Mobile Computing Bluetooth Low Energy on Microcontrollers

Slides: tmb.gr/mc-per

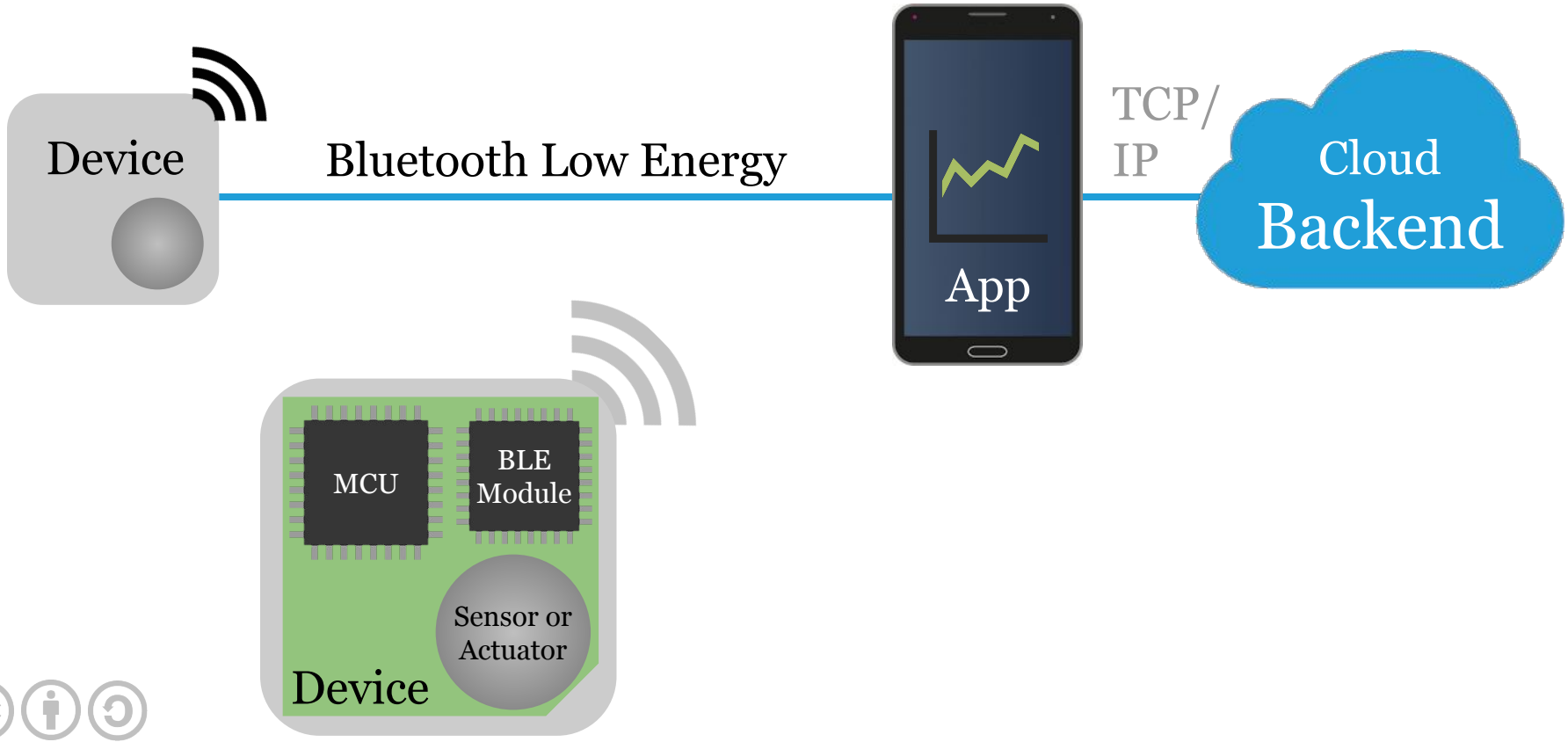
Overview

These slides introduce *BLE on microcontrollers*.

Examples for the peripheral and central roles.

Designing BLE services and characteristics.

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 Sense with 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]*
```

Standard service, defined by the Bluetooth SIG.

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.

Challenge, 1h+

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.