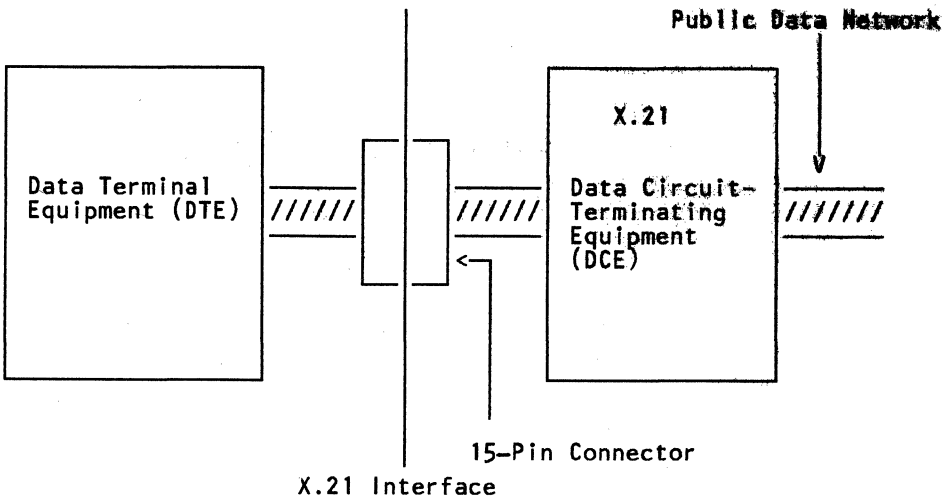


Figure 1-1. X.21 Interface

In the X.21 interface, DTE and DCE control signals are sent by a combination of steady state binary signals and coded character strings on the receive and transmit circuits. X.21 incorporates a provision in the physical interface for the newly developed, large-scale-integration (LSI) compatible, balanced, electrical, interchange circuits.

One of the attractive features of public data networks using the X.21 interface is the ability of the network to communicate detailed call-status information directly to the using DTE. Call-progress signals such as number busy, access barred, and changed number are passed from the network to the call-originating DTE to tell a user why a particular call was not completed. These signals can also indicate to the DTE that the call will be cleared due to problems and what these problems are.

The usefulness of circuit-switched networks using CCITT recommendation X.21 is further enhanced by a variety of additional facilities that the user can select. Depending on the network and the DTE implementation, the desired facilities can be activated either when the network service is subscribed to or when a facility registration request is entered into the network by means of the attached DTE. For detailed information on these optional user facilities, refer to the CCITT publication *Public Data Networks,* Volume VIII.2, for recommendations X.2 and X.21:

- Recommendation X.2, *International User Facilities in Public Data Networks,* contains information on the optional user facilities. Some facilities may be available on a per-call basis (facility registration request from a DTE), and others may be assigned for an agreed period at the request of the user. Information about the support of these user facilities is product specific; therefore, it is not included in this publication. Refer to the individual product publication for this information.

- Recommendation X.21, *Interface between Data Terminal Equipment (DTE) and Data Circuit-Terminating Equipment (DCE) For Synchronous Operation on Public Data Networks,* contains information on the facility registration/cancellation request procedures.

Interface Phases

User interaction with circuit-switched networks can be divided into four interface phases, which are analogous to a conventional switched telephone network operation. They are the quiescent, call-establishment, data-transfer, and clearing phases. User interaction with leased-circuit networks consists of two phases: the quiescent phase and the data-transfer phase.

Recommendation X.21 provides for the distinct separation of network signaling phases from the data-transfer phase. In the data-transfer phase, end-to-end data transparency is maintained. The DTE may transmit any bit configuration. Therefore, user-provided encryption is feasible during the data-transfer phase.

Recommendation X.21 divides the data communication operation into the following four phases.

1. *Quiescent Phase:* Applicable to both leased-circuit and circuit-switched services, this is the nonactive phase during which the DCE and the DTE indicate a ready or a not-ready state.
2. *Call-Establishment Phase:* To establish a circuit-switched connection, the DTE communicates with the DCE by way of the transmit and receive circuits using the characters of International Alphabet Number 5. For information on International Alphabet Number 5, refer to the CCITT publication *Data Transmission over the Telephone Network,* Volume VIII.1. SYN characters are used to obtain and maintain character synchronization between the DTE and the DCE during this phase.
3. *Data-Transfer Phase:* Indicated by a unique state of the X.21 interface control circuits, a full-duplex transparent transmission path is maintained between user DTEs for leased-circuit and circuit-switched services.
4. *Clearing Phase:* To release a circuit-switched connection, either the DTE or the DCE initiates a clear-request. The DCE then clears the connection, and the interface returns to a quiescent phase.

The public data network provides bit clocking to the DTE during all phases.

Interface States

Recommendation X.21 defines 28 unique states of the X.21 interchange circuits. These interface states are used by the DTE and DCE to signal each other the appropriate action to take during the four phases of a data communication operation. See Chapter 2 for additional information on the X.21 interface states.

Chapter 2. X.21 Characteristics

The X.21 interface is defined by a number of functional, mechanical, and electrical characteristics. This chapter provides basic information on these characteristics of the CCITT recommendation X.21 interface.

Functional Characteristics

The definitions of the interchange circuits used in the X.21 interface are given by recommendation X.24. The interface between the DTE and DCE is located at a connector, which is the interchange point (also called the line of demarcation). See Figure 2-1.

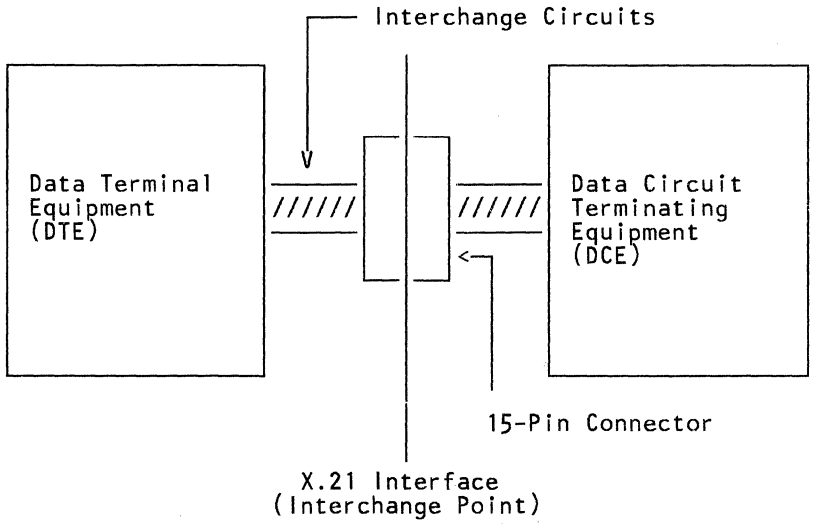


Figure 2-1. Interchange Point between DTE and DCE

Definition of Interchange Circuits

Figure 2-2 shows a list of the interchange circuits defined by CCITT recommendation X.21. Following Figure 2-2 is a brief description of each of these interchange circuits. For detailed information on the X.21 interchange circuits, refer to the CCITT publication *Public Data Networks,* Volume VIII.2, for recommendation X.24.

Interchange	Interchange	Data		Control		Timing	
Circuit Designation	Circuit Name	From DCE	To DCE	From DCE	To DCE	From DCE	To DCE
G	Signal ground or common return						
T	Transmit		X		X		
R	Receive	X		X			
C	Control				X		
I	Indication			X			
S	Signal Element Timing					X	
B	Byte Timing					X	

Figure 2-2. X.21 Interchange Circuits

Circuit G - Signal Ground

Circuit G is called either 'signal ground' or 'common return'. If required, this circuit interconnects the zero-volt reference points of the DTE and DCE to reduce external signal interference. Where a shielded interconnecting cable is used at the interface, the cable shield can be connected either to 'signal ground' (circuit G) or to 'protective ground' in accordance with national regulations. 'Protective ground' can also be connected to external grounds as required by any applicable electrical safety regulations.

Circuit T - Transmit

During the call-establishment phase and clearing phase, binary call-control signals, originated by the DTE, are transferred to the local DCE over circuit T. During the data-transfer phase, binary data, originated by the DTE and intended for transmission to the remote DTE, is transferred to the local DCE over circuit T.

Circuit R - Receive

During the call-establishment phase and clearing phase, binary call-control signals, originated by the network or the local DCE, are transferred to the local DTE over circuit R. During the data-transfer phase, binary data, as received from the remote DTE, is transferred to the local DTE over circuit R.

Circuit C - Control

During the call-establishment phase, an on condition on circuit C, in conjunction with call-control signals on circuit T, informs the local DCE of the DTE's state. In the data-transfer phase, circuit C should be on. In the quiescent and call-clearing phases, circuit C should be off.

Circuit I - Indication

An on condition on circuit I normally informs the local DTE that an end-to-end condition has been established. With circuit I on, any signals on circuit R contain information from a remote DTE. However, where the network allows a remote CCITT X.21 bis attachment and pseudo half-duplex operation, circuit I may go off during the data-transfer phase to indicate that the remote DTE is not transmitting data.

Circuit S - Signal Element Timing

Signals on circuit S provide the DTE with signal element timing information. The binary condition of this circuit is on and off for nominally equal periods of time. When the DTE presents a binary signal on circuit T and a binary condition on circuit C, the binary signal transitions nominally occur at the time of the transitions from off to on of circuit S. When the DCE presents a binary signal on circuit R and a binary condition on circuit I, the binary signal transitions nominally occur at the time of the transitions from off to on of circuit S. The DCE transfers signal element timing information on this circuit across the interface at all times.

Circuit B - Byte Timing

Signals on circuit B provide the DTE with 8-bit byte-timing information. IBM at this time has not implemented this circuit in its data terminal equipment.

Mechanical Characteristics

The mechanical characteristics of the X.21 interface are defined in the International Organization for Standardization (ISO) publication *Data Communication—15-pin DTE/DCE Interface Connector and Pin Assignments,* International Standard (IS) 4903. This standard specifies the interface connector and the pin assignments for the X.21 interchange circuits. Figure 2-3 shows a list of the pin assignments for the X.21 interchange circuits.

Pin Number	Interchange Circuit Assignment
1	See Note 1
2	T(A)
3	C(A)
4	R(A)
5	I(A)
6	S(A)
7	B(A)
8	G
9	T(B)
10	C(B)
11	R(B)
12	I(B)
13	S(B)
14	B(B)
15	See Note 2

Note 1: Pin 1 is used for connecting tandem sections of shielded interface cable. The shield can be connected to protective ground or to signal ground at either the DTE, DCE, or both in accordance with national regulations.

Note 2: Pin 15 is reserved for future international use.

Figure 2-3. X.21 Interchange Pin Assignments

ISO IS 4903 defines a 15-pin interface connector for both the DTE and the DCE. The DTE interface connector has 15 male contacts and a female shell as shown in Figure 2-4. The DCE interface connector has 15 female contacts and a male shell as shown in Figure 2-5. Contact numbering is also shown in Figures 2-4 and 2-5. For additional information on the mechanical characteristics of the X.21 interface, refer to the publication ISO IS 4903.

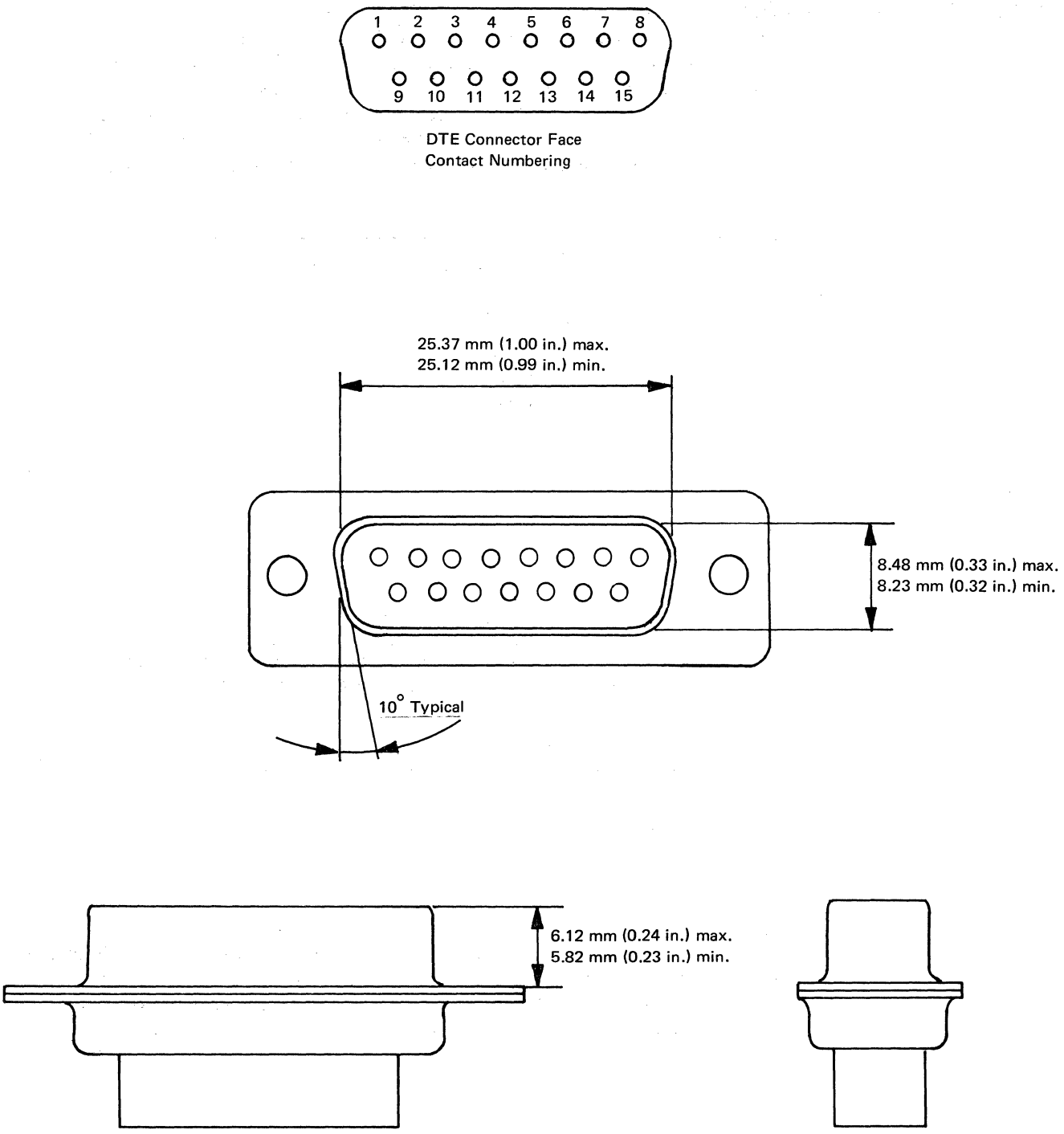
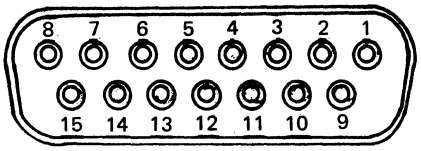


Figure 2-4. DTE Interface Connector



DCE Connector Face
Contact Numbering

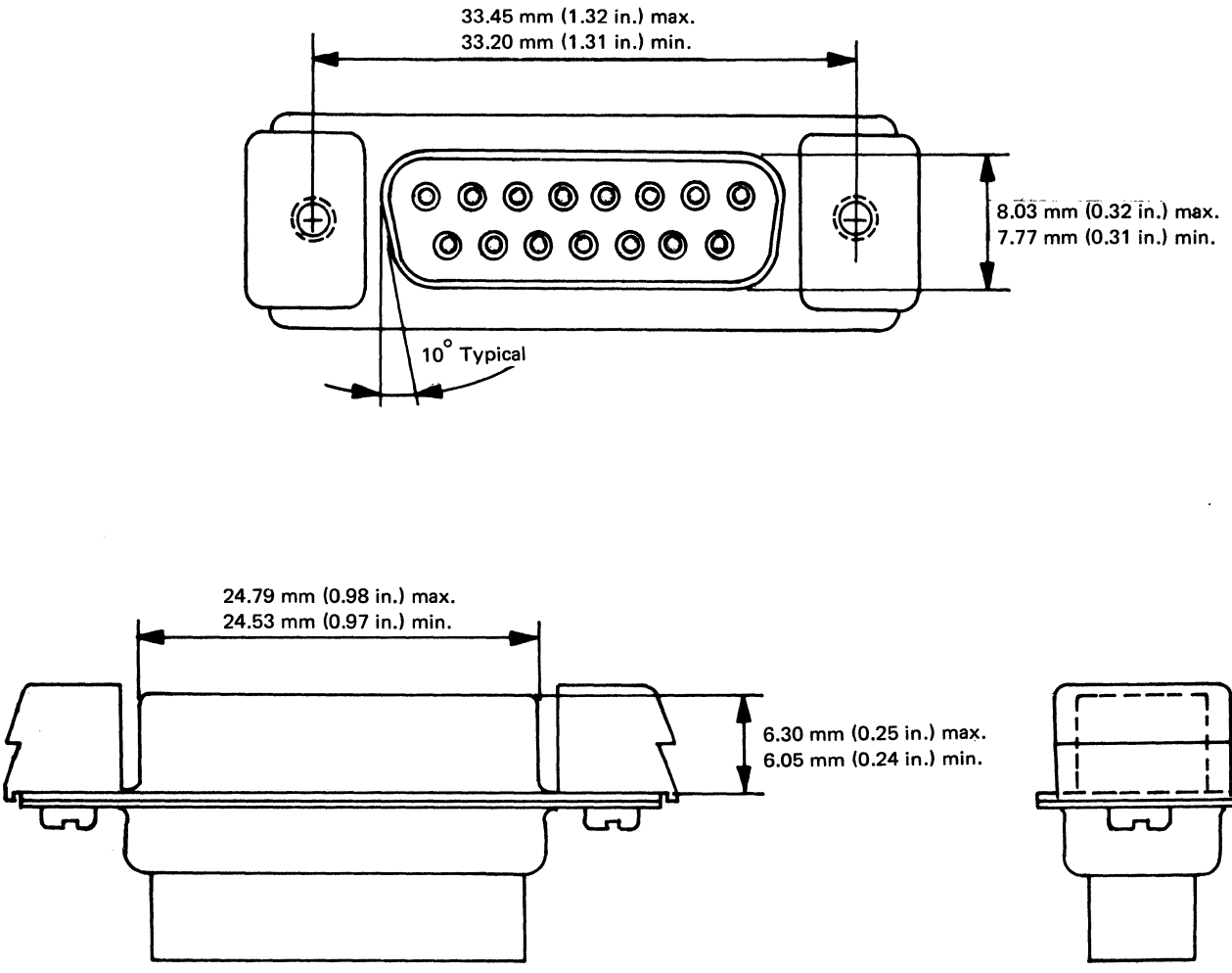


Figure 2-5. DCE Interface Connector

Electrical Characteristics

The X.21 interface as implemented by IBM uses the electrical characteristics defined by EIA RS-422-A, which meets the electrical characteristics of CCITT recommendation X.27. This recommendation specifies the electrical characteristics for balanced, double-current interchange circuits that use integrated circuit technology. CCITT recommendation V.11 specifies the same electrical characteristics for balanced interchange circuits as recommendation X.27. For detailed information on the electrical characteristics for the X.21 interface, refer to the following publications:

- CCITT, *Public Data Networks,* Volume VIII.2, for recommendation X.27.
- CCITT, *Data Transmission over the Telephone Network,* Volume VIII.1, for recommendation V.11.
- Electronic Industries Association (EIA) Standards RS-422-A.

Chapter 3. X.21 Interface States

This chapter provides information on the unique interface states defined by CCITT recommendation X.21. In recommendation X.21, the condition of the interchange circuits determines what is happening at the interface. During a data communication operation, the DTE uses the 'transmit' (T) and 'control' (C) interchange circuits to signal the DCE what action to take. The DCE uses the 'receive' (R) and 'indication' (I) interchange circuits to signal the DTE what action to take.

Interface States Defined by X.21

Figure 3-1 shows a list of the interface states that are defined by recommendation X.21. For detailed information on the interface states defined by X.21, refer to the CCITT publication *Public Data Networks,* Volume VIII.2 for recommendation X.21.

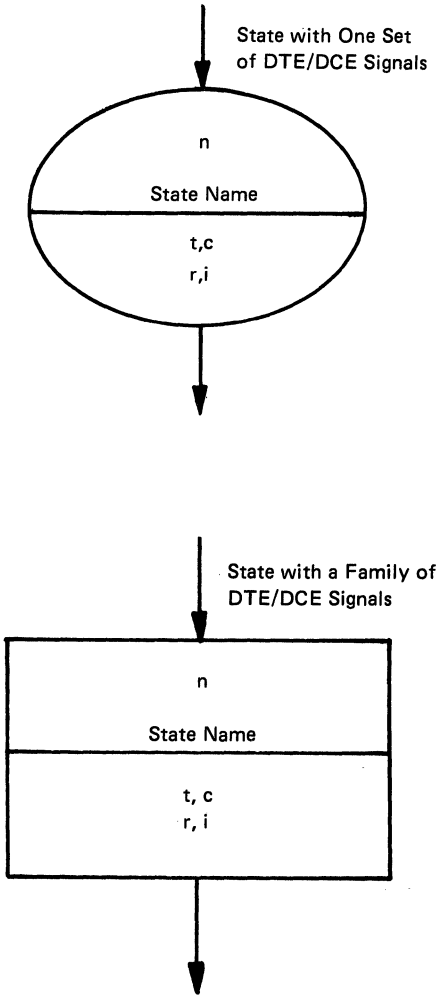
State Number	State Name
1	Ready
2	Call Request
3	Proceed to Select
4	Selection Signals
5	DTE Waiting
6A	DCE Waiting
6B	DCE Waiting
7	DCE Provided Information (Call Progress Signals)
8	Incoming Call
9	Call Accepted
10	DCE Provided Information (Called DTE line identification)
10bis	DCE Provided Information (Calling DTE line identification)
11	Connection in Progress
12	Ready for Data
13	Data Transfer
13S	Send Data
13R	Receive Data
14	DTE Controlled Not Ready, DCE Ready
15	Call Collision
16	DTE Clear Request
17	DCE Clear Confirmation
18	DTE Ready, DCE Not Ready
19	DCE Clear Indication
20	DTE Clear Confirmation
21	DCE Ready
22	DTE Uncontrolled Not Ready, DCE Not Ready
23	DTE Controlled Not Ready, DCE Not Ready
24	DTE Uncontrolled Not Ready, DCE Ready

Figure 3-1. X.21 Interface States

Interface State Diagrams

Recommendation X.21 defines those transitions between interface states that are allowed by all telecommunications Administrations. The recognized state transitions for each of the four phases of a data communication operation are

shown by means of state diagrams. Figure 3-2 shows the definitions for the symbols that are used in the state diagrams. Figures 3-3 through 3-6 are state diagrams for each interface phase. Transitions other than those shown are possible, but they may not be allowed by all telecommunication Administrations.



n	= state number
t	= signal on T circuit
c	= signal on C circuit
r	= signal on R circuit
i	= signal on I circuit
T	= Transmit interchange circuit
C	= Control interchange circuit
R	= Receive interchange circuit
I	= Indication interchange circuit
D	= DTE or DCE data signals
0	= steady binary 0 condition
1	= steady binary 1 condition
01	= alternate binary 0 and binary 1
X	= any value
Off	= continuous Off (binary 1)
On	= continuous On (binary 0)
IA5	= characters from International Alphabet Number 5 (CCITT Recommendation V.3)
BEL	= IA5 character, 0/7
SYN	= IA5 character, 1/6
+	= IA5 character, 2/11
↓	= transition between states

Figure 3-2. Definitions Used by Interface State Diagrams

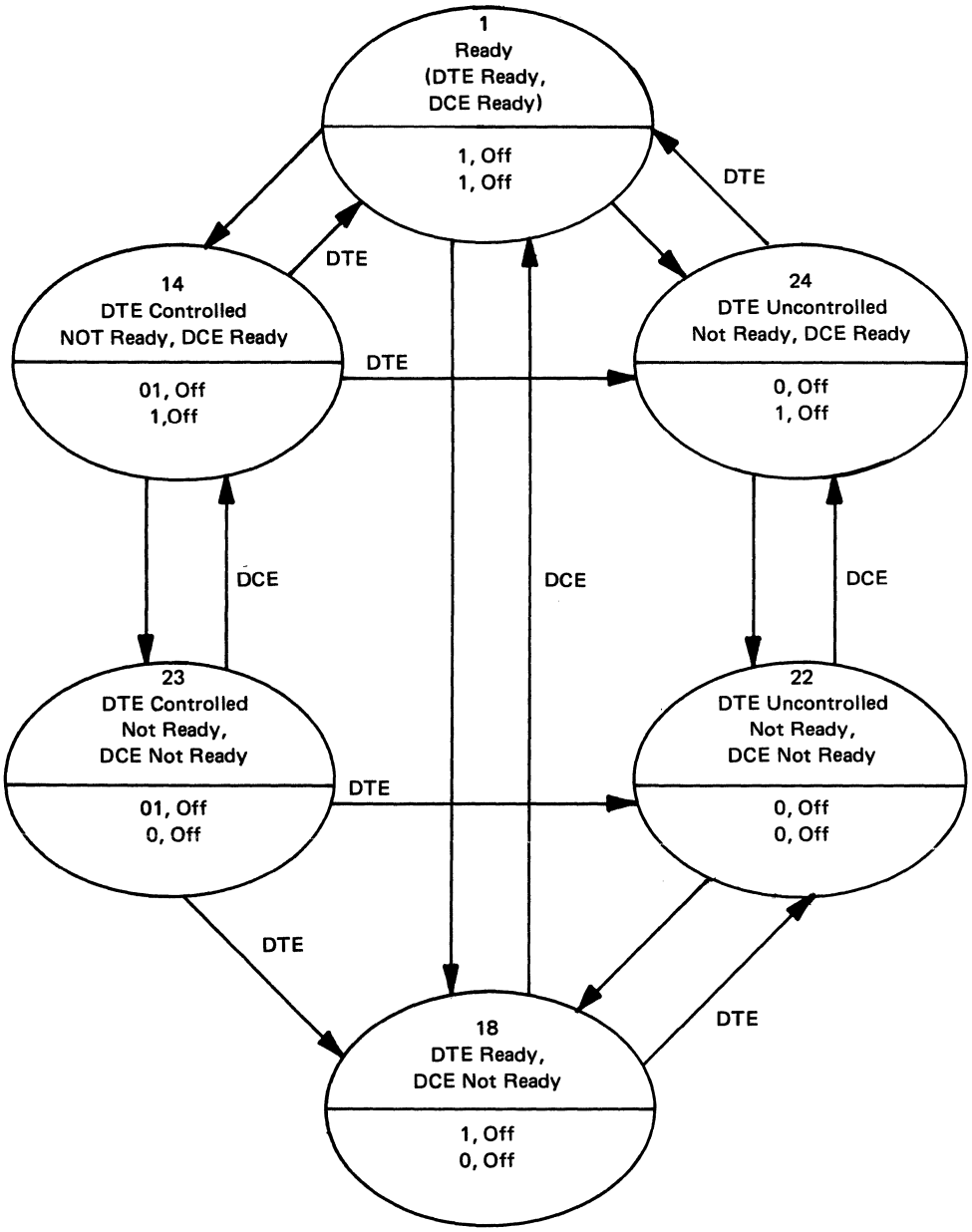


Figure 3-3. Quiescent Phase Interface State Diagram (Circuit-Switched Operation)

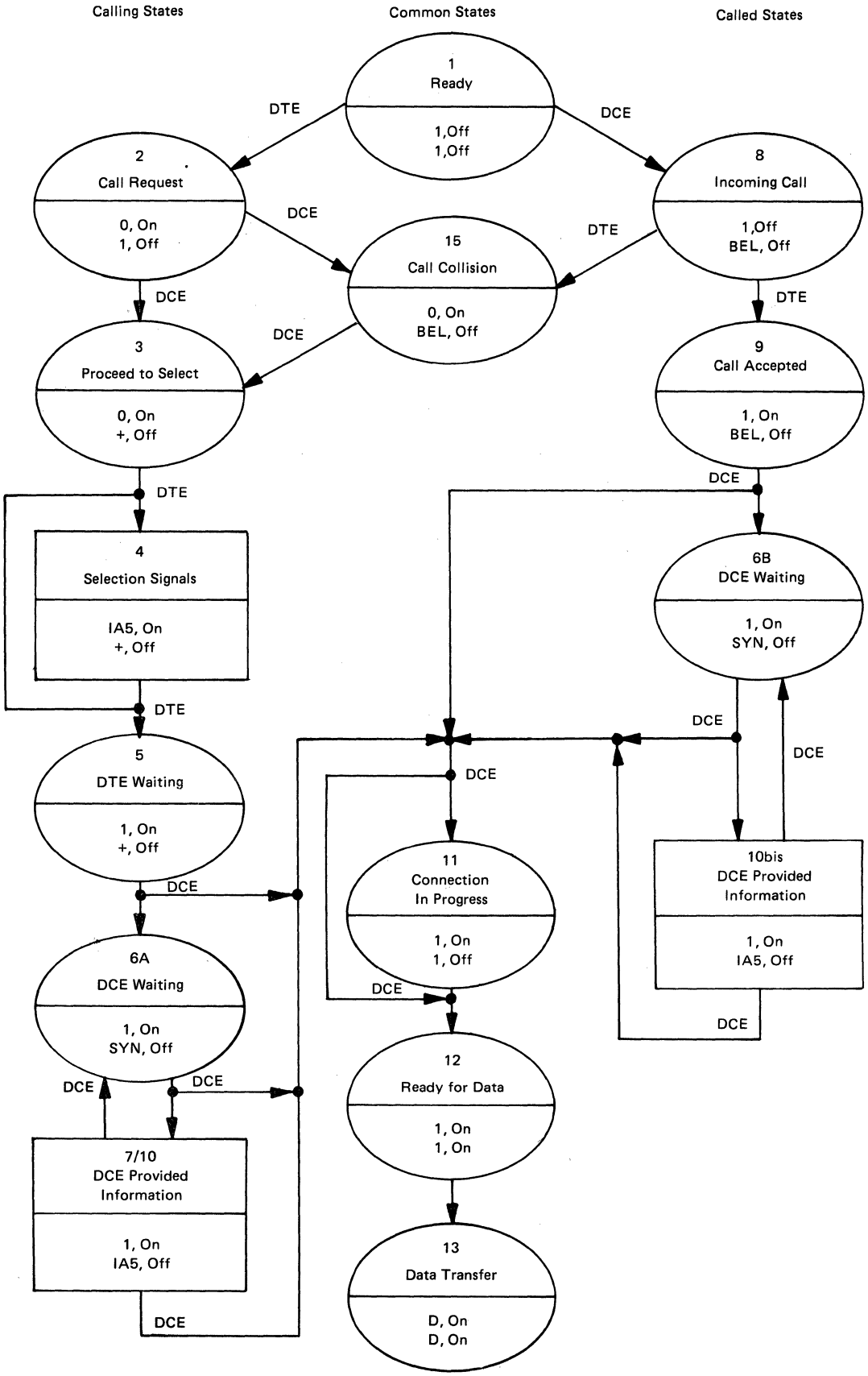


Figure 3-4. Call Establishment Phase and Data Transfer Phase Interface State Diagram (Circuit-Switched Operation)

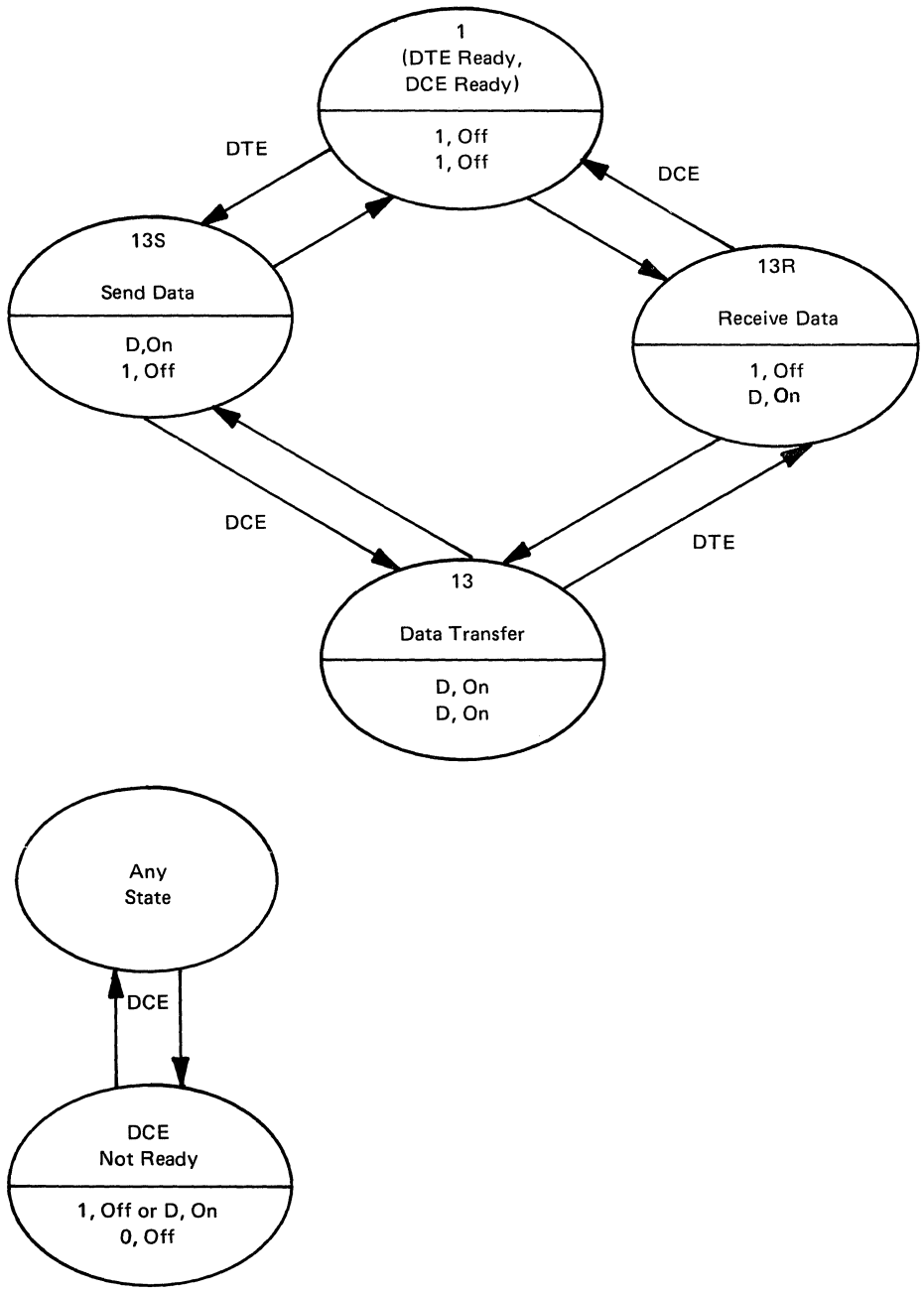
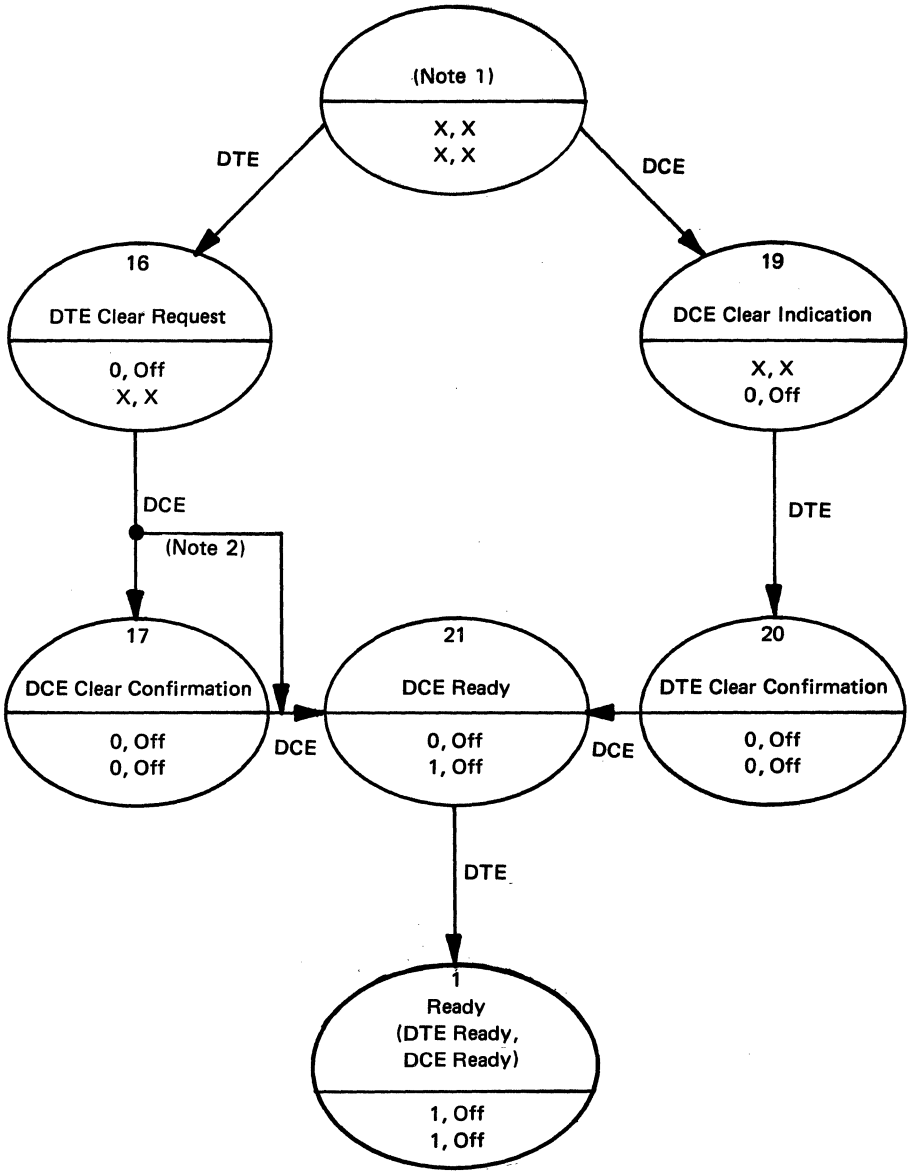


Figure 3-5. Data-Transfer Phase Interface State Diagram (Leased-Circuit Operation)



Note 1. This may be any sate shown in Figure 3-4 except 'ready' (state 1).

Note 2. This bypass of State 17 is no longer included in CCITT recommendation X.21, but it is accepted by IBM DTEs.

Figure 3-6. Clearing Phase Interface State Diagram (Circuit-Switched Operation)

Recognized Interface State Transitions

Recommendation X.21 defines the transitions from one state to another that are allowed by all telecommunication Administrations. See figure 3-7. For additional information on the interface state transitions that are recognized by X.21, refer to the CCITT publication *Public Data Networks,* Volume VIII.2, for recommendation X.21.

Figure 3-7. X.21 Recognized Interface State Transitions

State Number	State Name	DTE Circuits T	DTE Circuits C	DCE Circuits R	DCE Circuits I	DTE Transition to State No.	DCE Transition to State No.	Time-Limit / Time-Out Transition: To State No.	Time-Limit / Time-Out Transition: Time-Limit/ Time-Out No.	Time-Limit / Time-Out Transition: Terminated by State No.
1	Ready	1	Off	1	Off	2,13S,14,24	8,13R,18	1	T7	8
2	Call request	0	On	1	Off	----------	3,15	1	T1	3
3	Proceed to select	0	On	+	Off	4,15	----------	19	T11,T12	4,5
4	Selection signal	IA5	On	+	Off	5	----------	19	T13	EOS
5	DTE waiting	1	On	+	Off	----------	6A,11,12	16	T2	7,10,12,19
6A	DCE waiting	1	On	SYN	Off	----------	7,10,11,12	---	---------	---------
6B	DCE waiting	1	On	SYN	Off	----------	10bis,11,12	---	---------	---------
7	Call progress signal	1	On	IA5	Off	----------	6A,10,11,12	16	T3A,T3B	7,10,12,19
8	Incoming call	1	Off	BEL	Off	15,9	----------	1	T14A,T14B	9,15
9	Call accepted	1	On	BEL	Off	----------	6B,11,12	16	T4	10bis,12,19
10	DCE provided information	1	On	IA5	Off	----------	6A,11,12	---	---------	---------
10 bis	DCE provided information	1	On	IA5	Off	----------	6B,11,12	---	---------	---------
11	Connection in progress	1	On	1	Off	----------	12	---	---------	---------
12	Ready for data	1	On	1	On	----------	13	---	---------	---------
13	Data transfer	D	On	D	On	13R	13S,DCE not ready	---	---------	---------
13R	Receive data	1	Off	D	On	13	1	---	---------	---------
13S	Send data	D	On	1	Off	7	13	---	---------	---------
14	DTE controlled not ready, DCE ready	01	Off	1	Off	1,24	23	---	---------	---------
15	Call collision	0	On	BEL	Off	----------	3	---	---------	---------
16	DTE clear requestt	0	Off	X (Note 1)	X	----------	17	18	T5	21
17	DCE clear confirmation	0	Off	0	Off	----------	21	---	---------	---------
18	DTE ready									
	DCE not ready	1	Off	0	Off	22	1	---	---------	---------
	DCE not ready	D	On	0	Off	----------	1,13,13S	---	---------	---------
19	DCE clear indication	X (Note 1)	X	0	Off	20	----------	24	T15	20
20	DTE clear confirmation	0	Off	0	Off		21	18	T6	21
21	DCE ready	0	Off	1	Off	1	----------	24	T16	1
22	DTE uncontrolled not ready, DCE not ready	0	Off	0	Off	18	24	---	---------	---------
23	DTE controlled not ready, DCE not ready	01	Off	0	Off	18,22	14	---	---------	---------
24	DTE uncontrolled not ready, DCE ready	0	Off	1	Off	1	22	---	---------	---------
Any State (Note 1)	----------	X	X	X	X	16	19	---	---------	---------

Notes:

1. **'DCE clear indication' (state 19) or 'DTE clear request' (state 16) may be entered from any state except 'ready' (state 1).**

2. **Other transitions are not considered valid.**

Chapter 4. X.21 Interface Operation

The purpose of this chapter is to describe a specific DTE implementation of the X.21 interface that meets the requirements of CCITT recommendation X.21. The information in this chapter was derived from recommendation X.21 and its associated CCITT recommendations. It does not cover any unique characteristics of individual networks that deviate from X.21. Proper maintenance of the DTE portion of the X.21 interface depends on the DCE's providing test loop 3 as stated in recommendation X.21.

Note: Functions defined as optional by recommendation X.21 may not be provided by IBM DTEs that are capable of operating on a network using an X.21 interface. Also, this manual does not define possible restrictions on the use of an X.21 interface by individual PTTs, such as limitations on call retries and uniquely defined call progress signals (CPS) or CPS sequences. You should see documentation on the DTE to determine how a specific DTE implemented these national requirements.

Sequence-of-Events Diagrams

Figures in this chapter contain diagrams that show the basic sequence of events at the X.21 interface for circuit-switched operation and leased-circuit operation.

Diagram Conventions

The following conventions are used in each diagram:

- Diagrams are read from left to right.
- Abbreviations used for circuit names are:

T	transmit
R	receive
C	control
I	indication
S	signal element timing
t	signal on T circuit
r	signal on R circuit
c	signal on C circuit
i	signal on I circuit

- 'Transmit' and 'control' circuits are shown transitioning (changing from one binary state to another) at the same time. When both the T and C circuits are required to transition to present a state change, recommendation X.21 requires that they transition within plus or minus seven bit times of each other. Figure 4-1 shows the T and C circuits transitioning within plus or minus seven bit times of each other. This state change is signalled to the attached DCE for a minimum of 24 bit times unless the DCE responds to the change sooner.
- The DTE monitors the 'receive' and 'indication' circuits for DCE-initiated state changes, and responds to these after a period of 16 bit times.
- Clocking ('signal element timing' circuit) is shown in Figure 4-1 only. It is assumed to be present on all the other diagrams in this chapter. There is no byte-timing synchronization of T and C circuits with R and I circuits. All transitions of these circuits must be coincident with the off-to-on transition of the S circuit.

- The symbol —⟩⟨— used in the diagrams indicates an unknown number of bit times, with the maximum number of bits being limited by the time-limit or time-out of that particular sequence. If the symbol applies to a time interval involving IA5 characters, the interval will start and end on a character boundary.
- States and phases of the interface operation are shown at the bottom of each diagram. The broken horizontal line between states or phases indicates a transition from one to another. Only state transitions from one steady binary state to another are shown.
- The designation for a time-limit or a time-out is Tn, where n is the time-limit or time-out number.
- The symbol —⌒— used in the diagrams indicates a byte boundary.
- All characters for call control purposes are selected from International Alphabet No. 5 (IA5). For example, the SYN control character is shown as 1/6 on Figure 4-3. This 1/6 does not imply that the 1 appears before the 6 on the T or R circuits. The specific bit sequence is shown on Figure 4-1 and applies to all IA5 control characters. For additional information, refer to the CCITT publication *Data Transmission over the Telephone Network,* Volume VIII.1, for recommendation V.3.

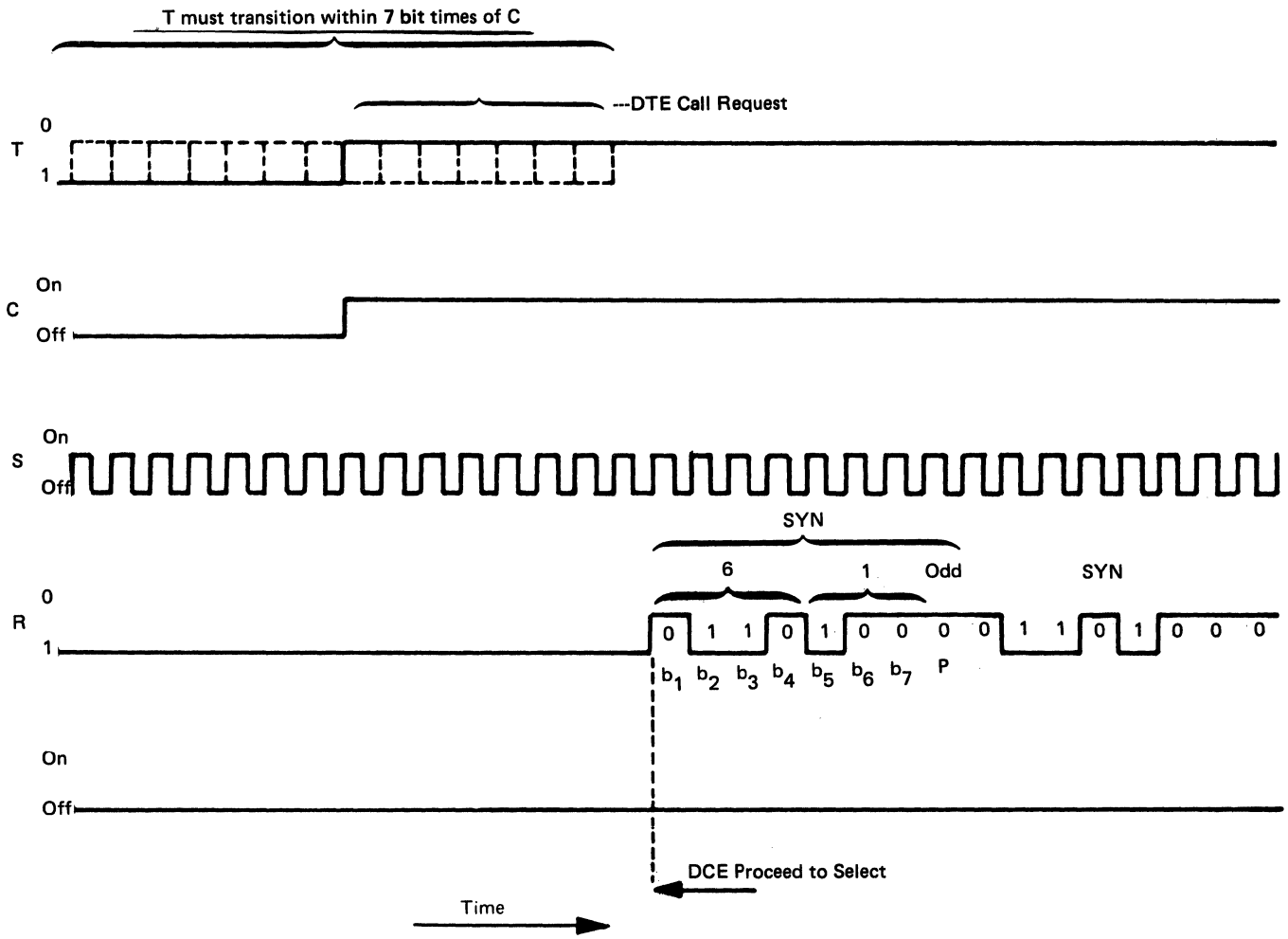


Figure 4-1. Transitions, Clocking, and Control Characters

Circuit-Switched Operation

The diagrams in Figures 4-2 through 4-9 show the sequence of events at the X.21 interface for circuit-switched operation with a public data network. These diagrams are designed so that you can mate them to each other in various combinations to show any sequence of events that is allowed by recommendation X.21. Each diagram lists the figure numbers of all other diagrams that can be mated to it.

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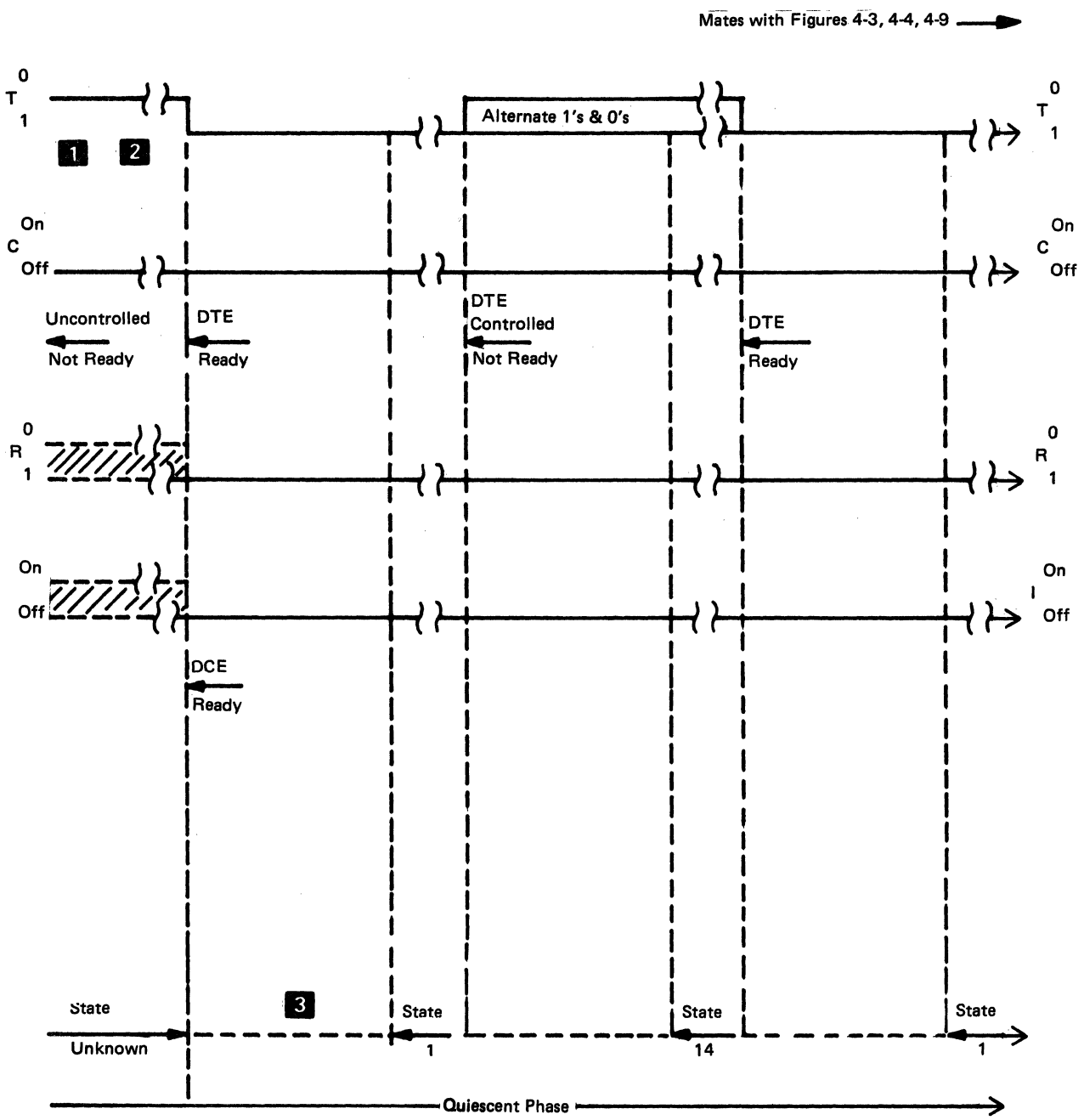

Figure 4-2. Quiescent Phase (DTE) (Part 1 of 2)

Notes:

1. The diagram shows the DTE going from 'uncontrolled not ready' to 'ready', then to 'controlled not ready' and back to 'ready' with the DCE signaling 'DCE ready'. This sequence is allowed and may be the normal sequence for a DTE that is going online with its communications. The DTE initiated state changes may not be recognized if the DTE goes directly to 'controlled not ready' from 'uncontrolled not ready'. It must first go to the 'ready' state, which means that both the DTE and the DCE must present 'ready'. There are other DTE power turn-on sequences allowed, including variations to a DTE's normal sequence when the DCE presents 'DCE not ready'. A 'DCE not ready' signal indicates that no service is available from the network. If the DTE attempts to go online with its communications but the DCE is signaling 'DCE not ready', the DCE out-of-service information will be presented to the user program or to the operator. The DTE may remain in its initial power-on condition ('DTE uncontrolled not ready' 'DTE controlled not ready' or 'DTE ready') or go to 'DTE ready'. 'DTE controlled not ready' may not be recognized at this time because the DCE is not signaling 'DCE ready'. A power-on reset (POR) will cause the DTE to assume the machine status that existed when power was initially switched on.

2. When the DTE presents t = 0 and c = off to the interface, it means one thing if the interface is in the quiescent phase and another if it is in any other phase. If the DTE has signalled 'call request' and then detects r = 0 and i = off, it will assume that it is in the call-control phase. If the DTE presents t = 0 and c = off to the interface while in the quiescent phase, it means 'DTE uncontrolled not ready'. This condition results in either state 22 or 24, depending on the state condition of the DCE. If the condition is presented in any other phase, it will mean either 'DTE clear request' or 'DTE clear confirmation'. Regardless of what state results from the t = 0 and c = off condition, the DTE will go to the 'ready' state ('DTE ready' and 'DCE ready') before it can go to 'DTE controlled not ready'. An exception to this can occur when time-limit T5 or T6 expires. See Figures 4-7 and 4-8 for this exception. Failure to go to 'ready' first may result in the DCE not recognizing the state change.

3. A state transition is that time between the initiation of a state change by one device and the recognition of the change (the new state) by the other device. The steady binary condition state transitions are shown on each diagram by a broken horizontal line. After the DTE starts to present the new state on both T and C circuits, the DCE must recognize the new state within 24 DTE bit times. After the new conditions are received on both the R and I circuits at the DTE for 16 contiguous bit times, the DTE must recognize the new state from the DCE. State changes identified by IA5 characters are different in that they require no response from the receiving device that the new state has been recognized. The receiving device identifies the new state on recognition of the first IA5 character that identifies the new state.

Figure 4-2. Quiescent Phase (DTE) (Part 2 of 2)

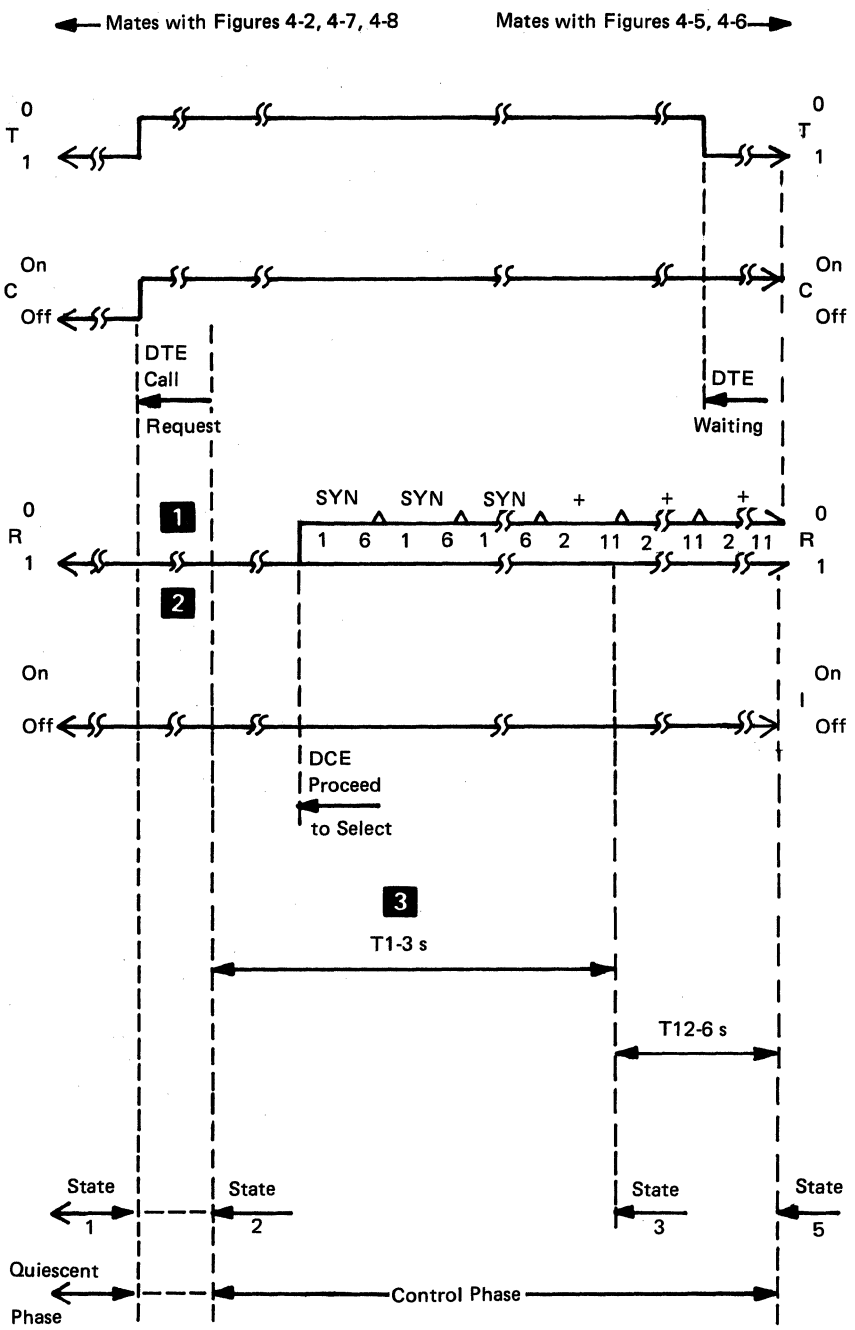

Figure 4-3. Call-Establishment Phase—Direct Call (Calling DTE) (Part 1 of 2)

Notes:

1. The requirement for state changes is that the DTE or DCE indicating the change must be prepared to hold the state change request for 24 bit times. The DTE (DCE is not included) receiving the change request may recognize the state change at a bit count as low as 16 bit times. After the DTE has started a state change, the DCE may recognize the state change at any time. It is possible, for example, for the DCE to recognize a 'call request' and start immediately transferring the first bit of a two SYN character sequence. This transfer could represent the start of a 'proceed to select' at the next bit time following the start (first bit) of a DTE initiated 'call request'. The 16 to 24 contiguous bit intervals for state changes may not apply when state changes are initiated by IA5 characters. State changes that do not require acknowledgment by the DTE may pass through states in less than 24 bit times.

2. The DTE goes to t = 0 and c = on ('DTE call request') only from the 'ready' state (state 1). See "Call Collision" in this chapter for a variation to this. When the DTE presents 'call request' (t = 0 and c = on) to the interface, the DTE must be prepared to receive either (1) a 'proceed to select' from the DCE, (2) a 'DCE clear indication' (r = 0 and i = off), or (3) in the case of a call collision, an 'incoming call' (r = BEL and i = off). In the case of the 'incoming call' (r = BEL and i = off), the DTE should ignore the 'incoming call' signal (two or more SYN characters preceding BEL characters) and wait for the DCE to abort the incoming call and present 'proceed to select' (two or more SYN characters immediately preceding + characters). The 'proceed to select' signals are expected on the same byte boundary as the SYN characters preceding the BEL. The DTE may go to 'clear request' (t = 0 and c = off) on a call collision. This 'DTE clear request' aborts the outgoing call and because the DCE aborts the incoming call, neither call is completed. In the case where the DCE presents a 'DCE clear indication' after the DTE presents 'call request', the DTE will assume that the interface is no longer in the quiescent phase and will proceed with the normal DCE clearing sequence. The DTE may under certain conditions go from 'call request' (t = 0 and c = on) to t = 0 and c = off. If the DCE has recognized the 'call request', it is expected to treat t = 0 and c = off as a 'DTE clear request' and proceed accordingly. If the DCE has not recognized the 'call request', it is expected to remain 'DCE ready' and the state will be interpreted as a quiescent phase state.

3. Time-limits (for example T1) are measured from state to state as interpreted by the receiving device. The device initiating the state change must consider the time required for the state change interpretation to be made by the receiving device. In the case of a 'call request', the maximum time allowed for the receiving device (the DCE) to interpret this change is 24 bit times. The responding state change ('proceed to select') from the DCE may start with SYN characters immediately upon receipt of 'call request' from the DTE. The DCE can stretch this out over 3 seconds before sending the IA5 character 2/11 (+). The 2/11 character defines the new state ('proceed to select') to the DTE. Receipt of the 2/11 character ends the T1 time-limit. If the DTE starts the T1 time-limit at the transition of the T and C circuits, 24 bit times will be added to the 3 second requirement to compensate for the delay in interpretation by the DCE. All time-limits must be handled similarly.

   The times shown for time-limits are the minimum times permitted by the DTE. No maximum time-limits are defined by recommendation X.21. Times shown for time-outs are the maximum times permitted for the DTE to respond to a signal from the DCE. No minimum time-outs are defined by recommendation X.21.

Figure 4-3. Call-Establishment Phase—Direct Call (Calling DTE) (Part 2 of 2)

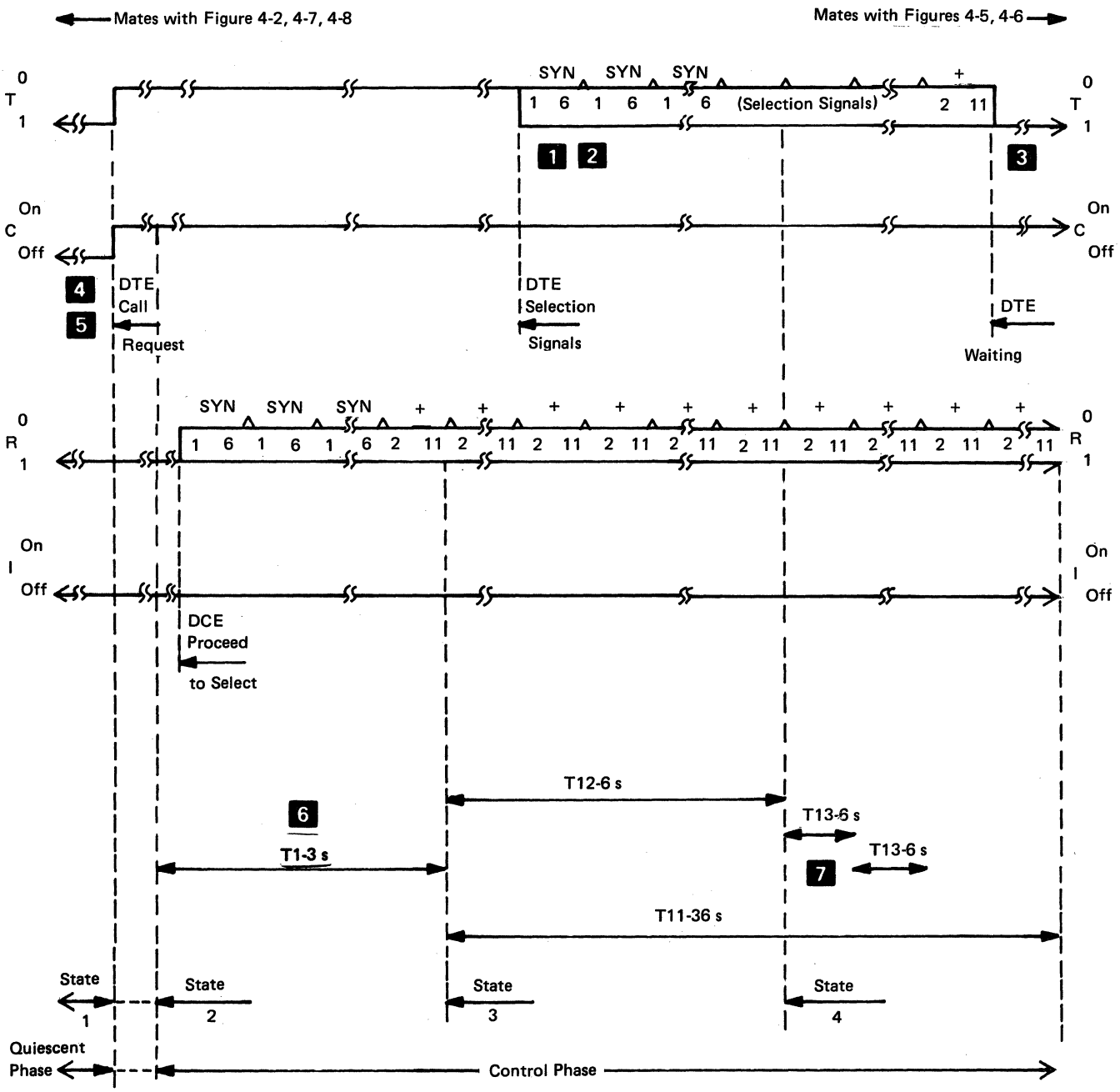

Figure 4-4. Call-Establishment Phase—Selection Signals (Calling DTE) (Part 1 of 2)

Notes:

1. All control signals presented on the T, C, R, and I circuits are aligned with the clock signal on the S circuit with the beginning of each control or indication bit change being aligned with the off-to-on transition of the clock signal. Transitions on the I circuit that are not aligned with the off-to-on transition of the S circuit will not be rejected because of this. Certain network conditions may make it impossible for the DCE to align the I-circuit transitions with the S-circuit transitions. The call control character (or the facility request character) on the T circuit may or may not be aligned with the call control characters (bytes) being received from the DCE on the R circuit. Odd parity is used for all IA5 control characters.

2. After the call control characters are started on either the T circuit by the DTE or on the R circuit by the DCE, byte synchronization (byte alignment) is maintained until transfer of all call control bytes (including SYN characters) for that circuit has been completed. State changes indicated by IA5 characters on the T and R circuits enter and exit the state on their respective character boundary. For an exception to the rule, see Figure 4-5, statement 5

3. If network-provided information is transferred by the DCE, the two or more SYN (1/6) characters preceding the first network-provided information character do not immediately appear on the R circuit. The DCE is expected to first recognize the selection signal ending character (2/11) presented by the DTE on the T circuit. The SYN characters should appear within 20 seconds of this recognition.

4. The requirement for state changes is that the DTE or DCE indicating the change must be prepared to hold the state change request for 24 bit times. The DTE (DCE is not included) receiving the change request may recognize the state change at a bit count as low as 16 bit times. After the DTE has started a state change, the DCE may recognize the state change at any time. It is possible, for example, for the DCE to recognize a 'call request' and start immediately transferring the first bit of a two SYN character sequence. This transfer could represent the start of a 'proceed to select' at the next bit time following the start (first bit) of a DTE initiated 'call request'. The 16 to 24 contiguous bit intervals for state changes may not apply when state changes are initiated by IA5 characters. State changes that do not require acknowledgment by the DTE may pass through states in less than 24 bit times.

5. The selection signal sequence is optional depending on what is offered by the specific network to which the DTE is attaching and what options the DTE is prepared to support. If direct call is offered and is used by the DTE, the DTE will go directly to 'DTE waiting' after receipt of 'proceed to select' and no selection signal will be transferred. If facility request and addressing or addressing alone is required, the selection sequence will be used. It is permissible to separate selection signal characters (any IA5 character other than a SYN character) within the sequence by one or more SYN characters. There is a 6-second time-out restriction between characters and a 36-second time-out for the total sequence.

6. Time-limits (for example T1) are measured from state to state as interpreted by the receiving device. The device initiating the state change must consider the time required for the state change interpretation to be made by the receiving device. In the case of a 'call request', the maximum time allowed for the receiving device (the DCE) to interpret this change is 24 bit times. The responding state change ('proceed to select') from the DCE may start with SYN characters immediately upon receipt of 'call request' from the DTE. The DCE can stretch this out over 3 seconds before sending the IA5 character 2/11 (+). The 2/11 character defines the new state ('proceed to select') to the DTE. Receipt of the 2/11 character ends the T1 time-limit. If the DTE starts the T1 time-limit at the transition of the T and C circuits, 24 bit times will be added to the 3 second requirement to compensate for the delay in interpretation by the DCE. All time-limits must be handled similarly.

7. The DTE assumes that time-out T13 starts with the reception of the first IA5 selection signal character by the DCE. It is reset as each new IA5 selection signal character (excluding SYN characters) is received. The times shown for time-limits are the minimum times permitted by the DTE for proper network operation. No maximum time-limits are defined by recommendation X.21. Times shown for time-outs are the maximum times permitted for the DTE to respond to a signal from the DCE. No minimum time-outs are defined by recommendation X.21.

Figure 4-4. Call Establishment Phase - Selection Signals (Calling DTE) (Part 2 of 2)

Mates with Figures 4-3, 4-4

Mates with Figures 4-6, 4-7, 4-8

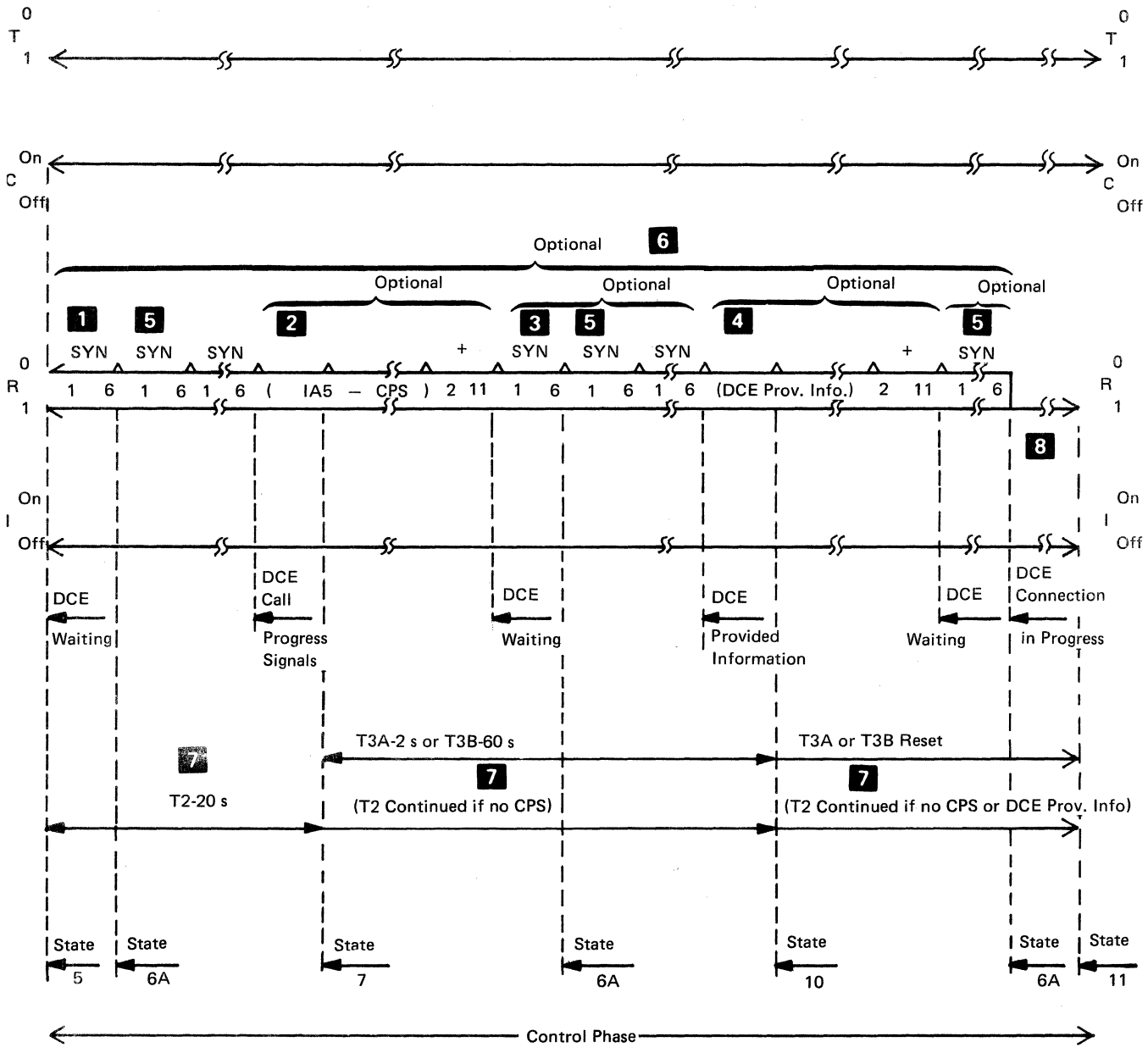

Figure 4-5. Call-Establishment Phase—Network-Provided Information (Part 1 of 2)

Notes:

1. The entire sequence of characters ('DCE waiting', call progress signals, or 'DCE-provided information') is optional to the DCE on a per call basis. If any characters other than SYN characters are transferred by the DCE on the R circuit after the 2/11 (+) of the 'proceed to select' state, they are expected to be preceded by a minimum of two SYN characters.

2. When the call-control phase is being used for facility addressing or direct call, call progress signals (CPS) may or may not be transferred to the DTE by the DCE. If they are, no special leading character(s) will identify the sequence, especially not one of the special characters or character sequences that identify one of the 'DCE-provided information' sequences. The call progress signal block ends with the 2/11 (+) character. Multiple blocks are possible, each ending with the 2/11 character, separated by 'DCE waiting' states (two or more SYN characters). Characters within a call progress signal block can also be separated by two or more SYN characters. Call progress signal sequences are not expected once the 'DCE-provided information' (calling or called line identification) sequence is started.

3. If no additional network-provided information (DCE-provided information) is to follow, this 'DCE-waiting' state is optional. If additional network-provided information is to follow, two or more SYN characters will follow the 2/11 (+) character at the end of the previous call progress signal block.

4. The 'DCE-provided information' sequence is optional. If provided, the sequence will be preceded by two or more SYN characters, with the first character or characters of the block identifying the information to follow. The only DCE-provided information defined by X.21 that can appear in the DTE calling sequence is the called-line identification.

   DCE-provided information appearing in a DTE called sequence is either calling-line identification or charging information. At present there are no 'DCE-provided information' sequences defined in X.21 that would cause more than one block to be transferred in any one sequence. Information characters within the 'DCE-provided information' block can be separated by two or more SYN characters.

5. During the call-control phase, the DCE may go directly from 'DCE waiting' to 'connection in progress' or 'ready for data'. Some DCEs may not, in this case, exit 'DCE waiting' on a character boundary. If the DCE does not exit 'DCE waiting' on a character boundary, the result could be valid IA5 characters (5/6 and 7/14) or invalid IA5 characters (bad parity) being presented as the last characters before the steady state (r = 1) is apparent. In either case, these characters are not interpreted as network errors.

6. During the call-control phase, the DCE may go directly from 'DTE waiting' to 'connection in progress' or to 'ready for data'.

7. Time-limit T2 is terminated by one of the following: the first call progress signal (state 7), 'DCE-provided information' (state 10), 'DCE ready for data', or 'DCE clear indication'. If T2 is terminated by state 7 or 10, time-limit T3 is initiated. A time-limit of 60 seconds (T3B) is set only if the first character of the 'call progress signal' or 'DCE-provided information' is an IA5 (0). This character identifies a call progress signal code group 0 (zero), which indicates a possible delay in the response to the call just initiated by the DTE. This character does not cause DCE clearing. If the first character is not a 0, a time-limit of 2 seconds (T3A) is set. Time-limit T3 is reset by one or more of the non-SYN characters received as a 'call progress signal' or 'DCE-provided information' sequence. A steady state condition, such as the signaling of 'DCE connection in progress', will not be used to reset T3. Each time T3 is reset, it is reset to the initial value determined by the first 'call progress signal' or 'DCE-provided information' character during this sequence. For example, if a 0 was detected as the first character, the time-limit will be T3B (60 seconds). Each time T3 is reset in this sequence, it is reset as a T3B time-limit.

8. The DCE 'connection in progress' is a state in the call-control phase. This state puts the call-control phase in a temporary hold until the network finishes its housekeeping before turning the end-to-end connection over to the DTEs. The DCE cannot predict when the network will be ready for data and cannot delay the presentation of "DCE ready for data' to the DTE. Therefore, the DCE 'connection in progress' can range from one bit time in duration to the expiration of time-limit T2 or T3. The DTE will be prepared to accept the condition where the DCE 'connection in progress' is presented to the DTE for less than 16 bit times.

Figure 4-5. Call-Establishment Phase—Network-Provided Information (Part 2 of 2)

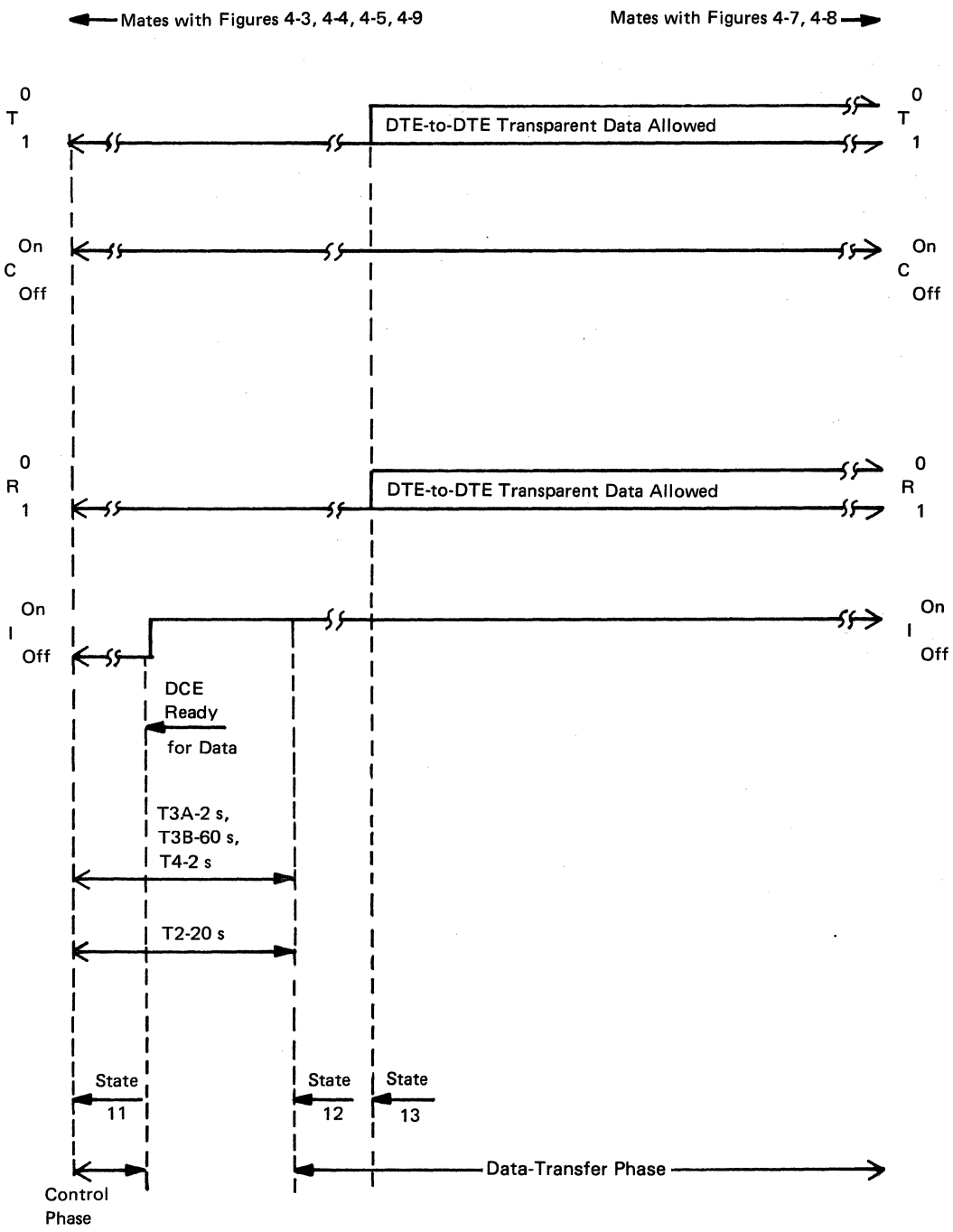

Figure 4-6. Data-Transfer Phase (DTE to DTE)

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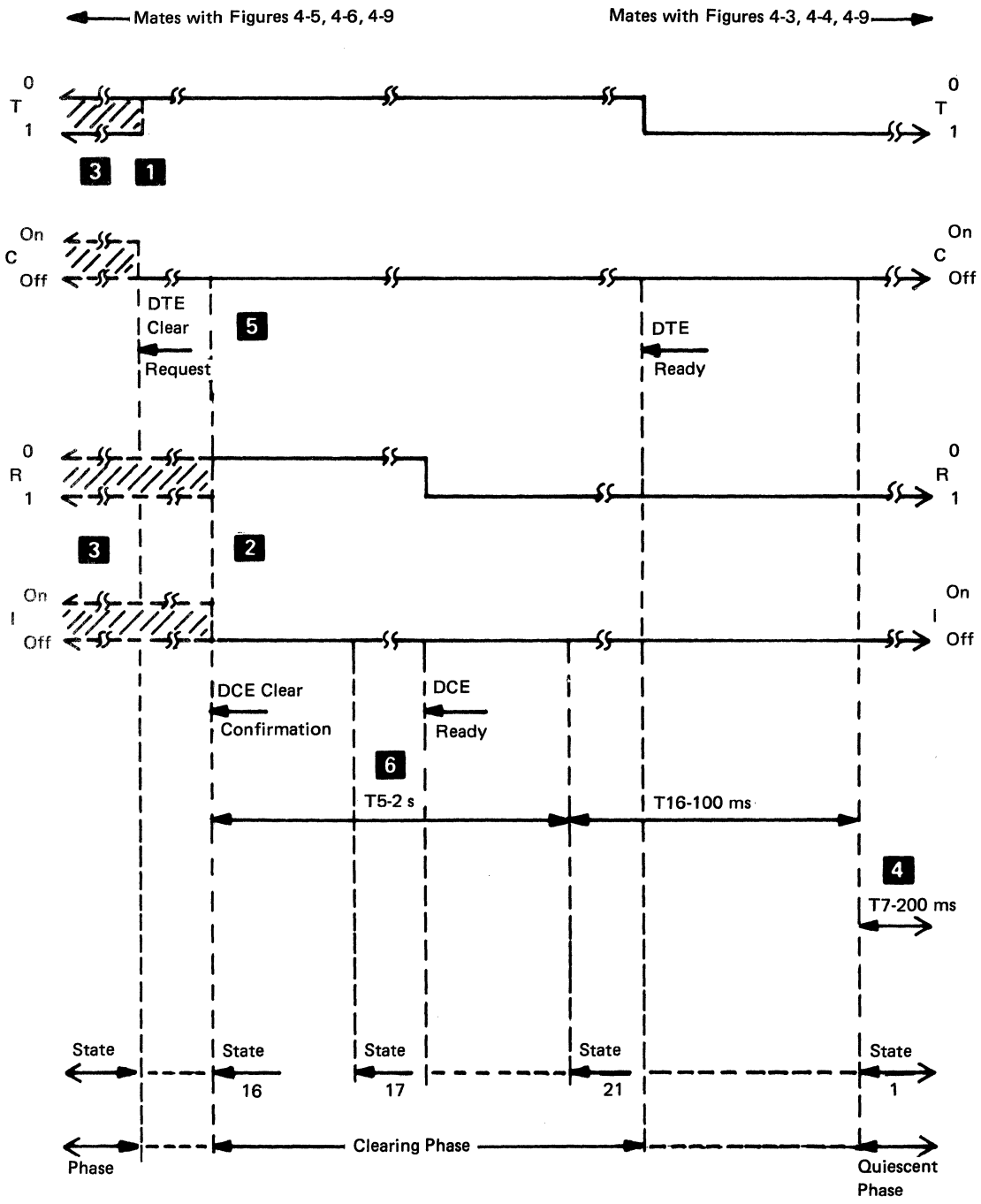


Figure 4-7. Clearing Phase (DTE) (Part 1 of 2)

Notes:

1. When the DTE presents t = 0 and c = off to the interface, it means one thing if the interface is in the quiescent phase and another if it is in any other phase. If the DTE has signalled 'call request' and then detects r = 0 and i = off, it will assume that it is in the call control phase. If the DTE presents t = 0 and c = off to the interface while in the quiescent phase, it means 'DTE uncontrolled not ready'. This condition results in either state 22 or 24, depending on the state condition of the DCE. If the condition is presented in any other phase, it will mean either 'DTE clear request' or 'DTE clear confirmation'. Regardless of what state results from the t = 0 and c = off condition, the DTE will go to the 'ready' state ('DTE ready' and 'DCE ready') before it can go to 'DTE controlled not ready'. Failure to do so may result in the DCE not recognizing the state change. An exception to this can occur when time-limit T5 or T6 expires. See statement 6.

2. 'DCE clear indication' or 'DCE clear confirmation' will not be recognized by the DTE until the r = 0 and i = off condition is set for 16 contiguous bit times. The I circuit may change unexpectedly for up to 10 ms because of line hits. Also, X.21 allows the interworking between V series DTEs, operating as X.21 bis attachments to the network, and X.21 DTEs attached at the other end. When the DTE is operating in half-duplex mode during the data transfer phase, the I circuit at the X.21 interface basically reflects the state of 'request to send' (RTS) circuit at the X.21 bis interface. This means that at any time that the X.21 bis DTE is not transferring data (RTS is off), the I circuit from the X.21 DCE is off. As long as the X.21 DCE does not set r = 0 and i = off for 16 contiguous bit times, the DTE must not interpret this as a 'clear indication' from the DCE.

3. The symbol (////) indicates that the state of this interchange circuit is unimportant to the clearing phase for the period shown. This same period can be important to the operation preceding the clearing phase. For example, the DTE-to-DTE data-transfer protocols used during the data-transfer phase must take into consideration the overlap of the data-transfer phase and the clearing phase shown on Figures 4-7 and 4-8. If the DTE goes to t = 0 and c = off or the DCE goes to r = 0 and i = off while in the quiescent phase, these conditions will not be interpreted as 'clear request' and 'clear indication', respectively. The interface remains in the quiescent phase and is interpreted as presenting one of the quiescent phase states.

4. The 'DCE-provided information' sequence for charge information only appears immediately following a DTE calling sequence in which charge information has been requested by a facility subscription or by the DTE as a facility request. This charge information appears as part of the IA5 selection signals in the call-control phase. Time-limit T7 only appears in this sequence. If T7 expires, no state change is required of the DTE. If the next exchange of information with the DCE is an incoming call, the DTE will recognize that this is not the charge information previously requested. Charge information is a functional option, which may or may not be offered by the network or the DTE. This description of its operation does not imply that the DTE supports the function.

5. If both the DTE and the DCE simultaneously initiate a clearing operation, a clearing collision will exist between them. Recommendation X.21 does not discuss the possibility of a clearing collision. The rules that apply to a clearing operation that is initiated by only one device (DTE or DCE) do not apply when both devices initiate a clearing operation. For example, if clearing is initiated by both devices, the DCE looks at the DTE's 'clear request' as a 'clear confirmation'. There is no minimum number of bit times defined by recommendation X.21 for the DCE to accept the 'clear confirmation' from the DTE. The possibility exists that the DCE will present 'DCE ready' to the interface before the DTE recognizes 16 contiguous bit times of 'DCE clear confirmation'. Therefore, the DTE will initiate a clearing operation by presenting to the interface a minimum of 24 bit times of t = 0 and c = off. The DTE then looks for 16 contiguous bit times of r = 1 and i = off ('DCE ready'). If the DTE detects 'DCE ready' at the interface before T5 time-limit expires, the DTE will present 'DTE ready' to the interface when it is ready to continue communications with the DCE.

6. Time-limits T5 and T6 are the maximum times allowed by recommendation X.21 for the DCE to respond to a 'DTE clear request' or 'DTE clear confirmation', respectively. If either T5 or T6 expires, the DTE regards the interface as 'DCE not ready'. The DTE interprets this as the network being out of service. During this period, the DTE may go to 'controlled not ready'. When the DTE detects a 'DCE ready' condition on the interface, the DTE regards the network as being in service. If the DTE is ready to continue communications with the DCE, the DTE will signal 'DTE ready' to the interface before time-out T16 expires.

Figure 4-7. Clearing Phase (DTE) (Part 2 of 2)

← Mates with Figures 4-5, 4-6, 4-9

Mates with Figures 4-3, 4-4, 4-9 →

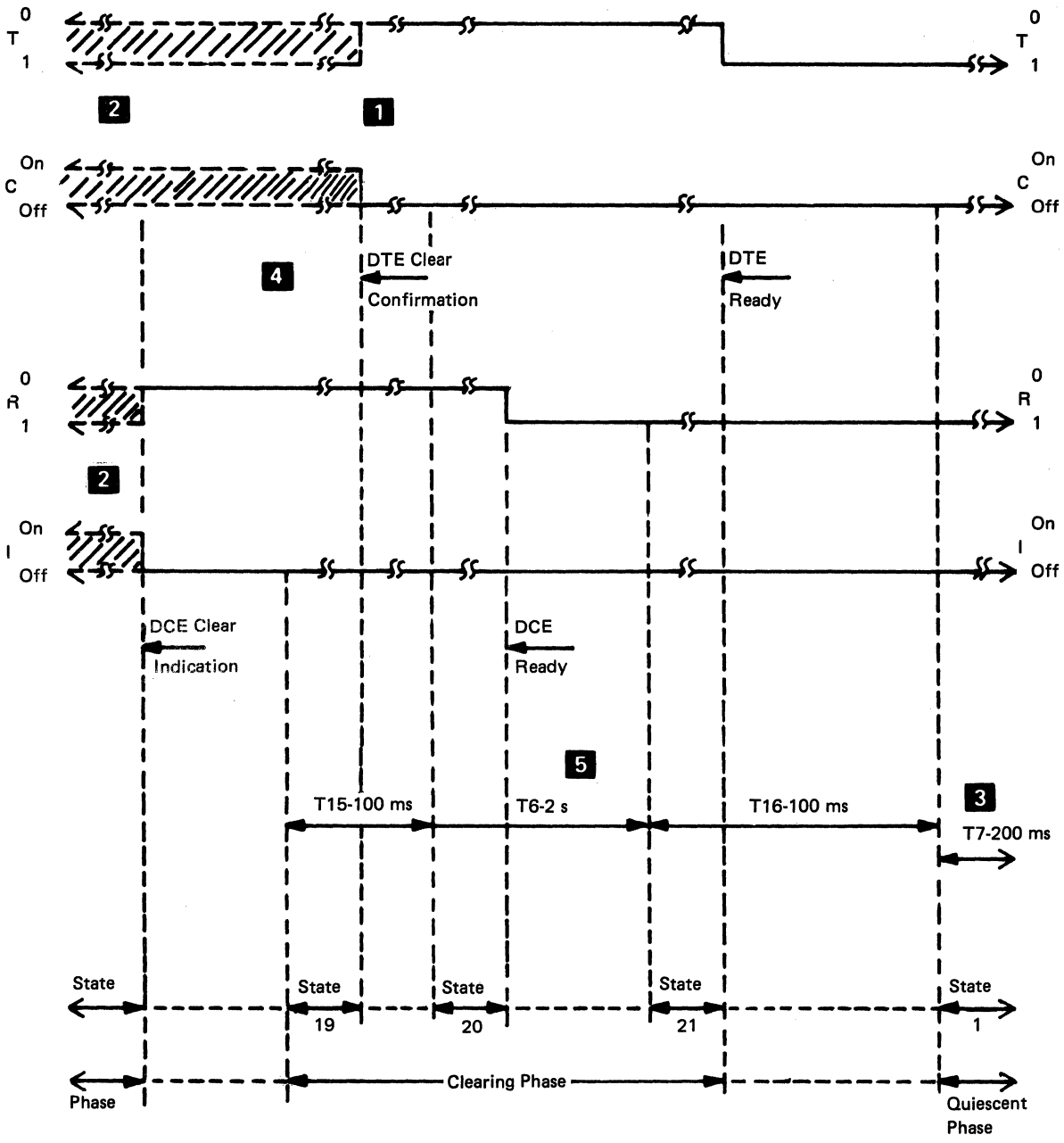


Figure 4-8. Clearing Phase (DCE) (Part 1 of 2)

Notes:

1. When the DTE presents t = 0 and c = off to the interface, it means one thing if the interface is in the quiescent phase and another if it is in any other phase. If the DTE has signalled 'call request' and then detects r = 0 and i = off, it will assume that it is in the call-control phase. If the DTE presents t = 0 and c = off to the interface while in the quiescent phase, it means 'DTE uncontrolled not ready'. This condition results in either state 22 or 24, depending on the state condition of the DCE. If the condition is presented in any other phase, it will mean either 'DTE clear request' or 'DTE clear confirmation'. Regardless of what state results from the t = 0 and c = off condition, the DTE will go to the 'ready' state ('DTE ready' and 'DCE ready') before it can go to 'DTE controlled not ready'. An exception to this can occur when time-limit T5 or T6 expires. See statement 5. Failure to do so may result in the DCE not recognizing the state change.

2. The symbol (////) indicates that the state of this interchange circuit is unimportant to the clearing phase for the period shown. This same period can be important to the operation preceding the clearing phase. For example, the DTE-to-DTE data-transfer protocols used during the data-transfer phase must take into consideration the overlap of the data-transfer phase and the clearing phase shown on Figures 4-7 and 4-8. If the DTE goes to t = 0 and c = off or the DCE goes to r = 0 and i = off while in the quiescent phase, these conditions will not be interpreted as 'clear request' and 'clear indication', respectively. The interface remains in the quiescent phase and is interpreted as presenting one of the quiescent phase states.

3. The 'DCE-provided information' sequence for charge information only appears immediately following a DTE calling sequence in which charge information has been requested by a facility subscription or by the DTE as a facility request. This charge information appears as part of the IA5 selection signals in the call-control phase. Time-limit T7 only appears in this sequence. If T7 expires, no state change is required of the DTE. If the next exchange of information with the DCE is an incoming call, the DTE will recognize that this is not the charge information previously requested. Charge information is a functional option, which may or may not be offered by the network or the DTE. This description of its operation does not imply that the DTE supports the function.

4. If both the DTE and the DCE simultaneously initiate a clearing operation, a clearing collision will exist between them. Recommendation X.21 does not discuss the possibility of a clearing collision. The rules that apply to a clearing operation that is initiated by only one device (DTE or DCE) do not apply when both devices initiate a clearing operation. For example, if clearing is initiated by both devices, the DCE looks at the DTE's 'clear request' as a 'clear confirmation'. There is no minimum number of bit times defined by recommendation X.21 for the DCE to accept the 'clear confirmation' from the DTE. The possibility exists that the DCE will present 'DCE ready' to the interface before the DTE recognizes 16 contiguous bit times of 'DCE clear confirmation'. Therefore, the DTE will initiate a clearing operation by presenting to the interface a minimum of 24 bit times of t = 0 and c = off. The DTE then looks for 16 contiguous bit times of r = 1 and i = off ('DCE ready'). If the DTE detects 'DCE ready' at the interface before T5 time-limit expires, the DTE will present 'DTE ready' to the interface before time-out expires if it is ready to continue communications with the DCE.

5. Time-limits T5 and T6 are the maximum times allowed by recommendation X.21 for the DCE to respond to a 'DTE clear request' or 'DTE clear confirmation', respectively. If either T5 or T6 expires, the DTE regards the interface as 'DCE not ready'. The DTE interprets this as the network being out of service. During this period, the DTE may go to 'controlled not ready'. When the DTE detects a 'DCE ready' condition on the interface, the DTE regards the network as being in service. The DTE will signal 'DTE ready' to the interface when it is ready to continue communications with the DCE.

Figure 4-8. Clearing Phase (DCE) (Part 2 of 2)

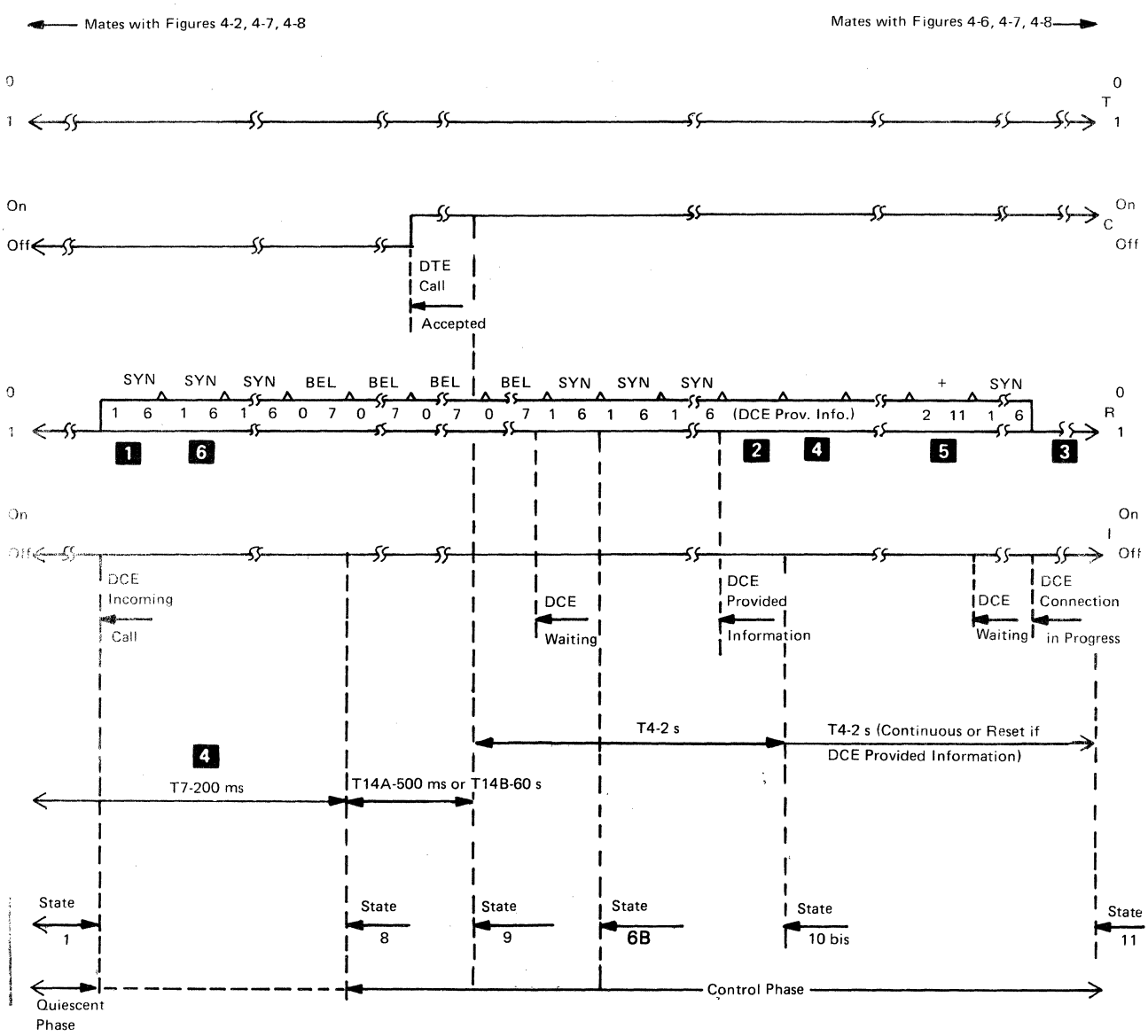


Figure 4-9. Call-Establishment Phase (Called DTE) (Part 1 of 2)

Notes:

1. After the call control characters are started on either the T circuit by the DTE or on the R circuit by the DCE, byte synchronization (byte alignment) is maintained until transfers of all call-control bytes (including SYN characters) for that circuit has been completed. State changes indicated by IA5 characters on the T and R circuits enter and exit the state on their respective character boundary. For an exception to the rule, see Figure 4-5, statement 5.

2. The 'DCE-provided information' sequence is optional. If provided by the network and available in the DTE, the sequence will be preceded by two or more SYN characters, with the first character or characters of the block identifying the information to follow. The only DCE-provided information defined by X.21 that can appear in the DTE calling sequence is the called-line identification.

   DCE-provided information appearing in a DTE called sequence is either calling-line identification or charging information. At present there are no 'DCE-provided information' sequences defined in X.21 that would cause more than one block to be transferred in any one sequence. Information characters within the 'DCE-provided information' block can be separated by two or more SYN characters.

3. The DCE 'connection in progress' is a state in the call-control phase. This state puts the call-control phase in a temporary hold until the network finishes its housekeeping before turning the end-to-end connection over to the DTEs. The DCE cannot predict when the network will be ready for data and cannot delay the presentation of 'DCE ready for data' to the DTE. Therefore, the DCE 'connection in progress' can range from one bit time in duration to the expiration of time-limit T2 or T3. The DTE will be prepared to accept the condition where the DCE 'connection in progress' is presented to the DTE for less than 16 bit times.

4. The 'DCE-provided information' sequence for charge information only appears immediately following a DTE calling sequence in which charge information has been requested by a facility subscription or by the DTE as a facility request. This charge information appears as part of the IA5 selection signals in the call-control phase. Time-limit T7 only appears in this sequence. If T7 expires, no state change is required of the DTE. If the next exchange of information with the DCE is an incoming call, the DTE will recognize that this is not the charge information previously requested. Charge information is a functional option which may or may not be offered by the network or the DTE. This description of its operation does not imply that the DTE supports the function.

5. If the 'DCE-provided information' block contains charge information, the 'DCE clear indication' is expected immediately following the last charging information block ending character 2/11 (+). The DTE may initiate the clearing phase by presenting 'DTE clear request' following receipt of the charge information. If not previously terminated by 'DCE clear indication', time-limit T4 will cause a 'DTE clear request'.

6. There is the possibility of a hang condition at this point that is not covered in recommendation X.21. There is no time-limit defined, except for a special case where T7 is used, for the period starting with the first SYN character of what appears to the DTE to be the start of an 'incoming call' signal. If the DCE presents a continuous stream of SYN characters because of a fault in the network, a hang condition exists with no defined escape mechanism. A time-limit of 1 second or longer may be implemented by the DTE to protect against this possible hang condition.

Figure 4-9. Call-Establishment Phase (Called DTE) (Part 2 of 2)

Call Collision

A call collision occurs when a 'call request' and an 'incoming call' appear on the interface simultaneously. Recommendation X.21 allows the DTE to turn on 'call request' until time-out T14 expires (0.5 s or 60 s). This causes the 'incoming call' to be rejected. Rejecting a call with a 'call request' after the DTE has sensed an incoming call is not intended. The IBM implementation is to examine the R and I circuits for a steady state r = 1 and i = off up to the last bit possible, before T and C circuits are set to t = 0 and c = on. From that point the DTE, looks for a 'proceed to select' indication (+ preceded by two or more SYN characters). An 'incoming call' (BEL preceded by two or more SYN characters) will be ignored and a 'proceed to select' (+ preceded by two or more SYN characters) will be expected. See Figure 4-10 for call collision implementation.

A variation to the preceeding implementation is shown on Figure 4-11. Before setting t = 0 and c = on as part of a 'call request' sequence, the DTE may present at least 24 bit times of state 1 (t = 1, c = off). This method may be used by a DTE that originates outgoing calls and rejects all incoming calls. The DTE originates an outgoing call by taking the interface from state 14 to state 1 for at least 24 bit times and then going to state 2 ('call request'). Before taking the interface to state 1, the DTE will examine the interface for a steady state r = 1, i = off up to the last possible bit. Once state 1 is signaled, the DTE will ignore IA5 control characters on the R circuit until after going to state 2 ('call request'). If a 'call collision' has occurred, or occurs at this point, the 'call collision' procedures discussed previously will be followed.

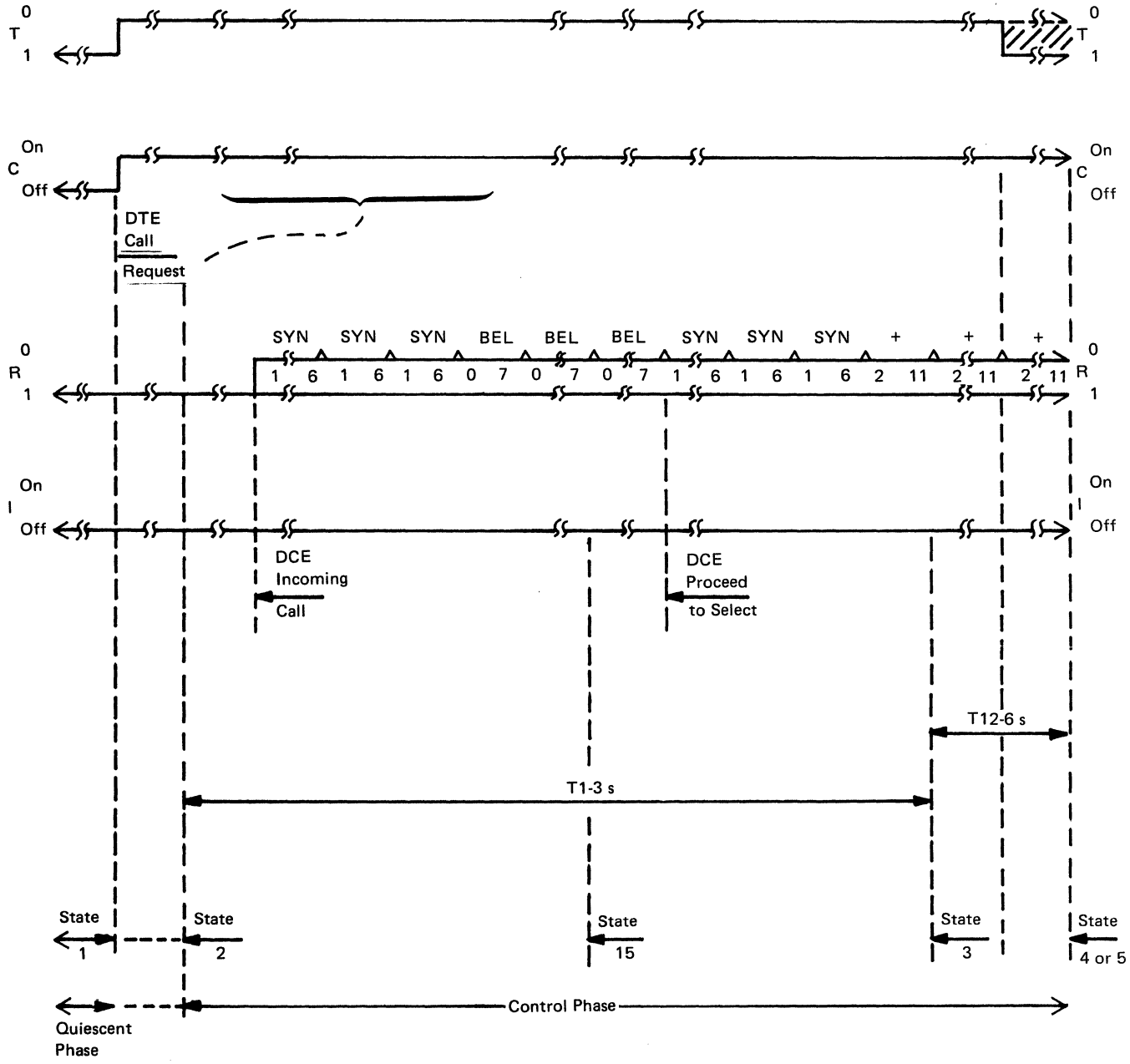


Figure 4-10. Call Collision (States 1-2-15-3 Sequence)

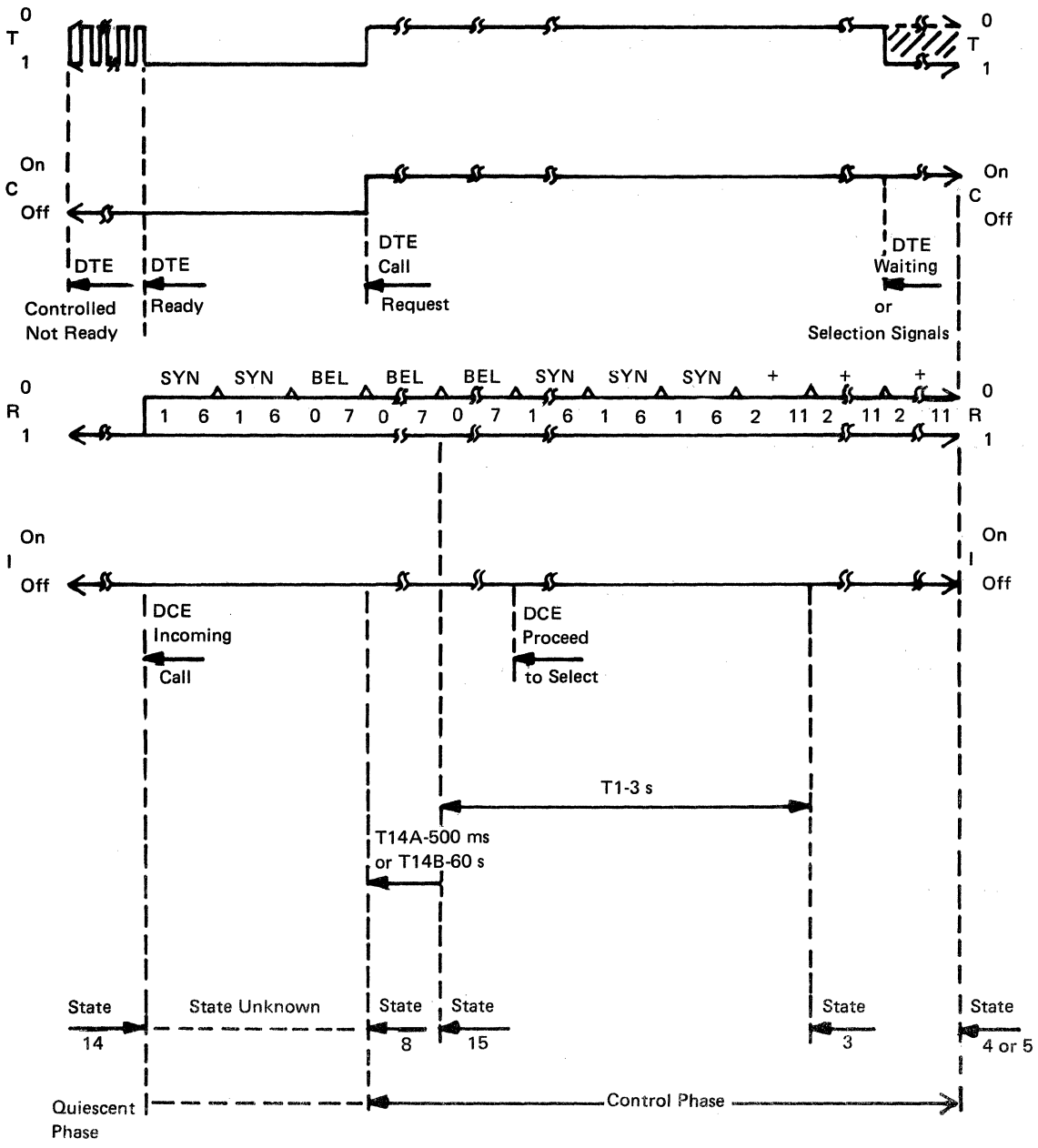


Figure 4-11. Call Collision (States 14-8-15-3 Sequence)

Network-Provided Information

Call progress signals and DCE-provided information are handled separately by recommendation X.21. For example, call progress signals appear in state 7 and DCE-provided information appears in state 10. However, when they are presented on the R circuit at the DTE interface, they appear identical and cannot be distinguished until the contents of each block are examined. The DTE is designed to receive call progress signals or DCE-provided information without making a distinction until the contents of each block are examined, and then act accordingly. Figure 4-12 is set up to show how the DTE treats network-provided information as a single entity. See Figure 4-12.

Call Progress Signals

Call progress signals are defined by recommendation X.21. These signals are return to the calling DTE, during the call-establishment phase to indicate the following:

- The circumstances that prevented a call connection being established to the called DTE
- The progress made towards establishing the connection requested

Call progress signals may also be a reply to a registration request, which is not part of the call-establishment phase.

For additional information on call progress signals, refer to the CCITT publication *Public Data Networks,* Volume VIII.2, for recommendations X.21 and X.96.

DCE-Provided Information

DCE-provided information signals are defined by recommendation X.21. The DCE provides line identification for both calling and called DTEs. The DCE also provides charging information to the DTE. For detailed information on DCE provided information, refer to the CCITT publication *Public Data Networks,* Volume VIII.2, for recommendation X.21.

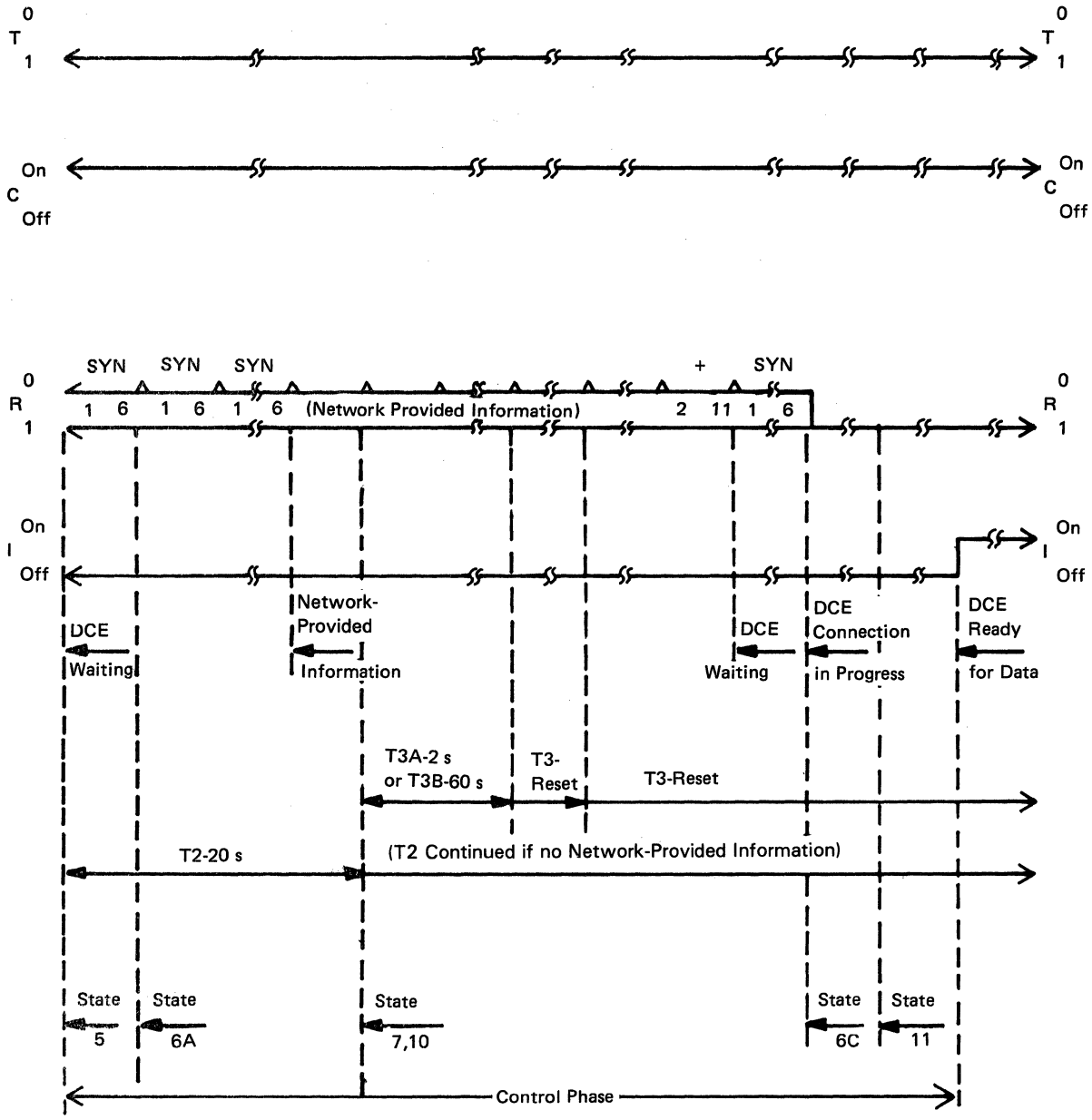


Figure 4-12. Network-Provided Information

Leased-Circuit Operation

Recommendation X.21 defines the operation of DTEs using a leased-circuit public data network. Figures 4-13 through 4-15 show the operation of DTEs using a leased circuit. Point-to-point and centralized multipoint operation are defined in recommendation X.21. The transfer of data from remote DTEs to a central DTE is under control of the data link protocol for centralized multipoint operation on a leased-circuit public data network. If two or more remote DTEs are allowed to transmit data at the same time, unsatisfactory conditions may result. Leased-circuit operation requires a very simple set of interface states to be passed between the DTE and the DCE. When the DTE has power on and is ready to communicate, the DTE sets the T circuit to t = 1. When the DCE is ready for signals to be passed between itself and the DTE, the DCE presents the steady state r = 1 and i = off to the DTE. When the DTE is ready to transmit data to the remote DTE, the DTE sets the C circuit to c = on, waits 24 bit times, and then places data intended for the remote DTE on the T circuit.

When circuit I is set to i = on, the DTE can expect to receive data from the remote DTE. The data link protocol controls the transfer of data between DTEs. The protocol defines when data can be placed on a DTE's T circuit in order for the data to be useful to the other DTE.

The initial state of the DTE or the DCE is 'not ready' caused by either power off at the device or power on with the device (DTE or DCE) presenting a 'not ready' state to the interface. Once the DTE is powered on, the DTE may present 'ready' to the interface immediately or wait until it is ready to communicate with the DCE. If the DCE is not already 'ready' or does not present 'ready' to the interface, within a preset time-limit (usually 3 seconds), after the DTE presents 'ready', the DTE may post an error condition to the user's program. See Figure 4-13 for the turn-on sequence used by a leased-circuit operation.

When both the DTE and the DCE are presenting 'ready' (state 1), the DTE may transmit data, receive data, or transmit and receive data simultaneously. The data link protocol controlling the DTEs determines which operation is done first. Before data, which is intended for the remote DTE, is placed on circuit T, circuit C is set to c = on for a minimum of 24 bit times. Receive data will be expected on circuit R immediately following circuit I being set to i = on. See Figure 4-14 for the data transfer phase used by a leased-circuit operation.

The DTE may signal 'ready' following 'data transfer' (state 13) without going to 'uncontrolled not ready' (t = 0, c = off). See Figure 4-15 for the turn-off sequence used by a leased-circuit operation.

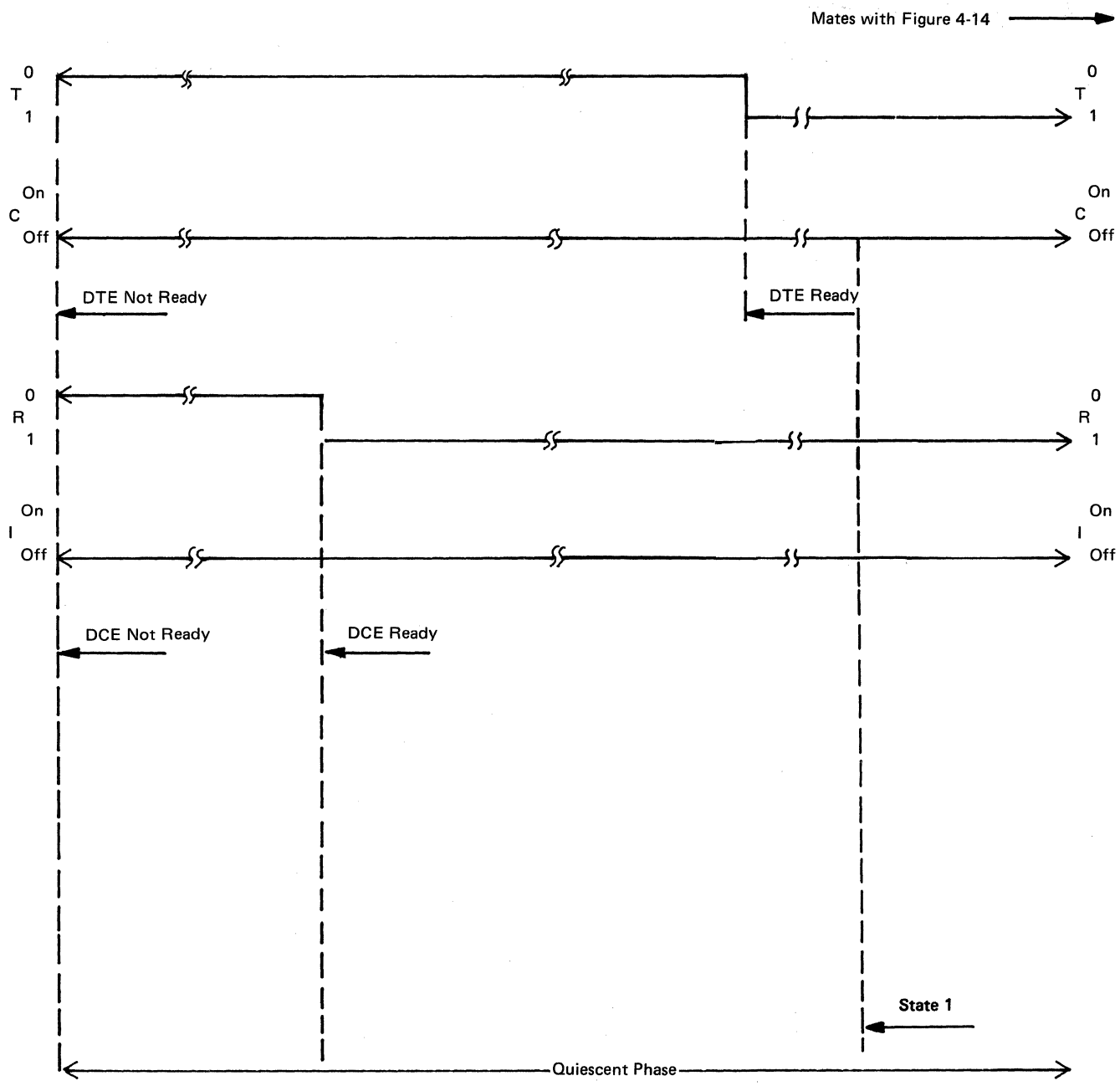
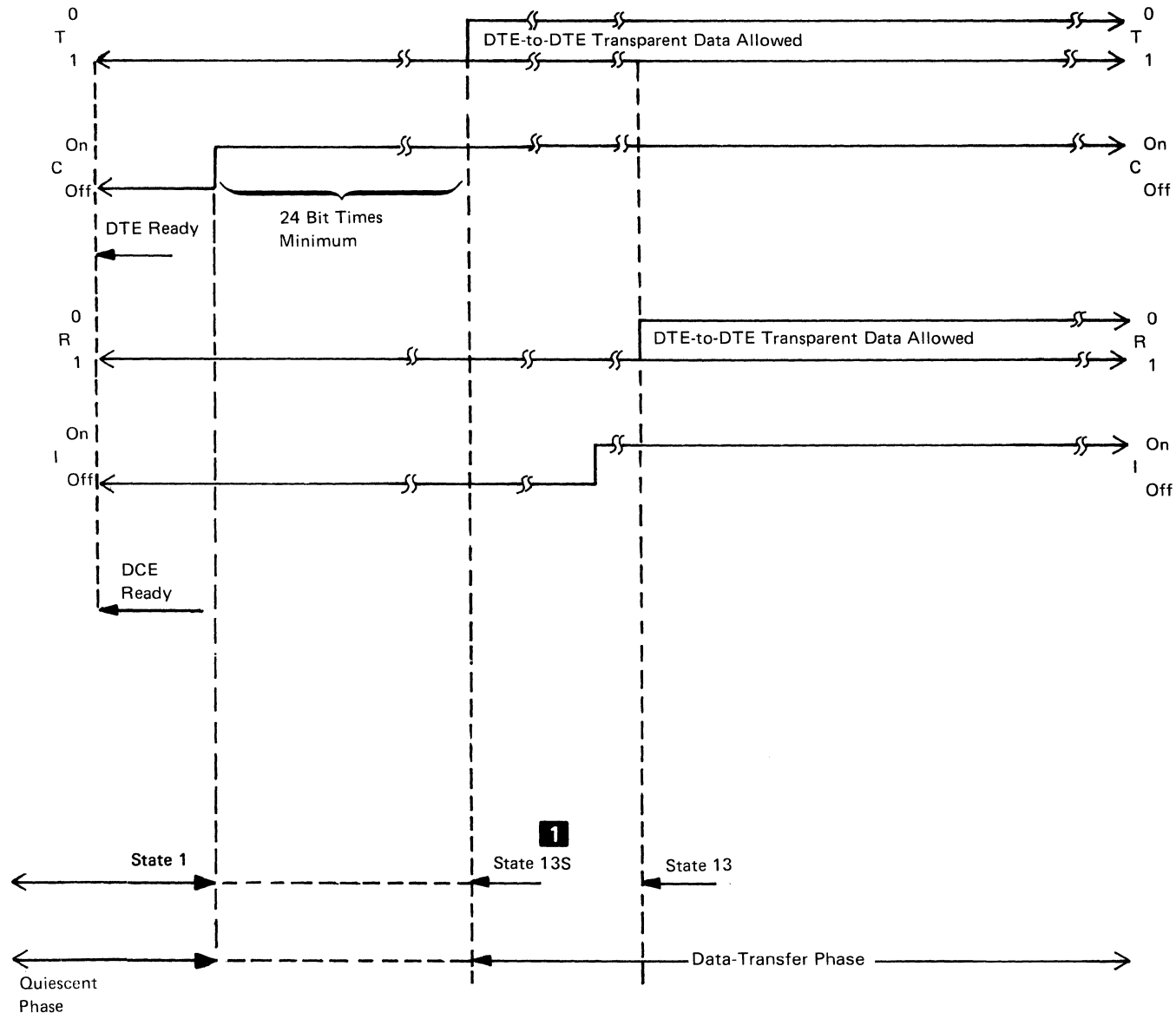


Figure 4-13. Quiescent Phase—Turn-On Sequence (Leased-Circuit Operation)

Mates with Figure 4-13

Mates with Figure 4-15



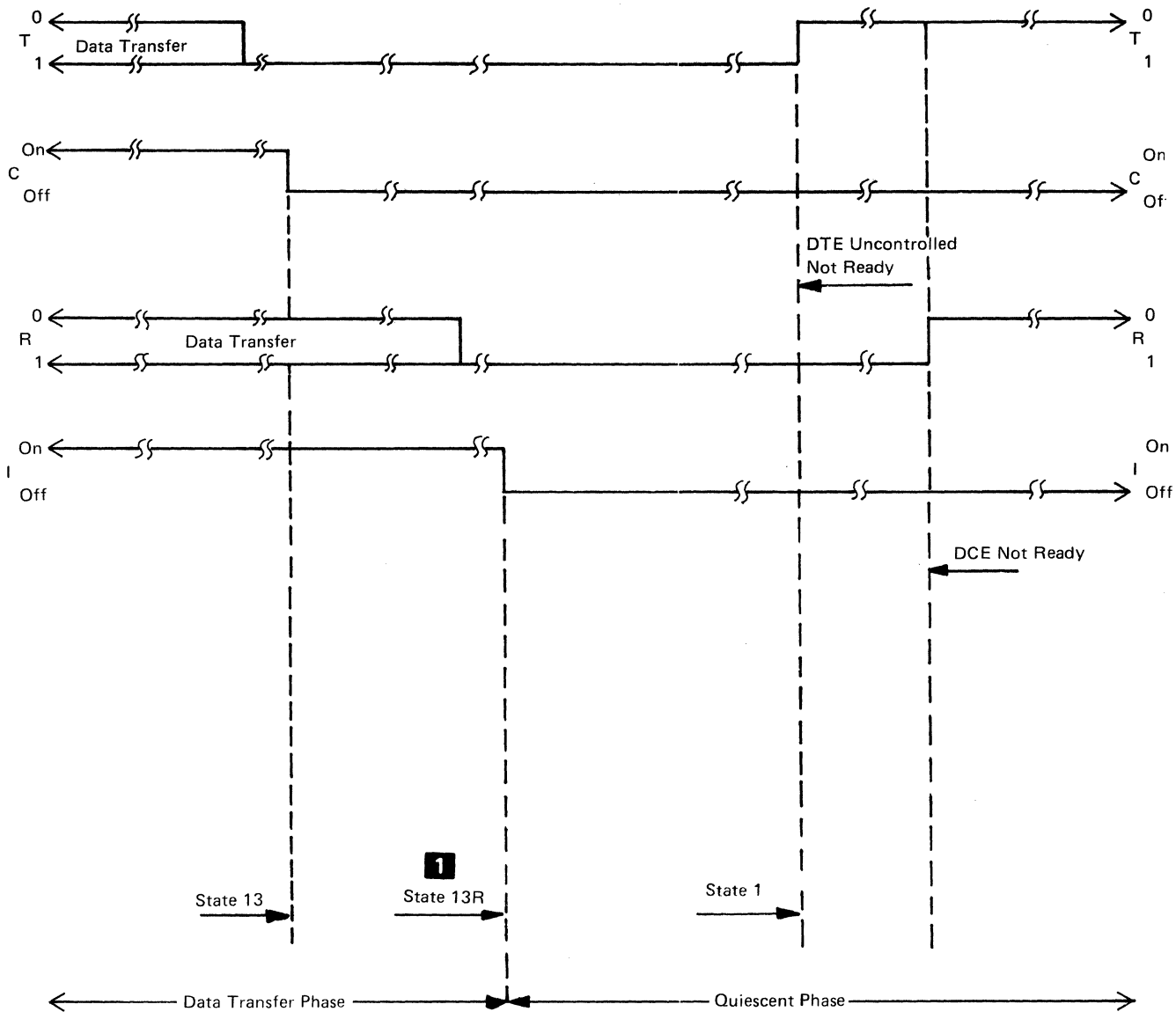
Note:

1 If circuits R and I are set to r = D and i = on before the T and C circuits are set to t = D and c = on, the interface will be at state 13R.

Figure 4-14. Data-Transfer Phase (Leased-Circuit Operation)

Mates with Figure 4-14

Mates with Figure 4-13



Note:

1 If circuits R and I are set to r = 1 and i = off before the T and C circuits are set to t = 1 and c = off, the interface will be at state 13S.

Figure 4-15. Quiescent Phase—Turn-Off Sequence (Leased-Circuit Operation)

Appendix A. DTE Time-Limits and DCE Time-Outs

This appendix describes the time-limits and time-outs defined by recommendation X.21. For additional information on DTE time-limits and DCE time-outs, refer to the CCITT publication *Public Data Networks,* Volume VIII.2, for recommendation X.21.

DTE Time-Limits

Under certain conditions, recommendation X.21 requires the DCE to respond to a signal from the DTE within a stated maximum time. If any of these maximum times is exceeded, the DTE will initiate the action indicated in Figure A-1. For greatest efficiency, the DTE will incorporate the time-limits shown in Figure A-1 into its design. The time-limits given in Figure A-1 are the maximum times allowed for the DCE to respond to a signal from the DTE. These time-limits are also the minimum times that a DTE must allow for proper network operation. Time-limits longer than those shown can be used by the DTE, but the use of a longer time-limit could reduce network utilization. A failure in DCE operation should be the only situation in which a time-limit is exceeded.

Time-Limit	Time-Limit Number	Started By	Normally Terminated By	Preferred Action to Be Taken When Time-Limit is Exceeded
3 s	T1	Signalling of 'call request' (state 2)	Reception of 'Proceed to select' (state 3)	DTE signals 'DTE ready' (state 1)
20 s	T2	Signalling end of selection or 'DTE waiting' (direct call) (state 5)	Reception of 'call progress signals', 'DCE provided information' 'ready for data' or 'DCE clear indication' (state 7, 10, 12, or 19)	DTE signals 'DTE clear request' (state 16)
2 s	T3A	Reception of 'call progress signals' OR 'DCE provided information' (state 7 or 10)	Reception of 'ready for data' or 'DCE clear indication' (state 12 or 19) Reset by additional 'call progress signals' or 'DCE provided information' (state 7 or 10)	
60 s	T3B (Note 1)	Reception of applicable 'call progress signals' (state 7)		
2 s	T4	Change of state to 'call accepted' (state 9)	Reception of 'ready for data' or 'DCE clear indication' (state 12 or 19) Reset by 'DCE provided information' (state 10 bis)	
2 s	T 5	Change of state to "DTE clear request" (state 16)	Change of state to "DCE ready" (state 21)	DTE regards the DCE as "DCE not ready" and signals "DTE ready" (state 18) or "DTE controlled not ready" (state 23)
2 s	T 6	Change of state to "DTE clear confirmation" (state 20)	Reception of "DCE ready" (state 21)	
200 ms	T 7	Change of state to 'ready' (state 1) when charge information has been requested	Reception of 'incoming call' (state 8)	DTE returns to normal operation and may note absence of charge information (state 10 bis)

Note 1. Time limit T3B applies to manually answering DTEs.

Figure A-1. DTE Time-Limits

DCE Time-Outs

Under certain conditions, recommendation X.21 requires the DTE to respond to a signal from the DCE within a stated maximum time. If any of these maximum times is exceeded, a time-out in the DCE is expected to initiate the actions shown in Figure A-2. These maximum times are taken into account in the DTE design. The time-outs given in Figure A-2 are the minimum time-out values used by the DCE in waiting for the appropriate DTE response. These time-outs are also the maximum times that are available to the DTE for response to the indicated DCE action. A failure in the DTE operation should be the only time when a time-out is exceeded.

Time-Out	Time-Out Number	Started By	Normally Terminated By	Action to Be Taken When Time-Out Expires
36 s	T11 (Note 1)	DCE signalling of 'proceed to select' (state 3)	DCE reception of end-of-selection signal	DCE signals 'DCE clear indication' (state 19) or transmits appropriate 'call progress signal' followed by 'DCE clear indication' (state 19)
6 s	T12	DCE signalling of 'proceed to select' (state 3)	DCE reception of first selection character or in the case of direct call, 'DTE waiting' (state 5)	
6 s	T13 (Note 1)	DCE reception of nth selection character (state 4)	DCE reception of (n+1)th selection character or end-of-selection signal	
500 ms	T14A	DCE signalling of 'incoming call' (state 8)	Change of state to 'call accepted' (state 9) or 'call collision' (state 15)	The DTE is noted as not answering. The DCE signals 'DCE ready' (state 1)
60 s	T14B (Note 2)			
100 ms	T15	Change of state to 'DCE clear indication' (state 19)	Change of state to 'DTE clear confirmation' (state 20)	DCE signals 'DCE ready' and marks 'DTE uncontrolled not ready' (state 24)
100 ms	T16	Change of state to 'DCE ready' (state 21)	Change of state to 'ready' (state 1)	DCE marks 'DTE uncontrolled not ready' (state 24)

Note 1. Time limits T11 and T13 do not apply when the 'direct calling' option is used.

Note 2. Time limit T14B is provided only when manually answering DTEs are allowed in the network.

Figure A-2. DCE Time-Outs

Appendix B. Abbreviations and Glossary

Abbreviations

C	control circuit
c	signal on control circuit
CCITT	International Telegraph and Telephone Consultative Committee
CPS	call progress signals
DCE	data circuit-terminating equipment
DTE	data terminal equipment
EIA	Electronic Industries Association
EOS	end of sequence
I	indication circuit
i	signal on indication circuit
IA5	International Alphabet No. 5
in.	inch
IS	International Standard
ISO	International Organization for Standardization
max.	maximum
min.	minimum
mm	millimeter
n	interface state number
No.	number
PTT	Post Telephone and Telegraph Administration
R	receive circuit
r	signal on receive circuit
RS	Recommended Standard
S	signal element timing circuit
s	second
T	transmit circuit
t	signal on transmit circuit

Glossary

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channel: In data transmission, a means of one-way transmission. Contrast with *circuit.*

***circuit:** (1) In data communications, a means of two-way communications between two data terminal installations. (2) Contrast with *channel.*

circuit-switched connection: (1) (SC1) A connection that is established on demand between two or more data stations allowing the exclusive use of a data circuit until the connection is released. (2) Contrast with *leased-circuit.*

communication channel: Synonym for *communication line.*

communication common carrier: In the U.S.A., a government-regulated private company that furnishes the general public with telecommunication service facilities; for example, a telephone or telegraph company. See also Post Telephone and Telegraph Administration.

communication facility: Anything used or available for use in furnishing data communication service.

communication line: (1) Any physical link, such as a wire or a telephone circuit, that connects one or more remote terminals to a communication control unit, or connects one communication control unit with another. (2) Synonymous with *communication channel.* (3) Contrast with *data link.*

***data circuit-terminating equipment (DCE):** (SC1) The functional unit of a data station that establishes, maintains, and releases a connection and provides those functions necessary for any code or signal conversion between the data terminal equipment and the data transmission line.

data communication: The transmission and reception of data.

data link: (1) (SC1) The assembly of parts of two data terminal equipments that are controlled by a link protocol, together with their interconnecting data circuit, that enables data to be transferred from a data source to a data sink. (2) The communication channel, modem, and communication controls of all stations connected to the communication channel, used in the transmission of information between two or more stations. (3) The physical connection and the connection protocols between the host and communication controller nodes via the host data channel. (4) Contrast with *communication line.*

data terminal equipment (DTE): (SC1) The functional unit of a data station that serves as a data source or a data sink and provides for the data communication control function to be performed in accordance with a link protocol.

direct call: A communications facility that avoids the use of address selection signals. The network interprets the call request signal as an instruction to establish a connection with a single destination address previously designated by the user.

***duplex:** (1) (ISO) In data communication, pertaining to a simultaneous two-way independent transmission in both directions. (2) Contrast with *half duplex.*

***duplex operation:** In data communication, a mode of operation of a data link in which data may be transmitted simultaneously in both directions over two channels.

duplex transmission: Data transmission over a data circuit in both directions at the same time.

feature: A specific design addition to an IBM product, quoted by the IBM sales manual and separately orderable.

***half duplex:** (1) In data communication, pertaining to an alternate, one way at a time, independent transmission. (2) Contrast with *duplex.*

***half duplex operation:** (ISO) In data communication, a mode of operation of a data link in which data may be transmitted in both directions, one way at a time.

half-duplex transmission: (SC1) Data transmission over a data circuit in either direction, one direction at a time; the choice of direction is controlled by the data terminal equipment.

leased-circuit: (1) (SC1) A connection established, without the use of switching facilities, for the exclusive use of two or more data stations. (2) Contrast with *circuit-switched connection.*

multipoint connection: A connection established between three or more data stations. The connection may include switching facilities.

network: See *user application network* and *public data network.*

point-to-point connection: A connection established between only two data stations. The connection may include switching facilities.

Post, Telephone, and Telegraph Administration (PTT): A generic term for the government-operated common carrier in countries outside the U.S.A. and Canada. See also *communication common carrier.*

public data network: A network established and operated by common carriers or PTT Administrations for the specific purpose of providing circuit-switched, packet-switched, and leased-circuit services to the public. Contrast with *user application network.*

telecommunication: (1) (SC1) Communication over a distance, as by telegraph or telephone. (2) Data transmission between a computing system and remotely located devices via a unit that performs the necessary format conversion and controls the rate of transmission.

terminal: (1) *A point in a system or communication network at which data can either enter or leave. (2) A device, usually equipped with a keyboard and some kind of display, capable of sending and receiving information over a communication channel.

user application network: A configuration of data processing products, such as processors, controllers, and terminals, established and operated by users for the purpose of data processing or information exchange, which may use transport services offered by common carriers or telecommunication Administrations. Contrast with *public data network.*

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