BLUETOOTH LOW ENERGY

IOS, Android examples
INTRODUCTION

On this presentation you will learn the basics about Bluetooth Low Energy. We're going to learn how to program simple apps in Android and iOS, learn about some modules and how to debug them.
WHAT IT IS

Is a wireless protocol specific for small devices with low bandwidth requirements and battery powered devices.

It's throughput is 5Kb to 10Kb and it's range from 2m to 5m (30 is possible but uses more battery) and the max amount of information that you can send at a time is 20 bytes.

Imagine a sensor as a server that provides some services (Battery status), on those services you have some Characteristics (Voltage, current, etc...)

Your phone will be the client, that can read/write information on those characteristics.
Some BLE Terminology

- Device is a BLE **peripheral** (advertiser, protocol slave) running a **server** (generating data).

- Phone is a BLE **central** (protocol initiator) running a **client** (receiving data).

- A device offers a **profile** which has a **service** which consists of **characteristics** (data values) and **descriptors**. They are accessed via a **UUID** or **handle**.

- A **heart rate** profile might include
  - **heart rate** service with **60** for **HRMeasurement** at **UUID 0x2A37**.
  - **battery** service might offer **97** with **“% full”** at **UUID 0x2A19**.
GAP

GAP is an acronym for the Generic Access Profile, and it controls connections and advertising in Bluetooth. GAP is what makes your device visible to the outside world, and determines how two devices can (or can't) interact with each other.

GAP defines various roles for devices, but the two key concepts to keep in mind are Central devices and Peripheral devices.

- Peripheral devices are small, low power, resource contrained devices that can connect to a much more powerful central device. Peripheral devices are things like a heart rate monitor, a BLE enabled proximity tag, etc.

- Central devices are usually the mobile phone or tablet that you connect to with far more processing power and memory.

GAP, GATT, CCC

Generic Access Protocol (GAP) controls advertising and unconnected interactions.

GAP is responsible for bonding, security, authentication.

Generic Attribute Profile (GATT) is how the protocol services transfer characteristic data

Once connected, GATT takes over with data transfer UUID/ handles, characteristics, and descriptors.

Client configuration characteristic (CCC) sets read, write, and notify for characteristics with variable properties.

CCC is a GATT characteristic, just like the data variables are, except it describes the data control.
GATT

GATT is an acronym for the Generic Attribute Profile, and it defines the way that two Bluetooth Low Energy devices transfer data back and forth using concepts called Services and Characteristics. It makes use of a generic data protocol called the Attribute Protocol (ATT), which is used to store Services, Characteristics and related data in a simple lookup table using 16-bit IDs for each entry in the table.

GATT comes into play once a dedicated connection is established between two devices, meaning that you have already gone through the advertising process governed by GAP.

The most important thing to keep in mind with GATT and connections is that connections are exclusive. What is meant by that is that a BLE peripheral can only be connected to one central device (a mobile phone, etc.) at a time! As soon as a peripheral connects to a central device, it will stop advertising itself and other devices will no longer be able to see it or connect to it until the existing connection is broken.
SERVICE AND CHARACTERISTICS

Imagine a BLE sensor as a information server that gives some kind of information, for instance the Battery Service, provides some characteristics (ex: Battery voltage level, current, time of recharge, etc.).

So basically a service will have one or more characteristics that can be read or written by another device (ie the phone).
LIGHTBLUE

It's an iOS app, that used on bluetooth low energy development, it has features that help both the firmware development as the IOS app that will communicate with a device. Some features:

• Show all BLE devices on the phone range

• List all services and characteristics of a device

• Allow you to write or read a characteristic

• Clone a BLE sensor and make the phone become a BLE sensor, so you can develop from another phone and test.

• Create a device with some characteristic and services
HARDWARE TEST

Basically we need the following hardware:

• BLE Nucleo shield (X-NUCLEO-IDB04A1)
• Nucleo STM32F4 (NUCLEO-F411RE, NUCLEO-F401RE)
• Iphone
• Android

The BLE module and the nucleo board communicate with a SPI interface
NUCLEO F411RE ARDUINO PINOUT
NUCLEO F401RE ARDUINO PINOUT
In order to use the BLE nucleo board with arduino or the nucleo f411re board we need to change the 0-ohm resistor R10 with the R11, or short with a cable these pins. Just remember that there is also a LED1 on this pin (D13) on the nucleo boards. (So don't use this led)

This pin is responsible for the SPI clock.

After this we also need to change the header file on the left, this code is part of the HW driver of the BLE nucleo board (X_NUCLEO_IDB0XA1)
On the Mbed ecosystem, the development of BLE applications is handled by the BLE_API library, which defines a SW layer to make the life of the firmware developer easier; this library offers some hardware support for some boards like the RedBearLab BLE Nano, but it also provides an abstraction layer (Bridge S/W) that allows other vendors to port their BLE modules.
CREATING A BLE PROJECT ONMBED

To give an example on what we can do we will create a BLE peripheral that will serve the following characteristics:

• Give the battery level

• Give characteristic to turn on/off a led

We can start by importing an example project from the BLE module mbed site, basically this will configure a project with BLE_API and the HW layer of the BlueNRG module.
Here we simply add the BLE_API and the services needed (Battery, Device Information, and Custom for Led control), then we define the custom service and characteristic for the led control.

On the last part we bind the characteristic to variables (Notice the 20 byte array limit)
int main(void) {
    uint8_t batteryLevel = 50; printf("Initialize BLE\r\n");
    ble.init();

    ble.gap().onDisconnection(disconnectionCallback);
    ble.gattServer().onDataWritten(writeCharCallback);

    // Setup battery service
    BatteryService batteryService(ble, batteryLevel);
    // Device Information
    DeviceInformationService deviceInfo(ble, "StarkIndustries", "Quadcopter", "SN1", "hw-revl", "fw-revl", "BetaVer");
    // add our custom service
    ble.addService(customService);

    // Setup advertising. Indicate that we only support bluetooth low energy, and our services
    ble.gap().accumulateAdvertisingPayload(GapAdvertisingData::BREDR_NOT_SUPPORTED | GapAdvertisingData::LE_GENERAL_DISCOVERABLE);
    ble.gap().accumulateAdvertisingPayload(GapAdvertisingData::COMPLETE_LIST_16BIT_SERVICE_IDS, (uint8_t *)uuid16_list, sizeof(uuid16_list));
    ble.gap().accumulateAdvertisingPayload(GapAdvertisingData::COMPLETE_LOCAL_NAME, (uint8_t *)DEVICE_NAME, sizeof(DEVICE_NAME));
    ble.gap().setAdvertisingType(GapAdvertisingParams::ADV_CONNECTABLE_UNDIRECTED);
    ble.gap().setAdvertisingInterval(1000); /* 1000ms */
    ble.gap().startAdvertising();

    // Main loop
    while (1) {
        ble.waitForEvent(); // this will return upon any system event (such as an interrupt or a ticker wakeup)
        // the magic battery processing
        batteryLevel++;
        if (batteryLevel > 100) {
            batteryLevel = 20;
        }
        batteryService.updateBatteryLevel(batteryLevel);
    }
}
```c
void disconnectionCallback(const Gap::DisconnectionCallbackParams_t *params) {
    printf("Start advertising\n\r");
    ble_gap().startAdvertising(); // restart advertising
}

// Handle writes to writeCharacteristic
void writeCharCallback(constGattWriteCallbackParams *params) {
    // check to see what characteristic was written, by handle
    if(params->handle == writeChar.getHandle()) {
        // toggle LED if only 1 byte is written
        if(params->len == 1) {
            led1 = params->data[0];
            (params->data[0] == 0x00) ? printf("led off\n\r") : printf("led on\n\r"); // print led toggle
        } else {
            printf("Data received: length = %d, data = 0x", params->len);
            for(int x=0; x < params->len; x++) {
                printf("%x", params->data[x]);
            }
            printf("\n\r");
        }
        // Update the readChar with what the phone write
        ble.updateCharacteristicValue(readChar.getHandle(), params->data, params->len);
    }
```
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