

RW BLE Wireless Power Transfer System Profile Interface Specification

Interface Specification

RW-BLE-PRF-WPTP-IS

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Revision History

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1 Overview

1.1 Document Overview

This document describes the non-standard interface of the RivieraWaves (RW) Bluetooth Low Energy (BLE) Wireless Power Transfer System Profile (WPTP) implementation. Throughout this document, the interface messages will be referred to as API messages for the profile block(s).

Their description will include their usage and reason for implementation to provide the user and developer a better understanding, to assist in the API in a full profile compliant higher application.

1.2 Introduction to Wireless Power Transfer System

This document describes the BLE profile implementation to support flexibly coupled wireless power transfer (WPT) systems. These systems are used for charging mobile devices. The stationary device usually have a mains connection and serve as power source called in this document the **Power Transmitting Unit (PTU)**. The mobile device is usually a recipient of the charge power and is called **Power Receiving Unit (PRU)**. The Profile provides a communication protocol to ensure interoperability.

The Alliance for Wireless Power (A4WP) WPT system was standardized to transfers power from a single Power Transmitter Unit (PTU) to one or more Power Receiver Units (PRU's.). Up to eight devices can be powered from a single PTU depending on transmitter and receiver geometry and power levels. The Bluetooth Low Energy (BLE) link in the A4WP WPT system is intended for control of power levels, identification of valid loads and protection of non-compliant devices.

Figure 1 below show one possibly configuration of a WPT system consisting if a single PTU and 5 PTUs, each of which is being actively charged and also maintaining an active BT LE link.

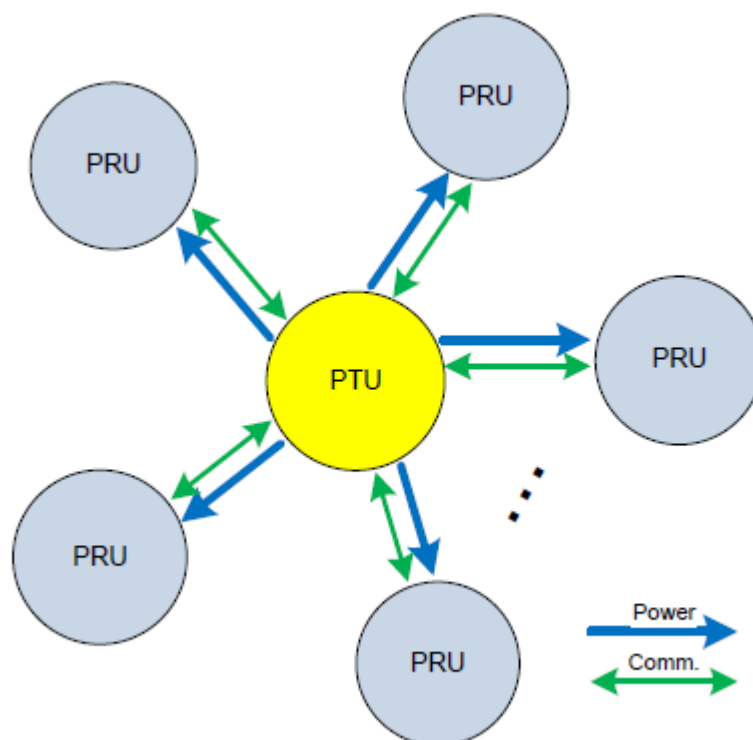


Figure 1 - A4WP WPTP Profile PTU / PRU Network (with 5 PRUs connected)

1.3 BLE Wireless Power Transfer System Profile Overview

The WPTP enables a collector device to connect and interact with Wireless Power Transfer System Device sharing its sensor's data.

This service has been implemented as a profile. Within this profile, two roles can be supported: Server role (WPTS) and Client role (WPTC). The Client must support the GAP Central Role and the Server must support the GAP Peripheral role. The profile requires a connection to be established between the two devices for its functionality.

The Alliance for Wireless Power (A4WP) documents present different use cases for this profile, their GATT, GAP and security, mandatory and optional requirements. The Wireless Power Transfer System Profile specifications have been adopted by the Rezenze Alliance for Wireless Power on November 5th 2014 ([1]). Related Test Specifications have been created and are referenced in ([2]).

The profile is implemented in the RW-BLE software stack as two tasks, one for each role. Each task has an API determined after the study of the profile specifications and test specifications, and it is considered to be minimalistic and designed for a future application which would combine the profile functionality with the device connectivity and security procedures.

The main focus of the Profile APIs is to abstract the user from the GATT interface in the system. It is expected that the final application will use the existing GAP interface to establish and manage device discovery and connections.

2 Wireless Power Transfer System Characteristics

The Wireless Power Transfer System (WPTS) supports the set of characteristics shown below in the Table 1. The details of these characteristics are detailed in the following sub-sections. The values for most of these characteristic are assumed to be held in the Application (not present in the ATT-DB). However, the PRU_STATIC characteristic value and the CCC for the Alert Characteristic and maintained in the ATT-DB.

Characteristic Name	Data Direction	Characteristic Enumerator	Properties	Description
PRU Static Parameter	PTU<-PRU	WPTS_IDX_PRU_STATIC_CHAR	Read	Contains static characteristics of the PRU. PTU initiates read when device connects (can be more)
PTU Static Parameter	PTU->PRU	WPTS_IDX_PTU_STATIC_CHAR	Write/Read	Contains static characteristics of the PTU. PTU initiates write when new device connects.
PRU Dynamic Parameter	PTU<-PRU	WPTS_IDX_PRU_DYNAMIC_CHAR	Read	Contains dynamic characteristics of the PRU. PTU initiates read from each device.
PRU Control	PTU->PRU	WPTS_IDX_PRU_CONTROL_CHAR	Write/Read	PRU ON/OFF control. PTU initiates write when command needs to be sent
PRU Alert	PTU<-PRU	WPTS_IDX_PRU_ALERT_CHAR	Read/Notify/Indicate	Notifies the PTU of overvoltage, over-current, over-temperature and self-protection conditions of the PRU.

Table 1 – Enumerated list of WPTS Characteristics - *enum wpts_att_list*

2.1.1 WPTS_IDX_PTU_STATIC_CHAR

This characteristic contains the static information about the PTU. This information is written by the PTU to the characteristic in the PRU, after connection. It contains the following elements, each of which is a single octet.

- ptu power
- maximum source impedance
- maximum load resistance
- class
- hardware revision
- firmware revision
- protocol revision
- number of devices supported

The detailed encoding of these fields in the characteristics is described in A4WP specification [1].

2.1.2 WPTS_IDX_PRU_STATIC_CHAR

This characteristic contains the static information about the PRU. This information can only be read by the PTU, and is normally read after connection is established. It contains the following elements:

- category
- pru information
- hardware revision
- firmware revision



- protocol revision
- prect_max
- vrect_min_static
- vrect_high_static
- vrect_set
- delta_r1_value

2.1.3 WPTS_IDX_PRU_DYNAMIC_CHAR

This characteristic contains the dynamic information about the PRU, it contains measurement data with values that change during the charging process on the PRU. This information can only be read by the PTU, and is normally read after connection is established and periodically after that (max 250ms interval). It contains the following elements:

- Optional fields validity
- vrect
- irect
- vout
- lout
- Temperature
- Vrect_min_dyn
- Vrect_high_dyn
- Vrect_set_dyn
- Pru alert
- Tester command

The detailed encoding of these fields in the characteristics is described in A4WP specification [1].

2.1.4 WPTS_IDX_PRU_CONTROL_CHAR

This characteristic is used to initiate PTU commands in the PRU. The PTU must write to this characteristic whenever it requires a state change in the PRU. This characteristic contains the following fields :

- Enables
- Permission
- Time set

The detailed encoding of these fields in the characteristics is described in A4WP specification [1].

2.1.5 WPTS_IDX_PRU_ALERT_CHAR

The PRU Alert characteristic enables a PTU to receive notifications/indications to inform the PTU of Over Voltage, Over Current, Over Temperature, Mode Transition etc.

It contains single octet containing a bit-field for the alerts, and an optional Bluetooth device address. The address field is only included if the mode-transition of the Alert field is non-zero.

The detailed encoding of the alert fields of this characteristic is described in A4WP specification [1].

A Client Configuration Characteristic (CCC) descriptor is associated with this characteristic, and it used to control the generation of Notifications and Indications of the value changes in this characteristic.

Descriptor Name	Requirements	Properties
PRU Alert Client Char Configuration Descr	Mandatory as notify/indication to be supported.	Read/Write

Table 2 – Alert CCC Descriptor



3 WPTP Service Discovery

The A4WP profile differs from other Bluetooth Low Energy profiles, in the manner service and characteristic discovery is performed. The GATT Service Discovery and Characteristic Discovery procedures are not explicitly required for this profile. Instead the Primary Service Handle for the WPT profile is obtained from the Advertising Data obtained by the PTU (from the Advertising data) during device discovery.

The A4WP profile specification dictates a specific order of the Characteristic definition, with each characteristic declaration, characteristic value and characteristic descriptor having a given handle offset relative to the A4WP primary service handle.

GATT_PRIMARY_SERVICE_UUID	Start of WPT Service	Primary Service Handle
GATT_CHARACTERISTIC_UUID	PRU Control Characteristic declaration	Primary Service Handle + 1
WPT_CHARGING_PRU_CONTROL_UUID	PRU Control Characteristic value	Primary Service Handle + 2
GATT_CHARACTERISTIC_UUID	PTU Static Parameter Characteristic declaration	Primary Service Handle + 3
WPT_CHARGING_PTU_STATIC_UUID	PTU Static Parameter Characteristic value	Primary Service Handle + 4
GATT_CHARACTERISTIC_UUID	PRU Alert Parameter Characteristic declaration	Primary Service Handle + 5
WPT_CHARGING_PRU_ALERT_UUID	PRU Alert Parameter Characteristic value	Primary Service Handle + 6
CCC_UUID	Client Characteristic Configuration UUID for PRU Alert	Primary Service Handle + 7
GATT_CHARACTERISTIC_UUID	PRU Static Parameter Characteristic declaration	Primary Service Handle + 8
WPT_CHARGING_PRU_STATIC_UUID	PRU Static Parameter Characteristic value	Primary Service Handle + 9
GATT_CHARACTERISTIC_UUID	PRU Dynamic Parameter Characteristic declaration	Primary Service Handle + 10
WPT_CHARGING_PRU_DYNAMIC_UUID	PRU Dynamic Parameter Characteristic value	Primary Service Handle + 11

Table 1 - WPTP Characteristic Declarations, Values and Handles

In this way, once the PTU receives the Primary Service handle for the WPT it can obtain all the required information about the WPT Gatt Database in the peer PRU, without the need to perform GATT Discovery. The reason for this mechanism is to shorten the time between ACL link establishment and PTU/PRU registration. A registration timer started on receipt of the first valid PRU advertisement and is stopped when the PTU writes the control characteristic to the PRU. The registration timer is 500ms and if it expires, prior to writing the control characteristic, the PTU shall terminate the connection to the PRU.



4 Common Fields of API

This section describes fields of the API primitives which are commonly used in the PTU and PRU. Most of these fields have equivalent fields in the characteristics, however the values and value ranges cannot be assumed to be the same. For example, the 'enables' field present in Control Characteristic is given as 3 separate fields on the API.

4.1 Enable_output

This value is set by the PTU in the PRU. A value of '1' allows the PRU to provide power to the load, before this it must draw less than 1.1 W. If a value is set to '0' then the PRU shall reduce its output to less than 1.1 W, within 1.1 seconds.

1 = Enable
0 = Disable

The Enable_output maps to the Bit 7 of the Enables field of the PRU Control Characteristic.

4.2 Enable_charge_indicator

This value is set by the PTU in the PRU. A value of '1' allows the PRU to indicate that charging may occur, otherwise set to '0'

1 = Enable
0 = Disable

The Enable_charge_indicator maps to the Bit 6 of the Enables field of the PRU Control Characteristic.

4.3 Adjust_power_command

This value is set by the PTU in the PRU. It instructs the PRU to adjust its power draw to less than a specific percentage of the maximum average power of the rectifier (Prect_Max). The value contained in this field maps to the Bits 4 & 5 of the Enables field of the PRU Control Characteristic

Value	Description	#define
0x00	Maximum Power	WPT_PRU_CONTROL_ADJUST_POWER_MAXIMUM
0x01	66% * P _{RECT_MAX}	WPT_PRU_CONTROL_ADJUST_POWER_0_66_MAX
0x02	33% * P _{RECT_MAX}	WPT_PRU_CONTROL_ADJUST_POWER_0_33_MAX
0x03	2.5W	WPT_PRU_CONTROL_ENABLE_POWER_2_5_WATT
Other	UNDEFINED	

If the PRU successfully adjusts its power it will provide a response to the PTU via the Adjust Power Response bit field of the Alert field of the PRU Dynamic Characteristic (which is read by the PTU at least every 250ms).

PTUs shall not send this command to PRUs that do not support the Adjust power command (determined by reading the information field of the PRU Static Characteristic, and contained in WPTC_RD_PRU_STATIC_RSP Event). A PTU shall not send more than one Adjust power command to a PRU in a two second period.

4.4 Permission

This value is set by the PTU in the PRU. This field is used to provide the PRU with information from the PTU about what is it allowed.

Value	Description	#define
0x00	Permitted without reason	WPT_PRU_CONTROL_PERMITTED_WITHOUT_REASON
0x01	Permitted with waiting time due to limited available power	WPT_PRU_CONTROL_PERMITTED_WITH_WAIT



0x80	Denied due to cross connection.	WPT_PRU_CONTROL_DENIED_DUE_CROSS_CONNECTION
0x81	Denied due to limited available power	WPT_PRU_CONTROL_DENIED_DUE_LIMITED_POWER
0x82	Denied due to limited PTU Number of Devices	WPT_PRU_CONTROL_DENIED_DUE_LIMITED_NUMBER_OF_DEVICES
0x83	Denied due to limited PTU Class support	WPT_PRU_CONTROL_DENIED_DUE_LIMITED_CLASS_SUPPORT
0x84	Denied due to high temperature at PTU	WPT_PRU_CONTROL_DENIED_DUE_TO_HIGH_TEMPERATURE
Other	RESERVED	

4.5 Time_set

This value can be set by the PTU in the PRU. It is used for cross connection checks and indicates the time in which the PRU is to create a valid load variation.

Value	Description	#define
0x00	Do not perform time set	WPT_PRU_CONTROL_SET_TIME_DO_NOT_SET
0x01	10ms	WPT_PRU_CONTROL_SET_TIME_10_MS
0x02	20ms.	WPT_PRU_CONTROL_SET_TIME_20_MS
0x03	30ms	WPT_PRU_CONTROL_SET_TIME_30_MS
0x04	40ms	WPT_PRU_CONTROL_SET_TIME_40_MS
0x05	50ms	WPT_PRU_CONTROL_SET_TIME_50_MS
0x06	60ms	WPT_PRU_CONTROL_SET_TIME_60_MS
0x07	70ms	WPT_PRU_CONTROL_SET_TIME_70_MS
0x08	80ms	WPT_PRU_CONTROL_SET_TIME_80_MS
Other	RESERVED	

The Time Set value shall be set to zero if the PRU does not support Time Set (determined from the information field of the PRU Static Characteristic, and contained in WPTC_RD_PRU_STATIC_RSP Event). For the PRU that supports Time Set, the PTU shall use a non-zero value at least once before using a Time Set value of zero.

4.6 ptu_power

This field indicates the power value of the PTU. The mapping of values in this field to actual power in Watts is given in Annex 1. The maximum value is 139 which is equivalent to a power of 61 watts.

4.7 ptu_max_source_impedance

This field is only relevant if its presence has been indicated in the “optional_fields_validity” field in the same API message. The value of this field indicates the maximum output impedance of the PA/filter in the PTU. The mapping between the values contained in this field and the PTUs maximum source impedance are given in Annex 1. The maximum value is 18 which corresponds to a source impedance of 375 ohms.



4.8 ptu_max_load_resistance

This field is only relevant if its presence has been indicated in the “optional_fields_validity” field in the same API message. The value of this field indicates the maximum PTU load resistance as seen at the input to the PTU resonator. The mapping between the values contained in this field and the PTUs maximum load resistance is given in Annex 1. The maximum value is 10 corresponding to a load resistance of 55 ohms.

4.9 ptu_class

This field defines the class to which the PTU is assigned

Value	Class	#define
0x00	Class 1	WPTP_PTU_CLASS_1
0x01	Class 2	WPTP_PTU_CLASS_2
0x02	Class 3	WPTP_PTU_CLASS_3
0x03	Class 4	WPTP_PTU_CLASS_4
0x04	Class 5	WPTP_PTU_CLASS_5
Other	RESERVED	

4.10 Hardware_rev

The current PTU or PRU hardware revision number. The numbering system for this field is vendor proprietary.

4.11 Firmware_rev

The current PTU or PRU firmware revision number. The numbering system for this field is vendor proprietary.

4.12 Protocol_rev

This field maps to the highest A4WP specification revision to which the PTU or PRU is certified. The following numbers are used :

Value	A4WP Revision
0	BSS v1.2.1
1	BSS v1.3

4.13 pru_category

The PRU is assigned a category number which indicates the maximum power it can draw from the PTU. (note : Some confusion here in the A4WP spec where Category 6&7 are also sometimes mentioned – but not defined as valid values in the GATT characteristic).

Value	Category	Power	#define
0x00	UNDEFINED	N/A	WPTS_CATEGORY_UNDEFINED
0x01	Category 1	TBD	WPTS_CATEGORY_1
0x02	Category 2	3.5w	WPTS_CATEGORY_2
0x03	Category 3	6.5w	WPTS_CATEGORY_3
0x04	Category 4	13w	WPTS_CATEGORY_4
0x05	Category 5	25w	WPTS_CATEGORY_5

Other	UNDEFINED		
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4.14 pru_information

This field indicates the optional capabilities supported in the PRU. It is interpreted as a bit-field as shown below. The PTU receiving this information should not invoke a command on a feature which not supported by the peer PRU.

Bit	Description	Values
7	NFC Receiver Supported	'1' NFC supported, Otherwise bit is set to '0'
6	Separate BTLE radio	'1' the BTLE radio is a separate entity in the PRU.
5	Power Control Algorithm	'1' if the preference is for Max System. Otherwise, this bit is set to '0' for VRECT_MIN_ERROR.
4	Adjust power capability	set to '1' if the PRU supports the Adjust power capability.
3	Charge Complete Connected	set to '1' if the PRU supports Charge Complete Connected Mode
2	PTU Test Mode	set to '1' if the PRU is capable of operating as a PRU simulator and is requesting that the PTU enter PTU Test Mode.
1,0	UNDEFINED	

4.15 prect_max

This is an 8 bit value, indicating the maximum rectifier power of the PRU. Values are given in increments of 100mw (e.g a value of 48 indicates a max rectifier power of 4.8w)

4.16 vrect_min_static

A 16bit value indicating minimum initial voltage of the rectifier, given in mV.

4.17 vrect_high_static

A 16bit value indicating the highest initial voltage of the rectifier, given in mV.

4.18 Vrect_set

The voltage currently set for the rectifier, given in mV. This values has to be between the min/max values of vrect_min_static and vrect_high_static.

4.19 ptu_num_devices_supported

Total number of devices supported by the PTU. Max value is 8.

4.20 Delta_r1_value

This is a 16bit value which indicate the change in the measured resistance of a PTU resonator when a PRU, with an open-circuit PRU resonator, is placed in the center of the charge area of the PTU resonator. The value is given in increments of 0.01 ohms. This is an optional component and is only valid if its presence is indicated by "delta_r1_value_present" = 1.

4.21 Delta_r1_value_present

This octet indicates if the value contained in the "delta_r1_value" field is valid. If the delta_r1_value field is valid if this field contains a value = '1'



4.22 Vrect

This is a 16bit value for the voltage at the PRU rectifier output. Value is given in mV. . This corresponds to the 'Vrect' field of the PRU Dynamic Characteristic

4.23 Irect

This is a 16bit value for the current at the PRU rectifier output. Value is given in mA. . This corresponds to the 'Irect' field of the PRU Dynamic Characteristic

4.24 Vout

This is a 16bit value for Voltage at Charge Battery Port of the PRU. Value is given in mV. This corresponds to the optional 'Vout' field of the PRU Dynamic Characteristic. The validity of its value in determined by the 'optional_value_field' of the API message.

4.25 Iout

This is a 16bit value for current at Charge Battery Port of the PRU. Value is given in mA. This corresponds to the optional 'Iout' field of the PRU Dynamic Characteristic. The validity of its value in determined by the 'optional_value_field' of the API message.

4.26 Temperature

This is an 8bit value indicating the temperature for the PRU. The minimum temperature is -40C, which is indicated by a value of zero. The temperature is given in one degree increments, thus the maximum temperature value is +215c. This corresponds to the optional 'temperature' field of the PRU Dynamic Characteristic. The validity of its value in determined by the 'optional_value_field' of the API message.

4.27 Vrect_min_dyn

A 16bit value indicating minimum dynamic voltage of the rectifier, given in mV. This corresponds to the optional 'Vrect_min_dyn' field of the PRU Dynamic Characteristic. The validity of its value in determined by the 'optional_value_field' of the API message.

4.28 Vrect_high_dyn

The current dynamic maximum rectifier voltage desired , given in mV. This corresponds to the optional 'Vrect_high_dyn' field of the PRU Dynamic Characteristic. The validity of its value in determined by the 'optional_value_field' of the API message.

4.29 Vrect_set_dyn

A 16bit value indicating the desired voltage for the rectifier, given in mV. This values has to be between the min/max values of Vrect_min_dyn and Vrect_high_dyn. This corresponds to the optional 'Vrect_set_dyn' field of the PRU Dynamic Characteristic. The validity of its value in determined by the 'optional_value_field' of the API message.

4.30 pru_alert

This is an 8bit bit-field which is used to transfer Alert conditions from the PRU to the PTU.

Bit	Name	#define	Description
7	PRU Over-voltage	WPTP_ALERT_OVER_VOLTAGE	set to '1', indicates that VRECT at the PRU has exceeded the OVP limit
6	PRU Over-current	WPTP_ALERT_OVER_CURRENT	Set to '1', indicates that IRECT at the PRU has exceeded the PRU's current limit.
5	PRU Over-temperature	WPTP_ALERT_OVER_TEMP	This bit, when set, indicates that measured temperature at the PRU



			has exceeded the PRU's temperature.
4	PRU Self Protection	WPTP_ALERT_PRU_SELF_PROTECTION	This bit, when set, indicates that the PRU is protecting itself by reducing power to its load.
3	PRU Charge Complete	WPTP_ALERT_CHARGE_COMPLETE	This bit, when set, indicates that the PRU does not require charging.
2	PRU Wired Charger Detect	WPTP_ALERT_WIRED_CHARGER_DETECT	This bit, when set, indicates that the PRU is powered by external wired power
1	PRU Charge Port	WPTP_ALERT_PRU_CHARGE_PORT	set to '1' to indicate that the PRU charge port output is activated
0	Adjust Power Response	WPTP_ALERT_ADJUST_POWER_RESPONSE	The Adjust Power Response bit is used to indicate whether or not the PRU has limited its power draw in response to the Adjust power command. If the PRU does limit its power draw according to the PTU Adjust power command, it shall set the 'Adjust Power Response' bit to '1'

This maps to values included in both the PRU Dynamic Characteristic and the PRU Alert Characteristic. For Alert indications sent to the Application the bottom two bits of this field are not used.

4.31 Mode_Transition

This field is used to inform the PTU of a Mode Transition in the PRU. A Mode Transition set to a non-zero value indicates to the PTU the duration of the pending Mode Transition procedure

- 00 -- No Mode Transition
- 01 – 2s mode transition time limit
- 02 – 3s mode transition time limit
- 03 – 6s mode transition time limit

This field maps to the Mode_Transition bits (Bit 0-1) of the Alert Characteristic value.

4.32 Tester Command

This field is optional and shall only be used when the PTU has previously been placed in test mode during device registration:

Command Number	Description
0x00	Normal operation power control
0x01	Increase I _{TX} by one step
0x02	Decrease I _{TX} by one step
0x03	ITX_COIL current shall not be adjusted
Other Values	Reserved

5 Structures on API

This section describes the structures which are used on the API. These structures correspond to the format of the characteristic values used in the WTP profile. They are used as members of unions on the API.

5.1 PTU Static

This structure is used to transfer information about the PTU Static Information across the API. This is used when the PTU writes the PTU Static Parameters to the PRU. The 'optional_fields_validity' is used to determine if the 'ptu_max_source_impedance' and 'ptu_max_load_resistance' values are valid in this API message and should be included in the corresponding characteristic write.

In C format - *struct wptc_ptu_static* or *struct wpts_ptu_static*

Type	Parameters	Description
uint8_t	<i>optional_fields_validity</i>	Defines which fields are valid: Bit 7 = 1: Max Impedance – is valid Bit 6 = 1: Max Resistance – is valid
uint8_t	<i>ptu_power</i>	Power of PTU (see conversion table in Annex 1)
uint8_t	<i>ptu_max_source_impedance</i>	Maximum source impedance of the PTU (see conversion table in Annex 1)
uint8_t	<i>ptu_max_load_resistance</i>	Maximum load resistance of the PTU (see conversion table in Annex 1)
uint8_t	<i>ptu_class</i>	PTU class, see section 4.9 for allowed values
uint8_t	<i>hardware_rev</i>	Revision of the PTU HW
uint8_t	<i>firmware_rev</i>	Revision of the PTU SW
uint8_t	<i>protocol_rev</i>	A4WP Supported Revision., see section 4.12
uint8_t	<i>ptu_num_devices_supported</i>	Maximum Number of Devices

5.2 PRU Static

In C format - *struct wptc_pru_static* or *struct wpts_pru_static* or *struct wpts_db_cfg*

Type	Parameters	Description
uint8_t	<i>protocol_rev</i>	A4WP Supported Revision, see section 4.12
uint8_t	<i>pru_category</i>	Category of PRU, see section 4.13 for valid values.
uint8_t	<i>pru_information</i>	Capabilities of PRU (bit field). see section 4.14 for description of bit field
uint8_t	<i>hardware_rev</i>	Revision of the PRU HW
uint8_t	<i>firmware_rev</i>	Revision of the PRU SW
uint8_t	<i>prect_max</i>	PRECT_MAX of the PRU. The value is in increments of 100mW
uint16_t	<i>vrect_min_static</i>	VRECT_MIN (static, first estimate). The value is in mV.
uint16_t	<i>vrect_high_static</i>	VRECT_HIGH (static, first estimate). The value is in mV.
uint16_t	<i>vrect_set</i>	VRECT_SET. The value is in mV.
uint8_t	<i>delta_r1_value_present</i>	Indicates if the "delta_r1_value" field contains a valid value.
uint16_t	<i>delta_r1_value</i>	Delta R1 caused by PRU. The PRU may report its Delta R1, if included, in increments of 0.01 ohms.

As the 'delta_r1_value' is optional in the characteristic, the 'delta_r1_value_present' field indicates if it contains a valid value.

5.3 PRU Dynamic

This structure is used to transfer PRU Dynamic Parameters across the API.

In C format - *struct wptc_pru_dynamic* or *struct wpts_pru_dynamic*

Type	Parameters	Description
uint8_t	<i>optional_fields_validity</i>	Defines which fields of the API event contain valid values. If an optional field is not indicated as valid in the parameter, its value should be ignored.
uint16_t	<i>vrect</i>	DC voltage at the output of the rectifier. mV
uint16_t	<i>irect</i>	DC current at the output of the rectifier. mA
uint16_t	<i>vout</i>	Voltage at charge/battery port. mV (optional field)
uint16_t	<i>iout</i>	Current at charge/battery port. mA (optional field)
uint8_t	<i>temperature</i>	Temperature of PRU. Deg C from -40C (optional field)

uint16_t	vrect_min_dyn	The current dynamic minimum rectifier voltage desired. mV (optional field)
uint16_t	vrect_set_dyn	Desired VRECT (dynamic value). mV (optional field)
uint16_t	vrect_high_dyn	The current dynamic maximum rectifier voltage desired. mV (optional field)
uint8_t	pru_alert	This is a bit-field which is used to transfer Alert conditions from the PRU to the PTU. See section 4.30 for a complete description of this field and range of values allowed.
uint8_t	tester_command	PTU Test Mode Command

The 'optional_fields_validity' is a bit-field indicates which of the fields in the API message are valid. If the bit is set the corresponding field is valid.

Bit No.	Field Validity	Values
7	Vout	('1' Present, '0' Absent)
6	Iout	('1' Present, '0' Absent)
5	Temperature	('1' Present, '0' Absent)
4	Vrect_min_dyn	('1' Present, '0' Absent)
3	Vrect_set_dyn	('1' Present, '0' Absent)
2	Vrect_high_dyn	('1' Present, '0' Absent)
1	NOT USED	N/A
0	NOT USED	N/A

5.4 PRU Control

This structure is used to control the operation of the PRU.

In C format - *struct wptc_pru_control* or *struct wpts_pru_control*

Type	Parameters	Description
uint8_t	enable_pru_output	0 – PRU Turn Off, 1 – PRU Turn On
uint8_t	enable_charge_indication	0 – No Charge Indication, 1 – Charge Indication
uint8_t	adjust_power_command	Instructs the PRU to adjust its power draw to less than a specific percentage of the maximum average power of the rectifier (Prect_Max) See Section 4.3 for full description of valid range and #define for this field
uint8_t	permission	This field is used to provide the PRU with information from the PTU about what is it allowed. See section 4.4 for description of this field and values allowed.
uint8_t	time_set	Time in which PRU is to create a valid load. For range of values see section 4.5

5.5 Mode Transition

This structure is used to transfer information about alert conditions with mode transition. The 'alert' field contains a bit field which indicates alert conditions in the PRU

In C format - *struct wptc_pru_mode_transition*

Type	Parameters	Description / Values
uint8_t	alert	Alert Condition in the PRU. Only bits 7-2 of the alert field are used in this structure.
uint_8	mode_transition	0x00 --- No Mode Transition 0x01 --- 2 sec Mode Transition Time Limit 0x02 --- 3 sec Mode Transition Time Limit 0x03 --- 6 sec Mode Transition Time Limit 0x04-0xFF -- UNDEFINED
uint_8	addr[6]	A Bluetooth device address which is to be used by the PTU/PTU when they attempt to reconnect.



6 PTU API

6.1 PTU API Messages

This section overviews the PTU API messages which are provided in “wptc_task.h”. Additional details on the fields of each message can be found in section 5 of this document.

6.1.1 WPTC_ENABLE_CMD

Source: TASK_APP

Destination: TASK_WPTC

Parameters:

Type	Parameters	Description
uint8_t	operation	Operation Code, filled by the profile
uint16_t	start_hdl	The primary service handle for the WPT service. This is normally obtained from the Advertising Data during device discovery. If the value given is ‘0x00’ then it is assumed no Service Handle is available and service and characteristic discovery will be performed.
uint8	registration	This is a flag to indicate if device registration should be initiated by the PTU. When set the Profile will automatically read the PRU_Static characteristic from the peer PRU.

Response: WPTC_CMP_EVT

WPTC_VALUE_IND

Description: This API message is used for enabling the Collector role (PTU) of the WPTC. This message contains the Service Handle for the WPT profile which is obtained during device discovery. The registration flag will determine if the registration flow should begin automatically. If ‘registration = 1’, the PRUs Static Characteristic is retrieved as part of this command, and will be delivered over API using the WPTC_VALUE_IND msg.

6.1.2 WPTC_READ_CMD

Source: TASK_APP

Destination: TASK_WPTC

Parameters:

Type	Parameters	Description
uint8_t	operation	Set by profile – should not be used by Application
uint8_t	read_code	Read Code 0x01 - WPTC_RD_PRU_CONTROL 0x02 - WPTC_RD_PTU_STATIC 0x03 - WPTC_RD_PRU_STATIC 0x04 - WPTC_RD_PRU_DYNAMIC 0x05 - WPTC_RD_PRU_ALERT

Response: WPTC_CMP_EVT

WPTC_VALUE_IND

Description: This message is used to request the read characteristic information from the server (PRU). The ‘read_code’ is used to determine which characteristic value is to be read from the PRU. The response is returned on a WPTC_VALUE_IND message.



6.1.3 WPTC_WRITE_CMD

Source: TASK_APP

Destination: TASK_WPTC

Parameters:

Type	Parameters	Description
uint8_t	operation	Operation Code, filled by the profile
uint8_t	write_code	Identifies what is to be written 0x06 - WPTC_WR_PRU_CONTROL 0x07 - WPTC_WR_PTU_STATIC 0x08 - WPTC_WR_ALERT_CCC
union	value	
struct wptc_pru_control	pru_ctrl	The PRU Control Information
struct wptc_ptu_static	ptu_static	The PTU Static Characteristic Information
uint16_t	alert_ccc	CCC descriptor of the Alert Characteristic

Response: WPTC_CMP_EVT

Description :- This message is used by the PTU to write information to the PRU. The element to be written is identified by the 'write_code'. When the write is completed a WPTC_CMP_EVT will be sent to the application.

6.1.4 WPTC_VALUE_IND

Source: TASK_WPTC

Destination: TASK_APP

Parameters:

Type	Parameters	Description
uint8_t	attribute_code	The attribute whose value is reported 0x01 - WPTC_PRU_STATIC_ATT_ID 0x02 - WPTC_PTU_STATIC_ATT_ID 0x03 - WPTC_PRU_CONTROL_ATT_ID 0x04 - WPTC_PRU_DYNAMIC_ATT_ID 0x05 - WPTC_PRU_ALERT_ATT_ID 0x06 - WPTC_PRU_MODE_TRANSITION_ID 0x07 - WPTC_PRU_ALERT_CCC_ATT_ID
Union	value	
struct wptc_pru_control	pru_ctrl	The PRU Control Information
struct wptc_ptu_static	ptu_static	The PTU Static Characteristic Information
struct wptc_pru_static	pru_static	The PRU Static Characteristic Information
struct wptc_pru_dynamic	pru_dynamic	The PRU Dynamic Characteristic Information
struct wptc_pru_alert	pru_alert	A (simple) Alert from the PRU
struct wptc_pru_mode_transition	pru_mode_transition	A mode Transition indication from the Peer PRU
uint16_t	alert_ccc	CCC descriptor of the Alert Characteristic

This message is sent to the application to indicate an attribute value. This can occur as a result of a 'WPTC_READ_CMD' or can be an unsolicited indication/notification from the PRU (ie.. ALERT indication). The 'attribute_id' identifies the contents of the message.



6.1.5 WPTC_CMP_EVT

Source: TASK_WPTS

Destination: TASK_APP

Parameters:

Type	Parameters	Description
uint8_t	Operation	Operation Code
uint8_t	Status	Status

Description: The API message is used by the WPTC task to inform the APP that procedure is complete in the client profile and returns the status field indicating the outcome of the procedure.

The valid operation codes are the following :

Operation Code	VALUE
WPTC_RD_PRU_CONTROL	0x01
WPTC_RD_PTU_STATIC	0x02
WPTC_RD_PRU_STATIC	0x03
WPTC_RD_PRU_DYNAMIC	0x04
WPTC_RD_PRU_ALERT	0x05
WPTC_WR_PRU_CONTROL	0x06
WPTC_WR_PTU_STATIC	0x07
WPTC_WR_ALERT_CCC	0x08
WPTC_ENABLE	0x09

7 PRU API

7.1 Environment

This Implementation is single instance task.

This role should be activated in the application that a Wireless Power Transfer Service is required; the provided API is capable of sending Alarm notifications, indications, and exchanging control and configuration information with the Client. The profile implementation forward requests to Read and Write Characteristic information from the Collector to the Application and returns the Application responses back to Client. Please, refer to “wpts_task.h” for implementation of this API.

Within the WPTS task several states are defined as shown in Figure 2. The 3 state are: **FREE**, **IDLE**, **OP_READ** and **OP_NOTIFY**,

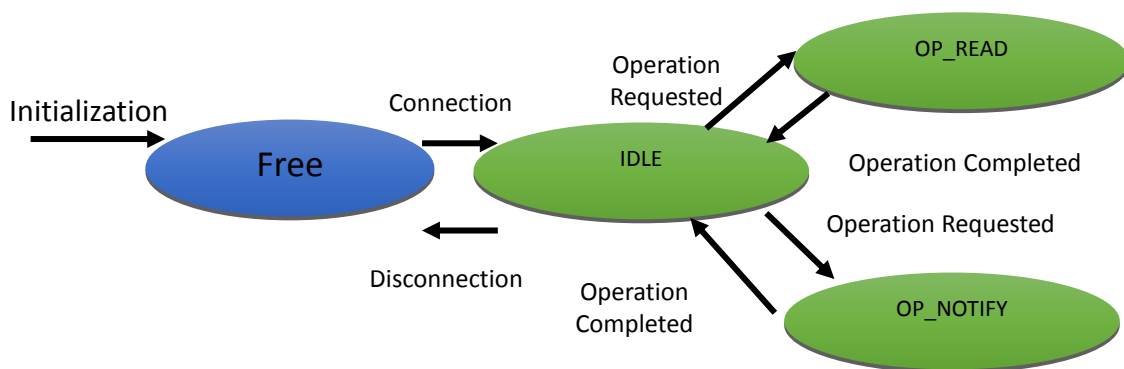


Figure 2 :- States of the WPT Server Implementation

7.2 PRU API Messages

7.2.1 Initialisation

During the initialization phase of the Wireless Power Transfer System Server, the memory for this task must be allocated using the message GAPM_PROFILE_TASK_ADD_CMD provided by the GAPM interface. Obtaining the start handle is important for the profile as it is used as a parameter in the advertising payload. This handle is then used by the client to access the characteristic without performing full service discovery. The start handle can be obtained in one of the 2 ways.

- 1/ Setting the start handle when initializing the service by calling GAPM_PROFILE_ADD_CMD with a the start handle set to a known value.
- 2/ Getting the start handle when initializing the service with “dynamic allocation” parameters. Application task should handle the GAPM message GAPM_PROFILE_ADDED_IND. In the handler the first parameter should be checked against the TASK_ID_WPTS and then obtaining the start_hdl that can be used.

During server initialization the PRU Static information is transferred to the profile and loaded into the ATT-DB. As this is static information it avoids this information being request from the Application during registration.

Type	Parameters	Description
struct wpts_db_cfg	param	The PRU Static information which is to be written to the local ATT-DB

Description: This API message shall be used to add one instance of the Wireless Power Transfer System Service in the database.



7.2.2 WPTS_ENABLE_CMD

Source: TASK_APP

Destination: TASK_WPTS

Parameters:

Type	Parameters	Description
uint16_t	Conidx	Identifier for the current connection. Obtained from the GAP during connection establishment
uint16_t	ntf_ind_cfg	Characteristic Configuration Descriptor bit field value for a bonded device: Bit 0 : Notifications Enabled Bit 1 : Indication enabled

Response: WPTS_CMP_EVT

Description: This API message shall be used after the connection with a peer device has been established. This starts internal state machine of the task. The connection identifier obtained during connection establishment has to passed as a parameter in 'conidx'.

If the device is bonded, the previous setting of the Alert CCC is passed into the profile using the 'ntf_ind_cfg' field.

7.2.1 WPTS_VALUE_IND

Source: TASK_WPTS

Destination: TASK_APP

Parameters:

Type	Parameters	Description
uint8_t	attrib_id	The attribute whose value is reported 0x02 - WPTC_PTU_STATIC_ATT_ID 0x03 - WPTC_PRU_CONTROL_ATT_ID 0x07 - WPTC_PRU_ALERT_CCC_ATT_ID
Union	value	
struct wpts_pru_control	pru_ctrl	The PRU Control Information
struct wpts_ptu_static	ptu_static	The PTU Static Characteristic Information
uint16_t	alert_ccc	CCC descriptor of the Alert Characteristic

This message is sent to the application to indicate an attribute needs to be updated – due to write request from peer PTU. This can occur as a result when the peer device wants to update the PRU Control Characteristic Value or modify the CCC setting for the Alert Characteristic.

7.2.2 WPTS_VALUE_REQ_IND

Source: TASK_WPTS

Destination: TASK_APP

Parameters:

Type	Parameters	Description
uint8_t	Attrib_id	The attribute whose value is requested 0x01 - WPTC_PRU_STATIC_ATT_ID 0x02 - WPTC_PTU_STATIC_ATT_ID 0x03 - WPTC_PRU_CONTROL_ATT_ID 0x04 - WPTC_PRU_DYNAMIC_ATT_ID 0x05 - WPTC_PRU_ALERT_ATT_ID

Response: WPTS_VALUE_CFM



Description: This message is used to Request the read of the PRU Information from the application. Information on four difference characteristic values can be requested.

NOTE :- As the PRU Static information is stored below the API in the ATT-DB, although shown here are a attribute which can be read, in reality the peers request to read the PRU static information will not result in an WPTS_VALUE_REQ_IND.

7.2.3 WPTS_VALUE_CFM

Source: TASK_APP

Destination: TASK_WPTS

Parameters:

Type	Parameters	Description
uint8_t	attrib_id	The item whose value was requested 0x01 - WPTC_PRU_STATIC_ATT_ID 0x02 - WPTC_PTU_STATIC_ATT_ID 0x03 - WPTC_PRU_CONTROL_ATT_ID 0x04 - WPTC_PRU_DYNAMIC_ATT_ID 0x05 - WPTC_PRU_ALERT_ATT_ID
uint8_t	status	Status of the operation: <ul style="list-style-type: none"> PRF_ERR_OK (0x00) Other error code value (except 0x00)
Union	value	
struct wpts_pru_control	pru_ctrl	The PRU Control Information
struct wpts_ptu_static	ptu_static	The PTU Static Characteristic Information
struct wpts_pru_static	pru_static	The PRU Static Characteristic Information
struct wpts_pru_dynamic	pru_dynamic	The PRU Dynamic Characteristic Information
struct wpts_pru_alert	pru_alert	Alert Information on the PRU

Description: The message supplies the value for the Read Request of the PRU Characteristic Value. This Message is the applications response to a WPTS_VALUE_REQ_IND message.

7.2.4 WPTS_PRU_ALERT_NOTIFY_CMD

Source: TASK_APP

Destination: TASK_WPTS

Parameters:

Type	Parameters	Description
uint8_t	pru_alert	This is a bit-field which is used to transfer Alert conditions from the PRU to the PTU. See section 4.30 for a complete description of this field and range of values allowed (the lower 2 bits of the pru_alert are not used and this not to be interpreted in this message)

Response: WPTS_CMP_EVT

Description: This message is used to notify the client of an alert condition. It excludes the Mode Transition which should be sent using the WPTS_PRU_MODE_TRANSITION_CMD.

7.2.5 WPTS_PRU_MODE_TRANSITION_CMD

Source: TASK_APP

Destination: TASK_WPTS



Parameters:

Type	Parameters	Description
uint8_t	pru_alert	This is a bit-field which is used to transfer Alert conditions from the PRU to the PTU. See section 4.30 for a complete description of this field and range of values allowed. (the lower 2 bits of the pru_alert are not used and this not to be interpreted in this message)
uint_8	mode_transition	0x00 --- No Mode Transition 0x01 --- 2 sec Mode Transition Time Limit 0x02 --- 3 sec Mode Transition Time Limit 0x03 --- 6 sec Mode Transition Time Limit 0x04-0xFF -- UNDEFINED
uint_8	addr[6]	A Bluetooth device address which is to be used by the PTU/PTU when they attempt to reconnect.

Description: This message is used to notify the client of a Mode Transition on the server.

7.2.6 WPTS_CMP_EVT

Source: TASK_WPTS

Destination: TASK_APP

Parameters:

Type	Parameters	Description
uint8_t	Operation	0x00 – Reserved 0x01 – WPTS_NTF_ALERT 0x02 – WPTS_IND_MODE_TRANSITION 0x03 - WPTS_ENABLE 0x04-0xFF - Reserved
uint8_t	Status	Status

Description: The API message is used by the WPTS task to inform the APP that a previously requested command is complete. For example this normally is used to inform the Application that the Mode_Transition_Indictate or Alert_Notify procedures is complete in the server and returns the status field indicating the outcome of the procedure.

8 Message Sequence Charts (MSCs)

This section uses message sequence charts to describe the operation of the profile. Message sequence charts are presented for the following scenarios.

8.1 Device Discovery and Connection

The operation of initial device discovery between and RW PTU and PRU is shown below in Figure 3.

The PRU becomes limited discoverable by initiating Undirected Advertising with the Advertising data containing the WPT UUID (to identify the service), the WPT Primary Service Handle and the PRU RSSI. To enable fast connections the Advertising interval should be less than 20ms.

The PTU configures LE scanning for optimal discovery and power performance, and initiates LE scanning. The interval chosen for scanning is dependent on state of the PTU and dependent on the number of links already existing. Short scan intervals or continuous scanning provide the fastest discovery time.

For each advertising report received the PTU checks if the WPT UUID is contained within the Advertising Data and also ensures that the PTU RSSI field meets requirements. If the PTU discover a device which meets the requirements for a connection, the PTU initiates a LE Connection. For unbonded devices the GAP General Connection Establishment procedure is used, however for bonded device the choice of connection establishment type is dependent on PTU requirements as described in A4WP specification [1].

Following connection establishment, both the PTU and PRU enable the profile. In the PTU the Primary Service Handle of the WPT obtained from the Advertising Data is passed to allow the WPTC to determine the Handle values for the Characteristics and Descriptors.

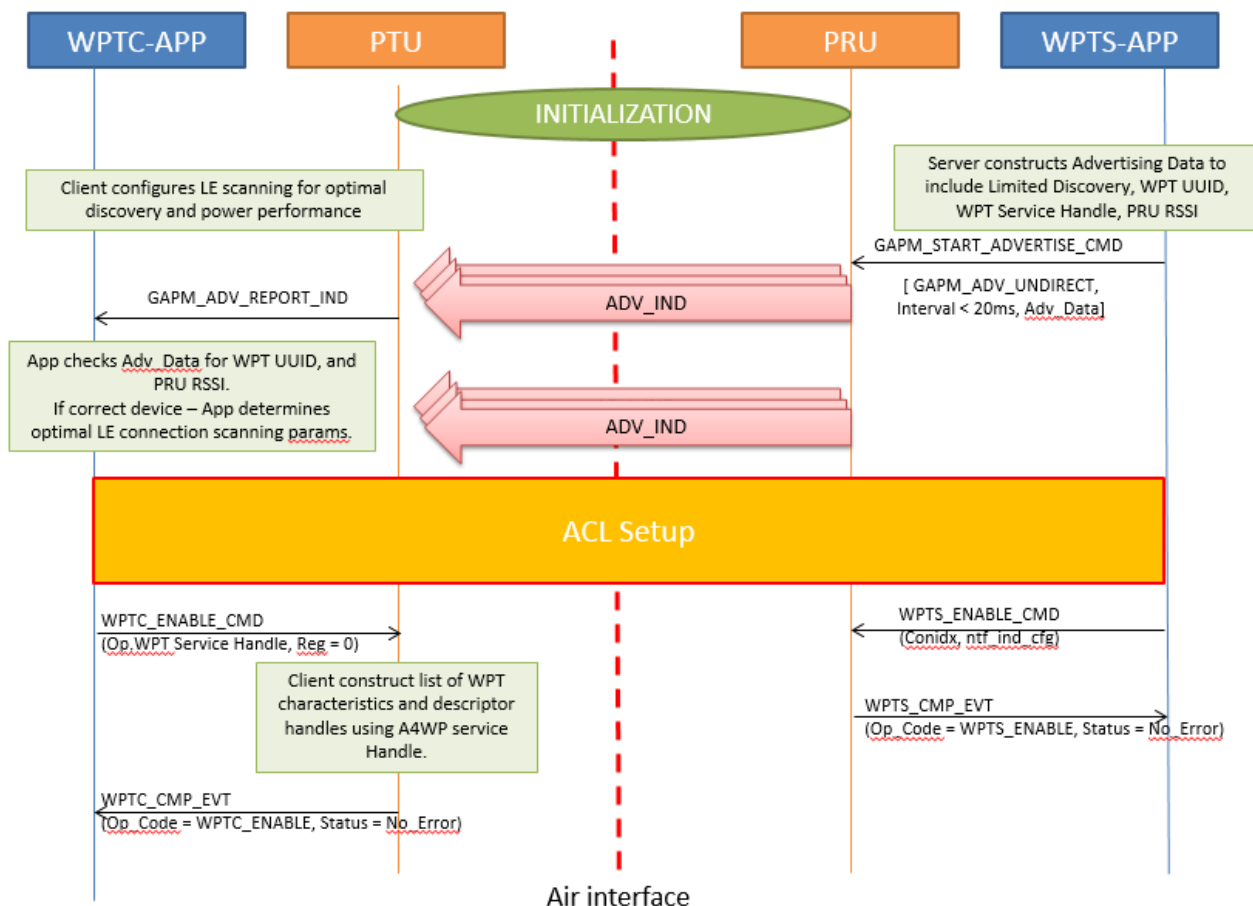


Figure 3 :- Device Discovery and Connection



The WPT places specific conditions for the acceptance of an Advertising. The PTU shall issue an attempt to establish a connection to the advertising device only if the following conditions are satisfied:

- The RSSI of the advertisement is greater than ADV_PWR_MIN (implementation dependent but -60dBm recommended) as measured at the receive antenna.
- The PTU observes an impedance shift close to the time of the advertisement.

If neither of these condition are satisfied the PTU should ignore advertisements from that device. However, if one of these conditions is satisfied then once the 11th Advertisement is received or more than 1.7 seconds has elapsed the PTU shall issue a connection request.

In all case the PTU shall issue a connection request within 50ms of receiving an acceptable Advertisement.

8.2 Device Registration

Figure 4 and 5 below shows the sequence of events for Device Registration. The PRU/PTU Static information is first exchanged using ATT-READ and ATT-WRITE-WITHOUT-RESPONSE. This is shown in Figure 4, where the PRU_Static Information is automatically retrieved as part of the WPTC_Enable_Cmd, which has Registration = 1. The Application then proceeds to write the PTU Static information into the PRU using WPTC_Write_Cmd.

As can be seen in Figure 5, Following the exchange of the Static information, The PRU Dynamic Information is then send form the PRU to the PTU using ATT-READ (the PRU Dynamic information will be retrieved from the PRU at least every 250ms). Finally the PTU writes modifies the state of the PRU by writing to the PRU control, using ATT-WRITE-WITHOUT-RESPONSE.

After writing to the PRU Control, the PTU can configure Alert notifications/indications as shown in Figure 6.

Following registration, the PTU should receive updates on the Dynamic Characteristic at least every 250ms. This is done by the PTU reading the Dynamic information at least every 250ms.

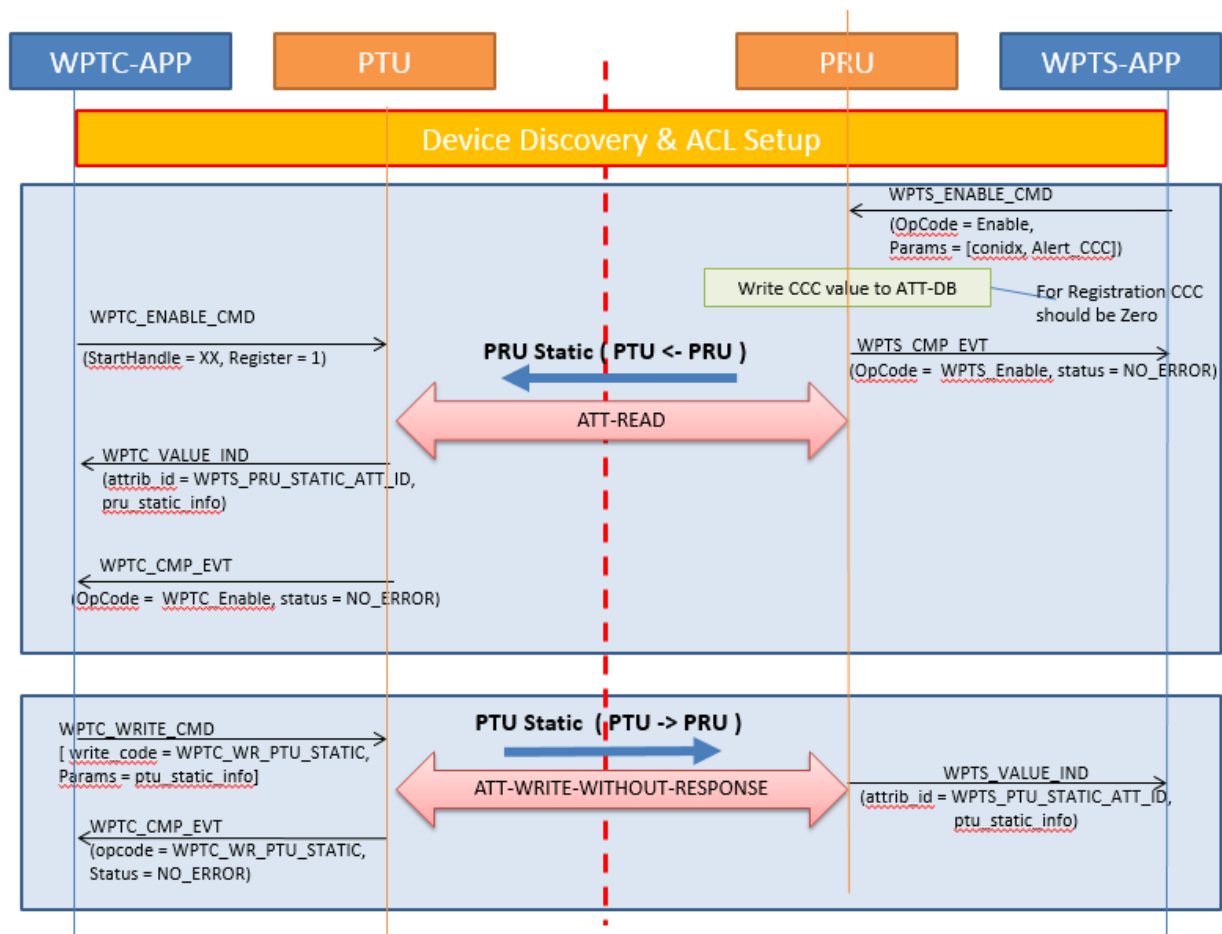


Figure 4 :- Device Registration – Part 1

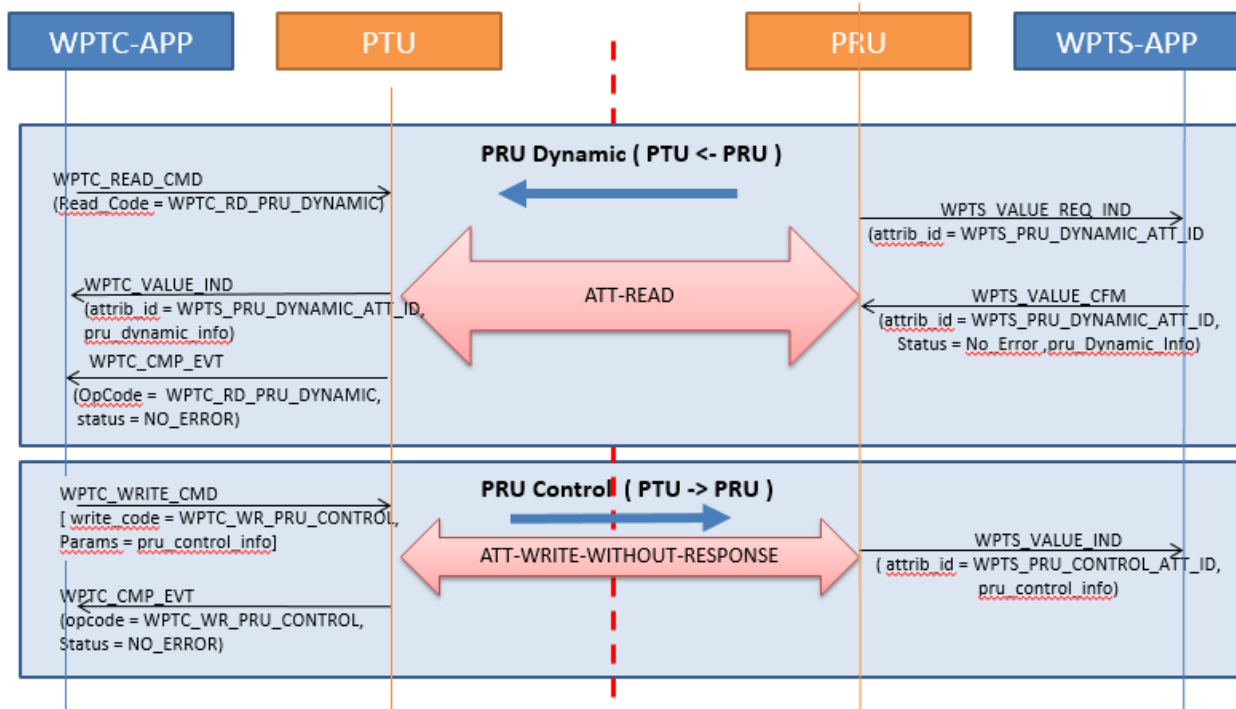


Figure 5 :- Device Registration – Part 2

8.3 Configuration of the Alert CCC

Following Registration the PTU configures the Alert CCC in the PRU to enable Notification and Indications. This allows the Alert_Notifications and Mode_Transition_Indications to be send from the PRU to the PTU.

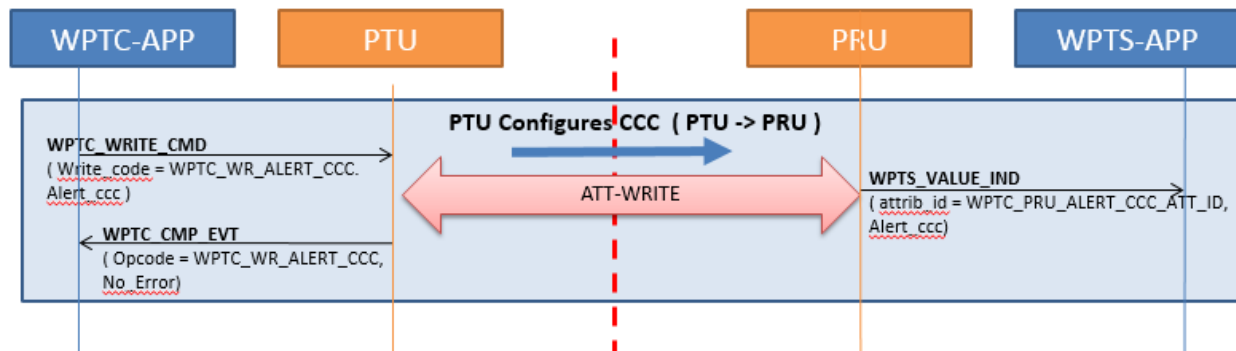


Figure 6 :- PTU Configuring the CCC for the Alert Characteristic in the PRU

8.4 Alert and Mode Transition

Figure 7 below shows the flow of messages at the API and GATT for both Alerting and Mode Transition. Alerting is used to inform the PTU of error conditions in the PRU, for example excess Voltage or Current, but does not include any Mode Transition information.

The Mode Transition informs the PTU of a specific error and intended actions to be taken by PRU to handle this error condition. This often involves the release of the BLE link and a reboot of the PRU. The Mode Transition message carries information on the length of time before the PRU is available for re-connection and the Bluetooth Device Address it will be using during advertising. Due to the sensitivity of the timing for re-connection the Mode Transition uses ATT-INDICATE which is acknowledged by the PTU. The WPTS_CMP_EVT is only sent when the ATT-INDICATE has been acknowledged, thus allowing the PRU to release link and perform re-boot on the receipt of WPTS_CMP_EVT.

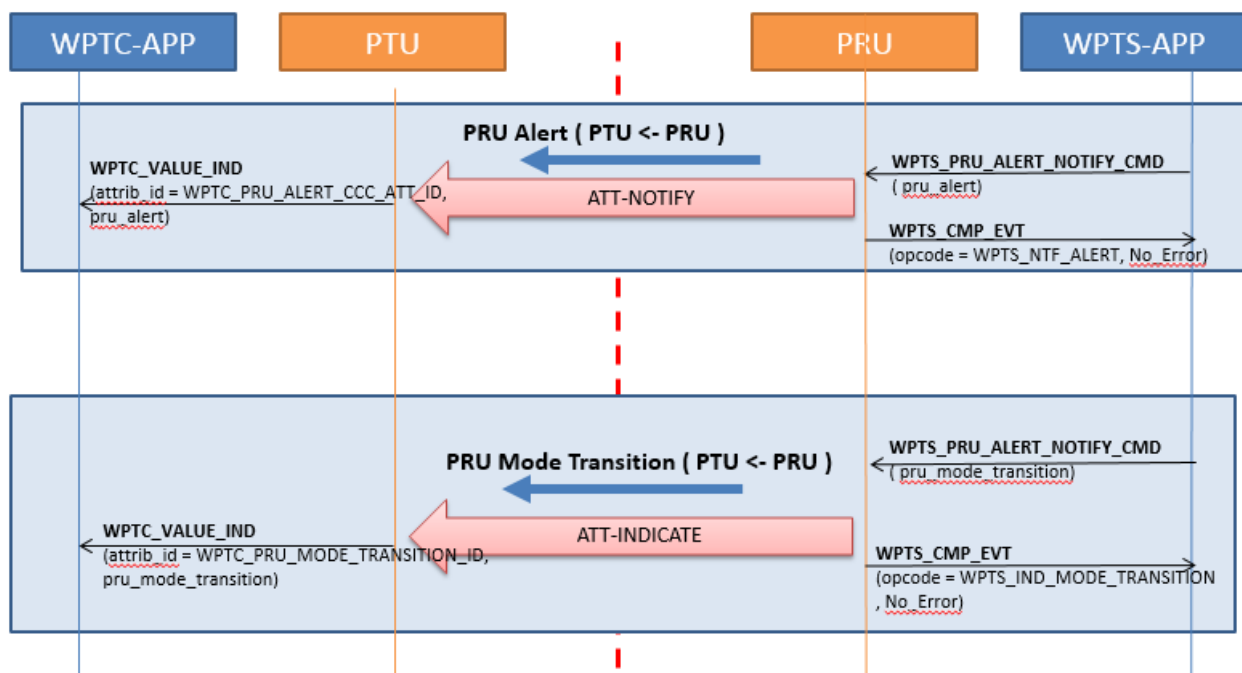


Figure 7 :- Alerts and Mode Transitions





Abbreviations

Abbreviation	Original Terminology
API	Application Programming Interface
BLE	Bluetooth Low Energy
GAP	Generic Access Profile
GATT	Generic Attribute Profile
WPTP	Wireless Power Transfer Profile
WPTS	Wireless Power Transfer Server Role
WPTC	Wireless Power Transfer Client Role
MSC	Message Sequence Chart
RW	RivieraWaves SAS
SM	Security Manager
PRU	Power Receive Unit
PTU	Power Transfer Unit
RFU	Reserved for Future Use



9 References

[1]	Title	A4WP Wireless Power Transfer System Baseline System Specification(BSS)		
	Reference	A4WP-S-0001 v1.3		
	Version	1.3	Date	2014-05-11
	Source	Alliance for Wireless Power		

[2]	Title	Wireless Power Transfer System Test Specification		
	Reference	WPTP_TS_0.0.1		
	Version	0.1	Date	2016-11-11
	Source	RivieraWave		

[3]	Title			
	Reference			
	Version		Date	
	Source			

[4]	Title			
	Reference			
	Version		Date	
	Source			



10 Annex 1

This section provide some of the mappings used in fields of the API. These mappings are identical to the mappings provided in the A4WP for the corresponding fields.

The fields covered here are :

- PTU_power (decimal value of field to power value in Watts)
- PTU Maximum Source Impedance (decimal value of field to Impedance in Ohms)
- PTU Max Load Resistance (decimal value of field to Resistance in Ohms)

10.1 PTU Power

Value	Pwr	Value	Pwr	Value	Pwr	Value	Pwr	Value	Pwr
0	0	32	4.4	64	13.6	96	28	128	50
1	0.1	33	4.6	65	14	97	28.5	129	51
2	0.2	34	4.8	66	14.4	98	29	130	52
3	0.3	35	5	67	14.8	99	29.5	131	53
4	0.4	36	5.2	68	15.2	100	30	132	54
5	0.5	37	5.4	69	15.6	101	30.6	133	55
6	0.6	38	5.6	70	16	102	31.2	134	56
7	0.7	39	5.8	71	16.4	103	31.8	135	57
8	0.8	40	6	72	16.8	104	32.4	136	58
9	0.9	41	6.3	73	17.2	105	33	137	59
10	1	42	6.6	74	17.6	106	33.6	138	60
11	1.1	43	6.9	75	18	107	34.2	139	61
12	1.2	44	7.2	76	18.4	108	34.8	140-255	RFU
13	1.3	45	7.5	77	18.8	109	35.4		
14	1.4	46	7.8	78	19.2	110	36		
15	1.5	47	8.1	79	19.6	111	36.6		
16	1.6	48	8.4	80	20	112	37.2		
17	1.7	49	8.7	81	20.5	113	37.8		
18	1.8	50	9	82	21	114	38.4		
19	1.9	51	9.3	83	21.5	115	39		
20	2	52	9.6	84	22	116	39.6		
21	2.2	53	9.9	85	22.5	117	40.2		
22	2.4	54	10.2	86	23	118	40.8		
23	2.6	55	10.5	87	23.5	119	41.4		
24	2.8	56	10.8	88	24	120	42		
25	3	57	11.1	89	24.5	121	43		
26	3.2	58	11.4	90	25	122	44		
27	3.4	59	11.7	91	25.5	123	45		
28	3.6	60	12	92	26	124	46		
29	3.8	61	12.4	93	26.5	125	47		
30	4	62	12.8	94	27	126	48		
31	4.2	63	13.2	95	27.5	127	49		



10.2 PTU Maximum Source Impedance

Value (Decimal)	PTU Maximum Source Impedance (ohms)
0	50
1	60
2	70
3	80
4	90
5	100
6	110
7	120
8	130
9	140
10	150
11	175
12	200
13	225
14	250
15	275
16	300
17	350
18	375
19 - 31	RFU

10.3 PTU Maximum Load Resistance

Value (Decimal)	PTU Max Load Resistance (ohms)
1	10
2	15
3	20
4	25
5	30
6	35
7	40
8	45
9	50
10	55
11 - 31	RFU