Multiplexer

3GPP 27.010 Mux implementation in cellular modules

Application note

Abstract

This document provides basic multiplexer information and a short description of how to implement a multiplexer driver according to 3GPP TS 27.010. This document serves as a reference to customers developing proprietary multiplexer drivers for communication with u-blox cellular modules using several virtual channels simultaneously.

Document information

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This document applies to the following products:

Product name
LEON-G1 series
LISA-U2 series
SARA-G3 series
SARA-G4 series
SARA-U2 series
TOBY-L2 series
TOBY-R2 series
LARA-R6 series
LARA-R2 series
SARA-R5 series
SARA-R4 series

Contents

1   Introduction

☞   The multiplexer protocol is not supported by TOBY-L2 "00" product versions.

This document describes the implementation of the multiplexer protocol for cellular modules. The following symbols are used to highlight important information within the document:

☞   An index finger points out key information pertaining to integration and performance.

⚠   A warning symbol indicates actions that could negatively impact performance or damage the device.

u-blox cellular modules support the 3GPP TS 27.010 multiplexer protocol [5]. It is possible to emulate several virtual connection channels on a single physical interface to access the module concurrently (e.g., it is possible to read phonebook contacts while receiving GPRS data).

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

The multiplexer has three operating options:

- basic
- advanced without error recovery
- advanced with error recovery

u-blox cellular modules only support the basic mode.

Module	Control channel	AT commands / data connection	GNSS tunneling	SAP (SIM Access Profile)	Remarks
TOBY-L2	Channel 0 (DLC0)	Channel 1 - 5			Multiplexer control channel as described in 3GPP TS 27.010 [5]
TOBY-R2	Channel 0 (DLC0)	Channel 1 - 5	Channel 6[1]		
LARA-R2	Channel 0 (DLC0)	Channel 1 - 5	Channel 6[2]		
LARA-R6	Channel 0 (DLC0)	Channel 1 - 2	Channel 3		
SARA-R5	Channel 0 (DLC0)	Channel 1 - 3[3]	Channel 4[4]		
SARA-R4	Channel 0 (DLC0)	Channel 1 - 2	Channel 3[5]		
LEON-G1	Channel 0 (DLC0)	Channel 1 - 5	Channel 6		
SARA-G300	Channel 0 (DLC0)	Channel 1 -2	Channel 6		
SARA-G310	Channel 0 (DLC0)	Channel 1 - 2	Channel 6		
SARA-G340	Channel 0 (DLC0)	Channel 1 - 5	Channel 6		
SARA-G350	Channel 0 (DLC0)	Channel 1 - 5	Channel 6		
SARA-G4	Channel 0 (DLC0)	Channel 1 - 5	Channel 6[6]		
SARA-U2	Channel 0 (DLC0)	Channel 1 - 5	Channel 6	Channel 7	
LISA-U2	Channel 0 (DLC0)	Channel 1 - 5	Channel 6	Channel 7[7]	

Table 1: Multiplexer configuration on u-blox cellular modules

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[1] Not supported by TOBY-R200-02B-00, TOBY-R202-02B-00

[2] Not supported by LARA-R204-02B and LARA-R211-02B-00

[3] Channel 3 only available in case of single UART configuration or in case the AUX UART is not configured as AT interface

[4] Channel 4 only available in case of single UART configuration or in case the AUX UART is not configured as GNSS tunneling interface

[5] Not supported by SARA-R422

[6] Not supported by SARA-G450-00C

[7] Not supported by LISA-U200-00S

1.1 Features and implementations

- Multiplexer Basic Option compliant to 3GPP TS 27.010 [5] is supported. All the required features are supported, within the limits identified in this document. If not specified in the document, the optional features described in 3GPP technical specification are not supported.
- The multiplexer can operate only at a fixed baud rate. Once the +CMUX AT command is sent and the autobauding is active (AT+IPR=0, where applicable), a switch to fixed rate is performed as soon as the multiplexer protocol is successfully activated. It is strongly recommended to enable the highest baud rate supported by the UE.
- On supported product series, every instance has its own AT command profile. For additional information, see section 4.
- Every instance has its own independent flow control, implemented by MSC packets (for more details, 3GPP TS 27.010 [5]).
- The response to only one test command (as specified in 3GPP TS 27.010 [5], section 5.4.6.3.4) is supported, since it is presumed that, when the connection DCE-DTE is established, it will not be lost. This behavior prevents looping TEST traffic.
- It is recommended to use hardware flow control (RTS/CTS) on the multiplexer physical port. If the ME power saving is enabled (e.g., AT+UPSV=1) and the UART interface is used, this configuration is mandatory.
- The flow control configuration of the multiplexer physical port is not changed when the multiplexer protocol is established (the configuration previously selected via the &K or +IFC AT commands is retained).
- Multiplexer timers and retransmission (T1, T2, T3, and N2, see 3GPP TS 27.010 [5]) have limited support. For more details, see section 2.
- No need to use multiplexer protocol with USB interface. USB multiplexing capability based on multiple CDCs should be used.
- The multiplexer is supported only on UART. Only one interface can be used at a time.

1.1.1 Unsupported multiplexer control channel messages

The messages and actions listed below are specified in 3GPP TS 27.0.10 [5], but not supported by u-blox module series.

- Parameter Negotiation (PN) command
- Flow Control On (FCon)
- Flow Control Off (FCoff)Command
- Remote Port Negotiation (RPN) command
- Remote Line Status (RLS) command
- Service Negotiation (SNC)Command
- Software flow control (XOn/XOff) on the DLCs is not supported and should be disabled.
- Multiplexer power control and wake-up mechanism via the power saving control (PSC) command is not supported. If power saving is enabled, power saving information towards the TE is indicated via the module CTS line (module output).

☞ On LISA-U2 / SARA-G3 / LEON-G1 series, RTS/CTS is forced active on the multiplexer physical port, when the multiplexer protocol is established. This configuration cannot be subsequently changed.

2   System parameters

The +CMUX AT command starts the multiplexer operation. This command enables the multiplexer to start up the multiplexer control channel. The TE multiplexer initiates this by sending an SABM frame on DLCI 0.

Once the multiplexer channel is established, other DLCs can be established. The multiplexer may negotiate the parameters associated with each DLC prior to its establishment or use the default values.

System parameters T1, N1, N2 and k can be configured by the multiplexer control channel, or the default values given here can be used. T2, T3 and subset system parameters are set by the +CMUX AT command.

In the basic mode, T1 is only used when SABM and DISC commands are sent by the module. The SABM command is never sent, because the DLC establishment procedure can only be initiated by the DTE. The DISC would only be triggered in response to a T2 timeout.

☞   For LISA-U2, SARA-U2, TOBY-R2 and LARA-R2 series, T1 and T2 timers and the retransmission mechanism are not implemented. For SARA-R4 series, only N1 parameter is implemented

☞   For SARA-R5 series, T1 timer is not implemented.

☞   For LEON-G1, SARA-G3, SARA-U2, LISA-U2, TOBY-L2, TOBY-R2, LARA-R2 and SARA-R5 series, only the MSC command requires a response, and is therefore the only one that involves T2. On LEON-G1 and SARA-G3 series, in case retransmission reaches the N2 number, the not responding DLC is released (i.e., the DCE starts a DISC for the not responding DLC).

☞   In SARA-U2, LISA-U2, TOBY-R2 and LARA-R2 series, instead, T2 is not implemented to avoid restrictions of the application response time.

☞   For all the modules, T3 is not implemented. This is because the wake-up procedure is not supported, since the power saving control relies on the underlying hardware (UART, SPI, etc.) power saving control mechanism.

☞   For more details about command syntax, see the corresponding u-blox AT commands manual [1], [2], [3], [4] of the series modules.

2.1   Acknowledgement timer (T1)

The acknowledgement timer governs the time that a station waits for an acknowledgement before resorting to other actions (e.g., transmitting a frame). The two stations may operate with different T1 values.

☞   For LEON-G1 and SARA-G3 series, this value is fixed at 253.

☞   For LISA-U2, SARA-U2, TOBY-L2, TOBY-R2, LARA-R2, LARA-R6, SARA-R5 and SARA-R4 series, the T1 timer is not implemented and the requested T1 value is not considered.

2.2   Maximum frame size (N1)

The N1 parameter defines the maximum number of octets that may be contained in an information field. It does not include octets added for transparency purposes.

The default value for the basic mode is 31 octets. The range is from 1 to 1509 octets.

2.3   Maximum number of retransmissions (N2)

The N2 parameter defines the maximum number of times that a station re-attempts a procedure requiring a response. The two stations may operate with a different value of N2.

☞   For LEON-G1, SARA-G3, TOBY-L2, LARA-R6, SARA-R5 series, the range is 0-5, with the default value 3.

☞   For LISA-U2, SARA-U2, SARA-R4, TOBY-R2, and LARA-R2 series, the N2 value is not considered, since the retransmission mechanism is not implemented. This could result in MSC commands not being received (which cannot be avoided even if retransmission is implemented). The DTE must guarantee correct MSC command reception in all operating scenarios, especially if the MSC commands are used to carry flow control information.

2.4   Window size (k)

The window size parameter (k) defines the maximum number of I frames that a DLC can have outstanding. Since u-blox cellular modules support only the MUX basic mode, this parameter is not supported.

2.5   Response timer for multiplexer control channel (T2)

The T2 timer is the amount of time that the multiplexer control channel waits before retransmitting a command.

T2 must be greater than T1.

☞   For LEON-G1, SARA-G3, TOBY-L2, SARA-R5 series, this value is fixed at 254.

☞   For LISA-U2, SARA-U2, TOBY-R2, SARA-R4, LARA-R6 and LARA-R2 series, the T2 timer is not implemented; the requested T2 value is not considered.

2.6   Response timer for wake-up procedure (T3)

The T3 timer is the amount of time that the transmitting station of a power wake-up command waits before raising an alarm when no response is received. This parameter is not considered, since the power wake-up procedure is not supported; instead, the underlying hardware (UART, SPI, etc.) power saving mechanism is used.

2.7 Multiplexer control channel setup mode (subset)

The subset 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. u-blox implementation does not support subsequent negotiation on a virtual channel basis.

Supported subset values are:

- 0 UIH frames used only
- 1 UI frames used only

☞ SARA-R5, LARA-R2, TOBY-R2, TOBY-L2, LISA-U2, SARA-U2, SARA-G4, SARA-R4, LEON-G1 and SARA-G3 "00" and "01" product versions do not support subset value 1.

3   Multiplexer packet format for basic option

Table 2 shows the frame structure in basic mode:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
1 octet	1 octet	1 octet	1 or 2 octets	Unspecified length but integral number of octets	1 octet	1 octet

Table 2: Frame Structure for Basic option

Opening and closing flags may appear in the information field of the frame. They cannot be used to determine the beginning and end of a frame. The Length Indicator for the frame must be used.

☞   In this document and in the 3GPP TS 27.010 [5] the bit fields are represented from the less significant bit (leftmost one) to more significant (rightmost one): B1(LSB) B2 B3 B4 B5 B6 B7 B8(MSB).

3.1   Flag

Flags (when included in the frame) always have value 0xF9.

3.2   Address

The Address field contains the Data Link Connection Identifier (DLCI), the C/R bit, and the address field extension bit (always 1). The C/R (command/response) bit identifies the frame as either a command or a response.

Bit No.	1	2	3	4	5	6	7	8
	EA	C/R		D	L	C	I	

Table 3: Format of Address Field

The DLCI identifies an individual user information stream, and it identifies connections between the TE and UE. Multiple DLCIs are supported, but the number is implementation specific. The DLCIs are dynamically assigned.

3.3   Control

The content of the control field defines the type of frame. Table 4 describes the frame control fields.

Frame Type	1	2	3	4	5	6	7	8	Notes
SABM (Set Asynchronous Balanced Mode)	1	1	1	1	P/F	1	0	0	
UA (Unnumbered Acknowledgement)	1	1	0	0	P/F	1	1	0	
DM (Disconnected Mode)	1	1	1	1	P/F	0	0	0	
DISC (Disconnect)	1	1	0	0	P/F	0	1	0	
UIH (Unnumbered Information with Header check)	1	1	1	1	P/F	1	1	1	
UI (Unnumbered Information)	1	1	0	0	P/F	0	0	0	Optional

Table 4: Coding of Control Field

In Table 4, P/F is the Poll/Final bit. The poll (P) bit set to 1 is used by a station to solicit (poll) a response or sequence of responses from the other station. The final (F) bit set to 1 is used by a station to indicate the response frame transmitted as the result of a soliciting (poll) command.

The poll/final (P/F) bit serves 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).

3.3.1   Set Asynchronous Balanced Mode (SABM) command

The SABM command sets the addressed station to Asynchronous Balanced Mode (ABM) where all control fields are one octet in length. The station confirms acceptance of the SABM command by transmission of a UA response at the first opportunity. Upon acceptance of this command, the DLC sends and receives state variables that are set to zero.

☞ u-blox implementation only supports DLC establishment initiated by the TE. SABM is therefore a mandatory command that the TE must issue before starting any kind of communication with a DLC. Repeat the SABM command for each DLC the TE wishes to establish a communication with.

3.3.2   Unnumbered Acknowledgement (UA) response

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

3.3.3   Disconnected Mode (DM) response

The DM response reports 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 an SABM command. If a DISC command is received while in disconnected mode a DM response should be sent.

3.3.4   Disconnect (DISC) command

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

3.3.5   Unnumbered Information with Header check (UIH) and unnumbered Information (UI) frames

The information is conveyed using UI or UIH frames. The support of UIH frames is mandatory, while the UI frames support is optional.

UIH frames are used where the integrity of the information being transferred is of lesser importance than its delivery to the correct DLCI. UI frames are used when it is important to know that data received is correct.

For the UIH frame, the FCS is calculated over only the address, control, and length fields. For the UI frame, the FCS is calculated over all fields (Address, Control, Length Indicator, Information).

The Address field identifies if the UI/UIH frame is a data or a control frame. If the Address refers to the DLC0, the UI/UIH frame is a command/response (based on C/R bit) frame.

3.3.5.1   UIH (UI) command and response

☞ UI frames are only supported by SARA-G3 "02" product versions.

The UIH (UI) command/response sends information without affecting the V(S) or V(R) variables at either station. Reception of the UIH (UI) command/response is a non-sequential number verified by the data link procedures; therefore, the UIH (UI) frame can be lost if a data link exception occurs during transmission of the protected portion of the command or it can be duplicated if an exception condition occurs during any reply to the command. There is no specified response to the UIH (UI) command/response.

3.4 Length indicator

Table 5 shows the format of the length indicator:

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

Table 5: Length field, first byte

Bits L1 to L7 indicate the length of the following data field. The default length is 31 bytes.

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 in that case 15 bits, L1-L15.

The second octet of the length field has the format shown in Table 6, and is only present when the EA field in the first byte is set to 0.

Bit	1	2	3	4	5	6	7	8
	L8	L9	L10	L11	L12	L13	L14	L15

Table 6: Length field, second byte

The length field is always present, even if the data field is empty.

3.5 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. The information field is only present in UI frames and UIH frames.

3.6 Frame checking sequence field (FCS)

The Frame Checking Sequence Field (FCS) is a checksum of the payload.

The FCS is the ones complement of the sum (modulo 2) of:

- the remainder of
  $x^k (x^7 + x^6 + x^5 + x^4 + x^3 + x^2 + x^1 + 1)$
  divided (modulo 2) by the generator polynomial
  $x^8 + x^2 + x + 1$,
  where k is the number of bits in the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding start and stop elements (start/stop transmission), and bits (synchronous transmission) and octets (start/stop transmission) inserted for transparency, and
- the remainder of the division (modulo 2) by the generator polynomial
  $x^8 + x^2 + x + 1$
  of the product of x^8 by the content of the frame existing between, but not including, the final bit of the opening flag and the first bit of the FCS, excluding start and stop elements (start/stop transmission), and bits (synchronous transmission) and octets (start/stop transmission) inserted for transparency.
  In the case of the UIH frame, the contents of the I-field are not included in the FCS calculation. FCS is calculated based 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. The FCS is calculated in the normal manner for all other frames in Table 4.

4 AT command / data interface

4.1 AT command profiles

☞ This section is not applicable to SARA-R4 and LARA-R6 series.

When using the AT command interface over a multiplexer channel, the following notes should be considered:

- Every virtual channel has its own AT command profile.
- The +UPSV is the only profile field that is shared among all channels (both virtual and physical). A change of this parameter for any channel applies to all other channels.
- The power-saving configuration selected by the +UPSV AT command acts directly on the physical device and therefore it is effective even if it is issued on a virtual channel. Since the mode is shared among all the channels (virtual or not), each channel has the capability of modifying the power saving configuration.
- On LEON-G1, SARA-G3, SARA-G4, SARA-U2, LISA-U2, TOBY-L2, TOBY-R2, LARA-R2, SARA-R5 series modules, &K and +IFC AT commands are applied to the multiplexer virtual devices. This means that they configure the multiplexer protocol to enable/disable the flow control via MSC packets on the selected DLC (see section 6.3).
- LEON-G1, SARA-G3, SARA-U2, LISA-U2, TOBY-L2, TOBY-R2, LARA-R2, SARA-R5 series ignore +ICF and +IPR AT commands if the multiplexer is active. It is possible to read/write a value (the "OK" result code is returned and the profile updated), but it has no effect on the module behavior.
- Using the software flow control (XOn/XOff) on virtual channels is not allowed. All the commands trying to set this mode are refused and an error result code is returned.

☞ AT channels are dynamically attached/detached in the multiplexer protocol. Each ATTACH operation results in a profile reload from the NVM. Therefore, a profile change (and in particular a change of the +UPSV command parameter) in one open channel due to open/close operations of another channel may occur. In the same way, when all the virtual channels are closed and the multiplexer protocol is uninstalled, the channel associated with the physical device is reattached; this also results in a profile reload.

4.2 UART lines state during MUX protocol execution

As described in 3GPP TS 27.010 [5] the multiplexer protocol implemented in u-blox cellular modules specifies that the notification of any change in the ITU-T V.24 lines is performed via a proper MSC packet.

☞ On LISA-U2 and SARA-U2 series modules, after every AT command response sent over an AT command DLC (channels from 1 to 5), the module sends an MSC command for the same DLC to TE with RTR flag to 1 (bit 1 of control signal octet), indicating that the DLC is ready to receive data. This is something redundant, since RTR has not changed during AT command execution. The 3GPP TS 07.10 [5] states about the MSC frame "Every time the signals change, the DTE or DCE sends this command to indicate the current status of each signal."

4.2.1 Exceptions for RING and DCD lines on UART

To ensure a high level of host responsiveness to module notified events, such as incoming calls or establishment of a data call, the UART RING and DCD lines have been customized. (An example of a module notified event is the host in power saving mode being rapidly woken up by an event notification using a line toggling.)

- **LEON-G1, SARA-G3 and SARA-G4 series modules**: if the multiplexer protocol is activated on the UART interface, the handling of UART RING and DCD physical output (from the module) lines is implemented. The two lines are physically driven in the same way as without multiplexer protocol. For these lines both MSC packet sending and physical line switch are implemented.
- **LISA-U2 / SARA-U2 / TOBY-R2 / LARA-R2 series modules**: UART RING and DCD output lines are physically changed in case of incoming voice or data call (RING line toggling) or established voice call (DCD line to ON for the entire call duration), even if the MUX protocol is installed on UART (and therefore MSC packet sending is implemented as well).
  This means that in any conditions (MUX installed or not on UART), the UART DCD line notifies the voice call establishment. In all the other scenarios (e.g., data call), if MUX is activated on UART, DCD line change is only notified to the TE via a MSC packet on the relevant DLC.
- **SARA-R5 series modules:** if the multiplexer protocol is activated on the UART interface for MT SMS related URCs, the RING line setting follows the +CNMI AT command configuration. Its change is only notified to the TE via a MSC packet on the relevant DLC (where the URC is sent). For all the other URCs, only the physical UART RING line is driven (no MSC packet sent to TE).
- **SARA-R42 "01B" product versions:** if the multiplexer protocol is activated on the UART interface, the handling of UART DCD physical output from the module line is not implemented, i.e., no DCD toggling for socket direct link command (+USOWR and +USOST). Accordingly for this line both MSC packet sending and physical line switch are not available .

4.2.2   Break signal in a MSC command packet from TE

On a DLC used as AT command interface (e.g. channel from 1 to 5 in section 1 for LEON-G1, SARA-G340, SARA-G350, SARA-G4, SARA-U2, LISA-U2, TOBY-L2, SARA-R5, TOBY-R2 and LARA-R2 series modules), the break signal octet reception in a MSC command frame from TE causes the module to act as in case of escape sequence reception (e.g. +++) in case of established data call.

See 3GPP TS 27.010 [5], section "5.4.6.3.7 Modem Status Command (MSC)" for details about the meaning and generation of the break signal octet.

See u-blox AT commands manual [1], [2], [3], [4]for details about the escape sequence detection effect on an active data call (i.e. AT interface in online data state).

☞ The module does not consider the length of break in units of 200 ms (L1-L4 in Table 8 of 3GPP TS 27.010 [5]). Only B1 bit is evaluated.

5 Linux reference driver

Below is a brief description of a multiplexer host driver for Linux systems. This can be used as a reference for developing a proprietary multiplexer driver, since most parts of the code are machine independent.

5.1 Gsm0710.c
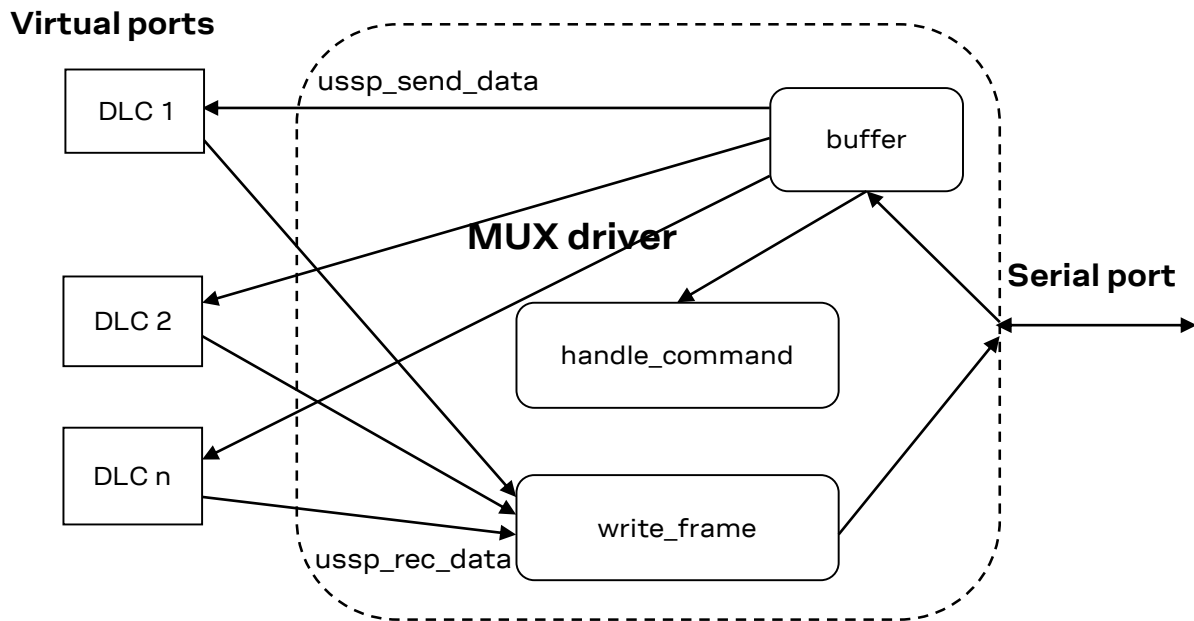
5.1.1 Main

The main program performs the following:

1. Parses the command line arguments. It sets some global variable and perhaps calls the "usage" function to show the help.
2. It goes to background or not (in the `daemonize()` function) depending on command line parameters.
3. Allocates memory for the structures used by the driver.
4. Starts the Mux protocol and initializes virtual ports. This part is handled by "openDevicesAndMuxMode" function (see section 5.1.2).
5. Continuously reads data from the TE serial port and writes it to the buffer (gsm0710_buffer_write), then extracts from it the single frames and forwards the payload (extract_frames) to the correct virtual channel (ussp_send_data) or performs a control action (handle_command). It also reads data from the virtual channels and writes it to the TE serial port (ussp_recv_data).
6. When terminated, it frees the allocated resources and closes the virtual ports and the Mux protocol.

5.1.2   openDevicesAndMuxMode

This part is Linux dependent; it creates symbolic links for the virtual ports and configures their parameters ("open_pty" function).

It opens and configures the physical serial port in "open_serialport" function.

Once the port is open it sends a simple "AT" command and waits for the OK answer, then it sends the Mux activation command (AT+CMUX=….), this part is handled by "initGeneric" function.

When the Mux protocol is established, it opens the virtual channels.

5.2   Buffer

This file contains general utility functions to manage data from/to the TE and to parse/from mux packets. These functions are platform independent. The functions that are mainly used are:

- `gsm0710_buffer_init`: Allocates memory for a new buffer and initializes it
- `gsm0710_buffer_destroy`: Frees allocated memory
- `gsm0710_buffer_write`: Writes data to the buffer
- `gsm0710_buffer_get_frame`: Gets a frame from buffer
- `destroy_frame`: Destroys a frame (free the memory allocated by gsm0710_buffer_get_frame)
- `make_fcs`: Calculates frame check sequence from given characters

6　Notes for developers

6.1　Enabling multiplexer trace messages

For debugging purposes, a special trace of the multiplexer protocol can be enabled.

LEON-G1 / SARA-G3 series	LISA-U2 / SARA-U2 / TOBY-R2 / LARA-R2 series	TOBY-L2 series	Description
`AT+XL1SET="muxtron"`	`AT+UMUX=1,11,255`	`AT+TRACE=127,,"MUX=1"`	Enable the trace
`AT+XL1SET="muxtroff"`	`AT+UMUX=0`	`AT+TRACE=127,,"MUX=0"`	Disable the trace

☞　On LISA-U2, SARA-U2, TOBY-R2, LARA-R2 series the +UMUX AT command offers a higher granularity in the multiplexer trace activation. See appendix C.1 for a complete command description.

　　This trace provides information (in form of ASCII output) about the multiplexer packets passing on the UART and on the DLCs.

☞　On LEON-G1 "07" product versions and onwards and SARA-G3 modules, the "muxtron:<value>" command is available. See appendix C.2 for the description.

☞　On TOBY-L2 series the +TRACE AT command allows configuring the MUX protocol logging. MUX logging is disabled by default, and the setting is not persistent. Issue the AT+TRACE command on the same AT terminal. See appendix C.3 for a complete command description.

☞　On SARA-R5 series, the +TRACE AT command allows configuring the MUX protocol logging. By default, MUX logging is enabled while MUX frame dump is not; the setting is persistent. The configuration requires the use of a binary filter that can be provided on demand.

6.2　Frame size

If the host driver sends packets bigger than the Maximum Frame Size (for more details see section 2.2), the module ignores the packets without returning any error.

6.3　Flow control on virtual channels

The flow control of the virtual channel is implemented in terms of MSC packets with the FC bit. If the application processor sets the FC bit to 1 for a particular DLC, the TE does not send data to the application processor for that DLC until FC returns to 0 for the same DLC. The TE has limited resources for buffering data, so if the DLC is involved in large data transfers (for example downloading data through a GPRS connection) a buffer overflow may occur if the time between FC=1 and FC=0 is too long; in this case data may be lost and there is no error indication.

The application processor should avoid (if possible) the use of this feature or keep the time interval with the FC=1 as small as possible.

6.4　Multiplexer start-up procedure

As described in the section 2, once the multiplexer channel is established, other DLCs can be established. This is up to the TE (see the section 3.3.1), which shall issue a SABM command before start any kind of communication with a DLC.

☞　On TOBY-L2 series, SABM frame shall be sent with a time interval of 5 s. Moreover, the TE shall establish all the required DLCs at the "same time", namely before performing any AT commands communication over the DLCs.

6.5   Multiplexer close-down procedure

Even if the multiplexer close-down is a symmetric procedure, in the u-blox cellular modules it is always requested by the TE.

The host should trigger the close-down procedure when all the DLCs are in an idle state that is when there is neither any pending AT command response not ongoing data connections.

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

Once the command to close down is received the multiplexer will close down each DLC via a DLC release command (DISC). The release of a DLC may be initiated by either station by the transmission of a DISC frame with the P-bit set to one. 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 a disconnected mode it will send a DM response.

When all the DLCs (except the DLCI 0 - multiplexer control channel) are closed down (disconnected mode) the multiplexer that initiated the close-down procedure 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.

☞   u-blox implementation also supports a clear down procedure where the TE sends a CLD before having close each DLC with a DISC command.

Appendix

A   Glossary

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
ASCII	American Standard Code for Information Interchange
AT	AT Command Interpreter Software Subsystem, or attention
ABM	Asynchronous Balanced Mode
C/R	Command/Response
CDC	Communications Device Class
CDMA	Code Division Multiple Access
CTS	Clear To Send
DCD	Data Carrier Detect
DISC	Disconnect
DLC	Data Link Connection
DLCI	Data Link Connection Identifier
DM	Disconnected Mode
EA	Extended Address
FCON	Flow Control ON
FCOFF	Flow Control OFF
FCS	Frame Check Sequence
FTP	File Transfer Protocol
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
LSB	Least significant bit
MSB	Most Significant Bit
MSC	Modem Status Command
MUX	Multiplexer
NVM	Non Volatile Memory
P/F	Poll/Final
RAM	Random Access Memory
RTR	Ready To Receive
RTS	Request To Send
SABM	Set Asynchronous Balanced Mode
SMS	Short Message Service
SPI	Serial Peripheral Interface
TE	Terminal Equipment
UA	Unnumbered Acknowledgement
UART	Universal Asynchronous Receiver-Transmitter
UE	User Equipment
UI	Unnumbered Information
UIH	Unnumbered Information with Header check
USB	Universal Serial Bus

Table 7: Abbreviations and terms

B Multiplexer transactions example

The following example illustrates the procedure to establish two DLCs (DLC0 (control) and DLC1 (AT command channel)). After establishment, an example of AT command issuing/response over DLC1 follows.

B.1 Multiplexer protocol establishment

From host driver SABM frame on DLCl0:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	03	3F	01	-	1C	F9

From host driver UIH frame on DLC0, modem status command:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	03	EF	0B	E3 07 07 8C 01	18	F9

From host driver SABM frame on DLCl1:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	3F	01	-	DE	F9

From host driver UIH frame on DLCl1, modem status command:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	EF	0B	E3 07 07 8C 01	DA	F9

From modem UA (answer to SABM) on DLCl0

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	03	73	01	-	D7	F9

From modem UIH frame on DLC0, modem status command:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	01	EF	0B	E1 07 07 8C 01	79	F9

From modem UA (answer to SABM) on DLCl1

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	73	01	-	15	F9

From modem UIH frame on DLC1, modem status command:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	05	EF	0B	E3 07 07 8C 01	BB	F9

B.2   Multiplexer protocol AT command communication

From host driver UIH frame on DLCI1, "AT+CPIN?":

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	EF	13	61 74 2B 63 70 69 6E 3F 0D	C8	F9

From modem UIH frame on DLC1, "+CPIN: READY":

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	05	EF	21	0D 0A 2B 43 50 49 4E 3A 20 52 45 41 44 59 0D	6E	F9

B.3   Multiplexer protocol close-down

From host driver DISC frame on DLC1:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	53	01	-	3F	F9

From modem UA frame on DLC1:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	07	73	01	-	15	F9

From host driver CLD command frame on DLC0:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	03	EF	05	C3 01	F2	F9

From modem CLD response frame on DLC0:

Flag	Address	Control	Length Indicator	Information	FCS	Flag
F9	01	EF	05	C1 01	93	F9

C   Multiplexer debug command

☞   SARA-G4, SARA-R4 and LARA-R6 series do not support multiplexer debug command.

These icons are used to indicate applicability to the related products:

- **LEON-G1** : LEON-G1 series
- **SARA-G3** : SARA-G3 series
- **LISA-U2** : LISA-U2 series
- **SARA-U2** : SARA-U2 series
- **TOBY-L2** : TOBY-L2 series
- **TOBY-R2** : TOBY-R2 series
- **LARA-R2** : LARA-R2 series

C.1   Debug command +UMUX

LISA-U2   **SARA-U2**   **TOBY-R2**   **LARA-R2**

The +UMUX command allows setting the multiplexer protocol's trace (debug) capabilities. For each DLC both a global and a local trace level can be set.

☞   The command is used only for testing / debugging purpose.

Type	Syntax	Response	Example
Set	AT+UMUX=<action>[,<p1>][,<p2>] [,<p3>][,<p4>][,<p5>][,<p6>][, <p7>][,<p8>][,<p9>][,<p10>]	OK	AT+UMUX=1,4,255 OK
Read	AT+UMUX?	+UMUX: <action>,<p1>,<p2>,<p3> ,<p4>,<p5>,<p6>,<p7>,<p8>,<p9> ,<p10> OK	+UMUX: 1,5,255,0,0,0,0,0,0,0,0 OK
Test	AT+UMUX=?	+UMUX: (list of supported <actions>),(list of supported <p1's>),(list of supported <p2's>),(list of supported <p3's>),(list of supported <p4's>),(list of supported <p5's>),(list of supported <p6's>),(list of supported <p7's>),(list of supported <p8's>),(list of supported <p9's>),(list of supported <p10's>) OK	+UMUX: (0,1),(0-5,11),(0-65535),,,,,,,, OK

C.1.1 Defined values

Parameter	Type	Description
<action>	Number	Operation to be performed: • 0 (factory-programmed value): MUX trace disabled • 1: MUX trace enabled
<p1>	Number	Global trace level: • 0: no global trace • 1-2: low trace load • 3: auxiliary trace (data dump) • 4: statistics trace • 5: power saving trace • 11: error detection trace All the trace capabilities for a <p1> value are included if higher values are selected.
<p2>	Number	Bitmask representing the list of the local trace capabilities over the available DLCs. The bit position corresponds to the corresponding DLC. If the trace capabilities must be activated the corresponding bit must be set to 1.
<p3>-<p10>	Number	Extended trace options (not supported) The read command always returns 0 for these parameters.

C.2 Debug command +XL1SET="muxtron:<value>"

LEON-G1　　　　**SARA-G3**

☞ Not supported by LEON-G1 "06" and previous version.

The +XL1SET command allows setting the multiplexer protocol's trace (debug) capabilities, with a configurable trace level.

☞ The command is used only for testing / debugging purpose.

☞ The multiplexer protocol debug information requires that trace capability is activated on the module; trace data must be collected on the serial interface configured as debug interface. If the trace data is filtered, keep the ASCII trace and the "mux" process traces active.

Type	Syntax	Response	Example
Set	`AT+XL1SET="muxtron:<value>"`	`OK`	`AT+XL1SET="muxtron:1"` `OK`

C.2.1 Defined values

Parameter	Type	Description
<value>	Number	Level of trace: • 1: base MUX trace (equivalent to the "muxtron" command) enabled • 2: extended MUX trace (enables the MUX frames dump) enabled

C.3 Debug with +TRACE AT command

TOBY-L2

☞ The +TRACE AT command setting for debug is not stored in the NVM, so every power cycle turns off this feature.

Type	Syntax	Response	Example
Set	`AT+TRACE=127,,"MUX=<umode>"`	`OK`	`AT+TRACE=127,,"MUX=1"` `OK`

C.3.1 Defined values

Parameter	Type	Description
`<umode>`	Number	Level of trace: • 0: MUX log disabled • 1: MUX log enabled (only basic information) • 2: MUX log enabled (full information without data dump) • 3: MUX log enabled (full information with data dump)

Related documentation

[1] u-blox AT commands manual, UBX-13002752
[2] u-blox SARA-R5 series AT commands manual, UBX-19047455
[3] u-blox SARA-R4 series AT commands manual, UBX-17003787
[4] u-blox LARA-R6 series AT commands manual, UBX-21064719
[5] 3GPP TS 27.010 3rd Generation Partnership Project; Technical Specification Group Terminals; Terminal Equipment to User Equipment (TE – UE) multiplexer protocol (Release 1999)

☞ For regular updates to u-blox documentation and to receive product change notifications, register on our homepage (www.u-blox.com).

Revision history

Revision	Date	Name	Comments
0	22-May-2011	lpah	Initial release
1	25-Nov-2011	lpah	Extended to include LISA-U2 series. Added section 4.2.
2	28-Mar-2012	mben	Extended "muxtron" command description Added SAP channel for LISA-U200-01x / LISA-U230-01x and further versions
3	19-Jul-2012	mben	Improved the timers and retransmission mechanism
4	22-Feb-2013	mben / acub	Some improvements. Added description for CDMA modules Last revision with docu number WLS-CS-11002
A	29-May-2013	mben	Extended to include SARA-G300 / SARA-G310 series
R07	16-Jun-2014	mben	Extended to include SARA-G340 / SARA-U2 series
R08	15-Apr-2015	mben	Extended the applicability to TOBY-L2 except for TOBY-L200-00S / TOBY-L210-00S
R09	08-Mar-2016	mben	Extended UI frames handling description
R10	04-Jul-2017	mben	Extended the document applicability to TOBY-R2 / LARA-R2 series
R11	19-Jun-2020	alos / asci	Some improvements to Multiplexer close-down procedure and to TOBY-L2 seriers Multiplexer start-up procedure. AddedTOBY-L2 multiplexer debug command by means of +TRACE AT command. Obsolete FW75 product removed.
R12	26-Oct-2020	mben / fvid	Extended document applicability to SARA-R5 and SARA-G4 series.
R13	20-May-2022	mmaz / dtro	Extended document applicability to SARA-R4 and LARA-R6 series
R14	28-Sep-2022	fdil	Added note for SARA-R42 "01B" product versions

Contact

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