Terminal I/O Profile
Client Implementation Guide

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APPLICABILITY TABLE

PRODUCTS

- BLUEMOD+SR
- BLUEMOD+S
- BLUEMOD+S42

CONTENTS

1. INTRODUCTION

1.1. Scope

This document describes the Terminal I/O client implementation.

1.2. Audience

This document is intended for Telit customers about to implement the Terminal I/O profile in their application.

1.3. Contact Information, Support

For general contact, technical support services, technical questions and report documentation errors contact Telit Technical Support at:

- TS-SRD@telit.com

Alternatively, use:

http://www.telit.com/support

For detailed information about where you can buy the Telit modules or for recommendations on accessories and components visit:

http://www.telit.com

Our aim is to make this guide as helpful as possible. Keep us informed of your comments and suggestions for improvements.

Telit appreciates feedback from the users of our information.

1.4.   Text Conventions

Danger – This information MUST be followed or catastrophic equipment failure or bodily injury may occur.

Caution or Warning – Alerts the user to important points about integrating the module, if these points are not followed, the module and end user equipment may fail or malfunction.

Tip or Information – Provides advice and suggestions that may be useful when integrating the module.

All dates are in ISO 8601 format, i.e. YYYY-MM-DD.

1.5. Related Documents

The *Terminal I/O Service Specification [3]* specifies the Terminal I/O Service and its characteristics.

The *Terminal I/O Profile Specification [2]* specifies the Terminal /IO Profile including server operating modes, server and client role requirements and connection, configuration and data exchange procedures.

- [1] Bluetooth SIG, „GENERIC ATTRIBUTE PROFILE (GATT)," 2013. [Online] Available: https://developer.bluetooth.org/TechnologyOverview/Pages/GATT.aspx
- [2] Terminal I/O Profile Specification
- [3] Terminal I/O Service Specification

2. GENERALS

Terminal I/O is a proprietary Bluetooth Low Energy GATT profile for bidirectional serial data communication and GPIO status information exchange developed by Telit.

Bluetooth Low Energy GATT communication is generally carried out between a server ("peripheral") and a client ("central").

With Terminal I/O, the server role is typically implemented by a Telit embedded module (e.g. BlueMod+SR, BlueMod+S etc.) meanwhile the client role - if not taken over by an embedded module as well - is implemented on a smart device.

While the Bluetooth Low Energy GATT functionality is regularly implemented within the smart device's operating system / Bluetooth protocol stack, the Terminal I/O client implementation must be provided by the application developer.

For App development under **Apple iOS®** and **Google Android®** Telit provides ready-to-use sample code of complete Terminal I/O client implementations including sample apps. Please contact Telit for further details.

3. TERMINAL I/O PROFILE OVERVIEW

3.1. Generic Attribute Profile (GATT)

A Bluetooth Low Energy connection always consists of a GATT server and a GATT client. The GATT server stores data values, which are hierarchically structured in services and characteristics (see figure below), while the GATT client can read and write these values and can be notified by the server on value changes. Each Characteristic has its own properties and can have an optional Client Characteristic Configuration, which allows configuration of the characteristic (e.g. enable notifications).

A short introduction to GATT is given in the document *"GENERIC ATTRIBUTE PROFILE (GATT)" from Bluetooth SIG [1]*.

Terminal I/O is a proprietary Bluetooth Low Energy GATT profile for bidirectional serial data communication and GPIO status information exchange developed by Telit.
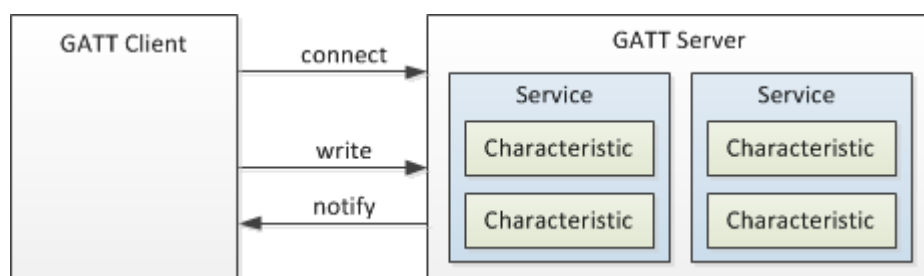

Figure 1: Hierarchical structure of GATT

3.2. GATT Structure of Terminal I/O Profile

The figure below shows the GATT structure of Terminal I/O (optional elements grayed out) defined in the *Terminal I/O Profile Specification [2]*.
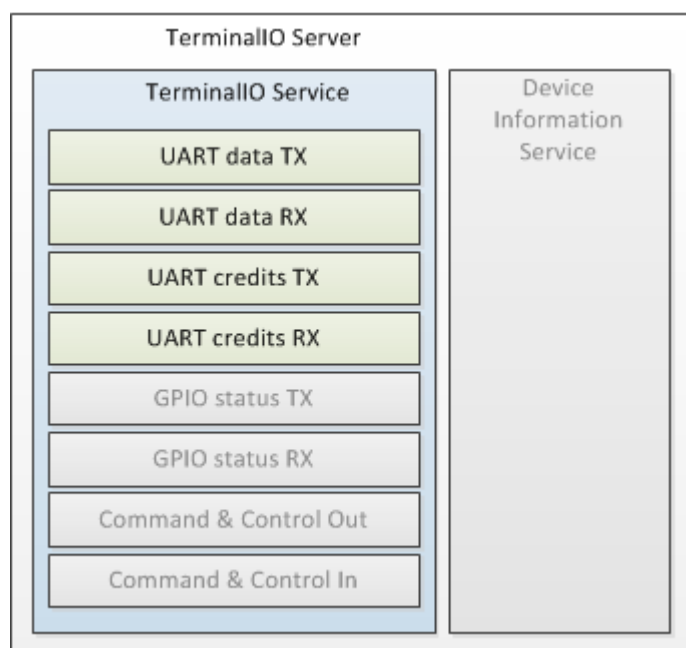
Figure 2: GATT structure of Terminal I/O Server

The UART data RX/TX characteristics are used for serial data exchange (see 7.2, 7.3).

The UART credits RX/TX characteristics are used for serial data flow control (see 7.4, 7.5).

The (optional) GPIO status RX/TX characteristics are used for transmission of GPIO status information.

The (optional) Command & Control In/Out characteristics are used for command exchange.

In the following chapters, only the mandatory characteristics (UART data, UART credits) will be discussed.

4. TERMINAL I/O CONNECTION SETUP

The figure below shows the Terminal I/O connection setup procedure.

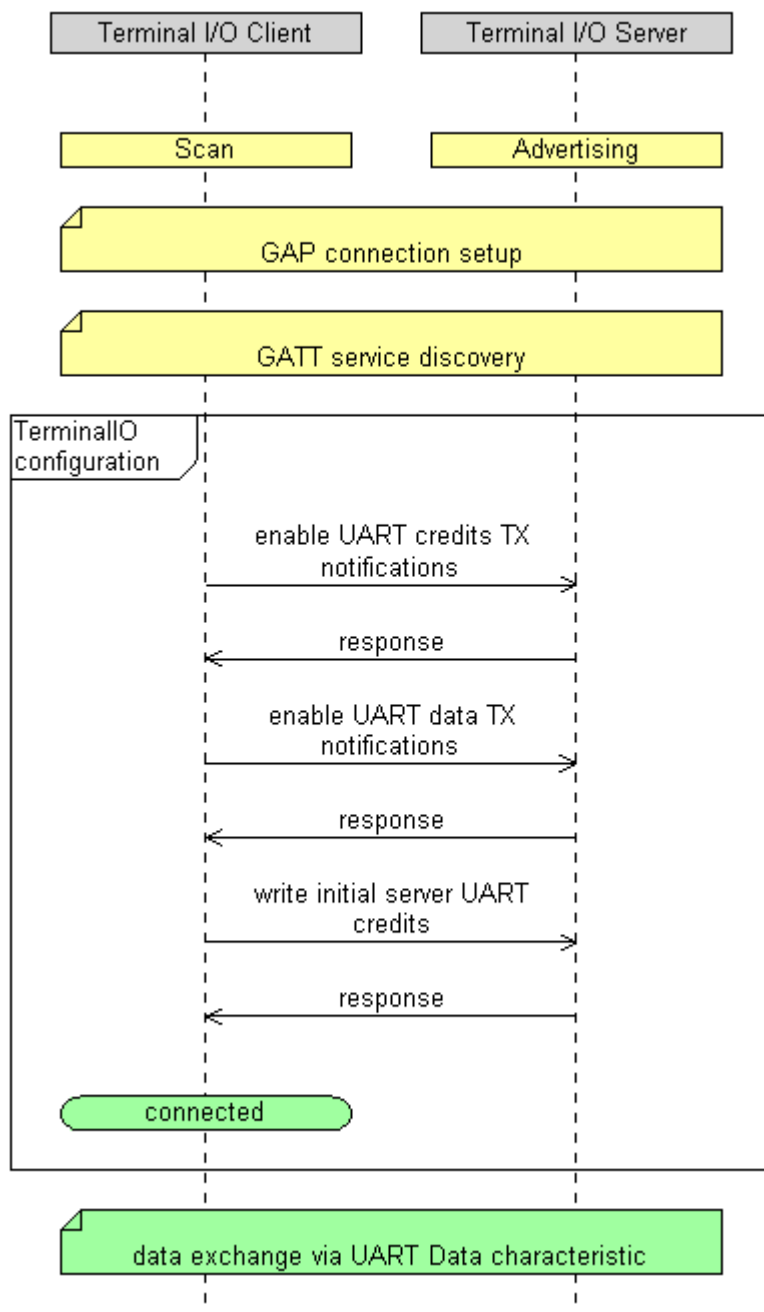*Figure 3: Terminal I/O connection setup*

In detail, the Terminal I/O connection setup consists of the following steps:

- The Terminal I/O client scans for Bluetooth Low Energy devices advertising the Terminal I/O service.
- The Terminal I/O client establishes a Bluetooth Low Energy GATT connection to a detected Terminal I/O server.
- The Terminal I/O client performs a service discovery on the Terminal I/O server.
- For the retrieved Terminal I/O service, the Terminal I/O client performs a characteristics discovery.
- The Terminal I/O client subscribes to indications of the UART credits TX characteristic (see 7.4).
- The Terminal I/O client subscribes to notifications of the UART data TX characteristic (see 7.2).
- The Terminal I/O client transmits initial UART credits to the server (see 7.5).
- Once the Terminal I/O client has received the response for the transmitted UART credits, the Terminal I/O connection is considered established and indications for the UART credits TX characteristic and notifications for the UART data characteristic shall be expected at any time.

The order of the connection setup sequence is mandatory. Especially, the subscription to the UART credits TX characteristic has to be completed **before** subscribing to the UART data TX characteristic.

It depends on the number of UART credits granted by the Terminal I/O server whether the client may write UART data to the server (see 5.2).

5. TERMINAL I/O UART DATA EXCHANGE

5.1. Receiving UART Data

The Terminal I/O server uses the UART data TX characteristic to send UART data to the Terminal I/O client via notifications.

In order to receive UART data, the Terminal I/O client has to entitle the Terminal I/O server to send data by granting UART credits via writing the number of credits to be granted to the UART credits RX characteristic (see 7.5).

1 UART credit refers to 1 UART data notification regardless of how many bytes (1 - 20) it may contain.

It is the Terminal I/O client's responsibility to grant an appropriate number of UART credits in order to ensure a smooth data flow and to avoid unnecessary data traffic on the UART credits RX characteristic.

5.2. Sending UART Data

The Terminal I/O client uses the UART data RX characteristic to send UART data to the Terminal I/O server.

UART data are sent by writing 1 - 20 bytes to the characteristic's value without response (see 7.3).

The Terminal I/O client shall send UART data only when UART credits granted by the Terminal I/O server (peripheral) are available.

1 UART credit refers to 1 UART data notification regardless of how many bytes (1 - 20) it may contain.

The Terminal I/O client receives a specific number of UART credits from the Terminal I/O server via indications on the UART credits TX characteristic (see 7.4).

It is the Terminal I/O client's responsibility to track the number of UART credits granted by the server (peripheral) by adding the number of received credits to a credit counter and decrementing the credit counter for each UART data packet written to the server. Once the credit counter reaches 0, the Terminal I/O client shall not send any UART data until having received additional UART credits from the server.

6. TERMINAL I/O BONDING AND SECURITY

For Terminal I/O connections, security requirements are determined by the Terminal I/O server (peripheral).

The Terminal I/O client performs the connection setup described in chapter 4. If the Terminal I/O server is configured to require a secure link, an appropriate authentication will be requested from the client during the subscription to the UART credits TX indications.

The client side of the bonding procedure will be carried out by the operating system's Bluetooth protocol stack.

After successfully finishing the bonding procedure, the Terminal I/O client shall proceed with the connection setup as described in chapter 4.

7. TERMINAL I/O GATT STRUCTURE IN DETAIL

7.1. Terminal I/O Service

UUID: 0xFEFB

This is the Terminal I/O GATT service containing all Terminal I/O characteristics.

7.1.1. Terminal I/O Manufacturer Specific Advertisement Data

The Terminal I/O server advertisements contain the following manufacturer specific data:

Figure 4: Terminal I/O manufacturer specific data

BYTE	ID	DESCRIPTION	VALUE
0	(1)	Length of manufacturer data	0x8
6	(2)	Advertising compatibility version	0x01
7	(3)	Terminal I/O server operation mode	see Table 2
8	(4)	Connection requested	0x01=true; 0x00=false

Table 1: Terminal I/O manufacturer specific data

VALUE	OPERATING MODE
0x00	Bonding only
0x01	Functional
0x10	Bondable and functional

Table 2: Terminal I/O operating mode values

7.2. UART Data TX Characteristics

UUID: 00000002-0000-1000-8000-008025000000

Type: uint8 array (20 bytes)

Properties: Notify

The Terminal I/O client uses the UART Data TX characteristic to receive UART data from the server (peripheral) via notifications.

7.3.   UART Data RX Characteristics

UUID: 00000001-0000-1000-8000-008025000000

Type: uint8 array (20 bytes)

Properties: Write without response

The Terminal I/O client uses the UART Data RX characteristic to write UART data to the server (peripheral).

7.4.   UART Credits TX Characteristics

UUID: 00000004-0000-1000-8000-008025000000

Type: uint8 (1 byte)

Properties: Indicate

The Terminal I/O client uses the UART Credits TX characteristic to receive UART credits (0 - 255) from the server (peripheral) via indications.

7.5.   UART Credits RX Characteristics

UUID: 00000003-0000-1000-8000-008025000000

Type: uint8 (1 byte)

Properties: Write

The Terminal I/O client uses the UART Credits RX characteristic to grant UART credits (0 - 255) to the server (peripheral).

8. TERMINAL I/O V2.0 VERSUS LEGACY V1.0

Compared with Terminal I/O v1.0, the v2.0 introduces several enhancements.

8.1. Credit Based Flow Control Mechanism

In general, GATT provides two mechanisms for over the air data exchange: exchange data "with response" or "without response".

The mechanism "with response" allows a reliable data exchange since the sender of the data receives a response for every data packet send to the remote device as soon as the data is received and processed by the remote device. This allows all sorts of error signaling and ensures that the receiving device can keep up with the data received (e.g. can forward it via UART that might have a slow baud rate or flow control mechanisms). The backdrop of this "with response" mechanism is that the sender of the data has to wait for a response after sending data before the next data can be send (single window operation), thus this mechanism does not allow high data throughput.

The mechanism "without response" allows the sending device to continuously sent data without having to wait for responses but provides no mechanism to prevent the sender from overrun the receiving device (e.g. forward data via UART is delayed due to a slow baud rate or flow control mechanisms) so the backdrop of the "without response" mechanism is that the data exchange is not reliable under non optimal conditions.

Terminal I/O v2.0 introduces a "credit based flow control" mechanism that combines the advantages of both of this mechanisms by allowing the data to be exchanged with the fast "without response" mechanism while providing an additional signaling channel for the reliable exchange of flow control information with the "with response" mechanism.

Due to this, Terminal I/O v2.0 allows fast **and** reliable data exchange while the legacy Terminal I/O v1.0 allowed only fast **or** reliable data exchange.

8.2. Uni-directional GATT Characteristics

Any data exchange via GATT is based on "characteristics" that may signal that they can receive, send or bidirectional exchange data.

Terminal I/O v1.0 was based on complex bidirectional characteristics but while Bluetooth low energy support became more popular in mobile devices, it turned out that such solution became not common and several popular mobile platforms had their difficulties with handling such complex bidirectional nature.

Due to this, Terminal I/O v2.0 now uses separate characteristics for each data exchange direction. This simplifies the profile implementation since every characteristic has a simple, clear functionality.

8.3. Unified UUID Definition

The Terminal I/O v1.0 service definition was completely based on 128bit UUIDs did not have any relation to each other. Such service definition requires that a remote device must handle each UUID completely separate what increases complexity and resource requirements.

Due to that Telit applied and received a unique and officially assigned 16bit UUID for the Terminal I/O profile from the Bluetooth SIG that is now used to identify the Terminal I/O v2.0 service. Additionally Telit assigned an own 128bit "base UUID" and ensured that all 128bit UUIDs used in the Terminal I/O v2.0 service are based on that base UUID what can simplify the profile implementation and reduce the resource requirements.

8.4. Defined Connected State for Profile Level Connection

Since the Terminal I/O profile is GATT based, but the GATT layer might shared with several other GATT based profiles on a given mobile platform, a Terminal I/O v1.0 implementation in such platform had their difficulties when it came to determine when exactly a Terminal I/O profile level connection is established and data exchange can be started.

Due to this, Terminal I/O v2.0 now defines the exact procedure how to signal on Terminal I/O profile level when an implementation can expect to receive and is allowed to send its first data.

8.5. Optional Enforcing of Secure and Encrypted Data Exchange

Certain use cases require that data is only exchanged encrypted between trusted devices that are re-authenticated for each new connection. Bluetooth low energy provides mechanisms to enforce such requirements but Terminal I/O v1.0 did not clearly specify how those security mechanisms are to be enforced.

Terminal I/O v2.0 clearly defines how to enforce security if required and ensures that every connection is authenticated so only encrypted data is exchanged in such cases.

8.6. Reduction of Required Advertisement Data

Terminal I/O defines information that must be included in the advertisement data to signal that a device can receive connections on Terminal I/O profile level. Since advertisement data can only have a defined limited size that might have to be shared with other information, Telit applied and received a unique and officially assigned 16bit UUID for the Terminal I/O profile from the Bluetooth SIG that replaces the proprietary 128Bit UUID that was previously used for Terminal I/O v1.0.

Due to this, additional device information can be included in the advertisement data of Terminal I/O v2.0 capable devices and the recognition and handling of such device is simplified for each implementation on a mobile platform that have to initiate a connection.

9.   GLOSSARY AND ACRONYMS

	Description
TTSC	Telit Technical Support Centre
USB	Universal Serial Bus
DTE	Data Terminal Equipment
UART	Universal Asynchronous Receiver Transmitter
I/O	Input Output
GPIO	General Purpose Input Output
GAP	Generic Access Profile
GATT	Generic Attribute Profile
UUID	Universal Unique Identifier

10. DOCUMENT HISTORY

Revision	Date	Changes
01	2013-09-19	First issue
02	2014-06-13	Adoption of Terminal I/O V2.1 Specification
03	2014-09-15	Introduced chapter "Terminal I/O v2.0 Versus Legacy v1.0"
04	2016-05-25	Telit cover page added
05	2016-08-18	Added BlueMod+S42 Converted to new Telit template

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