Message Sequence Charts
UART

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Table of Contents

0 Document Control

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0.2 References

[1] GSM 05.02 version 8.0.0 Release 1999
Digital cellular telecommunications system (Phase 2+);
Multiplexing and multiple access on the radio path

[2] GSM 04.60 version 6.3.0 Release 1997
Digital cellular telecommunications system (Phase 2+);
General Packet Radio Service (GPRS);
Mobile Station (MS) - Base Station System (BSS) interface;
Radio Link Control/ Medium Access Control (RLC/MAC) protocol

[3] GSM 04.08 version 6.3.0 Release 1997
Digital cellular telecommunications system (Phase 2+);
Mobile radio interface layer 3 specification

[4] GSM 03.64 version 6.1.0 Release 1997
Digital cellular telecommunications system (Phase 2+);
General Packet Radio Service (GPRS);
Overall description of the GPRS radio interface; Stage 2

[5] GSM 03.60 version 6.3.1 Release 1997
Digital cellular telecommunications system (Phase 2+);
General Packet Radio Service (GPRS);
Service description; Stage 2

[6] GSM 04.07 version 6.3.0 Release 1997
Digital cellular telecommunications system (Phase 2+);
Mobile radio interface signalling layer 3; General aspects

[7] GSM 04.64 version 6.3.0 Release 1997
Digital cellular telecommunications system (Phase 2+);
General Packet Radio Service (GPRS);
Mobile Station - Serving GPRS Support Node (MS-SGSN)
Logical Link Control (LLC) layer specification

[8] GSM 05.08 version 6.4.0 Release 1997
Digital cellular telecommunications system (Phase 2+);
Radio subsystem link control

[9] GSM 05.10 version 6.3.0 Release 1997
Digital cellular telecommunications system (Phase 2+);
Radio subsystem synchronization

[10] GSM 03.20 TS 100 929: July 1998 (GSM 03.20 version 6.0.1)
Security related network functions, ETSI

[11] Draft GSM 03.22: August 1998 (GSM 03.22 version 6.1.0)
Functions related to Mobile Station (MS) in idle mode and group receive mode, ETSI

[12] GSM 04.65 V6.3.0: Subnetwork Dependant Convergence Protocol
ETSI, March 1999

[13] ITU-T V42bis ITU-T, Recommendation V.42 bis 1990

[14] GSM 09.60 GPRS Tunneling Protocol (GTP) across the Gn and Gp Interface

[15] RFC 1661 IETF STD 51 July 1994
The Point-to-Point Protocol (PPP)

[16] RFC 1662 IETF STD 51 July 1994
PPP in HDLC-like Framing

[17] RFC 1570 January 1994
PPP LCP Extensions

[18] RFC 1989 August 1996
PPP Link Quality Monitoring

[19] RFC 1332 May 1992
The PPP Internet Protocol Control Protocol (IPCP)

[20] RFC 1877 December 1995
PPP IPCP Extensions for Name Server Addresses

[21] RFC 2153 May 1997
PPP Vendor Extensions

[22] RFC 1334 October 1992
PPP Authentication Protocols (for Password Authentication Protocol only)

[23] RFC 1994 August 1996
PPP Challenge Handshake Authentication Protocol (CHAP)

[24] TIA/EIA-136-370
Packet-Data Services – Enhanced General Packet Radio for TIA/EIA-136 (EGPRS-136) - Overview, Telecommunications Industry Association

[25] TIA/EIA-136-376
Packet-Data Services – EGPRS-136 Mobility Management, Telecommunications Industry Association

[26] TIA/EIA-136-972
Packet-Data Services – Stage 2 Description, Telecommunications Industry Association

0.3 Abbreviations

ACI	Application Control Interface
AGCH	Access Grant Channel
AT	Attention sequence "AT" to indicate valid commands of the ACI
BCCH	Broadcast Control Channel
BS	Base Station
BSIC	Base Station Identification Code
C/R	Command/Response
C1	Path Loss Criterion
C2	Reselection Criterion
CBCH	Cell Broadcast Channel
CBQ	Cell Bar Qualify
CC	Call Control
CCCH	Common Control Channel
CCD	Condat Coder Decoder
CCI	Compression and Ciphering Interface
CHAP	Challenge Handshake Authentication Protocol
CKSN	Ciphering Key Sequence Number
CRC	Cyclic Redundancy Check
DCCH	Dedicated Control Channel
DCOMP	Identifier of the user data compression algorithm used for the N-DPU
DISC	Disconnect Frame
DL	Data Link Layer
DM	Disconnected Mode Frame
DTX	Discontinuous Transmission
E	Extension bit
EA	Extension Bit Address Field
EL	Extension Bit Length Field
EMMI	Electrical Man Machine Interface
F	Final Bit
FACCH	Fast Associated Control Channel
FHO	Forced Handover
GACI	GPRS Application Control Interface
GMM	GPRS Mobility Management
GP	Guard Period
GRR	GPRS RR
GSM	Global System for Mobile Communication
HDLC	High-level Data Link Control
HISR	High level Interrupt Service Routine
HPLMN	Home Public Land Mobile Network
I	Information Frame
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscriber Identity
IP	Internet Protocol
IPCP	Internet Protocol Control Protocol
ITU	International Telecommunication Union
IWF	Interworking Function
Kc	Ciphering Key
L	Length Indicator
LAI	Location Area Information
LCP	Link Control Protocol

LISR	Low level Interrupt Service Routine
LLC	Logical Link Control
LPD	Link Protocol Discriminator
LQM	Link Quality Monitoring
M	More bit used to indicate the last segment of N-DPU
MAC	Medium Access Control
MCC	Mobile Country Code
MM	Mobility Management
MMI	Man Machine Interface
MNC	Mobile Network Code
MS	Mobile Station
MT	Mobile Termination
N(R)	Receive Number
N(S)	Send Number
NC	Network Control
NCC	National Colour Code
NCP	Network Control Protocol
NECI	New Establishment Causes included
N-PDU	Network Protocol Data Unit
NSAPI	Network Layer Service Access Point Identifier
OTD	Observed Time Difference
P	Poll Bit
P/F	Poll/Final Bit
PACCH	Packet Associated Control Channel
PAP	Password Authentication Protocol
PBCCH	Packet BCCH
PCCCH	Packet CCCH
PCOMP	Identifier of the protocol control information compression algorithm used for the N-DPU
PDCH	Packet Data Channel
PDP	Packet Data Protocol e.g. IP or X.25
PDTCH	Packet Data Traffic Channel
PRACH	Packet RACH
PSI	Packet System Information
PCH	Paging Channel
PCO	Point of Control and Observation
PDU	Protocol Data Unit
PL	Physical Layer
PLMN	Public Land Mobile Network
PPC	Packet Physical Convergence
PPP	Point-to-Point Protocol
PTP	Point to Point
QoS	Quality of Service
RACH	Random Access Channel
REJ	Reject Frame
RLC	Radio Link Control
RNR	Receive Not Ready Frame
RR	Radio Resource Management
RR	Receive Ready Frame
RTD	Real Time Difference
RTOS	Real Time Operating System
SABM	Set Asynchronous Balanced Mode
SACCH	Slow Associated Control Channel
SAP	Service Access Point
SAPI	Service Access Point Identifier

SDCCH	Stand alone Dedicated Control Channel
SDU	Service Data Unit
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
SM	Session Management
SMS	Short Message Service
SMSCB	Short Message Service Cell Broadcast
SNDCP	Subnetwork Dependant Convergence Protocol
SNSM	SNDCP-SM
SS	Supplementary Services
TAP	Test Application Program
TBF	Temporary Block Flow
TCH	Traffic Channel
TCH/F	Traffic Channel Full Rate
TCH/H	Traffic Channel Half Rate
TCP	Transmission Control Protocol
TDMA	Time Division Multiple Access
TE	Terminal Equipment - e. g. a PC
TFI	Temporary Flow Identifier
TLLI	Temporary Logical Link Identifier
TMSI	Temporary Mobile Subscriber Identity
TOM	Tunnelling of Messages
TQI	Temporary Queuing Identifier
UA	Unnumbered Acknowledgement Frame
UART	Universal Asynchronous Receiver Transmitter
UI	Unnumbered Information Frame
USF	Uplink State Flag
V(A)	Acknowledgement State Variable
V(R)	Receive State Variable
V(S)	Send State Variable
VPLMN	Visited Public Land Mobile Network

0.4 Terms

Entity:	Program which executes the functions of a layer
Message:	A message is a data unit which is transferred between the entities of the same layer (peer-to-peer) of the mobile and infrastructure side. Message is used as a synonym to protocol data unit (PDU). A message may contain several information elements.
Primitive:	A primitive is a data unit which is transferred between layers on one component (mobile station or infrastructure). The primitive has an operation code which identifies the primitive and its parameters.
Service Access Point:	A Service Access Point is a data interface between two layers on one component (mobile station or infrastructure).

1 Introduction

1.1 Multiplexer connection modes

Multiplexer operation is started by the use of the +CMUX command (see 3G TS 27.007). If ACI receives this command it starts the multiplexer and the multiplexer starts up the multiplexer control channel. The TE multiplexer initiates the establishment of the multiplexer control channel. Once the multiplexer control channel is established other DLCs (Data Link Connection) may be established. After establishing of a DLC, the multiplexer enters connected mode, for the particulare DLC, and transfer of information may commence.

If the TE wants close down it will release each DLC in turn. When all DLCs (except the multiplexer control channel) are closed down (disconnected mode) the TE will send a close-down message on the multiplexer control channel. When this message is acknowledged both stations will revert to the non-multiplexed mode. After closing of the multiplexer protocol, the UE and TE revert to normal AT mode.

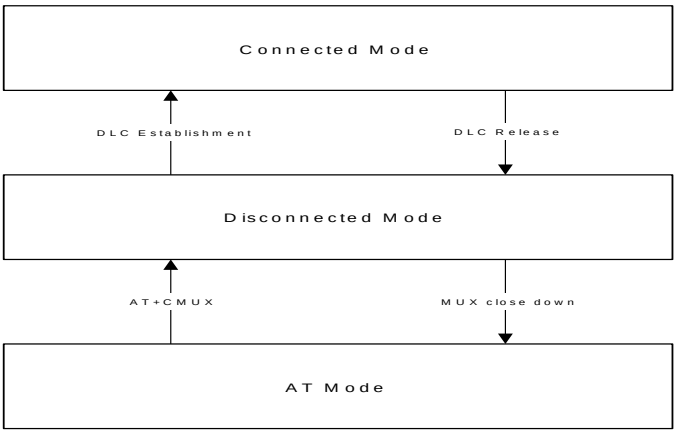


Figure 1-1: Connection Modes

1.1.1 AT command

Multiplexer operation is started by the use of the +CMUX command (see 3G TS 27.007).

Command:

+CMUX=<mode>[,<subset>[,<port_speed>[,<N1>[,<T1>[,<N2>[,<T2>[,<T3>[,<k>]]]]]]]]

Description:

<mode>: This parameter determines the multiplexer Transparency Mechanism.

<subset>: This parameter defines the way in which the multiplexer control channel is set up. A virtual channel may subsequently be set up differently but in the absence of any negotiation for the settings of a virtual channel, the virtual channel shall be set up according to the control channel <subset> setting.

<port_speep>: This parameter determines the multiplexer transmission rate.

<N1>: This parameter determines the maximum frame size. The value can be in the range of 1 – 32768.

<T1>: This parameter is the acknowledgement timer in units of ten milliseconds. The value can be in the range of 1 – 255.

<N2>: This parameter determines the maximum number of re-transmissions. The value can be in the range of 0 – 100.

<T2>: This parameter is the response timer for the multiplexer control channel in units of ten milliseconds. T2 must be longer than T1. The value can be in the range of 2 – 255.

<T3>: This parameter is the wake up response timer in seconds. The value can be in the range of 1 – 255.

<k>: This parameter determines the window size, for Advanced operation with Error Recovery options (Error Recovery is not supported). The value can be in the range of 1 – 7.

Defined values:

parameter	value	Comment
<mode>	0	Basic option (not supported)
	1	Advanced option
<subset>	0	UIH frames used only (default)
	1	UI frames used only (not supported)
	2	I frames used only (not supported)
<port_speed>	1	9600 bit/s
	2	19200 bit/s
	3	38400 bit/s
	4	57600 bit/s
	5	115200 bit/s
	6	230400 bit/s
<N1>	31	default value in Basic option
	64	default value in Advanced option
<T1>	10	default value (100 ms)
<N2>	3	default value
<T2>	30	default value (300 ms)
<T3>	10	default value (10 seconds)
<k>	2	default value

1.1.2 Multiplexer start up

On reception of the +CMUX AT command ACI instructs the multiplexer to start up. This begins with the establishment of the multiplexer control channel (Data Link Connection Identifier 0). The TE multiplexer initiates the establishment of the multiplexer control channel by sending a SABM frame on DLCI 0 using the procedures of subclause 1.1.4.

Once the multiplexer control channel is established other DLCs may be established also using the procedures of subclause 1.1.4. The multiplexers may negotiate the parameters associated with each DLC prior to establishment of a DLC or may use the defaults.

1.1.3 Multiplexer close down

Initiation of the close-down will come from higher layers in either the TE or UE. The multiplexer that initiated close-down procedure will usually send a close-down message on the multiplexer control channel. When this message is acknowledged both stations will revert to the non-multiplexed mode. The multiplexer can also closed down by using the procedure of subclause 1.1.5 for the control channel (DLCI 0).

If no response is received to the close-down command within time T2, the initiating station may retransmit it but must close down if no response message is received in time T3.

After closing of the multiplexer protocol, the UE and TE should revert to normal AT mode.

1.1.4 DLC establishment

The establishment of a DLC (Data Link Connection) will be initiated by the TE.

The TE transmits a SABM frame (see 1.4.1) with the P-bit set to 1. The address field contains the DLCI (DLC Identifier) value associated with the desired connection. If the UE is ready to establish the connection it will reply with a UA frame (see 1.4.2) with the F-bit set to 1. If the UE is not ready or unwilling to establish the particular DLC it will reply with a DM frame (see 1.4.3) with the F-bit set to 1.

Once a DLC has been established the stations are both said to be in a connected mode, for the particular DLC, and transfer of information may commence.

If no UA or DM response has been received after T1 the TE retransmit the SABM. This action must be repeated until a response is obtained or N2 expired. If N2 expired the TE acts as on reception of a DM frame.

If no parameter negotiation procedure is used, DLC parameters are the default one.

1.1.5 DLC release

The release of a DLC may be initiated by either station by the transmission of a DISC frame (see 1.4.4) with the P-bit set to one. Confirmation of the DLC release is signalled by the other station sending a UA frame with the F-bit set to 1. Once the DLC has been released the stations enter disconnected mode for that particular DLC.

If the station receiving the DISC command is already in a disconnected mode it will send a DM response.

If no UA or DM response has been received after T1 the initiating station must retransmit the DISC. This action must be repeated until a response is obtained or N2 expired. If N2 expired the initiating station acts as on reception of a DM frame.

1.2 Multiplexer Components

The following figure shows the components of the Multiplexer.

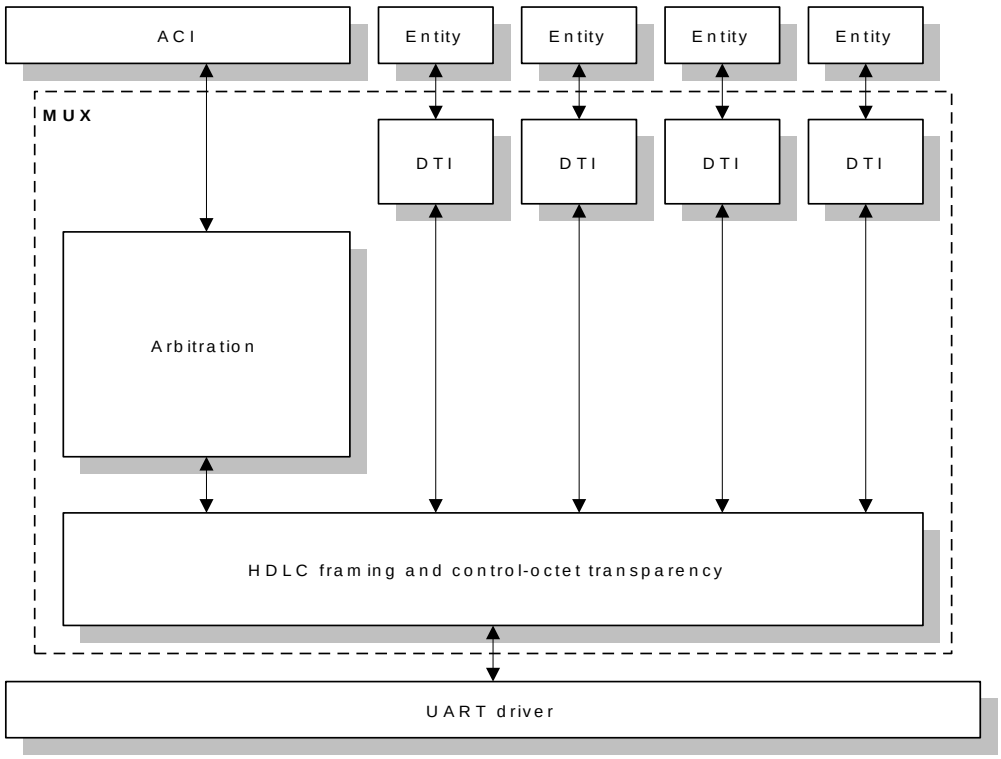


Figure 1-2: Multiplexer Components

1.3 Frame Format

A summary of the HDLC frame structure is shown below. This figure does not include bits inserted for synchronization (such as start and stop bits), nor any octets inserted for transparency. The fields are transmitted from left to right.

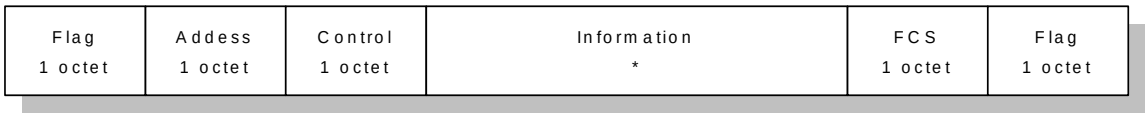


Figure 1-3: Frame Structure for Advanced option

1.3.1 Flag Sequence

Each frame begins and ends with a Flag Sequence, which is the binary sequence 01111110 (hexadecimal 0x7e). The implementations continuously check for this flag, which is used for frame synchronization.

Only one Flag Sequence is required between two frames. Two consecutive Flag Sequences constitute an empty frame, which is silently discarded.

1.3.2 Address Field

The Address field is a single octet, which contains the Data Link Connection Identifier (DLCI), the C/R bit and the address field extension (EA) bit as shown below.

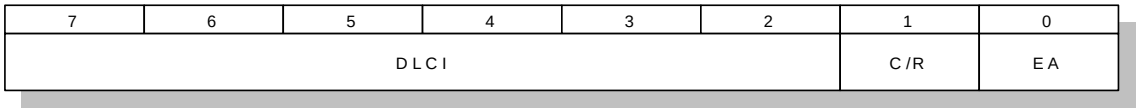


Figure 1-4: Format of Address Field

The DLCI is used to identify an individual user information stream as well as to identify connections between TE and UE. Multiple DLCIs shall be supported but the number is implementation-specific. The DLCIs are dynamically assigned. DLCI value 0 is reserved for the control channel. DLCI value 63 is reserved because of the special meaning in HDLC.

The C/R (command/response) bit identifies the frame as either a command or a response. This bit changes as shown below.

purpose	direction	C/R value
Command	TE ->UE	1
	UE -> TE	0
Response	TE ->UE	0
	UE -> TE	1
Information Transfer	TE ->UE	1
	UE -> TE	0

The EA bit is always set to 1, because the Address field must not be extended.

1.3.3 Control Field

The Control field is a single octet, which contains the Frame Type and and the Poll/Final (P/F) bit as shown below.

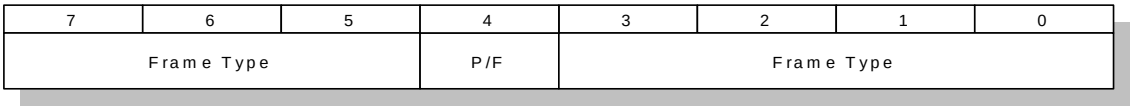


Figure 1-5: Format of Address Field

The Control field has the following values.

Frame Type	P/F = 0	P/F = 1
SABM (Set Asynchronous Balanced Mode)	forbidden	0x3f
UA (Unnumbered Acknowledgement)	forbidden	0x73
DM (Disconnected Mode)	0x0f	0x1f
DISC (Disconnect)	forbidden	0x53
UIH (Unnumbered Information with Header check)	0xef	0xff

The poll (P) bit set to 1 shall be used by a station to solicit (poll) a response or sequence of responses from the other station. The final (F) bit set to 1 shall be used by a station to indicate the response frame transmitted as the result of a soliciting (poll) command.

The poll/final (P/F) bit shall serve a function in both command frames and response frames. (In command frames, the P/F bit is referred to as the P bit. In response frames, it is referred to as the F bit). This bit changes as shown below.

purpose	direction	P/F value
Command	TE ->UE	1
	UE -> TE	1
Response	TE ->UE	1
	UE -> TE	1
Information Transfer	TE ->UE	0
	UE -> TE	0

On a particular DLCI, only one frame with a P bit set to 1 shall be outstanding in a given direction at a given time.

In the case where a SABM or DISC command with the P bit set to 0 is received then the received frame shall be discarded. In the case where a UA response is received with the F bit set to 0 then the received frame shall be discarded. If a unsolicited DM response is received then the frame shall be processed irrespective of the P/F setting.

1.3.4 Frame Check Sequence (FCS) Field

The Frame Check Sequence field is a single octet. The FCS field is calculated over all bits of the Address and Control field, not including any octets inserted for transparency.

The end of the Information field is found by locating the closing Flag Sequence and removing the Frame Check Sequence field.

1.4 Frame types

1.4.1 SABM command

The SABM command shall be used to establish a DLC. The station shall confirm acceptance of the SABM command by transmission of a UA response at the first opportunity.

The Control field value for a SABM frame is 0x3f.

1.4.2 UA response

The UA response shall be used by the station to acknowledge the receipt and acceptance of SABM and DISC commands.

The Control field value for a UA frame is 0x73.

1.4.3 DM response

The DM response shall be used to report a status where the station is logically disconnected from the data link. When in disconnected mode no commands are accepted until the disconnected mode is terminated by the receipt of a SABM command. If a DISC command is received while in disconnected mode a DM response should be sent.

The Control field value for a DM frame is 0x1f, but also frames with the Control field set to 0x0f shall be recognized as DM frames.

1.4.4 DISC command

The DISC command shall be used to terminate an operational or initialization mode previously set by a command. It shall be used to inform one station that the other station is suspending operation and that the station should assume a logically disconnected mode. Prior to actioning the command, the receiving station shall confirm the acceptance of the DISC command by the transmission of a UA response.

DISC command sent at DLCI 0 have the same meaning as the Multiplexer Close Down command.

The Control field value for a DISC frame is 0x53.

1.4.5 UIH frame

The UIH frame shall be used to send information. For the UIH frame, the FCS shall be calculated over only the address and control field.

The Control field value for a UIH comand/response frame is 0xff and the Control field value for a UIH information frame is 0xef.

1.5 Message format

Messages always exist in pairs; a command message and a corresponding response message. A response message has the same Type bits as the command that provoked it.

If a command does not produce a response within a time T2 the command may be sent again up to N2 times. If no response is received on the N2 transmissions, the multiplexer control channel should be considered faulty and an alarm raised. Resolution of the error situation is command dependent.

A summary of the message format is shown below. The fields are transmitted from left to right.

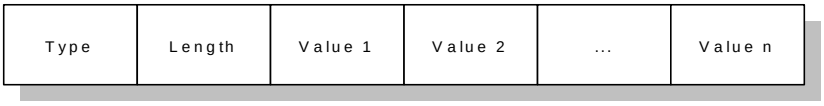


Figure 1-6: Message Format

Each box in the diagram represents a field of minimum size one octet. The type and length octets have extension bits so those fields may contain more than one octet.

Multiple messages may be included in the same frame (as long as the maximum frame size is not exceeded). Messages may not be split over more than one frame.

1.5.1 Type field

The first Type field octet has the following format:

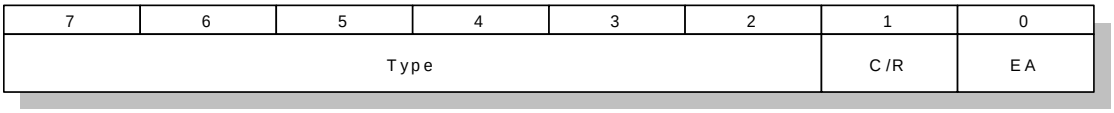


Figure 1-7: First Type Field

Subsequent Type field octets have the following format:

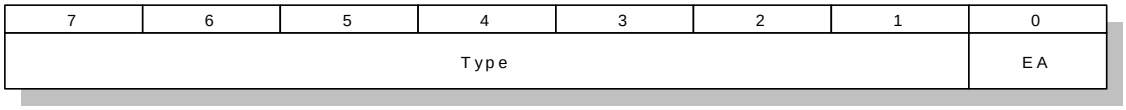


Figure 1-8: Subsequent Type Fields

The EA bit is an extension bit. The EA bit is set to 1 in the last octet of the sequence; in other octets EA is set to 0. If only one octet is transmitted EA is set to 1.

The C/R bit indicates whether the message is a command or a response. Notice that when UIH frames are used to convey information on DLCI 0 there are at least two different fields that contain a C/R bit, and the bits are set of different form. The C/R bit in the Type field shall be set as it is stated above, while the C/R bit in the Address field shall be set as it is described in subclause 1.3.2.

The Type bits indicate the type coding. Each command has a unique pattern of bits. This means that a single-octet type field can encode 63 different message types. Only single octet message types are defined in this specification.

1.5.2 Length field

The Length field octets have the following structure:

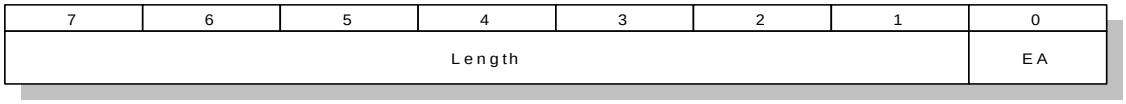


Figure 1-9: Length Fields

The EA bit is an extension bit. The EA bit is set to 1 in the last octet of the sequence; in other octets EA is set to 0. If only one octet is transmitted EA is set to 1.

The Length bits define the number of value octets that follow. Bit 1 of the first octet of the sequence is the LSB and bit 7 of the last octet of the sequence is the MSB of length value. A single-octet length field permits messages with up to 127 value octets to be constructed.

1.5.3 Value fields

The Value fields are zero or more octets, as indicated by the Length field. The contents of the value octets are separately defined for each message type.

1.6 Message types

This implementation supports the following values of the Type field:

Meassage	Command	Response
Multiplexer close down (CLD)	0xc3	0xc1
Flow Control On (FCon)	0xa3	0xa1
Flow Control Off (FCoff)	0x63	0x61
Modem Status Command (MSC)	0xe3	0xe1
Non Supported Command Response (NSC)	forbidden	0x11

1.6.1 Multiplexer close down

The multiplexer close down command is used to reset the link into normal AT command mode without multiplexing.

The Type field contains the value 0xc3 for a command and 0xc1 for a response.

The Length field contains the value 0 and there are no value octets.

1.6.2 Flow Control On

The flow control command is used to handle the aggregate flow. When either entity is able to receive new information it transmits this command.

The Type field contains the value 0xa3 for a command and 0xa1 for a response.

The Length field contains the value 0 and there are no value octets.

1.6.3 Flow Control Off

The flow control command is used to handle the aggregate flow. When either entity is not able to receive information it transmits the FCoff command. The opposite entity is not allowed to transmit frames except on the control channel (DLC=0).

The Type field contains the value 0x63 for a command and 0x61 for a response.

The Length field contains the value 0 and there are no value octets.

1.6.4 Modem Status Command

It is desired to convey virtual V.24 control signals to a data stream, this is done by sending the Modem Status Command (MSC). The MSC has one mandatory control signal byte and an optional break signal byte.

This command shall be sent prior to any user data after a creation of a DLC.

Figure 1-10: Modem Status Command Format

The Type field contains the value 0xe3 for a command and 0xe1 for a response.

The Length field contains the value 2 or 3 and there are 2 or 3 value octets.

Both the TE and UE uses this command to notify each other of the status of their own V.24 control signals. Every time the signals change, the TE or UE sends this command to indicate the current status of each signal. When a TE or UE receives a Modem Command it always sends a Response back. Such Response is a copy of the V.24 signals that are received from the Command frame that shall be returned.

The DLCI field identifies the specific DLC to which the command applies. The EA bit and bit 1 are always set to 1.

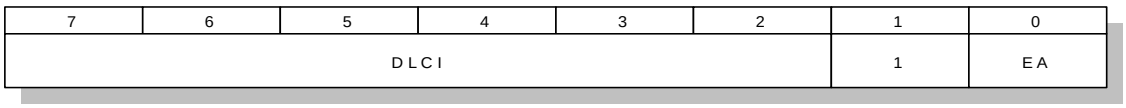


Figure 1-11: DLCI Field

The DLCI field is followed by the control signals field which contains a representation of the state of the signals. The EA bit is always set to 1 and bit 4 and 5 are always set to 0.

7	6	5	4	3	2	1	0
DV	IC	0	0	RTR	RTC	FC	EA

Figure 1-12: V.24 signals Field

Description of the V.24 signal field:

Abbreviation	Description
FC	Flow Control. The bit is set to 1 when the device is unable to accept frames.
RTC	Ready To Communicate. The bit is set to 1 when the device is ready to communicate.
RTR	Ready To Receive. The bit is set to 1 when the device is ready to receive data.
IC	Incoming call indicator. The bit is set to 1 to indicate an incoming call.
DV	Data Valid. The bit is set to 1 to indicate that valid data is being sent.

The mappings of the V.24 signals to the bits in the V.24 signal field for the receiver and sender are given in following tables.

V.24 signal field bit	TE receiving	UE receiving
RTC	DSR (Data Set Ready)	DTR (Data Terminal Ready)
RTR	CTS (Clear To Send)	RTS (Ready To Send)
IC	RI (Ring Indicator)	ignored
DV	DCD (Data Carrier Detect)	ignored

The break signal octet carries information about a break signal detected in the data stream for the DLC. The EA bit is always set to 1 and bit 2 and 3 are always set to 0.

7	6	5	4	3	2	1	0
Break Length				0	0	Break	EA

Figure 1-13: Break signal Field

The meanings of the bits are shown below.

Bits	Description
Break	The bit is set to 1 when the device sends a break signal.
Break Length	Length of break signal in units of 200ms. Bit 4 is LSB and bit 7 is MSB.

1.6.5 Non Supported Command

This response is sent whenever a command type is not supported by the receiving entity.

Type	Length	Non Supported Type

Figure 1-14: Non Supported Command Response Format

The Type field contains the value 0x11 for a response.

The Length field contains the length of the Type field of the command which is not supported.

The value octets contain the Type field of the non supported command. The C/R bit shall be set to the same value as the C/R bit in the Type field of the not supported command frame.

1.7 Priority

Each data stream has a priority associated with it. The priority is a number in the range 0-63 with lower numbers having higher priority. The TE assigns a priority to each DLC and informs the UE of the priority by means of the multiplexer control channel. In the absence of a message assigning priorities DLCs shall be given the priority according to the following DLCI Assignment table.

DLCI number	Priority	Notes
0	0	control channel
1 – 7	7	
8 – 15	15	
26 – 23	23	
24 – 31	31	
32 – 39	39	
40 – 47	47	
48 – 55	55	
56 – 61	61	
62 – 63		Reserved

Handling of DLC with equal priorities should not favour one over the others. The DLC with the highest priority shall not block any of the lower priorities DLC. Interleaving of higher priority and lower priority frames is necessary in order to avoid permanent blocking of lower priority channels.

If a station receives a command with the P bit set to 1, transmission of a response with the F bit set to 1 shall take precedence over transmission of other commands, with the exception of the mode setting commands (SABM or DISC).

2 Protocol

Primitives between UART and Driver are just for test purpose! The final implementation will not use these primitives! The interface between UART-entity and the UART-driver is a function-interface in the final implementation. These primitives are used here to descibe the behavior of the multiplexer.

2.1 Flow Control

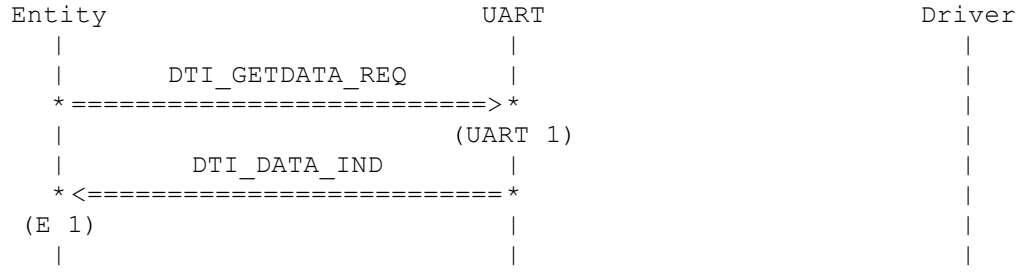
Every data transmission of UART is controlled by flow control, so that it can be ensured that the layers are able to process the data and no buffer overflow occurs.

Before any data primitive is allowed to send, the corresponding layer has to indicate that it is ready to receive data by sending a flow control primitive. After sending a data primitive, the corresponding layer has to indicate again that it is ready to receive data befor send a new data primitive.

UART has a special interface to transmit data to the upper layer. This interface called Data Transmission Interface (DTI). It is only used for data transmission and flow control. Any other UART control primitives are described in the UART SAP.

The flow control primitives are only shown in this chapter. All data primitives in further chapters are shown without there corresponding flow control primitives. It is assumed that the corresponding flow control primitive was sent before sending such data primitive.

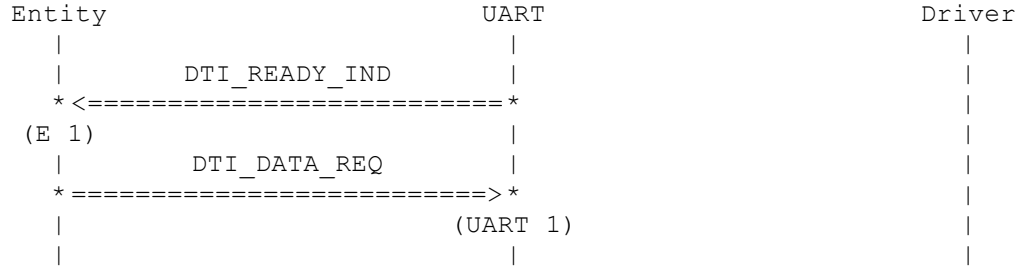
2.1.1 Data transfer to an entity



(UART 1)
Entity indicates to UART that it is ready to receive one Data primitive. (Flow Control primitive)

(E 1)
If there are data to send from UART then the data are delivered to the upper layer. (Data primitive)

2.1.2 Data transfer from an entity

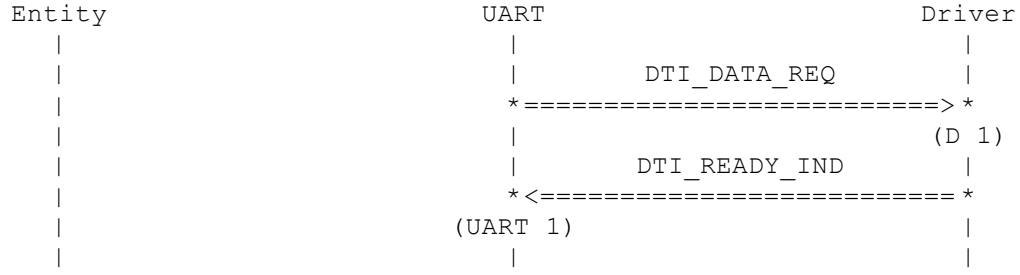


(E 1)
UART indicates to Entity that it is ready to receive one Data primitive. (Flow Control primitive)

(UART 1)
If there are data to send to UART then the data are delivered to the lower layer. (Data primitive)

2.1.3 Data transfer to the TE

The shown primitives are just for test purpose. The final implementation will not use these primitives! The interface between UART-entity and the UART-driver is a function-interface in the final implementation.

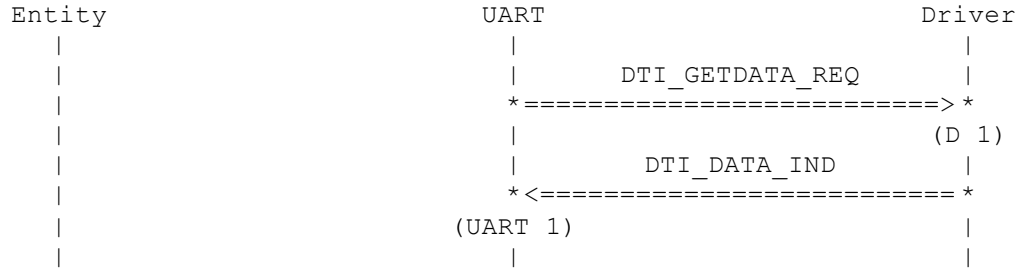


(D 1)
If there are data to send to Driver then the data are delivered to the TE. (Data primitive)

(UART 1)
Driver indicates to UART that it has delivered the data to the TE. (Flow Control primitive)

2.1.4 Data transfer from the TE

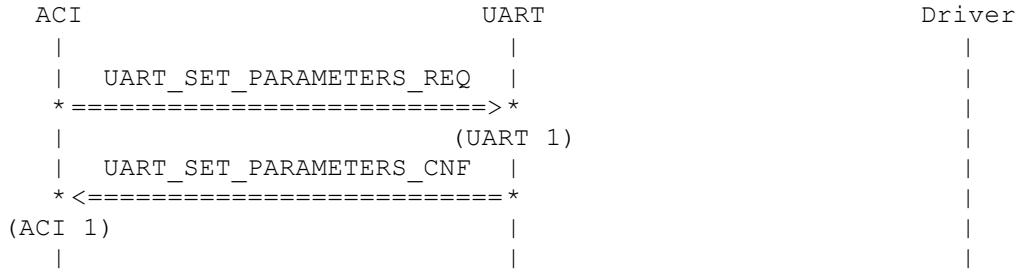
The shown primitives are just for test purpose. The final implementation will not use these primitives! The interface between UART-entity and the UART-driver is a function-interface in the final implementation.



(D 1)
UART indicates to Driver that it is ready to receive one Data primitive. (Flow Control primitive)

(UART 1)
If there are data to send from Driver then the data are delivered to UART. (Data primitive)

2.2 Communication parameters setting



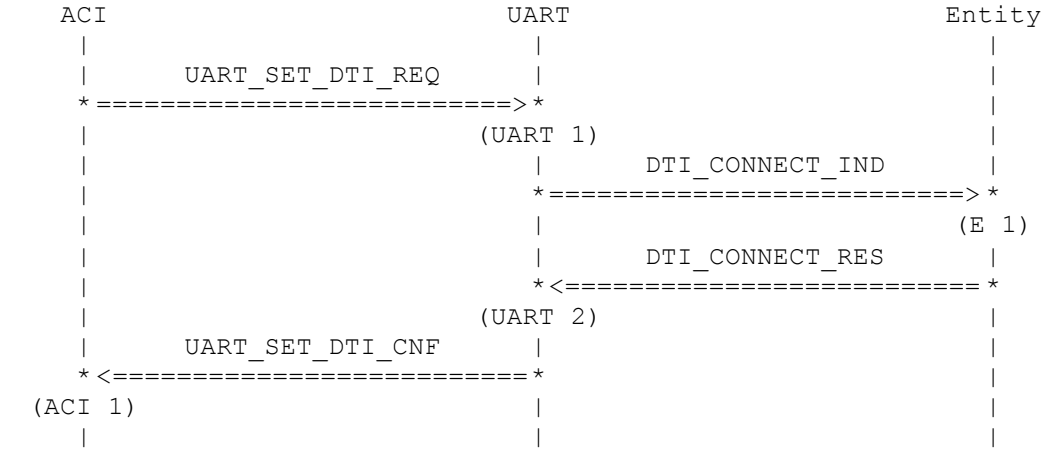
(UART 1)
ACI sends UART the parameters the serial connection (baudrate, bits per character, stop bits, parity bit, flow control, escape sequence settings).

(ACI 1)
UART sends all still to send data over the serial link (flush). After that it sets the new communication parameters.

2.3 DTI connection Establishment

2.3.1 Usual DTI connection Establishment

2.3.1.1 UART initiated



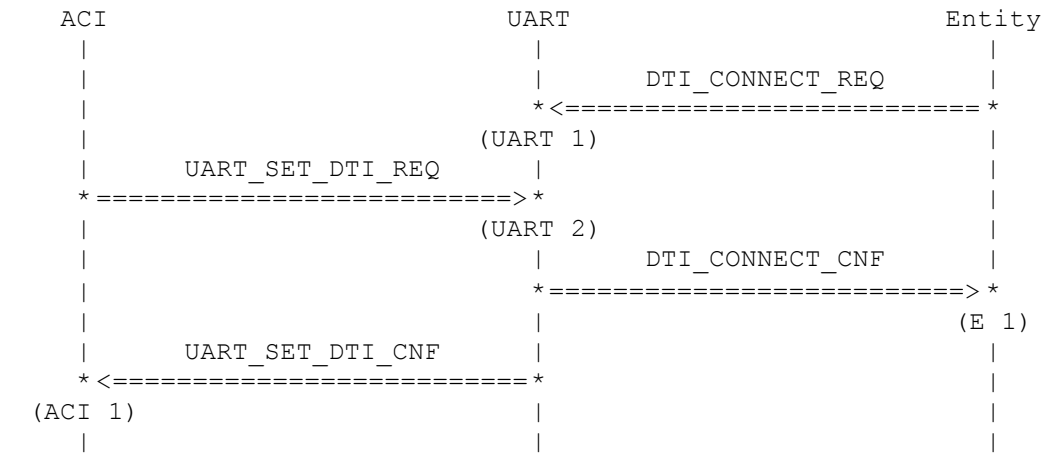
(UART 1)
ACI gives UART the parameters for a certain DTI connection.

(E 1)
UART initializes the DTI link and sends a Connect primitive to the entity.

(UART 2)
The entity has also initialized the DTI link and sends a Connect Confirm primitive.

(ACI 1)
The DTI connection is established and UART sends a Confirm primitive to ACI.

2.3.1.2 Entity initiated



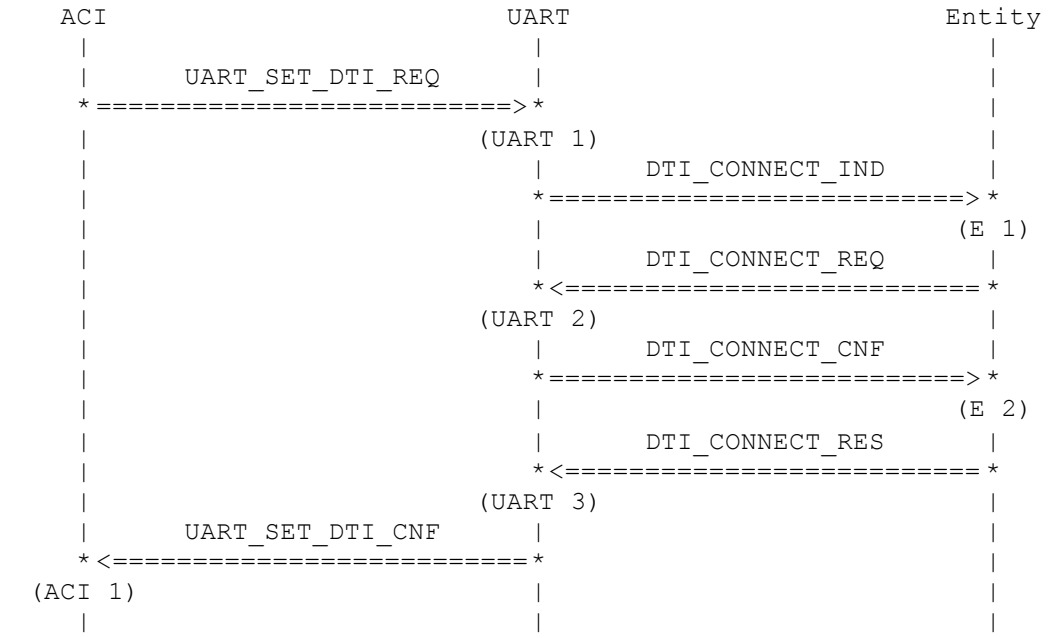
(UART 1)
The entity is earlier initialized than UART. It sends a DTI Connect primitive.

(UART 2)
ACI gives UART the parameters for the DTI connection.

(E 1)
UART initializes the DTI link and sends a Connect Confirm primitive to the entity.

(ACI 1)
The DTI connection is established and UART sends a Confirm primitive to ACI.

2.3.1.3 Collision



(UART 1)
ACI gives UART the parameters for a certain DTI connection.

(E 1)
UART initializes the DTI link and sends a Connect primitive to the entity.

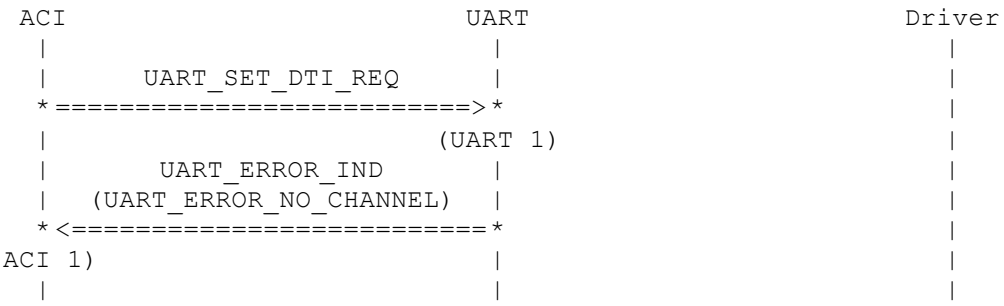
(UART 2)
The entity is initialized at the same time. It also sends a DTI Connect primitive.

(E 2)
UART sends a Connect Confirm primitive to the entity and waits for the Confirm primitive from the entity.

(UART 3)
The entity sends the Connect Confirm primitive.

(ACI 1)
The DTI connection is established and UART sends a Confirm primitive to ACI.

2.3.2 DTI connection Establishment fails

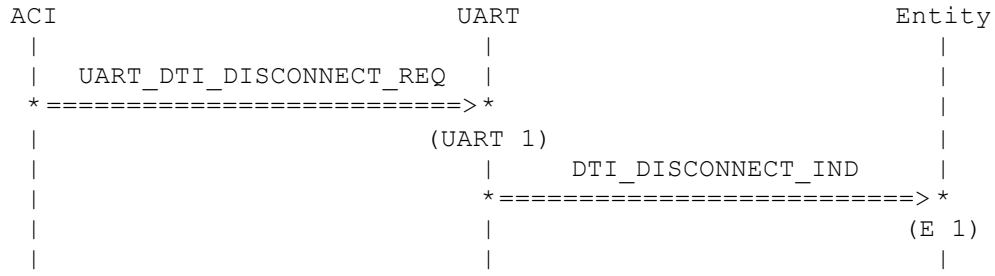


(UART 1)
ACI gives UART the parameters for a certain DTI connection.

(ACI 1)
If UART is unable to open a VSI channel for this DTI connection it sends an Error primitive.

2.4 DTI disconnection

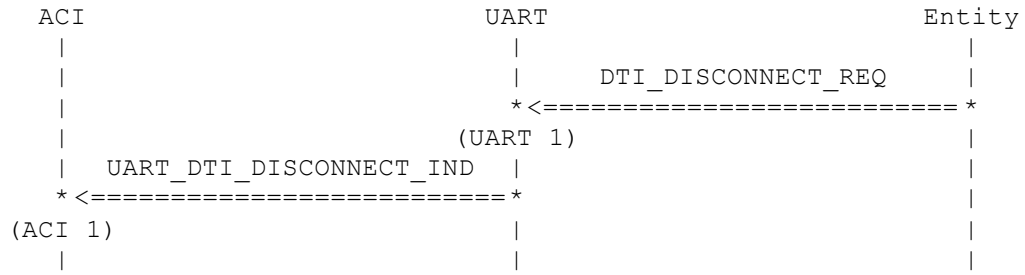
2.4.1 ACI initiated disconnection



(UART 1)
ACI requests a disconnection of certain DTI link.

(E 1)
UART sends a Disconnect primitive to the entity and closes the DTI connection. This operation does not release the muliplexer channel (DLC).

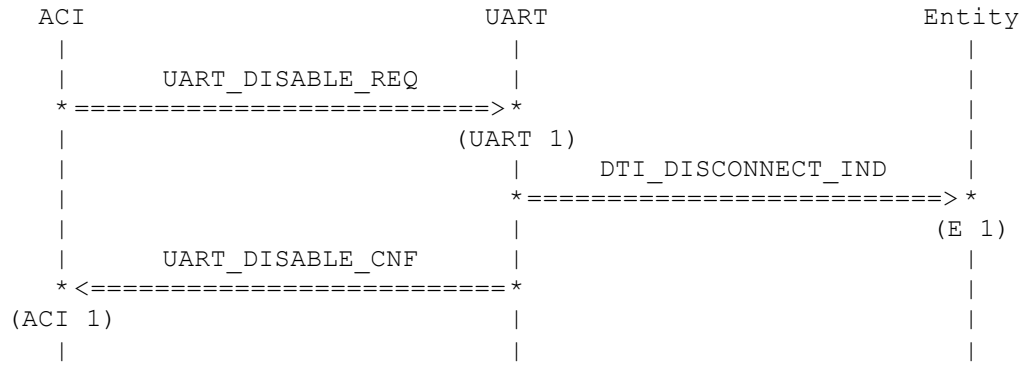
2.4.2 Entity initiated disconnection



(UART 3)
The entity sends the Disconnect primitive to close the DTI link.

(ACI 1)
UART closes the DTI connection and informs ACI. This operation does not release the muliplexer channel (DLC).

2.5 Disable UART



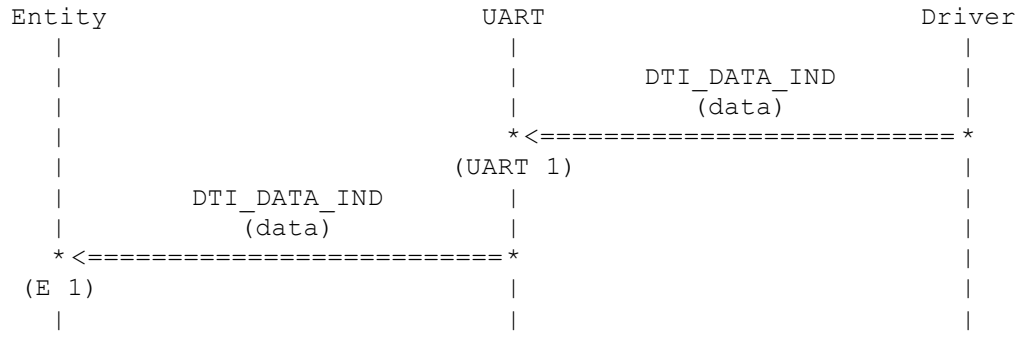
(UART 1)
To turn off all UART operations ACI sends a Disable primitive to UART. If UART is in multiplexer mode it turns off the multiplexer.

(E 1)
UART closes all DTI links by sending a Disconnect primitive to each DTI peer entity. But before it sends all still not sent data over the serial connection (flush).

(ACI 1)
After all data is flushed, each DTI link is closed and the UART-driver is disableed the UART entity sends a Confirm primitive to ACI.

2.6 Data Transfer in Non-Multiplexed mode

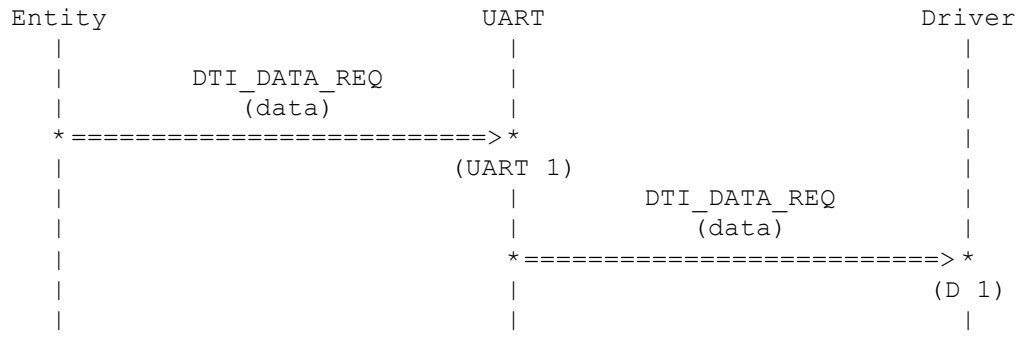
2.6.1 Send data to an entity



(UART 1)
TE sends data (unstrutured octet stream) to UART.

(E 1)
UART sends the data to the DTI connected entity.

2.6.2 Send data from an entity



(UART 1)
Entity sends data to UART.

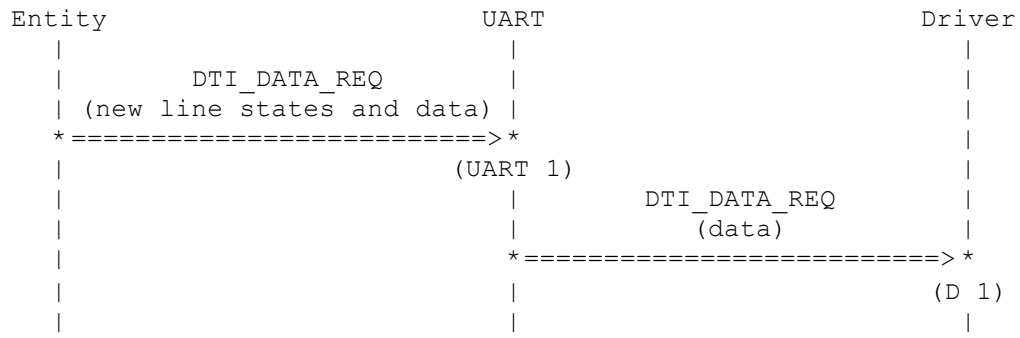
(E 1)
UART sends the data to the TE.

2.7 Line states transmission

2.7.1 Usual line states transmission

DTI Data primitives also include line state values. These line state values are used to set outgoing lines and to inform the DTI peer entity about a change of incomming lines. Outgoing lines are Data Set Ready (DRS), Data Carrier Detect (DCD) and Clear To Send (CTS). Incomming lines are Data Terminal Ready (DTR) and Ready To Send (RTS). One value is used to forward incomming and outgoing Break signals.

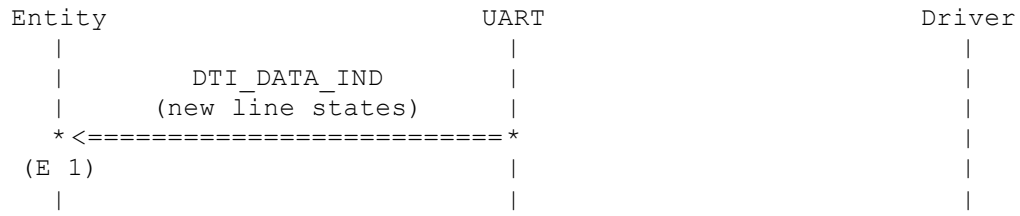
2.7.1.1 Set outgoing lines



(UART 1)
UART receives a Data primitive with new line states and data to send. After flushing of the driver buffer it sets the new line states.

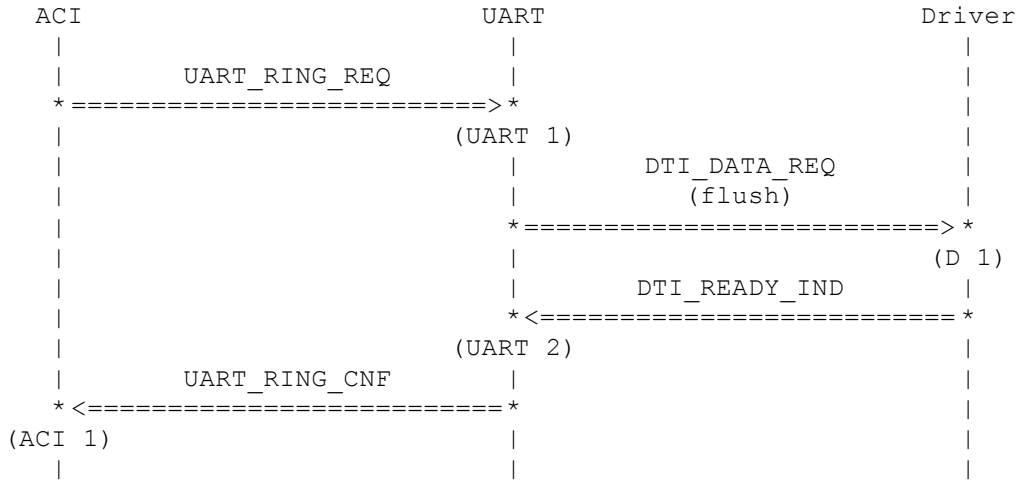
(D 1)
Now UART sends the received data.

2.7.1.2 Forward incomming lines



(E 1)
If the UART-entity receives new line states from the UART-driver it forwards these new line states to the entity.

2.7.2 Set or Reset Ring indicator



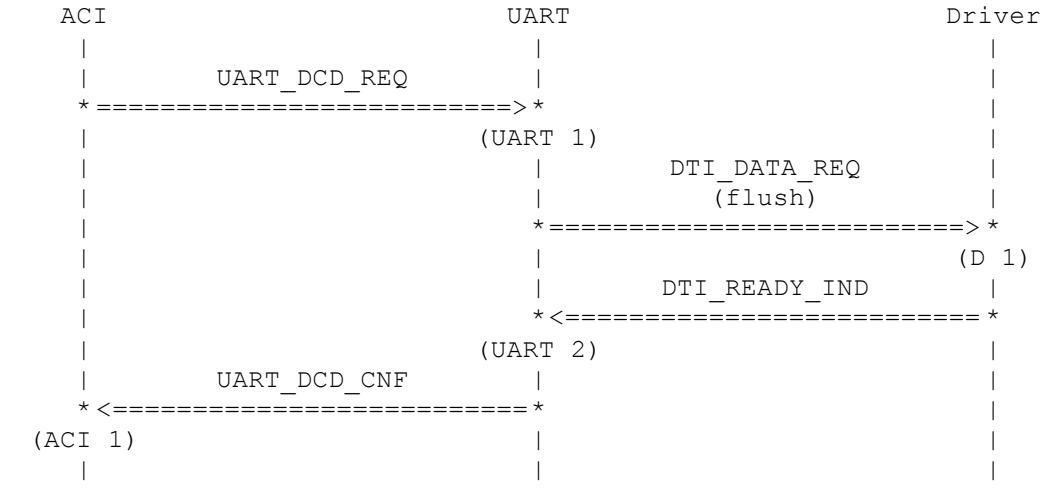
(UART 1)
ACI wants to set/reset the Ring indicator.

(D 1)
UART sends all still to sent data (flush) of the appropriate connection.

(UART 2)
The UART-driver informs the UART entity that it has flushed the data.

(ACI 1)
Now the UART-entity sets/resets the Ring indicator and sends a Confirm primitive to ACI.

2.7.3 ACI initiated Set or Reset of Data Carrier Detect (DCD)



(UART 1)
ACI wants to set/reset the DCD line.

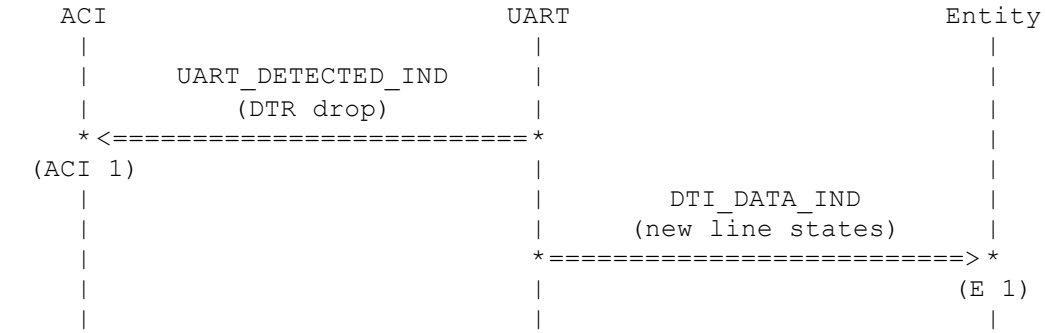
(D 1)
UART sends all still to sent data (flush) of the appropriate connection.

(UART 2)
The UART-driver informs the UART entity that it has flushed the data.

(ACI 1)
Now the UART-entity sets/resets the DCD line and sends a Confirm primitive to ACI.

2.7.4 Receive drop of Data Terminal Ready (DTR)

There is a different behavior is case of DTR drop, because ACI has also to be informed about this event.



(ACI 1)
If a drop of the DTR line is detected UART informs ACI about this event.

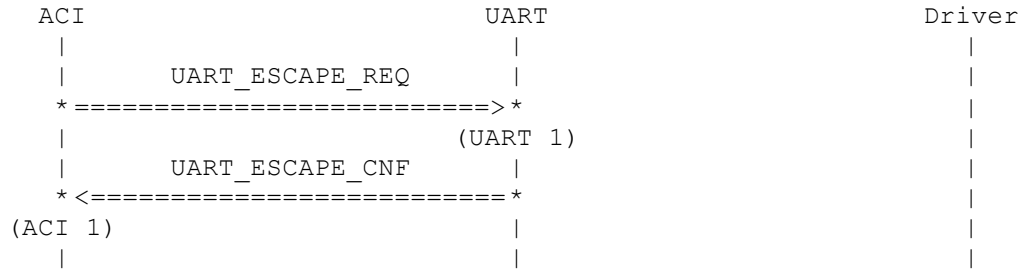
(E 1)
UART also informs the entity about the change of the DTR line.

2.8 Escape Sequence detection (+++)

An Escape Sequence can be sent by the TE to interrupt or terminate the data stream and get back to AT command mode. An Escape Sequence starts with a Guard Period of time where no data is sent (usually 1 second). After that the TE has to send three Escape Characters (usually '+') within a new Guard Period. In the next Guard Period data must not sent to get an Escape Sequence. Escape Sequence detection is done by the UART-driver in non-multiplexed mode and it is done by the UART-entity in multiplexed mode.

Configuration of Escape Sequence values (Guard Period, Escape Character) is done by ACI parameters setting (2.2).

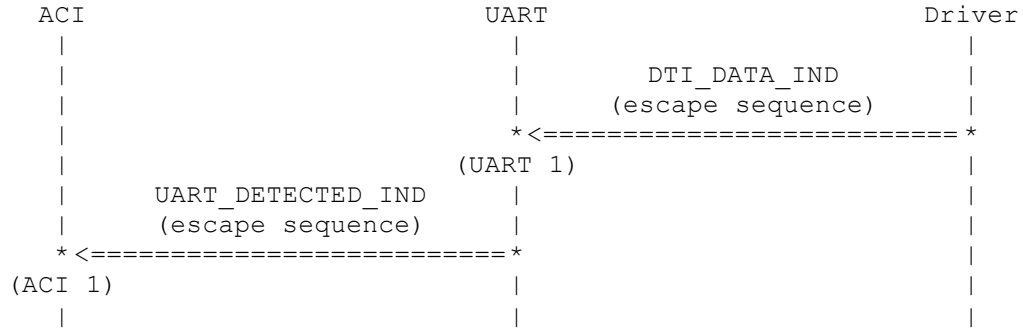
2.8.1 Turn Escpae Sequece detection on or off



(UART 1)
ACI uses this primitive to enable or disable Escape Sequence detection for a certain channel. By default Escape Sequence detection is enabled.

(ACI 1)
UART-entity sends a Confirm primitive to ACI.

2.8.2 Reception of Escape Sequence

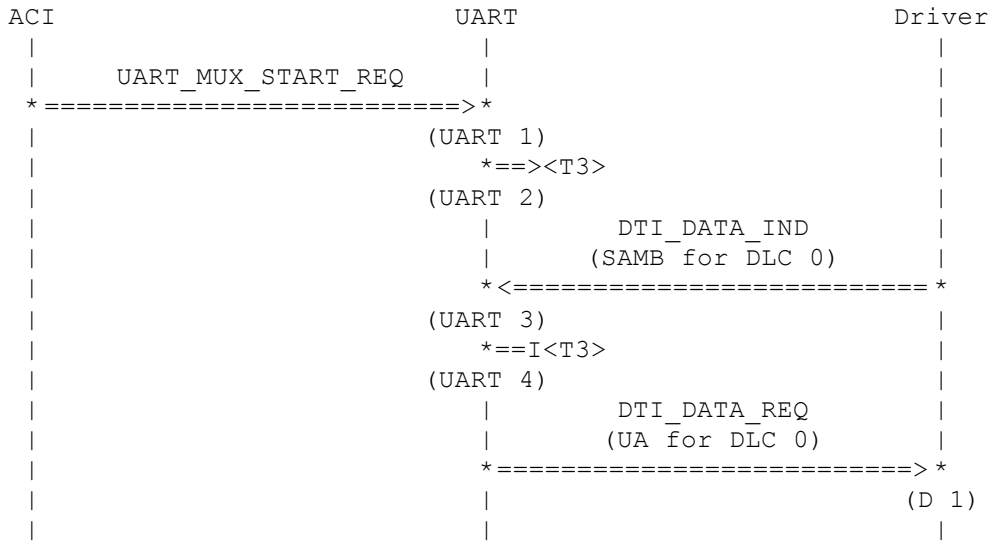


(UART 1)
UART receives an Escape Sequence that is detected either by the UART-driver or by the UART-entity.

(ACI 1)
UART informs ACI about the detected Escape sequence.

2.9 Link Establishment

2.9.1 Usual Link Establishment



(UART 1)
ACI starts multiplexer operation by sending the Start primitive. The Start primitive includes some initial settings for multiplexer operation.

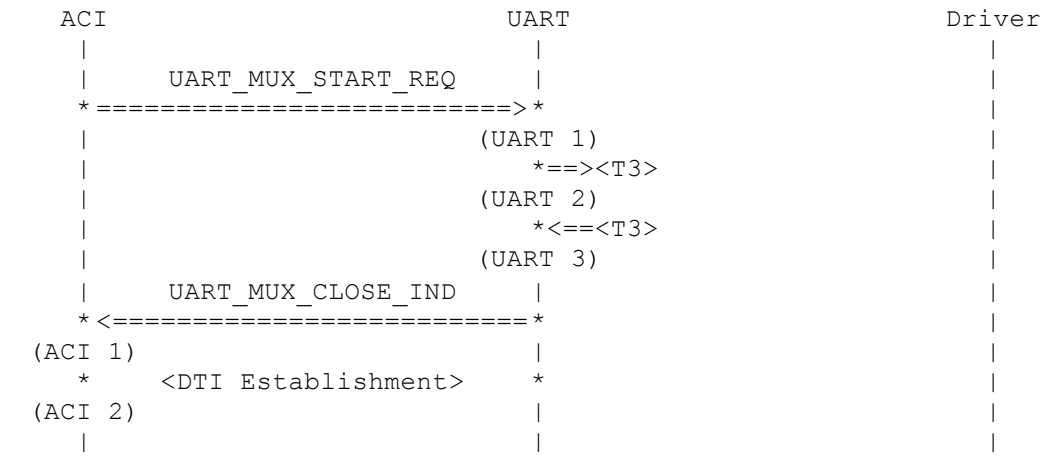
(UART 2)
UART starts T3 to time waiting for the SABM frame.

(UART 3)
TE sends a SABM frame for the Control Channel (DLC 0).

(UART 4)
Because of the reception of the SABM frame UART stops T3.

(D 1)
UART answers with an UA frame for the Control Channel (DLC 0).

2.9.2 Link Establishment fails



(UART 1)
ACI starts multiplexer operation by sending the Start primitive. The Start primitive includes some initial settings for multiplexer operation.

(UART 2)
UART starts T3 to time waiting for the SABM frame.

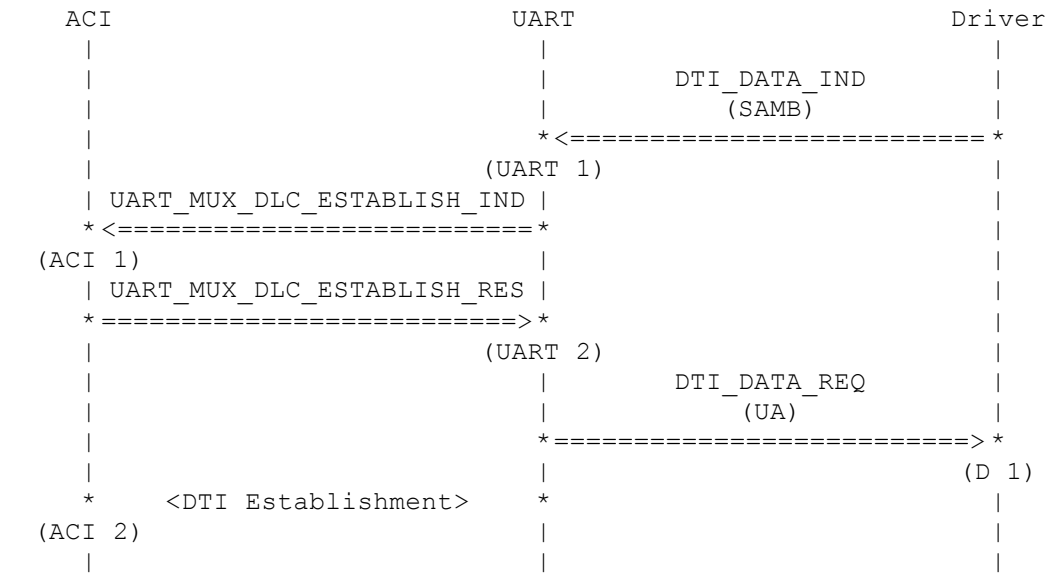
(UART 3)
Timer T3 expired. UART does not wait for SABM frame any longer.

(ACI 1)
Because multiplexer operation establishment has failt UART informs ACI about the multiplexer Close-down.

(ACI 2)
ACI initiates establishment of a DTI connection associated with the AT mode (see 2.2).

2.10 DLC Establishment

2.10.1 Usual DLC Establishment



(UART 1)
TE sends a SABM frame for any channel except Control Channel.

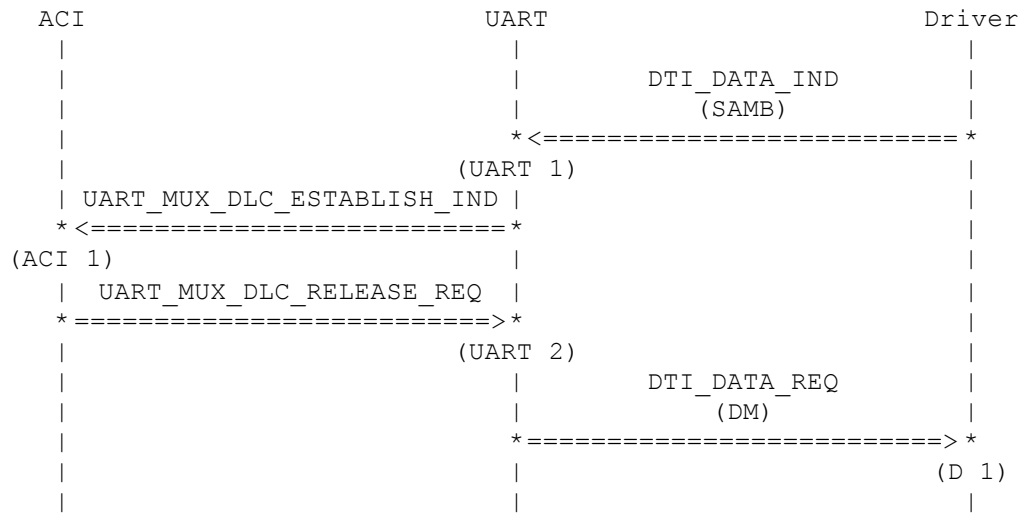
(ACI 1)
UART informs ACI about the reception and additional parameter settings given in the SABM frame.

(UART 2)
ACI answers with a possitive response if it decides to create this channel.

(D 1)
UART sends an appropriate UA frame to the TE to confirm the channel establishment.

(ACI 2)
ACI initiates establishment of a DTI connection associated with this DLC (see 2.2).

2.10.2 Rejected DLC Establishment



(UART 1)
TE sends a SABM frame for any channel except Control Channel.

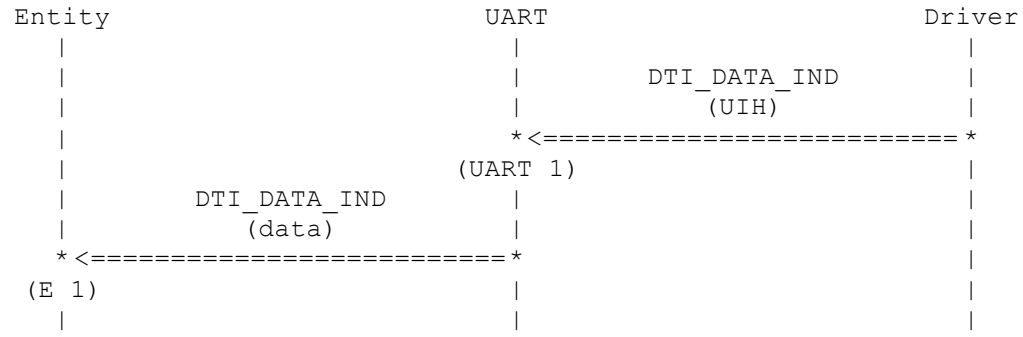
(ACI 1)
UART informs ACI about the reception and additional parameter settings given in the SABM frame.

(UART 2)
ACI answers with a negative response if it decides not to create this channel.

(D 1)
UART sends an appropriate DM frame to the TE to reject the channel establishment.

2.11 Data Transfer in Multiplexed mode

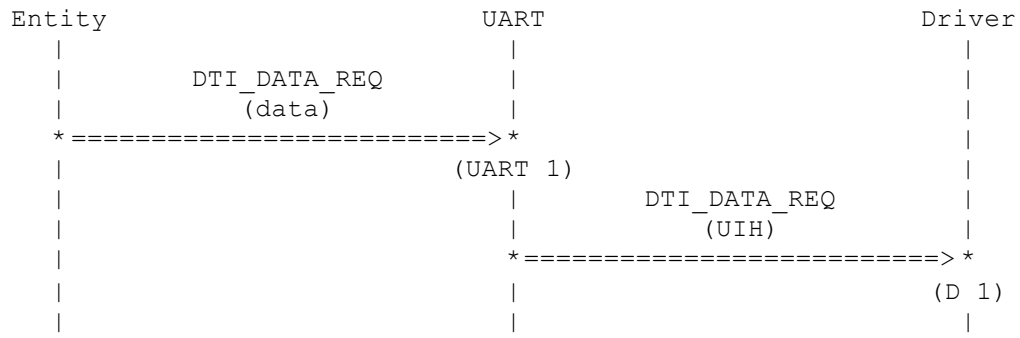
2.11.1 Send data to an entity



(UART 1)
TE sends an UIH frame with data for a certain channel.

(E 1)
UART sends the data to the entity specified by the channel number.

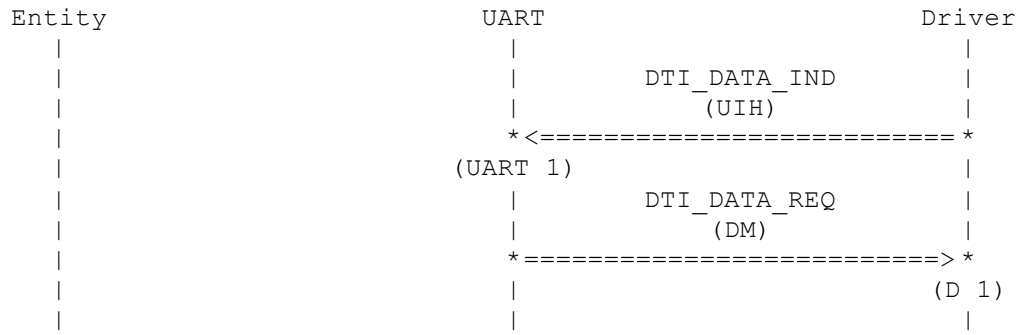
2.11.2 Send data from an entity



(UART 1)
Entity sends data to UART.

(E 1)
UART sends the data to the TE uses the appropriate channel number for this entity.

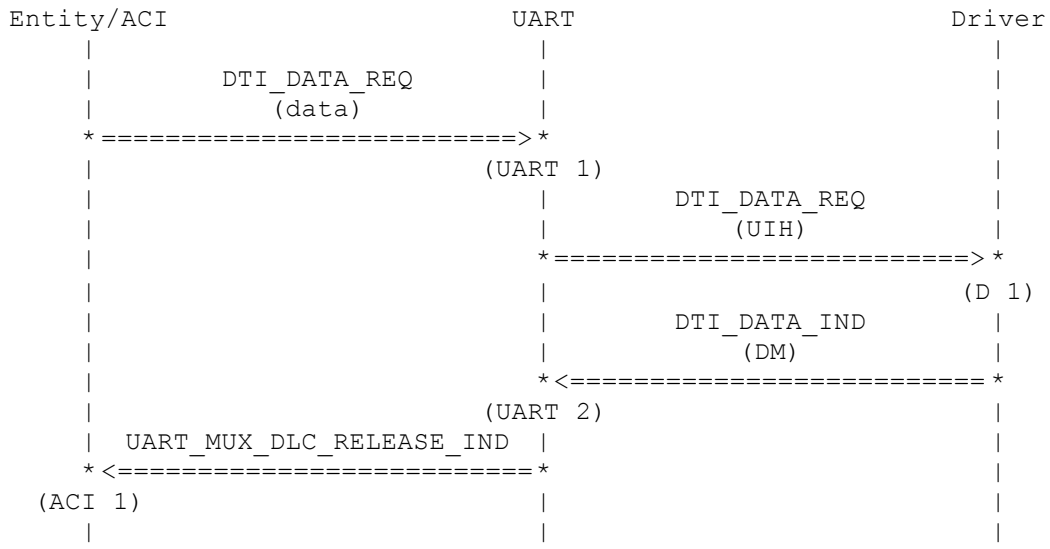
2.11.3 Data for an already released channel



(UART 1)
TE sends an UIH frame with data for a certain channel.

(D 1)
Because the specified channel is in Disconneced mode UART responds with a DM frame.

2.11.4 Get Disconnected Mode response



(UART 1)
Entity sends data to UART.

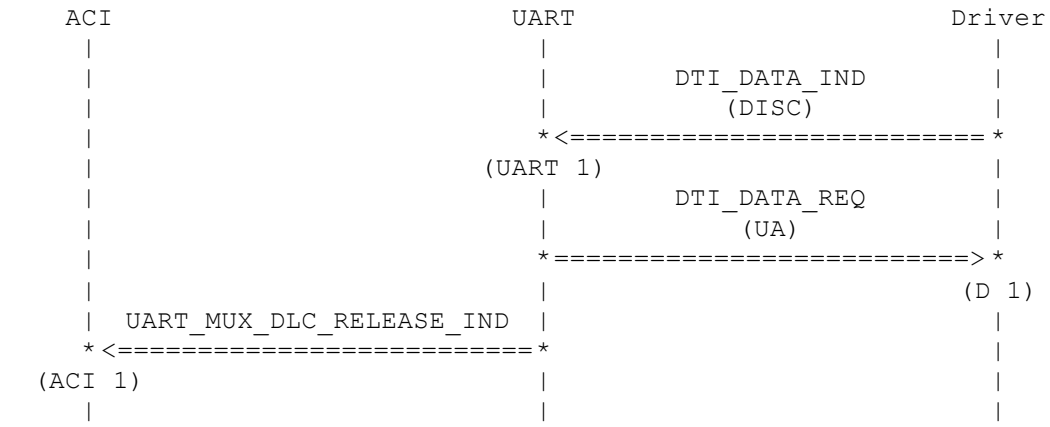
(D 1)
UART sends the data to the TE uses the appropriate channel number for this entity.

(UART 2)
TE has already released the specified channel so it responses with a DM frame.

(ACI 1)
UART informs ACI about the reception. This also includes the fact that the DTI connection for this channel is getting off and the channel enters Disconnected mode.

2.12 DLC Release

2.12.1 TE initiated DLC Release

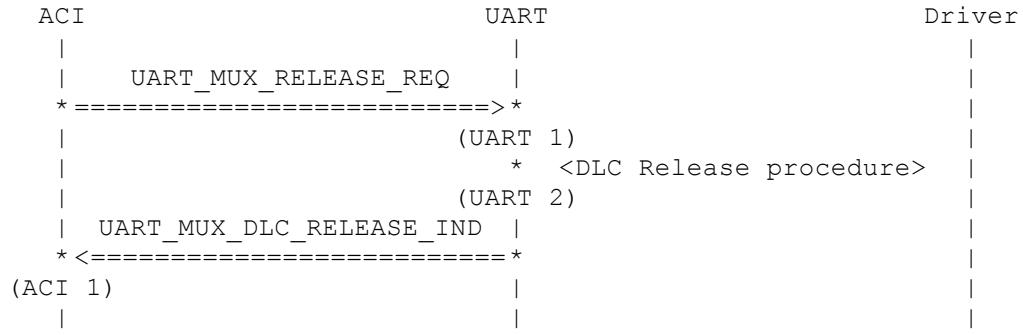


(UART 1)
TE sends a DISC frame for any established channel except Control channel.

(D 1)
UART sends an appropriate UA frame to the TE to confirm the channel release.

(ACI 1)
UART informs ACI about the release. This includes the fact that the DTI connection for this channel got off.

2.12.2 ACI initiated DLC Release

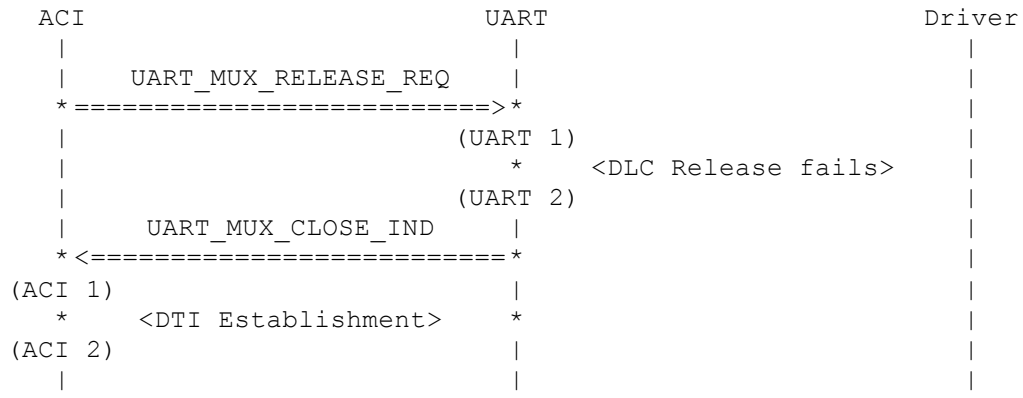


(UART 1)
ACI indicates by sending the Release primitive that it wants to release one particuare channel except Control channel.

(UART 2)
UART uses the DLC Release procedure to release the specified channel (see 2.12.4).

(ACI 1)
UART informs ACI about successful release. This includes the fact that the DTI connection for this channel got off.

2.12.3 ACI initiated DLC Release fails



(UART 1)
ACI indicates by sending the Release primitive that it wants to release one particuare channel except Control channel.

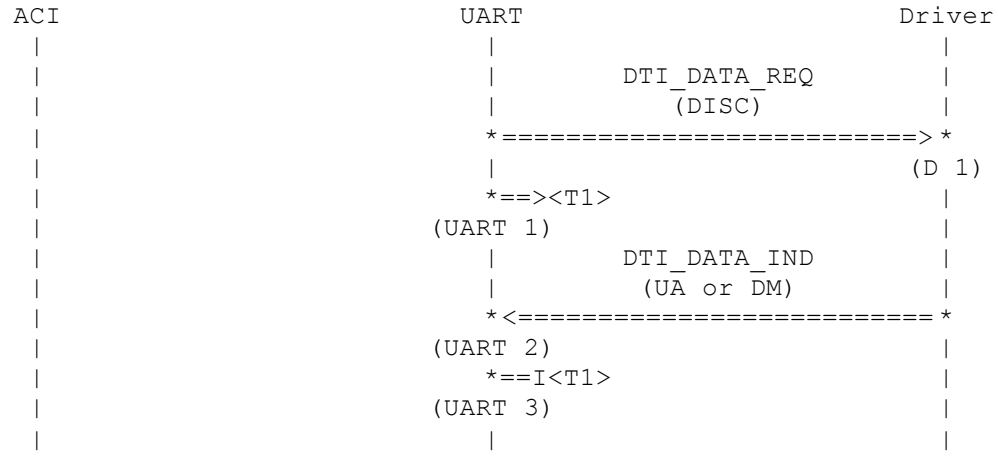
(UART 2)
UART uses the DLC Release procedure to release the specified channel, but the TE does not answer (see 2.12.4.3).

(ACI 1)
Because the peer multiplexer has not response UART informs ACI about the multiplexer Close-down. This includes the fact that all DTI connections got off.

(ACI 2)
ACI initiates establishment of a DTI connection associated with the AT mode (see 2.2).

2.12.4 DLC Release procedure

2.12.4.1 Usual DLC Release



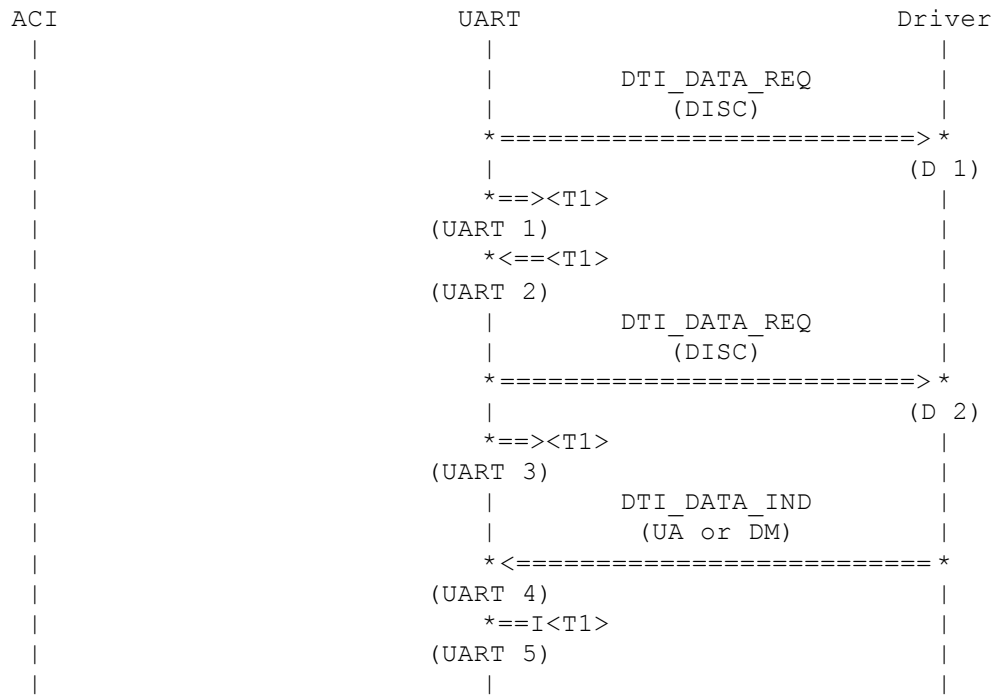
(D 1)
UART sends a DISC frame for a certain channel.

(UART 1)
UART starts T1 to time waiting for a response frame.

(UART 2)
TE answers either with an UA frame or with a DM frame for the appropriate channel.

(UART 3)
Because of the reception of a response frame UART stops T1.

2.12.4.2 Retransmission in DLC Release



(D 1)
UART sends a DISC frame for a certain channel.

(UART 1)
UART starts T1 to time waiting for a response frame.

(UART 2)
Timer T1 expired.

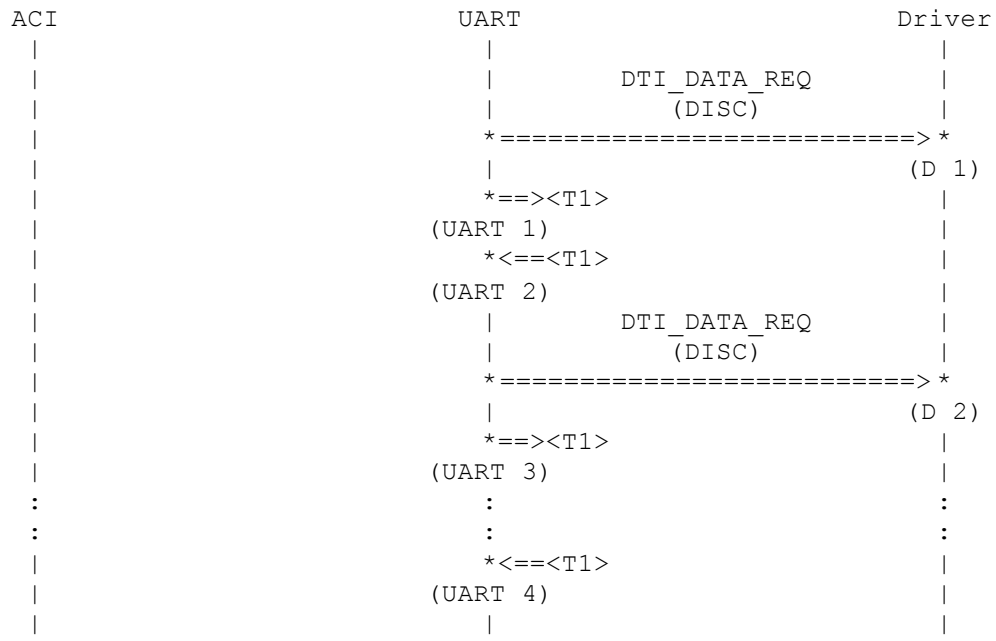
(D 2)
Because the counter for retransmissions is not zero yet UART transmitts DISC frame again and decreases the retransmission counter by one.

(UART 3)
UART starts T1 again to time waiting for a response frame.

(UART 4)
TE answers either with an UA frame or with a DM frame for the appropriate channel.

(UART 5)
Because of the reception of a response frame UART stops T1.

2.12.4.3 DLC Release fails



(D 1)
UART sends a DISC frame for a certain channel.

(UART 1)
UART starts T1 to time waiting for a response frame.

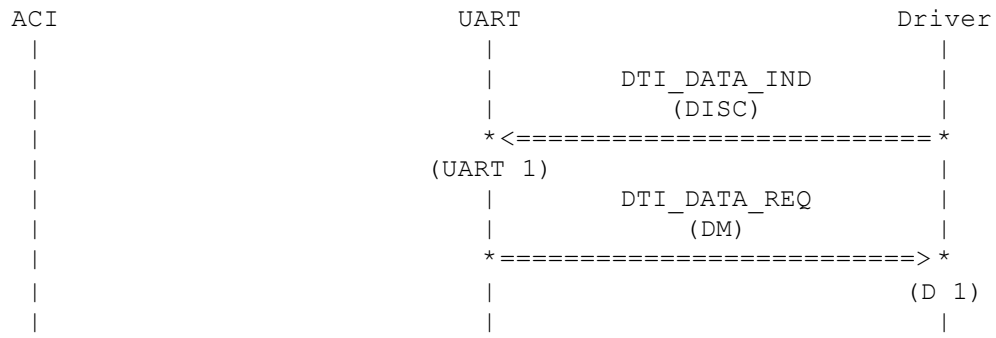
(UART 2)
Timer T1 expired.

(D 2)
Because the counter for retransmissions is not zero yet UART transmitts DISC frame again and decreases the retransmission counter by one.

(UART 3)
UART starts T1 again to time waiting for a response frame.

(UART 4)
This sequence will be repeated until an appropriate response is received or Timer T1 expired and the counter for retransmissions is zero. In the second case the multiplexer is closed because of the assumption that the multiplexer peer is not working any more. That also means all DTI connectons are closed.

2.12.5 Already released DLC

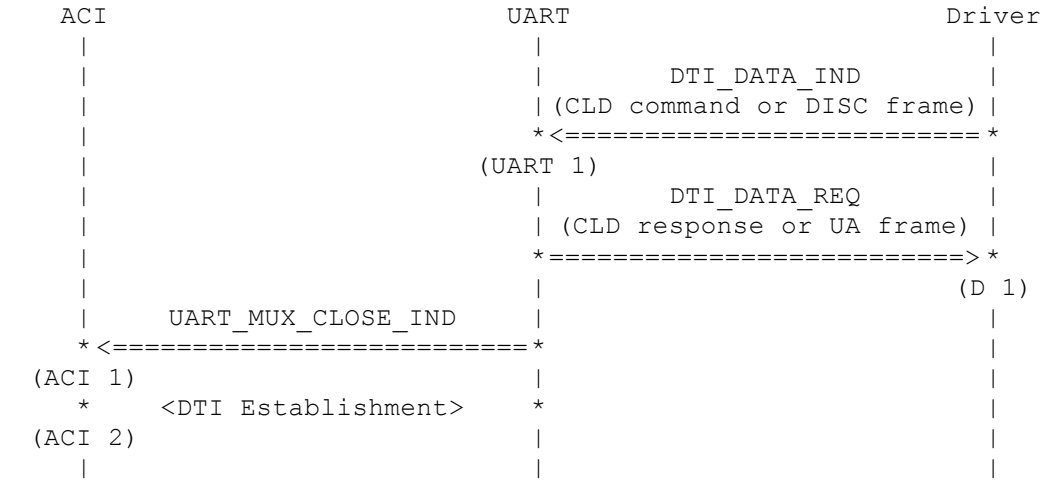


(UART 1)
TE sends a DISC frame for any established channel except Control Channel.

(D 1)
Because the specified DLC is already released UART sends an appropriate DM frame to the TE.

2.13 Link Close-down

2.13.1 TE initiated Close-down



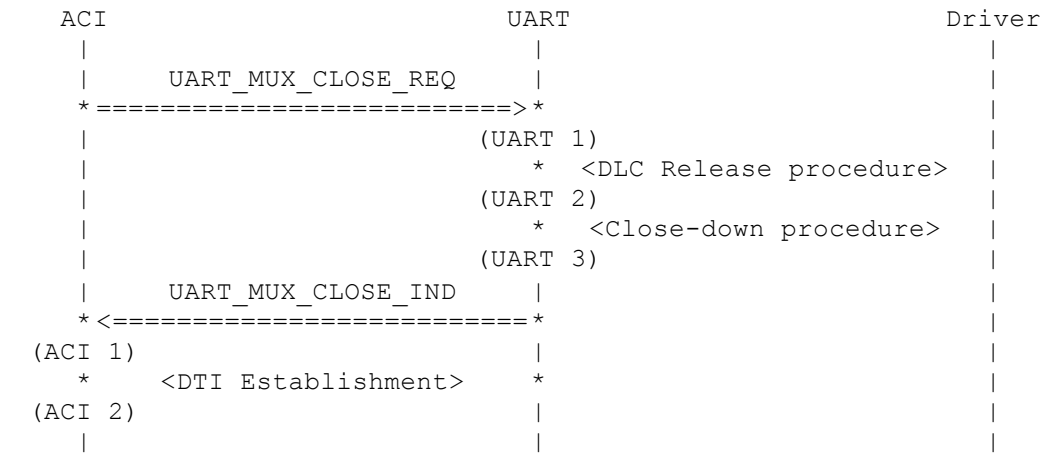
(UART 1)
TE sends the multiplexer close-down command (CLD) to UART. This means that the multiplexer operation must be terminated. An alternative to this command is a DISC frame for Control channel.

(D 1)
If TE have sent the multiplexer close-down command UART sends an appropriate CLD response to the TE to confirm the multiplexer close-down. If TE have sent a DISC frame UART sends an appropriate UA frame to the TE.

(ACI 1)
UART informs ACI about the multiplexer Close-down. This also includes the fact that all DTI connections got off.

(ACI 2)
ACI initiates establishment of a DTI connection associated with the AT mode (see 2.2).

2.13.2 ACI initiated Close-down



(UART 1)
ACI sends the Close primitive to UART.

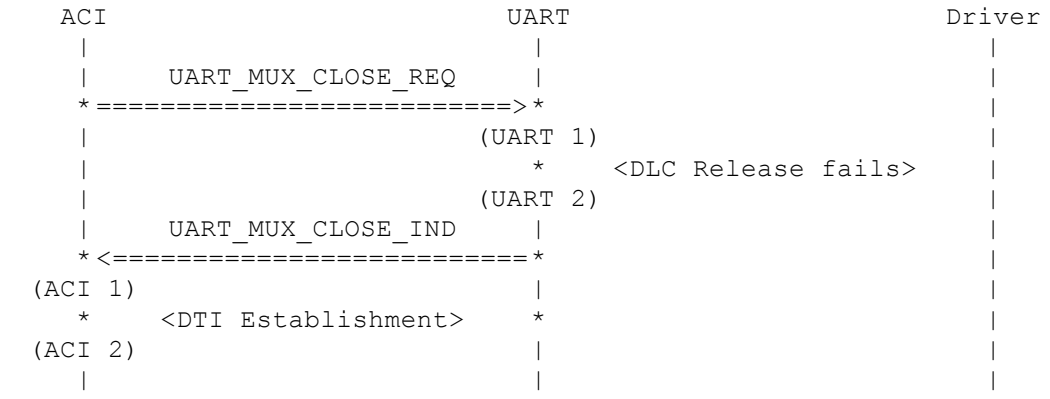
(UART 2)
UART releases all DLCs by use the Release procedure described in 2.12.4.

(UART 3)
After releasing all DLCs UART uses the Close-down procedure to terminate the multiplexer link (see 2.13.4).

(ACI 1)
UART informs ACI that all DTI connections got off and UART returns to normal AT command mode.

(ACI 2)
ACI initiates establishment of a DTI connection associated with the AT mode (see 2.2).

2.13.3 ACI initiated Close-down and DLC Release fails



(UART 1)
ACI sends the Close primitive to UART.

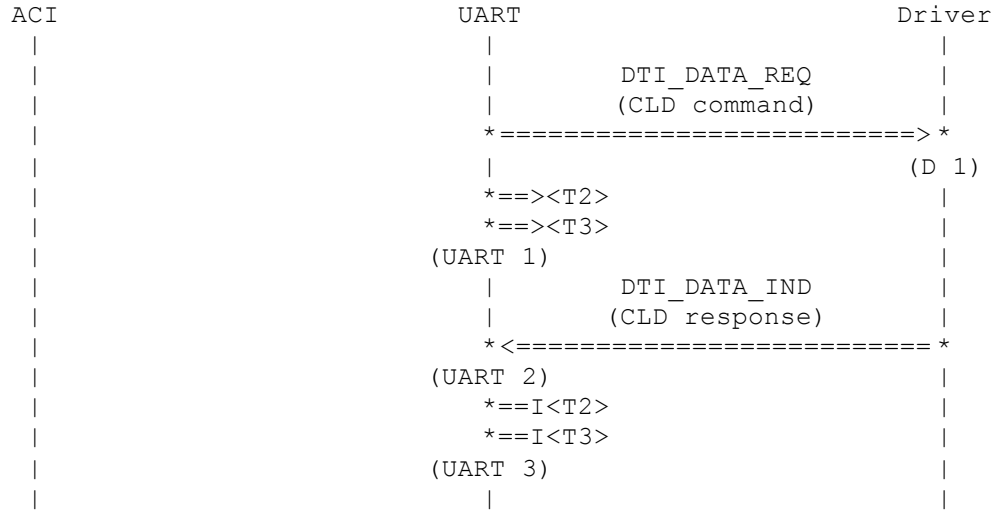
(UART 2)
UART releases all DLCs by use the Release procedure described in 2.12.4.3, but the TE does not answer.

(ACI 1)
Because DLC Release fails UART assums that the multiplexer peer is not woking any more and closes all DTI connections. UART informs ACI that all DTI connections got off and returns to normal AT command mode.

(ACI 2)
ACI initiates establishment of a DTI connection associated with the AT mode (see 2.2).

2.13.4 Close-down procedure

2.13.4.1 Usual Close-down



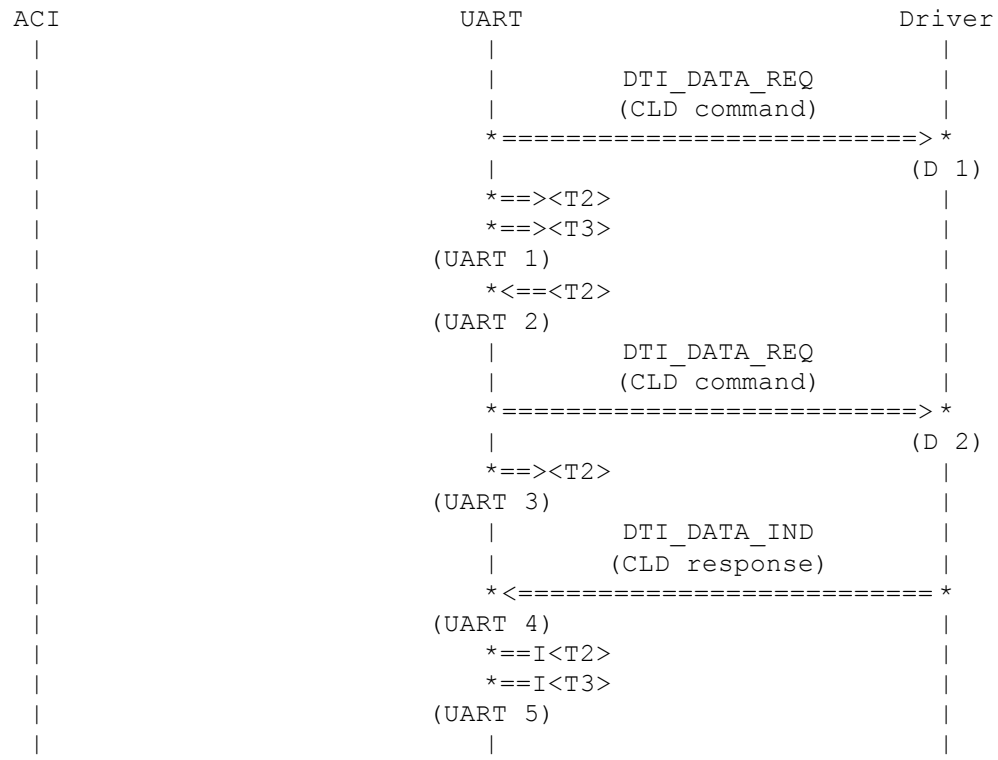
(D 1)
UART sends a multiplexer Close-down (CLD) command to the TE.

(UART 1)
UART starts T2 and T3 to time the response for the CLD command.

(UART 2)
TE sends the CLD response to UART and close-down the multiplexer.

(UART 3)
UART stops T2 and T3 because of the reception of the response and goes back to normal AT command mode.

2.13.4.2 Retransmission in Close-down



(D 1)
UART sends a multiplexer Close-down (CLD) command to the TE.

(UART 1)
UART starts T2 and T3 to time the response for the CLD command.

(UART 2)
Timer T2 expired.

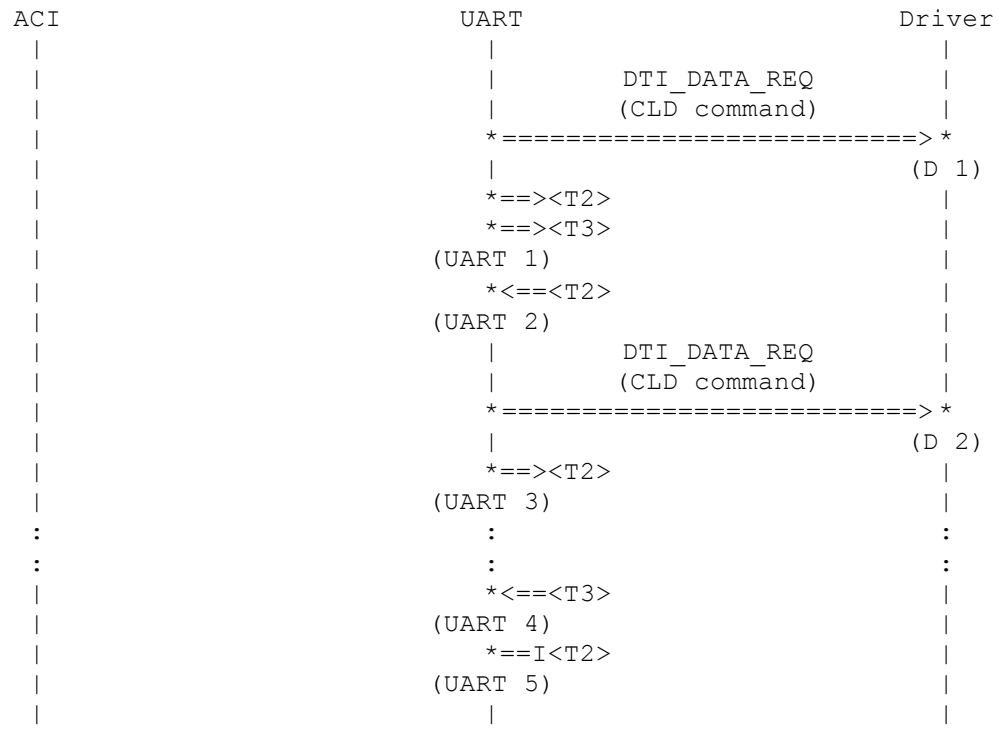
(D 2)
Because T3 is not expired yet UART transmitts CLD command again.

(UART 3)
UART starts T2 again to time waiting for a response frame.

(UART 4)
TE sends the CLD response to UART and close-down the multiplexer.

(UART 5)
UART stops T2 and T3 because of the reception of the response and goes back to normal AT command mode.

2.13.4.3 Close-down without response



(D 1)
UART sends a multiplexer Close-down (CLD) command to the TE.

(UART 1)
UART starts T2 and T3 to time the response for the CLD command.

(UART 2)
Timer T2 expired.

(D 2)
Because T3 is not expired yet UART transmitts CLD command again.

(UART 3)
UART starts T2 again to time waiting for a response frame.

(UART 4)
This sequence will be repeated until an appropriate response is received or the Timer T3 expired. In the second case the multiplexer will be closed-down without the reception of an appropriate response.

(UART 5)
UART stops T2 because it is not needed any longer and goes back to normal AT command mode.