Mobile Computing Bluetooth Low Energy on Microcontrollers

Slides: tmb.gr/mc-per

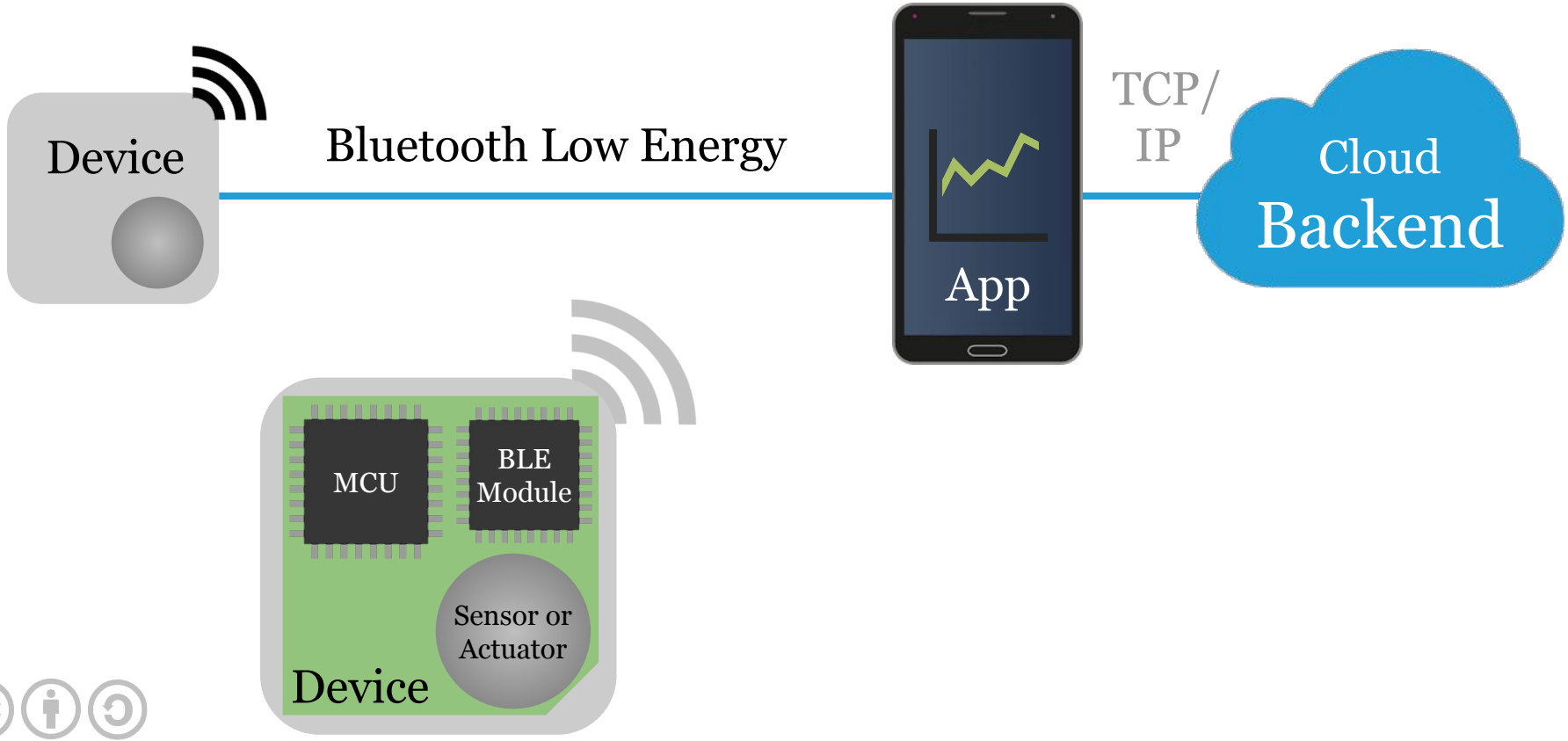
Overview

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): 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]*`

*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: 0x0002 [W]
TX (device transmits data) UUID: 0x0003 [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,
  rssiAtOneMeter);
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 examples.

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

Test the scanner with a (simulated) HRM peripheral.

Adapt the scanner to scan for the beacon observable.

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

Thanks for your time.