

# Mobile Computing Bluetooth Low Energy on Microcontrollers

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Slides: [tmb.gr/mc-per](https://tmb.gr/mc-per)

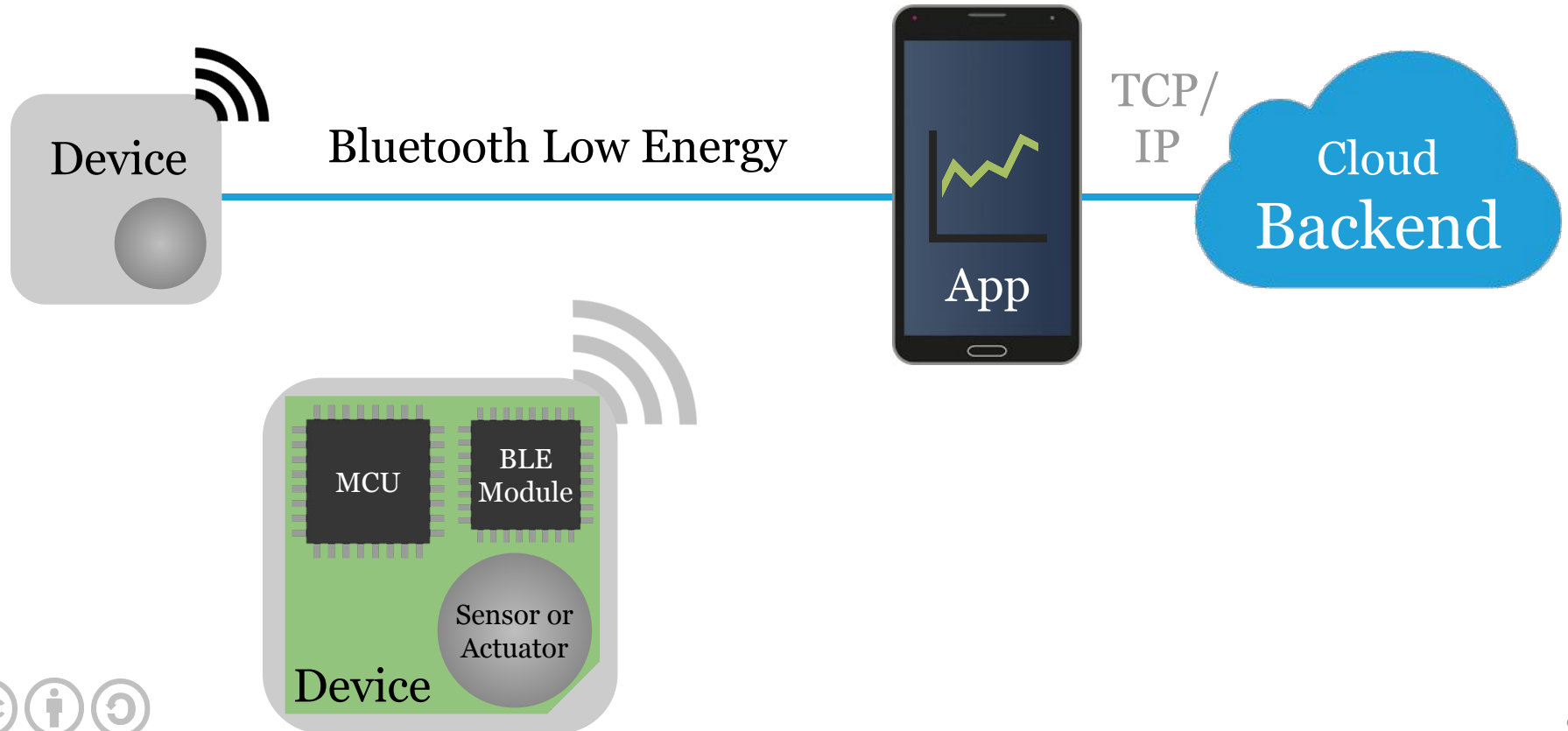
# Overview

These slides introduce *BLE on a microcontroller*.

How to implement a central or peripheral device.

With services, characteristics and descriptors.

# Reference model



# Prerequisites

Install the Arduino IDE and set up the nRF52840,

Check the Wiki entry on [Installing the Arduino IDE](#).

[Set up the Feather nRF52840 Express](#) for Arduino.

Setting up the board also installs this [BLE library](#).

For testing, a smartphone with BLE is required.

# BLE on the nRF52840

The nRF52840 can take the peripheral or central role.

The [Adafruit BLE library source code](#) and [examples](#) provide some "documentation" and a starting point.

To implement or use a peripheral, we have to know its API, consisting of service and characteristic UUIDs.

# Heart rate service

This service is intended for fitness heart rate sensors:

**Heart Rate Service** UUID (16-bit): 0x**180D**

This service includes the following characteristics:

**Heart Rate Measurement**                      UUID: 0x**2A37** [N]

**Body Sensor Location**                      UUID: 0x**2A38** [R]

**Heart Rate Control Point**                      UUID: 0x**2A39** [W]\*

\*See also **Heart Rate Service** specification.

# nRF52840 HRM BLE peripheral [.ino](#)

```
hrmSvc = BLEService(0x180D); // See HRM spec
hrmChr = BLECharacteristic(0x2A37); // See spec

hrmSvc.begin(); // to add characteristics
hrmChr.setProperties(CHR_PROPS_NOTIFY); ...
hrmChr.begin(); // adds characteristic

uint8_t hrmData[2] = { 0b00000110, value };
hrmChr.notify(hrmData, sizeof(hrmData));
```

# Hands-on, 10': HRM BLE peripheral

Build and run the previous nRF52840 BLE example.

Use the *.ino* link on the page to get the example code.

Explore the HRM example using a smartphone app\*.

Try to enable notifications to get value updates.

\*Try [nRF Connect for Android](#) or [iOS](#).



# nRF52840 HRM BLE central `.ino`

```
BLEClientService hrmSvc(UUID16_SVC_HEART_RATE);  
BLEClientCharacteristic hrmChr(UUID16_CHR_...);  
  
// part of setup()  
Bluefruit.begin(0, 1); // 1 central connection  
hrmSvc.begin();  
hrmChr.setNotifyCallback(notifyCbck);  
hrmChr.begin(); // implicitly added to service  
Bluefruit.Central.setConnectCallback(connCbck);
```

# nRF52840 HRM BLE central (ff.) [.ino](#)

```
void connCbck(uint16_t connHandle) {  
    if (hrmSvc.discover(connHandle)) {  
        if (hrmChr.discover()) {  
            hrmChr.enableNotify();  
        } else { ... }  
    } else {  
        Bluefruit.disconnect(connHandle);  
    }  
}
```

# nRF52840 HRM BLE central (ff.) [.ino](#)

```
Bluefruit.Scanner.setRxCallback(scanCbck);  
Bluefruit.Scanner.filterUuid(hrmSvc.uuid);  
Bluefruit.Scanner.restartOnDisconnect(true);  
Bluefruit.Scanner.start(0); // non-stop  
  
void scanCbck(ble_gap_..._report_t* report) {  
    // optional: check for device address  
    Bluefruit.Central.connect(report);  
}
```

# Hands-on, 10': HRM BLE central

Build and run the previous nRF52840 BLE example.

Use the *.ino* link on the page to get the example code.

Open the Arduino serial monitor to enter a message.

Use a second nRF52840\* as a HRM peripheral.

\*Or your smartphone as a [peripheral simulator](#).

# 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: 0x**0002** [W]

TX (device transmits data) UUID: 0x**0003** [N]

This service is becoming a de facto standard.

# nRF52840 UART BLE peripheral [.ino](#)

```
// UUID: 6E400001-B5A3-F393-E0A9-E50E24DCCA9E
uint8_t const uartSvcUuid[] = { 0x9E, 0xCA, ...,
0xB5, 0x01, 0x00, 0x40, 0x6E }; // lsb first

uartSvc = BLEService(uartSvcUuid); // 128-bit
rxChr = BLECharacteristic(rxChrUuid); // 128-b.
txChr = BLECharacteristic(txChrUuid); // 128-b.

txChar.setProperties(CHR_PROPS_NOTIFY);
rxChar.setProperties(CHR_PROPS_WRITE);
```

# Hands-on, 10': UART BLE peripheral

Build and run the previous nRF52840 BLE example.

Use the *.ino* link on the page to get the example code.

Write bytes to RX with a generic BLE explorer app.

Check the serial monitor to see the received bytes\*.

\*Why do some bytes not show up?

# nRF52840 UART BLE central

.ino

```
Bluefruit.begin(0, 1); // 1 central connection
uartSvcClient.begin();
uartSvcClient.setRxCallback(rxCbck); // read
Bluefruit.Central.setConnectCallback(connCbck);

void connCbck(uint16_t connHandle) {
    if (uartSvcClient.discover(connHandle)) {
        uartSvcClient.enableTXD(); // enable notify
        uartServiceClient.print(...); // write data
        ... } }
```



# nRF52840 UART BLE central (ff.) [.ino](#)

```
Bluefruit.Scanner.setRxCallback(found);

void found(ble_gap_evt_adv_report_t* report) {
    if (...Scanner.checkReportForService(
        report, uartServiceClient)) {
        Bluefruit.Central.connect(report);
    } else {
        Bluefruit.Scanner.resume();
    }
}
```

# Hands-on, 10': UART BLE central

Build and run the previous nRF52840 BLE example.

Use the *.ino* link on the page to get the example code.

Open the Arduino serial monitor to enter a message.

Use a second nRF52840 as a UART peripheral.

# nRF52840 Beacon BLE observable `.ino`

```
BLEBeacon beacon(  
    beaconUuid, // AirLocate UUID  
    beaconMajorVersion,  
    beaconMinorVersion,  
    rssAtOneMeter);  
beacon.setManufacturer(0x004C); // Apple  
startAdvertising();  
  
suspendLoop(); // save power
```

# nRF52840 Scanner BLE central

.ino

```
Bluefruit.begin(0, 1); // Central
Bluefruit.Scanner.setRxCallback(found);
Bluefruit.Scanner.start(0);

void found(ble_gap_evt_adv_report_t* report) {
    Serial.printBufferReverse( // little endian
        report->peer_addr.addr, 6, ':');
    if (Bluefruit.Scanner.checkReportForUuid(...))...
    Bluefruit.Scanner.resume();
}
```

# Hands-on, 10': Scanner BLE central

Build and run the previous nRF52840 BLE example.

Use the *.ino* link on the page to get the example code.

Add a *checkReportForUuid()* for the Battery Service.

Can you spot the UUID in the advertising data?

Bonus: Scan for Covid-19 apps as described [here](#).

# Summary

The nRF52840 can take the peripheral or central role.

To build/use a service we need its 16-/128-bit UUID.

Peripherals set up services, update characteristics.

Centrals connect to read, write or get notifications.

The specific value format depends on the service.

# Homework, max. 3h

Design and implement an API for the **SHT30 sensor**.

Create UUIDs for your service and its characteristics.

Chose a data format that fits the sensor value range.

Consider to allow reading, writing or notifications.

Test your peripheral with a generic BLE explorer.

# Feedback or questions?

Join us on [MSE TSM MobCom](#) in MS Teams

Or email [thomas.amberg@fhnw.ch](mailto:thomas.amberg@fhnw.ch)

Thanks for your time.