Wireless Communication: BLE

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March 20, 2021

Agenda for Discussion

1. Bluetooth Low Energy
2. Generic Access Profile
3. Advertising
4. Generic Attribute Profile
5. What we haven't told you?
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Bluetooth Low Energy (BLE)

Bluetooth Low Energy

- Low cost, low power but also low bandwidth and low complexity.
- Introduced in 2010 with Bluetooth 4.0.
- Different from Bluetooth Classic (ER/BDR/HS).
- Bluetooth LE is used for periodic transfer of data while Bluetooth Classic is used for streaming (file sharing, music, voice).
- Can run for extended period of time off a coin cell.

Bluetooth Low Energy

- Rapid growth of BLE is due to smartphones, tablets and mobile computing.
- Early adoption by mobile industry heavyweights like Apple and Samsung.
- BLE is desgined to be extensible framework for exchanging data.

Bluetooth Device Configurations

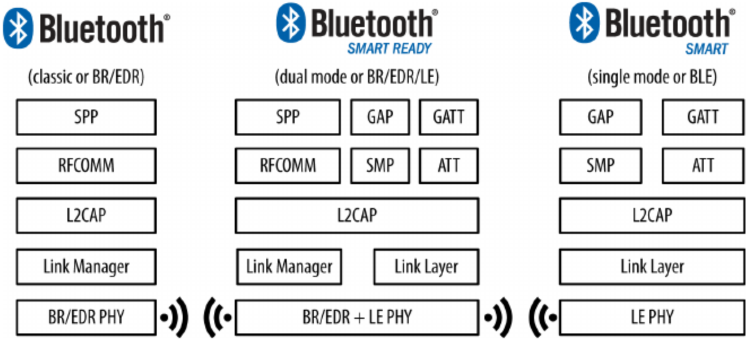


Figure 1: Bluetooth device configurations and compatibility

Limitations

- Potential maximum throughput of 5-10 KB/s.
- Can reliably trasmit upto 30 meters but typical range is clocked at 2-5 meters to save power.

Protocols and Profiles

- **Protocols** are building blocks used by all devices conformant with the spec.
- **Profiles** are features/functionalities either covering basic modes of operation or specific use-cases. Profiles define how protocols should be use.

Broadcasting and Connections

- Broadcasting allows pushing small amount of data on a fixed schedule to multiple devices. No security.
- Connections allow transmitting a lot more data between two devices in both directions. Security included.

Generic Access Profile

- **Generic Access Profile** provides a framework that all BLE implementations must follow to discover each other, broadcast data and form connections.
- GAP defines roles and modes.

GAP Roles

- Broadcaster
- Observer
- Central
- Peripheral

Broadcaster

- Optimized for transmit-only applications.
- Broadcast role periodically sends out advertising packets with data.
- A way to transmit data to more than one peer at a time.
- 31 bytes payload. Can be increased to 62 bytes with **scan response**.

Observer

- Optimized for receive-only applications that want to collect data from broadcasting devices.
- The observer role listens for data embedded in advertising packets from broadcasting peers.

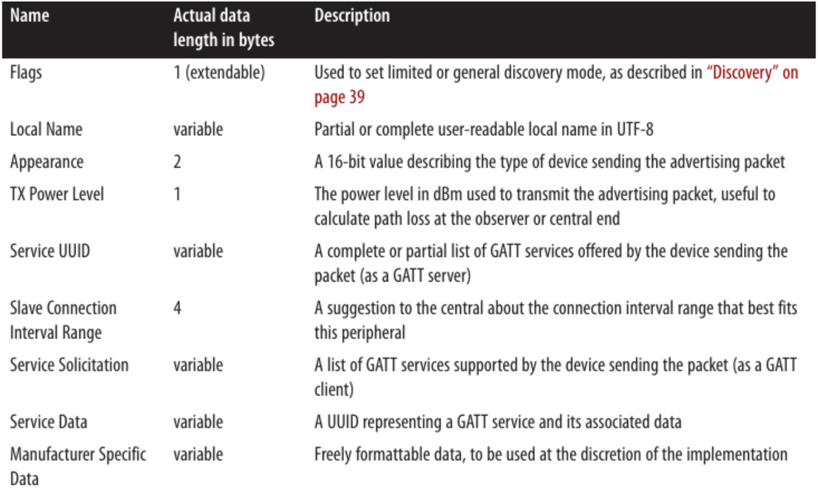
Central and Peripheral

- Central role is capable of establishing multiple connections to peers and is always the initiator of connections.
- Peripheral role uses advertising packets to allow centrals to find it and, subsequently, to establish a connection with it.

Advertising

- Broadcasting or advertising allows sending 31 bytes or 62 bytes of data.
- **But what is the format?**
- The data is collection of structures each of which contain length (1 byte), advertising data type (AD type, 1 byte), and actual data.
- Each structure is a separate item of user data.

Advertising



Name	Actual data length in bytes	Description
Flags	1 (extendable)	Used to set limited or general discovery mode, as described in "Discovery" on page 39
Local Name	variable	Partial or complete user-readable local name in UTF-8
Appearance	2	A 16-bit value describing the type of device sending the advertising packet
TX Power Level	1	The power level in dBm used to transmit the advertising packet, useful to calculate path loss at the observer or central end
Service UUID	variable	A complete or partial list of GATT services offered by the device sending the packet (as a GATT server)
Slave Connection Interval Range	4	A suggestion to the central about the connection interval range that best fits this peripheral
Service Solicitation	variable	A list of GATT services supported by the device sending the packet (as a GATT client)
Service Data	variable	A UUID representing a GATT service and its associated data
Manufacturer Specific Data	variable	Freely formattable data, to be used at the discretion of the implementation

Generic Attribute Profile (GATT)

- Whereas GAP defines low-level interactions, GATT serves as the data model.
- Data is organized hierarchically in services, characteristics and descriptors.
- GATT also defines roles different from GAP.
- GATT is usable after central establishes a connection with a peripheral.

GATT Roles

- **Client** sends requests to server and receives responses from it. It can also request server-initiates updates.
- **Server** sends responses for client requests. It also sends server-initiated updates when configured by the client.

UUIDs

- UUIDs are 128 bit numbers guaranteed to be globally unique with a high probability.
- UUIDs are used throughout Bluetooth specification for identifying profiles, services, characteristics, etc.
- A UUID is written in 8-4-4-4-12 form
  xxxxxxxx-xxxx-xxxx-xxxx-xxxxxxxxxxxx
- Alternatively, 16 and 32 bit UUIDs are used to save space and bandwidth.

Attribute Hierarchy

- An attribute is smallest data entity defined by GATT.
- Attributes are used to compose Services, characteristics and descriptors.
- A service is a feature. For example, battery level service, heart rate measurement service.
- A service contains many characteristics which store value. For example, battery level service may have a read only characteristic called battery level.
- Descriptors provide more information about the characteristic.
- Services, characteristic and descriptors are identified by UUIDs.

Characteristic Properties

- A characteristic may have associated properties such as None, read, write, read and write, notify and indicate.
- Notify and indicate enable server-initiated updates for reading characteristic value.
- For notify and indicate, a special descriptor called Client Characteristic Configuration Descriptor (CCCD) is mandatory.
- **Aside** You can think of the Hierarchy being stored on BLE device as a table where each row is an attribute identified by a handle (row number).

What we haven't told you?

- Bluetooth radio uses 2.4 GHz ISM band and divides this band in 40 channels from 2.4Ghz to 2.4835Ghz.
- 3 channels for advertising and 37 for connections.
- Bluetooth device stack is divided into Host, Controller and Application.
- Host contains GAP, GATT, **Attribute Protocol, L2CAP and Security Manager**.
- Scan interval, scan window, advertising interval.
- Advertising packet types such as connectable, non-scannable, directed.

What we haven't told you?

- Connections consist of connection intervals and connection events.
- GAP modes such as non-discoverable, limited discoverable and peer procedures such as limited discovery and name discovery.
- Attribute caching and Service/Characteristic Discovery.
- Mandatory GAP service (0x1800) and GATT service (0x1801).

References

- Townsend, Kevin, et al. *Getting Started With Bluetooth Low Energy*, O'Reilly Media, 2014.
- *Make: Bluetooth*, Make: Community, 2015.

Thank You!

Post your queries on: helpdesk@e-yantra.org