Mobile Computing Bluetooth Low Energy Personal Area Networks

Slides: tmb.gr/mc-ble

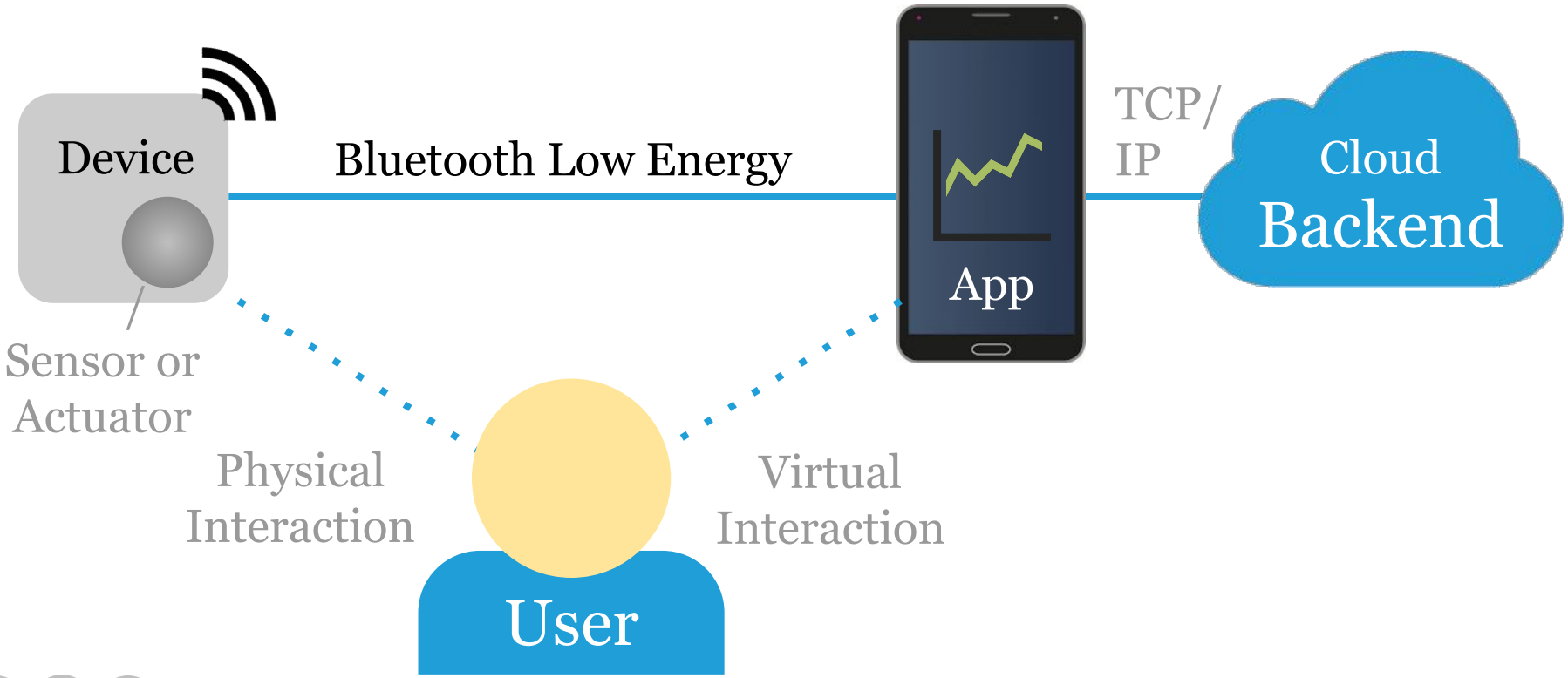
Overview

These slides introduce *Bluetooth Low Energy*.

Which are the roles of involved parties.

How a BLE service is structured.

Reference model



Bluetooth Low Energy (BLE)

BLE is a power-efficient Bluetooth variant (since 4.0).

BLE is well suited for small, battery powered devices.

It uses less energy than Wi-Fi and way less than 4/5G.

Range is ~30 m, data rate 1 Mbps, frequency 2.4 GHz.

The standard is maintained by the Bluetooth SIG.

How BLE works

Peripherals advertise the data they have, over the air.

Centrals scan for nearby peripherals to discover them.

The central connects to a peripheral and uses its data.

Data is structured into *services* and *characteristics*.

BLE protocol stack

Application — application specific code and formats
BLE library — thin, language-specific wrapper library

GATT — services & characteristics | GAP — discovery
ATT — attribute transport | SMP — security manager
L2CAP — logical link control and adaptation protocol

Link layer — exposed via the host controller interface
Physical layer — dealing with actual radio signals

Generic Access Profile (GAP)

GAP defines the following roles, communication types:

Broadcaster and *observer* (connectionless, one-way).

Peripheral and *central* (bidirectional connection).

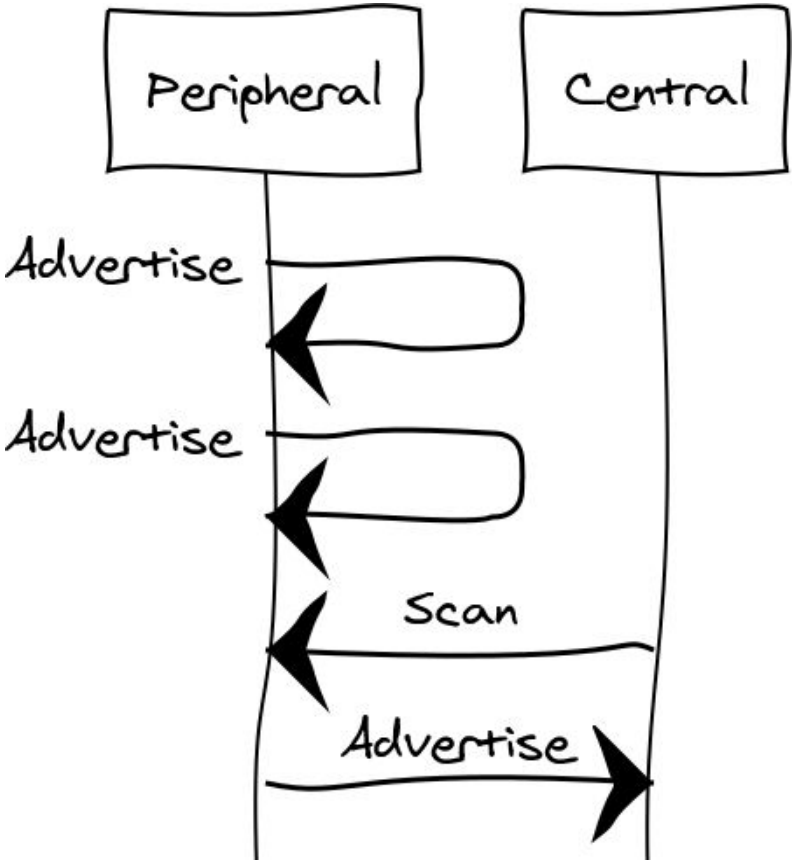
Each device supports one or more of these roles.

We start with peripheral and central roles.

Advertising

A peripheral *advertises* its services by broadcast, in a regular interval.

A central *scans* for all or a subset of services and gets device addresses and, if it's been sent, advertised data.



Attribute Transport (ATT)

ATT allows a *client* to access attributes on a *server*.

An *attribute* has a handle, a UUID and permissions.

An *attribute handle* is a server-assigned, 16-bit ID.

A *UUID* is a 16/128-bit universally unique identifier.

Permissions allow you to read, write or get notified.

See Bluetooth spec v5.3, p.279 & Assigned Numbers.

Generic Attribute Profile (GATT)

GATT is a simple application level protocol for BLE.

It's connection-based, with a *client* and a *server* role.

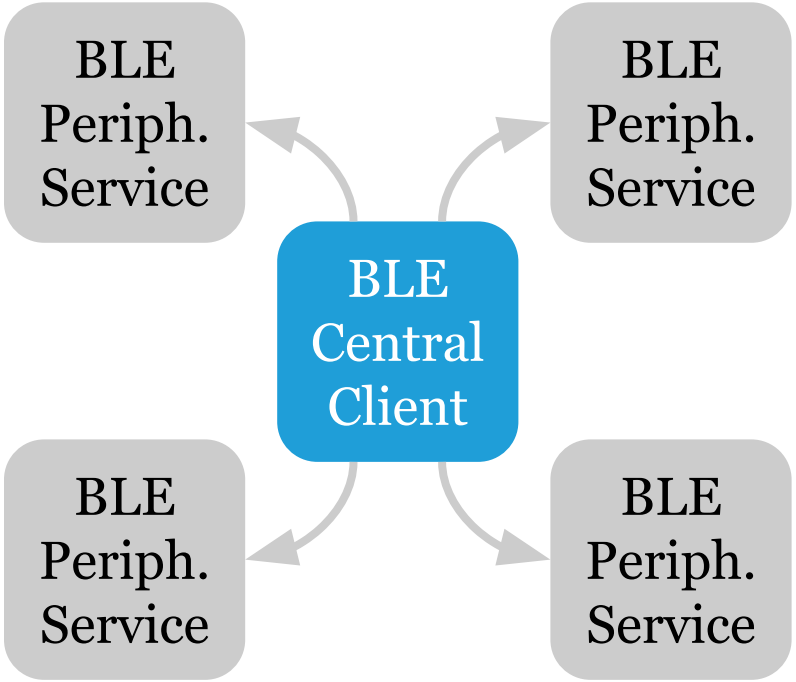
This enables a BLE device to provide a RESTful API.

A "GATT API", or *profile*, is a collection of *services*.

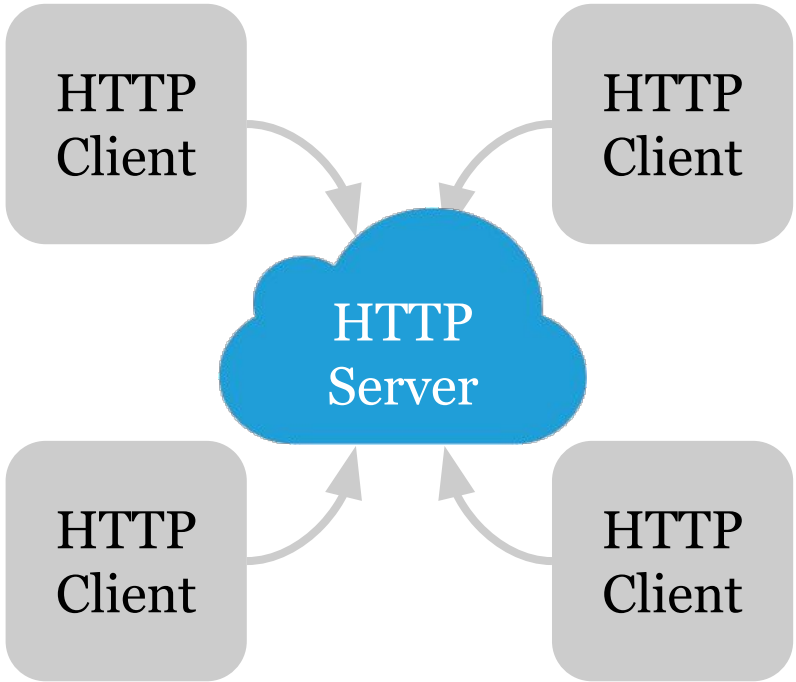
Usually, peripherals act as servers, central is client.

See Bluetooth spec v5.3, p.280 & List of Services.

BLE


BLE Periph. Service
BLE Periph. Service
BLE Central Client
BLE Periph. Service
BLE Periph. Service

HTTP


HTTP Client
HTTP Client
HTTP Server
HTTP Client
HTTP Client

Services

A *GATT service* is a collection of characteristics.

Services encapsulate the behavior of part of a device.

In addition, such a service can refer to other services.

There are standard* and custom services and profiles.

*E.g. the Battery Service or the Heart Rate Service.

Characteristics

A *GATT characteristic** has a value and descriptors.

A *value* encodes data "bits" that form a logical unit.

Descriptors are defined attributes of a characteristic.

Supported procedures: read, write and notifications.

*E.g. *Battery Level* or *Heart Rate Measurement*.

Descriptors

A *GATT descriptor* describes a characteristic value.

E.g. *Presentation Format* or *Valid Range* descriptor.

Descriptors also allow to configure characteristics.

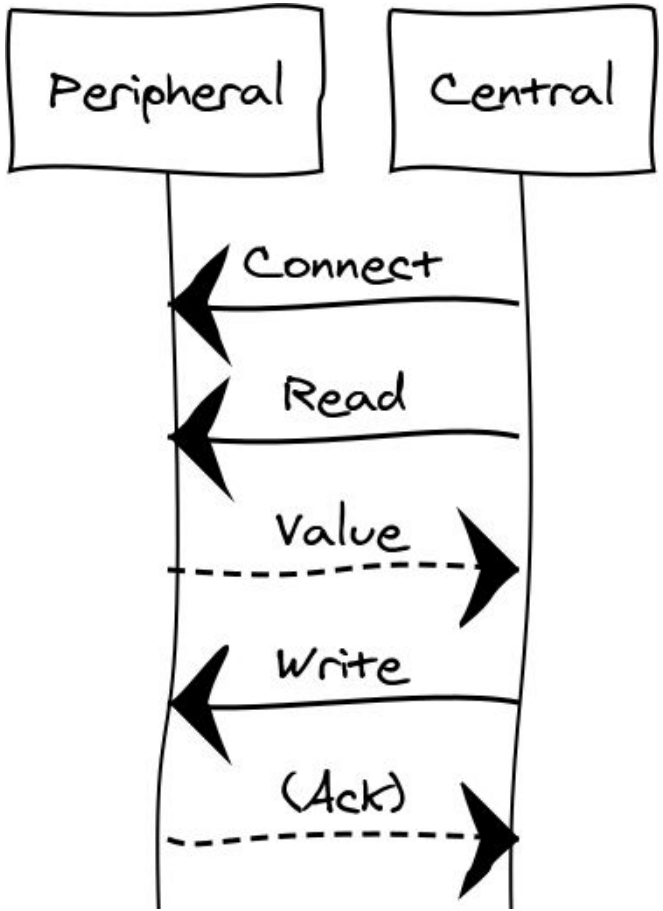
E.g. *Client Characteristic Configuration* descriptor allows a client to enable or disable notifications.

Read and write

Connect = the central connects to a peripherals BLE address.

Read = value of a characteristic or its descriptors is returned.

Write = characteristic value, or characteristic descriptor value is set, with/without response.

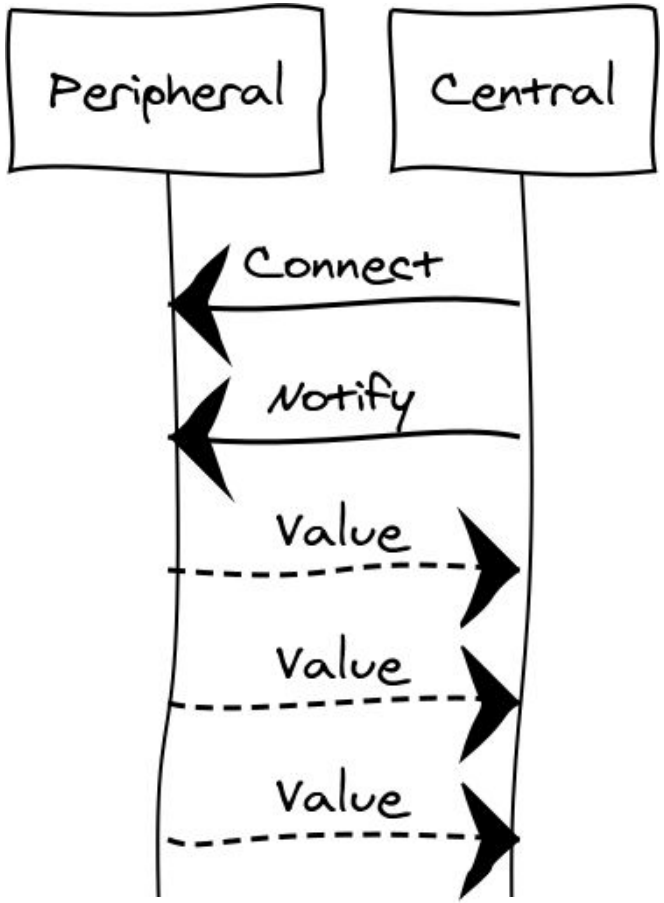


Notifications

Notify = *Client Characteristic Configuration* descriptor of a characteristic, UUID `0x2902`, is set to `0x0001` using *Write*.

Value = A *Handle Value Notification* is sent if value changes.

See Bluetooth spec v5.3, p.1489.



BLE explorer apps

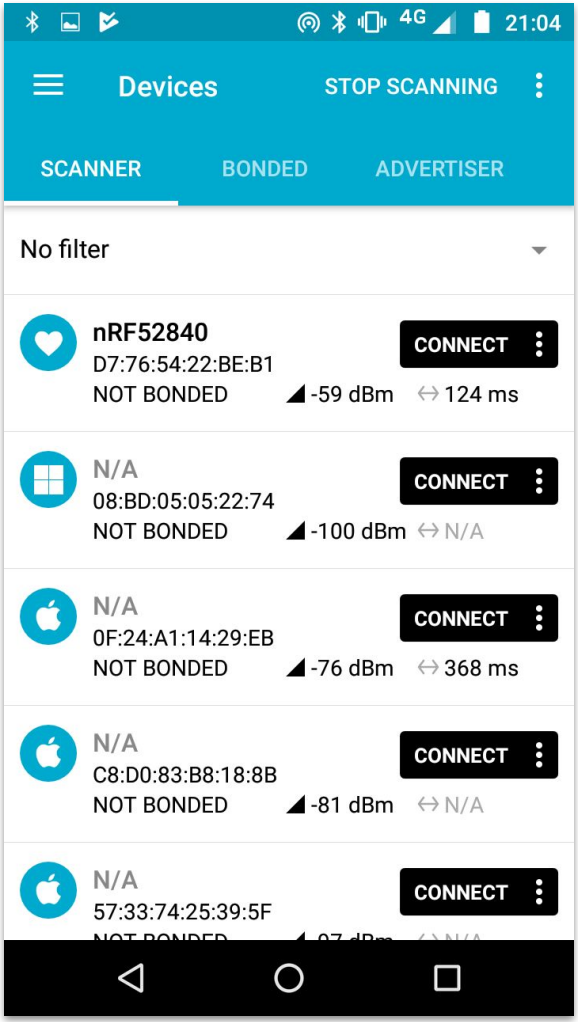
For debugging, use any generic BLE explorer app:

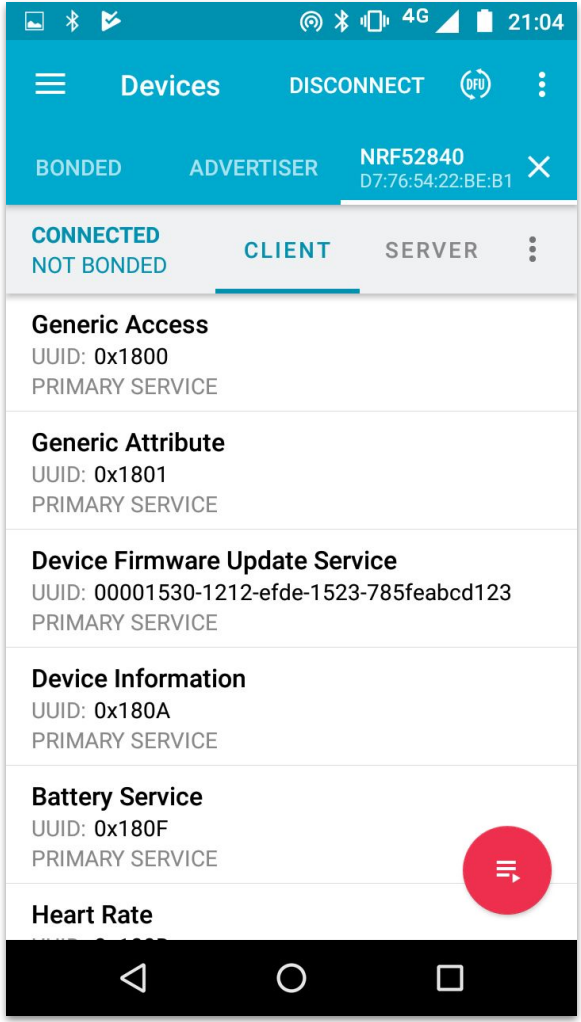
Find BLE explorer apps on the Google Play Store.

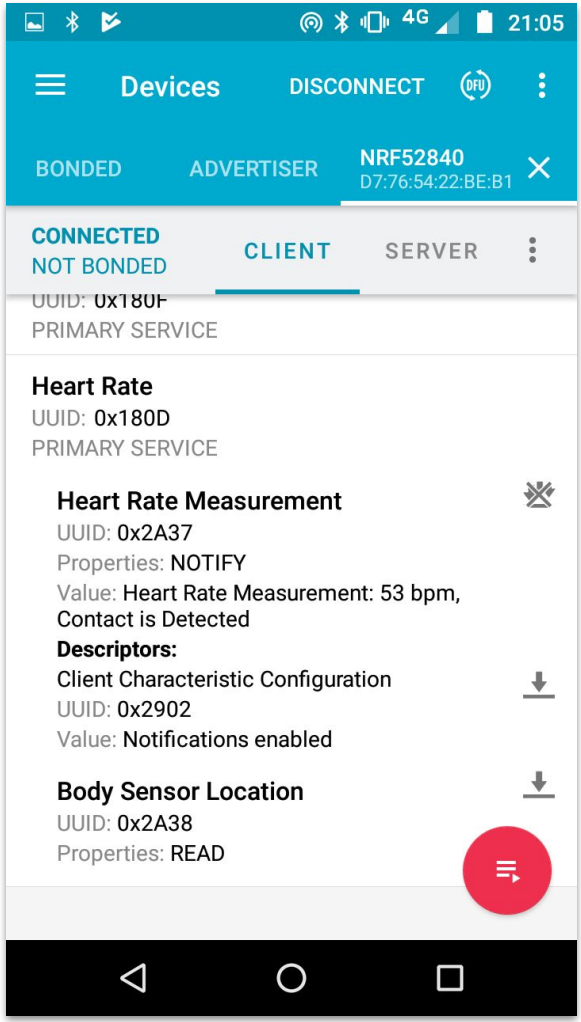
Search for "BLE explorer" in the iOS App Store.

Smartphones can act as central or peripheral.

Exploring is a great way to learn about BLE.


21:04
Devices
STOP SCANNING
SCANNER
BONDED
ADVERTISER
No filter
nRF52840
D7:76:54:22:BE:B1
NOT BONDED
-59 dBm
124 ms
CONNECT
N/A
08:BD:05:05:22:74
NOT BONDED
-100 dBm
N/A
CONNECT
N/A
0F:24:A1:14:29:EB
NOT BONDED
-76 dBm
368 ms
CONNECT
N/A
C8:D0:83:B8:18:8B
NOT BONDED
-81 dBm
N/A
CONNECT
N/A
57:33:74:25:39:5F
CONNECT


21:04
Devices
DISCONNECT
BONDED
ADVERTISER
NRF52840
D7:76:54:22:BE:B1
CONNECTED
NOT BONDED
CLIENT
SERVER
Generic Access
UUID: 0x1800
PRIMARY SERVICE
Generic Attribute
UUID: 0x1801
PRIMARY SERVICE
Device Firmware Update Service
UUID: 00001530-1212-efde-1523-785feabcd123
PRIMARY SERVICE
Device Information
UUID: 0x180A
PRIMARY SERVICE
Battery Service
UUID: 0x180F
PRIMARY SERVICE
Heart Rate


21:05
Devices
DISCONNECT
BONDED
ADVERTISER
NRF52840
D7:76:54:22:BE:B1
CONNECTED
NOT BONDED
CLIENT
SERVER
UUID: 0x180F
PRIMARY SERVICE
Heart Rate
UUID: 0x180D
PRIMARY SERVICE
Heart Rate Measurement
UUID: 0x2A37
Properties: NOTIFY
Value: Heart Rate Measurement: 53 bpm,
Contact is Detected
Descriptors:
Client Characteristic Configuration
UUID: 0x2902
Value: Notifications enabled
Body Sensor Location
UUID: 0x2A38
Properties: READ

Heart rate service

This service is intended for fitness heart rate sensors:

`Heart Rate Service UUID (16-bit): 0x180D`

This service includes the following characteristics:

```
Heart Rate Measurement      UUID: 0x2A37 [N]
Body Sensor Location        UUID: 0x2A38 [R]
Heart Rate Control Point    UUID: 0x2A39 [W]*
```

Standard service, defined by the Bluetooth SIG.

Nordic UART service

This service provides a serial connection over BLE:

Nordic UART Service custom (128-bit) UUID:
0x6E400001-B5A3-F393-E0A9-E50E24DCCA9E

This service includes the following characteristics:

RX (device receives data) UUID: 0x0002 [W]
TX (device transmits data) UUID: 0x0003 [N]

This service is becoming a *de facto* standard.

Beacons

Beacons, e.g. Apple iBeacon are *broadcaster* devices.

Any *observer* can read the data which they advertise.

Lookup of "what a beacon means" requires an app.

Except for Physical Web / Eddystone beacons.

These contain an URL to be used right away.

Security

BLE has security mechanisms for pairing and more.

Pairing: exchanging identity and keys to set up trust.

Device chooses *Just Works*, *Passkey Entry* or OOB.

Or numeric comparison and ECDH for key exchange.

Some apps add encryption on the application layer.

Summary

BLE provides low power, personal area connectivity.

A BLE central scans for peripherals, who advertise.

Each BLE peripheral provides one or more services.

Services allow to read/write characteristic values.

Descriptors allow to configure notifications.

Feedback or questions?

Join us on MSE TSM MobCom in MS Teams

Or email thomas.amberg@fhnw.ch

Thanks for your time.