Document Revision History

Date	Description	Author	Version
18-June-2019	Initial version.	G. Beckstein	0.1
24-June-2019	Revised from internal comments	G. Beckstein	0.2
1-July-2019	Modified services/characteristics to more closely mirror LWM2M	G. Beckstein	0.3
17-July-2019	Changed ICM20602 and LSM9DS1 data struct members from int16 to float	G. Beckstein	0.4
23-October-2019	Changed temperature Celsius (0x2A1F) to temperature (0x2A6E)	G. Beckstein	0.5
23-October-2019	Added Firmware Revision String characteristic (0x2A26) to Device Information Service (0x180A)	G. Beckstein	0.5

Sign-Off

		Signature	Date
Marketing	☐		
Operations	☐		
Purchasing	☐		
Engineering	☐		

Distribution

CEO	☐
Admin	☐
Engineering	☐
Marketing	☐
Operations	☐
Purchasing	☐

1.0 Purpose

This BLE Protocol Specification (BPS) document describes the Bluetooth Low Energy (BLE) profile of the Agora Product. This specification is based on standards published by the Bluetooth SIG and the array of sensors built into the Agora hardware.

For detailed hardware functionality, please refer to the Hardware Functional Specification (DES0263).

2.0 Document Conventions

General definition of requirement terms:

- SHALL - This word means that the definition is an absolute requirement of the specification.
- SHALL NOT - This phrase means that the definition is an absolute prohibition of the specification.
- SHOULD- This word means that there may exist valid reasons in particular circumstances to ignore a particular item, but the full implications must be understood and carefully weighed before choosing a different course.
- SHOULD NOT - This phrase means that there may exist valid reasons in particular circumstances when the particular behavior is acceptable or even useful, but the full implications should be understood, and the case carefully weighed before implementing any behavior described with this label.
- MAY - This word mean that an item is truly discretionary.

3.0 References

Description	Document	Rev / Date	Owner

4.0 Acronyms and Abbreviations

Term	Description
EPI	Embedded Planet Inc.
BSP	Board Support Package
SIG	Bluetooth Special Interest Group
BLE	Bluetooth Low Energy (aka Bluetooth Smart)
GAP	Generic Access Profile (part of BLE specification)
GATT	Generic Attribute Profile (part of BLE specification)
UUID	Universally Unique Identification Number
IAQ	Indoor Air Quality
IMU	Inertial Measurement Unit
ALS	Ambient Light Sensor

5.0 Definitions

Term	Description
BLE Characteristic	A BLE endpoint encapsulating a single data point. Characteristics typically expose up to 20 bytes at a time of data in a single transaction.
BLE Service	A service defines a set of mandatory and optional characteristics that exist under one UUID.
BLE Profile	A profile defines a set of mandatory and optional services that exist on a device.
BLE Peripheral	A connectable device that periodically broadcasts advertisements of its presence with a small payload describing itself. A BLE central can connect to this device.
BLE Central	A device that scans for advertising peripherals and issues connection packets. (e.g.: a BLE-enabled smartphone)

6.0 Description of Pairing Procedure

6.1 Advertising – No Paired Centrals

When first powered on, the Agora device shall advertise as a BLE peripheral. It shall advertise in **undirected connectable mode**. In this mode, the peripheral allows persistent connections from central devices and periodically broadcasts general advertisements to all nearby central devices.

The advertisement payload shall contain identifiable information that will distinguish the Agora BLE peripheral from other nearby BLE peripherals. This identifiable information shall consist of at least:

1.) The **128-bit Agora BLE Service UUID** as described in section 7. This may be used by the central device application to filter unrelated BLE peripherals.
2.) The **last two bytes of the device's Bluetooth MAC address** which may be used to uniquely identify a single Agora device when several are advertising within range.

6.2 Connection Procedure and Pairing

When a connection is initiated by a central device, for example a compatible application on a nearby gateway, the Agora device shall request the connection security to be upgraded. As the central, the gateway application is responsible for carrying out this request and may choose to initiate the **BLE bonding procedure**.

During the BLE bonding procedure, encryption keys are securely exchanged between the central and peripheral. Both the central and peripheral store the keys and unique identifiers in non-volatile memory.

6.3 Advertising – Paired Centrals

When an Agora device powers on and has a previously paired central stored in memory, it shall advertise as a BLE peripheral in **directed connectable mode**. In this mode, advertisements shall be targeted towards **the last central** the Agora device was connected to. This enables a connection to be established more quickly with a previously paired central.

If the intended central fails to reconnect within several seconds, the Agora device shall then revert to advertise in undirected connectable mode as described in section 6.1.

7.0 Agora BLE Profile Description

Custom BLE service UUIDs from a single manufacturer typically derive from the same 128-bit base UUID. The Embedded Planet base UUID is shown in the table below:

Base UUID
0000xxxx-8dd4-4087-a16a-04a7c8e01734

The 'x' characters indicate the position of the alias of BLE properties (service and characteristic UUIDs).

Services and characteristics standardized by the Bluetooth SIG cover common BLE application requirements. Standardized services and characteristics are typically identified by a shorter, 16-bit UUID. This 16-bit UUID can be expanded using the Bluetooth SIG's 128-bit base UUID. However, for brevity, this document will only refer to the short-form, 16-bit UUID of standard services and characteristics.

The Agora product encompasses several product variants with optional components left unpopulated in some cases. As a result, some services described below may not be present in the profile of a specific Agora unit. If a service is not present it means that part is not populated on the board. The connected application should be aware of this and respond to missing services appropriately.

7.1   Services

The Agora BLE profile shall consist of several standardized and custom services. Bluetooth SIG standardized services included in the profile are listed in the table below:

Standard Services

UUID	Name	Relevant Specification
0x1800	Generic Access Service	org.bluetooth.service.generic_access
0x180A	Device Information Service	org.bluetooth.service.device_information

Each on-board sensor or actuator is associated with a corresponding custom service. Custom services are described in the table below:

Custom Services

Alias	Name	Full UUID
0x0001	BME680 Service	00000001-8dd4-4087-a16a-04a7c8e01734
0x0002	Si7021 Service	00000002-8dd4-4087-a16a-04a7c8e01734
0x0003	ICM-20602 6-Axis IMU Service	00000003-8dd4-4087-a16a-04a7c8e01734
0x0004	LSM9DS1 9-Axis IMU Service	00000004-8dd4-4087-a16a-04a7c8e01734
0x0005	MAX44009 Ambient Light Service	00000005-8dd4-4087-a16a-04a7c8e01734
0x0006	VL53L0X Time-of-Flight Service	00000006-8dd4-4087-a16a-04a7c8e01734
0x0008	LED Service	00000008-8dd4-4087-a16a-04a7c8e01734
0x0009	Battery Voltage Service	00000009-8dd4-4087-a16a-04a7c8e01734

The characteristics of each of these services are described in the following sections.

Non-standardized characteristics will be associated with a specified data format as outlined by the Bluetooth SIG here. The units of the data will also be described. This information shall be available "on-air" by accessing the specific characteristic's Characteristic Presentation Format descriptor.

7.1.1   Generic Access Service

The Generic Access service contains generic information about the device. All available Characteristics are read only. The table below summarizes implemented characteristics of this service:

Standard Characteristics

UUID	Name	Permissions	Relevant Specification
0x2A00	Device Name	Read	org.bluetooth.characteristic.gap.device_name
0x2A01	Appearance	Read	org.bluetooth.characteristic.gap.appearance

7.1.2   Device Information Service

The Device Information Service exposes manufacturer and/or vendor information about a device. The table below summarizes implemented characteristics of this service:

Standard Characteristics

UUID	Name	Permissions	Relevant Specification
0x2A29	Manufacturer Name	Read	org.bluetooh.characteristic.manufacturer_name_string
0x2A24	Model Number String	Read	org.bluetooth.characteristic.model_number_string
0x2A25	Serial Number String	Read	org.bluetooth.characteristic.serial_number_string
0x2A26	Firmware Revision String	Read	org.bluetooth.characteristic.firmware_revision_string
0x2A27	Hardware Revision String	Read	org.bluetooth.characteristic.hardware_revision_string
0x2A28	Software Revision String	Read	org.bluetooth.characteristic.software_revision_string

7.1.3   BME680 Service

The BME680 is a highly integrated environmental sensor capable of transducing ambient temperature, pressure, relative humidity, and relative VOC concentration. By combining these readings, the application can give a measure of indoor air quality (IAQ). The BME680 service characteristics are listed in the table below:

Standard Characteristics

UUID	Name	Permissions	Relevant Specification
0x2A6E	Temperature	Read, Notify, Indicate	org.bluetooth.characteristic.temperature
0x2A6F	Humidity	Read, Notify, Indicate	org.bluetooth.c haracteristic.humidity
0x2A6D	Pressure	Read, Notify, Indicate	org.bluetooth.characteristic.pressure

Custom Characteristics

Alias	Name	Units (ID)	Data format (ID)	Permissions	Full UUID

0x1001	Estimated CO2 Concentration	Concentration in ppm (0x27C4)	float32 (0x14)	Read, Notify, Indicate	00001001-8dd4-4087-a16a-04a7c8e01734
0x2001	Estimated b-VOC Equivalents	Concentration in ppm (0x27C4)	float32 (0x14)	Read, Notify, Indicate	00002001-8dd4-4087-a16a-04a7c8e01734
0x3001	Indoor Air Quality Score (0-500)	Unitless (0x2700)	uint16 (0x06)	Read, Notify, Indicate	00003001-8dd4-4087-a16a-04a7c8e01734
0x4001	Indoor Air Quality Accuracy Score (0-3)	Unitless (0x2700)	uint8 (0x04)	Read, Notify, Indicate	00004001-8dd4-4087-a16a-04a7c8e01734
0x5001	Gas Resistance	Ohm (0x272A)	uint32 (0x08)	Read, Notify, Indicate	00005001-8dd4-4087-a16a-04a7c8e01734

The Indoor Air Quality Score corresponds to the descriptions in the following table:

IAQ Index	Air Quality	Impact (long-term exposure)	Suggested action
0 – 50	Excellent	Pure air; best for well-being	No measures needed
51 – 100	Good	No irritation or impact on well-being	No measures needed
101 – 150	Lightly polluted	Reduction of well-being possible	Ventilation suggested
151 – 200	Moderately polluted	More significant irritation possible	Increase ventilation with clean air
201 – 250[9]	Heavily polluted	Exposition might lead to effects like headache depending on type of VOCs	optimize ventilation
251 – 350	Severely polluted	More severe health issue possible if harmful VOC present	Contamination should be identified if level is reached even w/o presence of people; maximize ventilation & reduce attendance
> 351	Extremely polluted	Headaches, additional neurotoxic effects possible	Contamination needs to be identified; avoid presence in room and maximize ventilation

7.1.4 Si7021 Service

The Si7021 combines a relative humidity and temperature sensor. It offers a redundant temperature and humidity reading when populated with the BME680 (described in section 7.1.1), or a simpler solution for temperature and humidity sensing if used alone. The Si7021 service exposes a subset of the characteristics included in the BME680 service.

Standard Characteristics

UUID	Name	Permissions	Relevant Specification
0x2A6E	Temperature	Read, Notify, Indicate	org.bluetooth.characteristic.temperature
0x2A6F	Humidity	Read, Notify, Indicate	org.bluetooth.characteristic.humidity

7.1.5 ICM-20602 6-Axis IMU Service

The ICM-20602 is a 6-axis inertial measurement unit providing 3-axis accelerometer and 3-axis gyroscope readings.

Custom Characteristics

Alias	Name	Units (ID)	Data format (ID)	Permissions	Full UUID
0x1003	Accelerometer XYZ	Acceleration (0x2713)	struct (0x1B) (see 7.1.5.1)	Read	00001003-8dd4-4087-a16a-04a7c8e01734
0x2003	Gyroscope XYZ	Angular Veloctity (0x2743)	struct (0x1B)	Read	00002003-8dd4-4087-a16a-04a7c8e01734

7.1.5.1 Accelerometer/Gyroscope XYZ Structure

The accelerometer and gyroscope XYZ characteristics shall contain a struct that encapsulates three 32-bit floating-point values for each axis, X, Y, and Z, respectively. They shall be packed into a 12-byte packet.

7.1.6 LSM9DS1 9-Axis IMU Service

The LSM9DS1 is a 9-axis IMU and offers an additional/alternate source of accelerometer and gyroscope data as well as 3-axis magnetometer data. As such, the LSM9DS1 service contains the same characteristics as the ICM-20602 Service (described in section 7.1.3) and additional characteristics related to the magnetometer functionality.

Custom Characteristics

Alias	Name	Units (ID)	Data format (ID)	Permissions	Full UUID
0x1003	Accelerometer XYZ	Acceleration (0x2713)	struct (0x1B) (see 7.1.5.1)	Read	00001003-8dd4-4087-a16a-04a7c8e01734
0x2003	Gyroscope XYZ	Angular Velocity (radians/sec) (0x2743)	struct (0x1B)	Read	00002003-8dd4-4087-a16a-04a7c8e01734
0x3004	Magnetometer XYZ	Magnetic Flux Density (teslas) (0x272D)	struct (0x1B)	Read	00003004-8dd4-4087-a16a-04a7c8e01734

7.1.7 MAX44009 Ambient Light Sensor Service

The MAX44009 incorporates two ambient light sensors – each having a different response to various wavelengths of light. One of the sensors rejects infrared light to better represent the ambient light conditions as seen by the human eye. The

other sensor accepts more infrared and less visible light. The two readings are combined to provide a more "realistic" reading under a variety of lighting conditions.

The MAX44009 ALS Service has the following characteristics:

Custom Characteristics

Alias	Name	Units (ID)	Data format (ID)	Permissions	Full UUID
0x1005	Ambient Light	Lux (0x2731)	float32 (0x14)	Read, Notify, Indicate	00001005-8dd4-4087-a16a-04a7c8e01734

7.1.8 VL53L0X Time-of-Flight Service

The VL53L0X time-of-flight sensor can measure the distance to nearby objects up to 2 meters away. An example application of this data is the possibility of tamper detection if the device is moved or opened by an unauthorized person.

The VL53L0X Time-of-Flight Service has the following characteristics:

Custom Characteristics

Alias	Name	Units (ID)	Data format (ID)	Permissions	Full UUID
0x1006	Distance	Meter (0x2701) (in increments of 0.001)	uint16 (0x06)	Read, Notify, Indicate	00001006-8dd4-4087-a16a-04a7c8e01734

7.1.9 LED Service

The LED service exposes read/write control to the state of the on-board LED. This service functions identically to the service implemented in the Mbed-OS BLE LED example application found here. A value of true is associated with the illuminated LED state.

Custom Characteristics

Alias	Name	Units (ID)	Data format (ID)	Permissions	Full UUID
0x1008	LED State	Unitless (0x2700)	boolean (0x01)	Read, Write	00001008-8dd4-4087-a16a-04a7c8e01734

7.1.10 Battery Voltage Service

The Battery Voltage Service exposes a raw reading of the current on-board battery voltage. This can be used to estimate remaining battery life.

Custom Characteristics

Alias	Name	Units (ID)	Data format (ID)	Permissions	Full UUID
0x1009	Battery Voltage	Volts (0x2728)	float32 (0x14)	Read, Notify, Indicate	00001009-8dd4-4087-a16a-04a7c8e01734