BG96

MUX Application Note

LPWA Module Series

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Revision History

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-	2020-07-28	Harding HU	Creation of the document
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1 Introduction

The document defines Quectel MUX (multiplexer) protocol between UE and TE and provides examples of how to use the MUX function on Quectel BG96 module.

2 Overview of Quectel Multiplexing System

The multiplexer provides mechanisms for conveying streams of data between TE and UE over a single physical port. Quectel multiplexing system creates 4 virtual channels on one physical port to transmit multiple streams of data simultaneously. It enables the physical port to act like four real physical channels for the application. Every virtual channel supports SMS, PPP dialing, etc.

All data from the application is packed into different frames, and the frames consist of the data and protocol fields which clearly indicate the channel number, length of the information, FCS, and so on. The frames are transmitted as one stream via the serial port. After arriving at the other peer, the data is unpacked as four streams by the multiplexer protocol stack and transmitted to the application. In addition to the information field, the control signals are also simulated.

Each channel between TE and UE is called a DLC (Data Link Connection) and is established separately and sequentially.

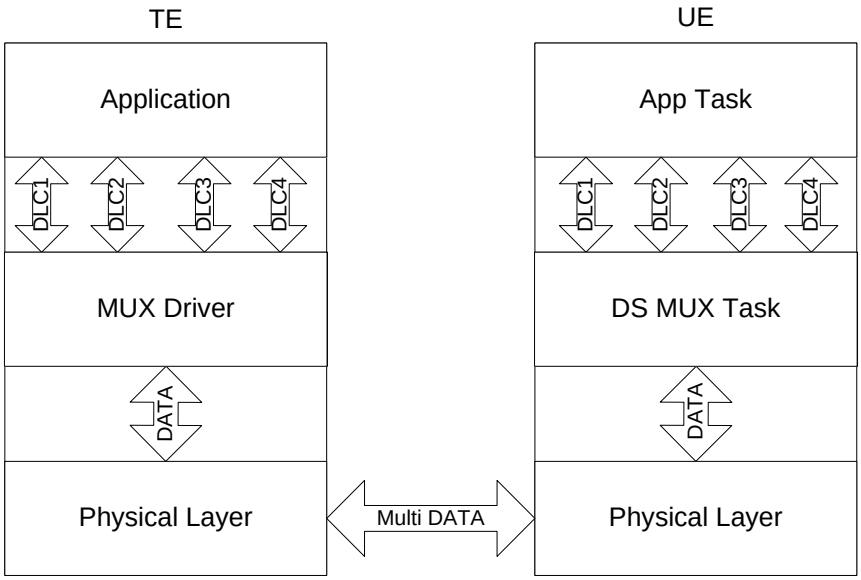

Figure 1: MUX Architecture

3 MUX AT Command

3.1. AT Command Syntax

3.1.1. Definitions

- **<CR>** Carriage return character.
- **<LF>** Line feed character.
- **<...>** Parameter name. Angle brackets do not appear on the command line.
- **[...]** Optional parameter of a command or an optional part of TA information response. Square brackets do not appear on the command line. When an optional parameter is omitted, the new value equals to the previous value or the default settings, unless otherwise specified.
- **Underline** Default setting of a parameter.

3.1.2. AT Command Syntax

All command lines must start with "**AT**" or "**at**" and end with **"<CR>"**. Information responses and result codes always start and end with a carriage return character and a line feed character: **<CR><LF><response><CR><LF>**. Throughout this document, only the commands and responses are presented, while carriage return and line feed characters are deliberately omitted.

Table 1: Types of AT Commands and Responses

Command Type	Syntax	Description
Test Command	**AT+<cmd>=?**	Returns the list of parameters and value ranges set by the corresponding Write Command or internal processes.
Read Command	**AT+<cmd>?**	Returns the currently set value of a parameter or parameters.
Write Command	**AT+<cmd>=<p1>[,<p2>[,<p3>[...]]]**	Sets parameter values.
Execution Command	**AT+<cmd>**	Reads non-variable parameters affected by internal processes in the module.

3.2. AT+CMUX Multiplexing Mode

This command enables/disables the multiplexing protocol control channel and sets parameters for the control channel.

AT+CMUX Multiplexing Mode	
Test Command **AT+CMUX=?**	Response **+CMUX: (**list of supported **<transparency>),(**range of supported **<subset>**s**),(**range of supported **<port_speed>**s**),(**range of supported **<N1>**s**),(**range of supported **<T1>**s**),(**range of supported **<N2>**s**),(**range of supported **<T2>**s**),(**range of supported **<T3>**s**),(**range of supported **<k>**s**)** **OK**
Read Command **AT+CMUX?**	Response **+CMUX: <transparency>[,<subset>[,<port_speed>[,<N1>[,<T1>[,<N2>[,<T2>[,<T3>[,<k>]]]]]]]]** **OK**
Write Command **AT+CMUX=<transparency>[,<subset>[,<port_speed>[,<N1>[,<T1>[,<N2>[,<T2>[,<T3>[,<k>]]]]]]]]**	Response **OK** If there is an error related to ME functionality: **+CME ERROR: <err>** If there is any other error: **ERROR**
Maximum Response Time	300 ms
Characteristics	The command takes effect immediately. The configuration is not saved.

Parameter

<transparency>	Integer type. Multiplexer transparency mechanism. 0 Basic option
<subset>	Integer type. 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, and the virtual channel shall be set up according to the control channel **<subset>** setting. 0 UIH frames used only 1 UI frames used only (no supported)

	2 I frames used only (no supported)
<port_speed>	Integer type. Transmission rate of the physical port. 1 9600 bit/s 2 19200 bit/s 3 38400 bit/s 4 57600 bit/s 5 115200 bit/s 6 230400 bit/s 7 460800 bit/s
<N1>	Integer type. Maximum frame size. Range: 1–32768. Default value: 127.
<T1>	Integer type. Acknowledgement timer, that is, the time UE waits for an acknowledgement before resorting to another action (e.g. transmitting a frame). Range: 1–255. Default value: 10. Unit: ten milliseconds.
<N2>	Integer type. Maximum number of re-transmissions. Range: 0–100. Default value: 3.
<T2>	Integer type. Response timer for the multiplexer control channel. Range: 2–255. Default value: 30. Unit: ten milliseconds. **<T2>** must be longer than **<T1>**.
<T3>	Integer type. Wake up response timer. Range: 1–255. Default value: 10. Unit: second.
<k>	Integer type. Window size (Not supported currently).

Example

```
AT+CMUX=0
OK
AT+CMUX?
+CMUX: 0,0,5,127,10,3,30,10,2

OK
```

NOTE

AT+CMUX can only be executed on the main UART since the modules only support multiplexer function on UART1.

4 Multiplexer Protocol

This chapter explains the technical details of the multiplexer protocol.

4.1. Frame Structure

All information transmitted between the TE and UE is conveyed in frames.

Table 2: MUX Frame Structure

Opening Flag	Address	Control	Length	Information	FCS	Closing Flag
1 octet	1 octet	1 octet	1–2 octet	Multiple octets	1 octet	1 octet

4.1.1. Flag Sequence Field

Each frame begins and ends with a flag sequence octet (0xF9).

4.1.2. Address Field

The address field consists of a single octet. It contains the Data Link Connection Identifier (DLCI), the C/R bit and the address field extension bit as shown in the figure below.

Table 3: Address Field

Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
EA	C/R	DLCI					

4.1.2.1. DLCI

The DLCI identifies the virtual channel between TE and UE. Multiple DLCIs shall be supported but the number is implementation-specific. The DLCIs are dynamically assigned.

4.1.2.2. C/R

The C/R (command/response) bit identifies the frame as either a command or a response. TE sends a command to the UE with the C/R bit set to 1, and the UE responses with the C/R bit set to 1. The UE sends a command with the C/R bit set to 0, and the TE responses with the C/R bit set to 0.

Table 4: C/R Bit Usage

Command/Response	Direction	C/R Value
Command	TE → UE	1
	UE → TE	0
Response	UE → TE	1
	TE → UE	0

4.1.2.3. EA

EA bit extends the range of the address field. When the EA bit is set to 1 in an octet, it signifies that this octet is the last octet of the length field. When the EA bit is set to 0, it signifies that another octet of the address field follows.

NOTE

EA=1 is supported only currently.

4.1.3. Control Field

The content of the control field defines the type of frame. See ***Chapter 4.2*** for details of the frame types.

Table 5: Coding of Control Field

Frame Type	HEX (P/F=0)	1	2	3	4	5	6	7	8
SABM (Set Asynchronous Balanced Mode)	0x2F	1	1	1	1	P/F	1	0	0
UA (Unnumbered Acknowledgement)	0x63	1	1	0	0	P/F	1	1	0
DM (Disconnected Mode)	0x0F	1	1	1	1	P/F	0	0	0

DISC (Disconnect)	0x43	1	1	0	0	P/F	0	1	0
UIH (Unnumbered Information with Header check)	0xEF	1	1	1	1	P/F	1	1	1
UI (Unnumbered Information)	0x03	1	1	0	0	P/F	0	0	0

P/F is the Poll/Final bit. The poll (P) bit set to 1 shall be used by one 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 refers to the P bit; in response frames, it is referred to as the F bit.)

NOTE

UI frame is not supported by Quectel BG96 module currently.

4.1.4. Length Field

Table 6: The Structure of Length Field

Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
E/A	L1	L2	L3	L4	L5	L6	L7

The L1 to L7 bits indicate the length of the following data field for the information field less than 128 bytes.

The range of the length field may be extended by use of the EA bit. When the EA bit is set to 1 in an octet, it signifies that this octet is the last octet of the length field. When the EA bit is set to 0, it signifies that a second octet of the length field follows. The total length of the length field is 15 bits in that case.

4.1.5. Information Field

The information field is the payload of the frame and carries the user data and any convergence layer information. The field is octet structured and only presents in UIH frames.

4.1.6. FCS Field

In the case of the UIH frame, the contents of the information field shall not be included in the FCS

calculation. FCS is calculated on the contents of the address, control and length fields only. This means that only the delivery to the correct DLCI is protected, but not the information.

4.2. Frame Types

4.2.1. SAMB

SABM is a command frame and is used to establish DLC between TE and UE.

4.2.2. UA

The UA frame is a response to SABM or DISC frame, as illustrated in the following figure.

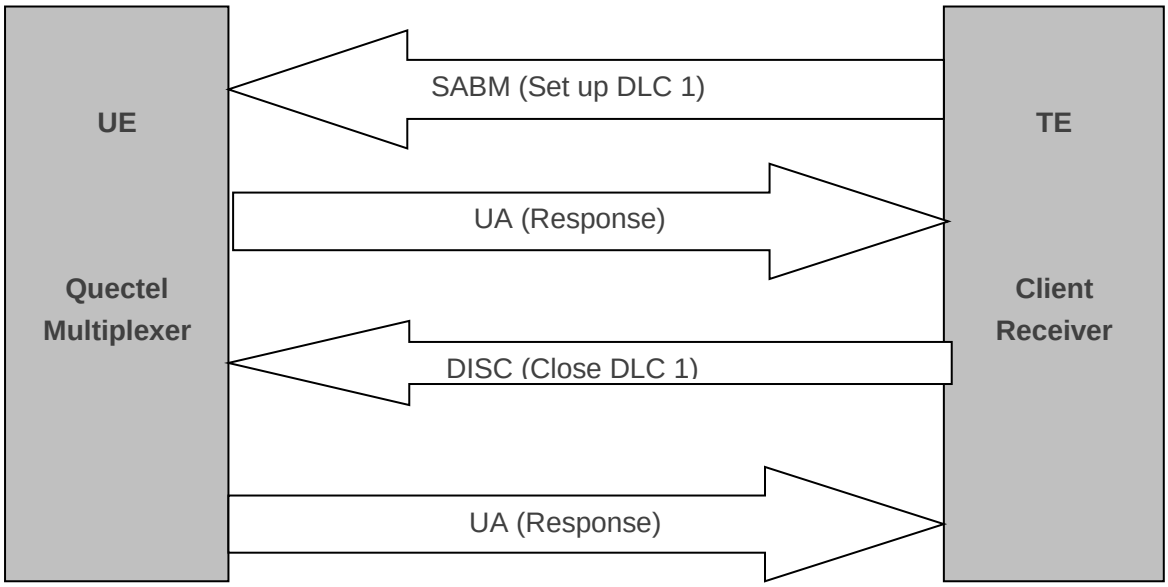

Figure 2: UA Frame (Response)

4.2.3. DM

The DM response frame is 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 is sent.

4.2.4. DISC

DISC is a command frame and is used to close down DLC. Prior to executing the command, the receiving station shall confirm the acceptance of the DISC command by the transmission of a UA response. See the figure above.

4.2.5. UIH

The UIH command/response sends user data at either station.

4.3. Multiplexer Control Channel

At the initiation of communication between the TE and UE, a control channel is set up with DLCI 0. This channel is used to convey information between the two multiplexers.

Multiplexer control channel is the basic channel which is used to establish a DLC, launch power saving, wake up from power saving and implement flow control mechanism.

4.3.1. Message Format

All UIH frames are transmitted through the control channel and conform to the following type, length and value format.

Table 7: Message Format

Type	Length	Value 1	Value 2	…	Value n

Each box in this table represents a field of minimum size one octet.

4.3.1.1. Type Field

The first type field octet has the following format:

Table 8: Message Format – Type Field

1	2	3	4	5	6	7	8
EA	C/R	T1	T2	T3	T4	T5	T6

The EA bit is an extension bit. It is set to 1 in the last octet of the sequence. In other octets, EA is set to 0. In Quectel multiplexing system, only one octet is transmitted so EA is always set to 1.

The C/R bit indicates whether the message is a command or a response.

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

4.3.1.2. Length Field

The length field octet has the following structure:

Table 9: Message Format – Length Field

1	2	3	4	5	6	7	8
EA	L1	L2	L3	L4	L6	L6	L7

The EA bit is an extension bit. It is set to 1 in the last octet of the sequence. In other octets EA is set to 0. In Quectel multiplexing system, only one octet is transmitted so EA is always set to 1.

The L bits define the number of value octets that follows. L1 is the LSB and L7 is the MSB; this permits messages with up to 127 value octets to be constructed.

4.3.1.3. Value Field

The contents of the value octets are defined for each message type in ***Chapter 4.3.2***.

4.3.2. Message Type and Actions

4.3.2.1. Power Saving Control (PSC)

The power saving control messages use the following type field octet:

Table 10: Power Saving Control Message – Type Field Format

1	2	3	4	5	6	7	8
EA	C/R	0	0	0	0	1	0

The length byte contains the value 0 and there are no value octets.

If the UE wants the TE to enter a low-power state, it transmits a power saving control command; then the

TE replies with a power saving control response.

4.3.2.2. Multiplexer Close Down (CLD)

The multiplexer close down command is used to reset the link into normal AT command mode without multiplexing. The multiplexer closes down messages use the following type field octet:

Table 11: Multiplexer Close-down Message – Type Field Format

1	2	3	4	5	6	7	8
EA	C/R	0	0	0	0	1	1

The length byte contains the value 0 and there are no value octets.

4.3.2.3. Flow Control On Command (FCon)

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

The length byte contains the value 0 and there are no value octets.

The type field octet has the following format:

Table 12: Flow Control On Command – Type Field Format

1	2	3	4	5	6	7	8
EA	C/R	0	0	0	1	0	1

4.3.2.4. Flow Control Off Command (FCoff)

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 length byte contains the value 0 and there are no value octets.

The type field octet has the following format:

Table 13: Flow Control Off Command – Type Field Format

1	2	3	4	5	6	7	8
EA	C/R	0	0	0	1	1	0

4.3.2.5. Modem Status Command (MSC)

It is desired to convey virtual V.24 control signals to a data stream by sending the MSC command. The MSC command has one mandatory control signal byte and an optional break signal byte. This command is only relevant when the basic option is chosen.

Send this command prior to any user data after a creation of a DLC.

Table 14: Modem Status Command

Command	Length	DLCI	V.24 Signals	Break Signals (optional)

The length byte contains the value 2 or 3 and there are 2 or 3 value octets.

Both the DTE and DCE use this command to notify each other of the status of their own V.24 control signals. The length of the MSC command is either 4 or 5 bytes depending on the break signal.

The command field octet has the following format:

Table 15: Modem Status Command – Command Field Format

1	2	3	4	5	6	7	8
EA	C/R	0	0	0	1	1	1

The C/R bit indicates if it is a Modem Status Command or Modem Status Response.

Every time the signals change, the DTE or DCE sends this command to indicate the current status of each signal. When a DTE or DCE receives a Modem Command, it always sends a Response back. The mappings of the V.24 signals to the bits in the control signal octet for the receiver and sender are given in ***Table 19*** and ***Table 20*** below, respectively.

In a MSC command it is the status of the sender's own V.24 signals that is sent, but in a Response it is copy of the V.24 signals that are received from the Command frame that is returned.

The DLCI field identifies the specific DLC to which the command applies. Bit 2 is always set to 1 and the EA bit is set according to the description in ***Chapter 4.1.2.3***.

Table 16: Format of Address Field

Bit 1	Bit 2	Bit 3	Bit 4	Bit 5	Bit 6	Bit 7	Bit 8
EA	1	DLCI					

The DLCI field is followed by the control signals field which contains a representation of the state of the signals in accordance with the format below. The use of the extension bit allows other octets to be added to cater for other circumstances. At present, an optional second octet is defined for handling the transmission of break signals.

Table 17: Format of Control Signal Octet

Bit No.	1	2	3	4	5	6	7	8
Signal	EA	FC	RTC	RTR	Reserved (0)	Reserved (0)	IC	DV

Description of the control signal byte:

Bit 1: The EA bit is set to 1 in the last octet of the sequence; in other octets EA is set to 0. In Quectel multiplexing system, only one octet is transmitted so EA is always set to 1.

Bit 2: Flow Control (FC). The bit is set to 1 when the device is unable to accept frames.

Bit 3: Ready to Communicate (RTC). The bit is set to 1 when the device is ready to communicate.

Bit 4: Ready to Receive (RTR). The bit is set to 1 when the device is ready to receive data.

Bit 5: Reserved for future use. Set to zero by the sender, ignored by the receiver.

Bit 6: Reserved for future use. Set to zero by the sender, ignored by the receiver.

Bit 7: Incoming Call Indicator (IC). The bit is set to 1 to indicate an incoming call.

Bit 8: Data Valid (DV). The bit is set to 1 to indicate that valid data is being sent.

The control byte is mapped to V.24 signals according to the two tables below:

Table 18: Mapping from the Control Signal Octet by a Receiving Entity

Control Signal Byte	DTE Receiving		DCE Receiving	
Bit number, name	Signal	V.24 circuit	Signal	V.24 circuit
3, RTC	DSR	107	DTR	108/2
4, RTR	CTS	106	RFR [1)]	133
7, IC	RI	125	Ignored	-
8, DV	DCD	109	Ignored	-

NOTE

[1)] Circuit 133, RFR (Ready for Receiving) is commonly assigned to the connector pin that is alternatively used for circuit 105, RTS (Ready to Send).

Table 19: Mapping to the Control Signal Octet by a Sending Entity

Control Signal Byte	DTE Sending		DCE Sending	
Bit number, name	Signal,	V.24 circuit	Signal	V.24 circuit
3, RTC	DTR	108/2	DSR	107
4, RTR	RFR [1)]	133	CTS	106
7, IC	Always 0	-	RI	125
8, DV	Always 1	-	DCD	109

NOTE

[1)] Circuit 133, RFR (Ready for Receiving) is commonly assigned to the connector pin that is alternatively used for circuit 105, RTS (Ready to Send).

If a station is unable to transmit frames because of flow control but wishes to stop accepting further frames itself, it may still send frames containing no user data (i.e. only the control signal octet and, optionally, the break signal octet) in order to control signal flow.

4.4. Procedures

4.4.1. DLC Establishment

In most cases the establishment of a DLC will be initiated by the TE. However, the protocol is balanced and the initiation may come from the UE. The action taken by the higher layers of the TE upon the initiation of the establishment of a DLC from the UE is outside the scope of this document.

The station wishing to establish a DLC transmits a SABM frame with the P-bit set to 1. The address field contains the DLCI value associated with the desired connection. If the responding station is ready to establish the connection, it will reply with a UA frame with the F-bit set to 1. If the responding station is not ready or unwilling to establish the particular DLC, it will reply with a DM frame 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 initiating station may retransmit the SABM. This action may be repeated until a response is obtained or action is taken by a higher layer.

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

4.4.2. DLC Release

The release of a DLC may be initiated by either station by the transmission of a DISC frame with the P-bit set to 1. Confirmation of the DLC release is signaled 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 disconnected mode, it will send a DM response.

If no UA or DM response has been received after T1, the initiating station may retransmit the DISC. This action may be repeated until a response is obtained or action is taken by a higher layer.

4.4.3. Information Transfer

4.4.3.1. Information Data

In Quectel multiplexing system, information is conveyed using UIH frames. UIH frames may also be used for data in situations where the delays inherent in error-recovery procedures are unacceptable, such as transmission of voice data.

The transmitter takes information from the convergence layer for the particular DLC and places it in the

information field of the transmitted frame. Once a UIH frame has been correctly received, the contents of its information field are passed to the convergence layer.

The frames sent by the initiating station have the C/R bit set to 1 and those sent by the responding station have the C/R bit set to 0. Both stations set the P-bit as 0. See ***Chapter 4.1.2.2*** for more details about C/R bit.

The maximum length of the information field in UIH frames is **<N1>** in **AT+CMUX**.

4.4.4. Time-out Considerations

In order to detect a no-reply or lost-reply condition, each station provides a response time-out function (T1). The expiry of the time-out function is used to initiate appropriate error recovery procedures.

The duration of the time-out function in the two stations is unequal in order to resolve contention situations.

The time-out function is started whenever a station has transmitted a frame for which a reply is required. When the expected reply is received, the time-out function is stopped. If during the interval that the time-out function is running, other frames are sent for which acknowledgements are required, the time-out function have to be restarted.

If the response time-out function runs out, a command with the P-bit set to 1 may be (re)transmitted, and the response time-out function is restarted.

4.4.5. Flow Control

Quectel multiplexing system supports software flow control mechanism. Software flow control is implemented by *3GPP TS 27.010* MSC, FCoff and FCon message frames.

TE sends MSC message to UE with FC bit set to 1 in V.24 control signals when TE refuses to accept frames, and with FC bit set to 0 to inform recovery of receiving frames. When receiving MSC, UE sends a response to indicate recovery of data transmission.

TE sends FCoff command to UE when it refuses to accept anything except for the control messages on DLC0. In such a case, UE stops sending any frame through all the data channels except the control channel which is still alive and free to send any control message. TE can send FCon command to UE to recover the transmission. When UE receives FCoff or FCon command, it sends a response back.

The difference between MSC and FCon is that the former only controls one of the data channels, while the latter controls all the data channels except control channel.

5 Examples

5.1. Samples for Frame Structure

Sample 1:

Opening Flag	Address Field	Control Field	Length Field	FCS	Closing Flag
F9	03	3F	01	1C	F9
Header	DLCI 0	SABM Frame	0, No Information Filed		Tail

This sample is a SABM frame to open DLCI 0.

Sample 2:

Opening Flag	Address Field	Control Field	Length Field	Information Field	FCS	Closing Flag
F9	05	EF	09	41 54 49 0D	58	F9
Header	DLCI 1	UIH Frame	4	AT command string **"ATI<CR>"**		Tail

This sample is a UIH frame to transmit the AT command string "**ATI<CR>**".

Sample 3:

Opening Flag	Address Field	Control Field	Length Field	Information Field	FCS	Closing Flag
F9	01	EF	0B	E3 07 07 0D 01	79	F9
Header	DLCI 0	UIH Frame	5	MSC Message, Length 3		Tail

This sample is a MSC message carried in UIH frame to transmit V2.4 signal 0x0D.

5.2. Channels Establishment

Step 1: Launch Multiplexer

No.	Step	Data Direction	Hex	Comment
1	TE launches UE multiplexer function via AT command	TE → UE	41 54 2B 43 4D 55 58 3D 30 0D	**AT+CMUX=0<CR><LF>**
	UE sends a response	TE ← UE	41 54 2B 43 4D 55 58 3D 30 0D 0D 0A 4F4B 0D 0A	**AT+CMUX=0<CR><LF>OK<CR><LF><CR><LF>**

Step 2: Establish DLCI 0

No.	Step	Data Direction	Hex	Comment
1	TE requests to establish control channel DLCI 0 by sending SABM frame	TE → UE	F9 **03 3F** 01 1C F9	SABM Frame
	UE replies with the UA response upon receiving SABM frame and accepts to create DLCI 0	TE ← UE	F9 **03 73** 01 D7 F9	UA Frame

Step 3: Establish DLCI 1–4

No.	Step	Data Direction	Hex	Comment
1	TE requests to establish DLCI 9 by sending SABM frame	TE → UE	F9 **27 3F** 01 0B F9	
	UE replies with the DM response upon receiving SABM but refuses to create DLCI 9	TE ← UE	F9 **27 1F** 01 21 F9	
2	TE requests to establish DLCI 1 by sending SABM frame	TE → UE	F9 **07 3F** 01 DE F9	
	UE replies with the UA response upon receiving SABM and accepts to create DLCI 1	TE ← UE	F9 **07** 73 01 15 F9	
	TE sends MSC message frames	TE → UE	F9 **01** EF 0B E3 07 **07** 0D 01 79 F9	
	UE replies with a response	TE ← UE	F9 **03** EF 0B **E1** 07 **07** 0D 01 18 F9	
3	TE requests to establish DLCI 2 by sending SABM frame	TE → UE	F9 **0B** 3F 01 59 F9	

	UE replies with the UA response upon receiving SABM and accepts to create DLCI 2	TE ← UE	F9 **0B** 73 01 92 F9
	TE sends MSC message frames	TE → UE	F9 **01** EF 0B **E3** 07 **0B** 0D 01 79 F9
	UE replies with a response	TE ← UE	F9 **03** EF 0B **E1** 07 **0B** 0D 01 18 F9
4	Establishment of DLCI 3 and DLCI 4 are the same as above.		
5	By now, 4 channels have come into existence, and Quectel multiplexing system can work normally.		

This sample is a MSC message carried in UIH frame to transmit V2.4 signal 0x0D.

5.3. Frame Transmission

After the control channel and data channels are established, TE and UE can transmit data to each other through UIH frames.

Frame Transmission:

No.	Step	Data Direction	Hex	Comment
1	TE sends the AT command string **"ATI<CR>"** on DLCI 1	TE → UE	F9 **05 EF** 09 **41 54 49 0D** 58 F9	UIH Frame
	UE replies with a response on DLCI 1	TE ← UE	F9 **05 EF** 09 **41 54 49 0D** 58 F9 F9 **05 EF** 65 0D 0A 51 75 65 63 74 65 6C 0D 0A 42 47 39 36 0D 0A 52 65 76 69 73 69 6F 6E 3A 20 42 47 39 36 4D 41 52 30 32 41 30 37 4D 31 47 0D 0A 0D 0A **4F 4B 0D 0A** 19 F9	UIH Frame
2	TE sends the AT command string "**AT<CR>**" on DLCI 2	TE → UE	F9 **09 EF** 07 **41 54** 0D 35 F9	UIH Frame
	UE replies with a response on DLCI 2	TE ← UE	F9 **09 EF** 07 41 54 0D 35 F9 F9 **09 EF** 0D 0D 0A 4F 4B 0D 0A D8 F9	UIH Frame
3	Frame transmission on DLCI 3 and DLCI 4 are the same as above.			

5.4. Power Saving Mode and Wake-up

Enter Power Saving Mode:

No.	Step	Data Direction	Hex	Comment
1	TE sends PSC message on DLCI 0	TE → UE	F9 **03** EF 05 **43** 01 F2 F9	PSC Command Frame
	UE replies with a response on DLCI 0	TE ← UE	F9 **03** EF 05 **41** 01 F2 F9	PSC Response Frame
2	UE enters power saving mode, and TE sends F9 continuously	TE → UE	F9 F9 F9 F9……	

Wake-up from Power Saving Mode:

No.	Step	Data Direction	Hex	Comment
1	TE sends wake up flags	TE → UE	F9 F9 F9 F9	
	UE replies with a response	TE ← UE	F9 F9 F9 F9	
2	UE is woken up, and data transmission is recovered			

5.5. Flow Control

Flow Control:

No.	Step	Data Direction	Hex	Comment
1	UE sends MSC message with FC bit set to 1 on control channel DLCI 0, to indicate refusing to accept anything on DLCI 1.	TE ← UE	F9 **01** EF 0B **E3** 07 07 **8F** 01 79 F9	
2	UE sends MSC message with FC bit set to 0 on control channel DLCI 0, to indicate recovery of DLCI 1 data transmission.	TE ← UE	F9 **01** EF 0B **E3** 07 07 **8D** 01 79 F9	
3	TE sends MSC message with FC bit set to 1 on control channel DLCI 0, to indicate refusing to accept anything on DLCI 1.	TE → UE	F9 **01** EF 0B **E3** 07 07 **8F** 01 79 F9	
4	TE sends MSC message with FC bit set to 0 on control channel DLCI 0, to indicate recovery of DLCI 1 data transmission.	TE → UE	F9 **01** EF 0B **E3** 07 07 **8D** 01 79 F9	

5	TE sends FCoff message on DLCI 0, to indicate refusing to accept anything on all DLCs except DLCI 0.	TE → UE	F9 **01** EF 05 **63** 01 93 F9
6	TE sends FCon message through DLCI 0, to indicate recovery of data transmission.	TE → UE	F9 **01** EF 05 **A3** 01 93 F9

5.6. Synchronization

After the data channels are established, TE and UE are synchronized and data transmission is normal. Every transmission is implemented by frames which begins with a starting flag (0xF9) and ends with a closing flag (0xF9). So it is called that multiplexer is synchronized with flag 0xF9. Transmitting bytes other than 0xF9 between frames is considered as faulty or synchronization lost and needs re-sync.

Synchronization:

No.	Step	Data Direction	Hex	Comment
1	TE receives error frame	TE ← UE	F9 01 EF 05	
2	TE sends sync flag to re-sync with UE	TE → UE	F9 F9 F9	
3	UE replies with three hex values F9 to indicate bytes received	TE ← UE	F9 F9 F9	
4	TE tests AT command transmission through DLCI 1 after re-sync	TE → UE	F9 05 EF 07 **41 54 0D** 06 F9	
	UE replies with a response and synchronization has been reset to normal	TE ← UE	F9 05 EF 07 **41 54 0D 67 F9 F9 25 EF 0D 0D 0A 4F 4B 0D 0A** 8A F9	

NOTES

1. Quectel BG96 module is not initiative to send sync flags (F9), even though UE receives error frames.
2. When the module is not in power saving mode and receives more than 2 sync flags, it will send only 3 sync flags to TE, even if it receives more than 3 sync flags.
3. When the module is in power saving mode, it will send the number of sync flags (F9) received from TE.

5.7. Close-down of Multiplexer

Close-down Procedures:

No.	Step	Data Direction	Hex	Comment
1	TE sends DISC frame to request for closing down DLCI 1	TE → UE	F9 **07 53** 01 3F F9	
	UE replies with the UA frame to accept the request	TE ← UE	F9 **07 73** 01 15 F9	
2	TE sends DISC frame to request for closing down DLCI 2	TE → UE	F9 **0B 53** 01 B8 F9	
	UE replies with the UA frame to accept the request	TE ← UE	F9 **0B 73** 01 92 F9	
3	TE sends DISC frame to request for closing down DLC 3	TE → UE	F9 **0F 53** 01 7A F9	
	UE replies with the UA frame to accept the request	TE ← UE	F9 **0F 73** 01 50 F9	
4	TE sends DISC frame to request for closing down DLC 4	TE → UE	F9 **13 53** 01 77 F9	
	UE replies with the UA frame to accept the request	TE ← UE	F9 **13 73** 01 5D F9	
5	TE sends CLD message frame to request for closing down multiplexer on DLCI 0	TE → UE	F9 **03** EF 05 **C3** 01 F2 F9	
	UE acknowledges the CLD message to accept the request	TE ← UE	F9 03 EF 05 **C1** 01 F2 F9	
6	By now, the multiplexer is closed down.			

6 Appendix A References

Table 20: Related Documents

SN	Document Name	Remark
[1]	3GPP TS 27.010 version 9.0.0	3rd Generation Partnership Project; Technical Specification Group Terminals; Terminal Equipment to User Equipment (TE-UE) multiplexer protocol
[2]	Quectel_BG96_AT_Commands_Manual	AT commands manual of Quectel BG96 module

Table 21: Terms and Abbreviations

Abbreviation	Description
ABM	Asynchronous Balanced Mode
CLD	Multiplexer Close Down
C/R	Command/Response
DCE	Data Communications Equipment
DISC	Disconnect
DLC	Data Link Connection
DLCI	Data Link Connection Identifier
DM	Disconnected Mode
DTE	Data Terminal Equipment (typically computer, MCU, external controller)
DV	Data Valid
FC	Flow Control
FCS	Frame Check Sequence
FCoff	Flow Control Off Command

FCon	Flow Control On Command
IC	Incoming Call Indicator
MSC	Modem Status Command
MUX	Multiplexer
PSC	Power Saving Control
RFR	Ready for Receiving
RTC	Ready to Communicate
RTR	Ready to Receive
RTS	Ready to Send
SABM	Set Asynchronous Balanced Mode
TE	Terminal Equipment
UA	Unnumbered Acknowledgement
UE	User Equipment
UI	Unnumbered Information
UIH	Unnumbered Information with Header Check