Mobile Computing Bluetooth Low Energy on Android Smartphones

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Slides: tmb.gr/mc-cen

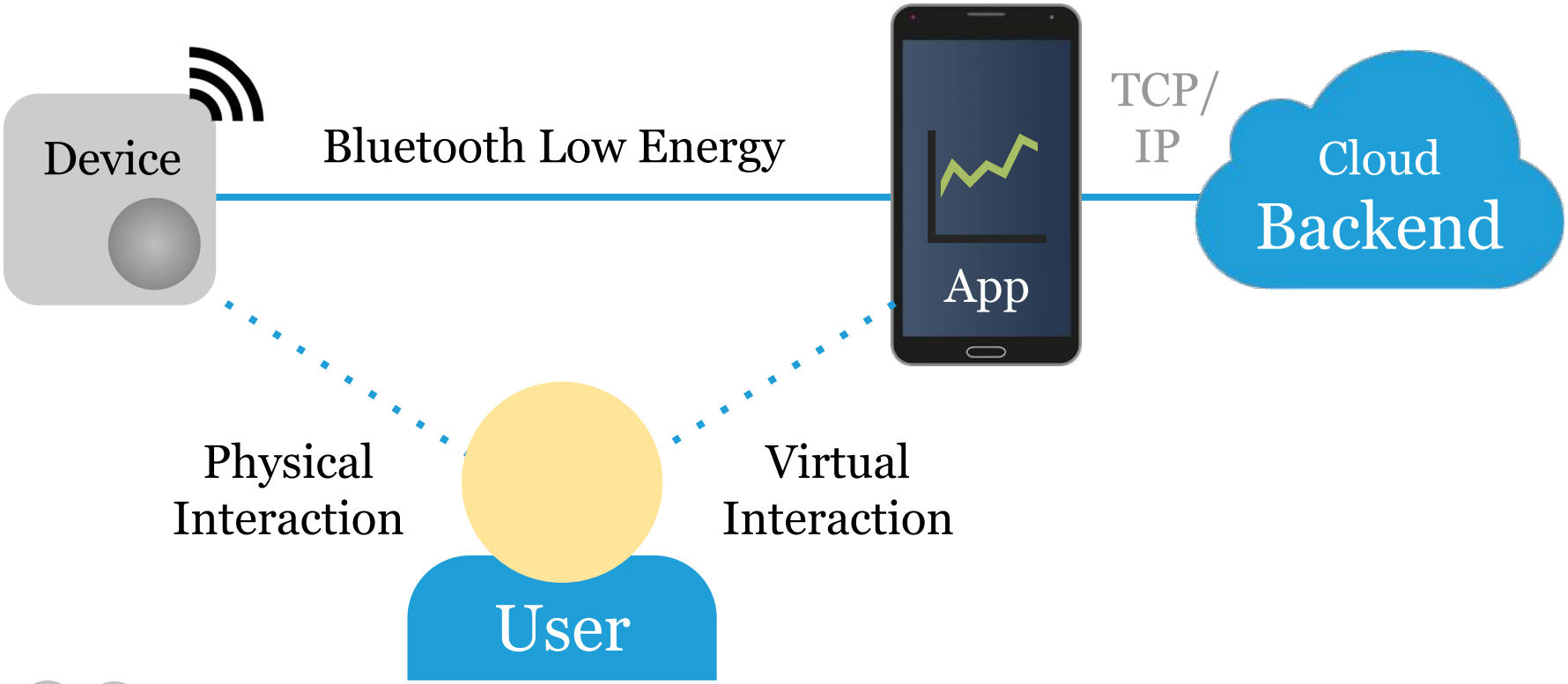
Overview

These slides introduce *BLE on Android smartphones*.

How to implement the central role, as a GATT client.

Scanning, reading, writing and getting notifications.

Reference model



BLE on Android

Android has built-in BLE support* since API level 18.

A smartphone can take the central or peripheral role.

The Android SDKs BLE API is rather tricky to use.

Luckily there are some good 3rd party libraries.

*Next to Bluetooth Classic (Headset, A2DP, HDP).

Adding permissions

Add these permissions to your app manifest file:

`android.permission.`**`BLUETOOTH`** 18+

`android.permission.`**`BLUETOOTH_ADMIN`** 18+

Also, as BLE discovery is privacy critical*, add:

~~`android.permission.ACCESS_COARSE_LOCATION`~~ 23+

`android.permission.`**`ACCESS_FINE_LOCATION`** 29+

*E.g. beacons might reveal your location to apps.

Checking hardware capability

Indicate usage of BLE in your app manifest file:

```
<uses-feature
android:name="android.hardware.bluetooth_le"
android:required="true"/><!-- or false -->
```

And test if BLE is available on the current system:

```
if (getPackageManager().hasSystemFeature(
  PackageManager.FEATURE_BLUETOOTH_LE)) { … }
```

Setting up a BluetoothAdapter

Get the BluetoothAdapter via BluetoothManager:

```
final BluetoothManager bluetoothManager =
  (BluetoothManager) getSystemService(
    Context.BLUETOOTH_SERVICE);
BluetoothAdapter bluetoothAdapter =
  bluetoothManager.getAdapter();
```

Ensuring Bluetooth is enabled

If Bluetooth is not enabled, ask the user to enable it:

```
if (bluetoothAdapter != null &&
  bluetoothAdapter.isEnabled()) { …
} else {
  Intent enableBtIntent = new Intent(
    BluetoothAdapter.ACTION_REQUEST_ENABLE);
    startActivityForResult(
      enableBtIntent, REQUEST_ENABLE_BT);
}
```

Getting a scanner

Get a BluetoothLeScanner to scan for BLE devices:

```
BluetoothLeScanner scanner =
  bluetoothAdapter.getBluetoothLeScanner();
```

The Handler runs a *Runnable** on another thread:

```
static final long SCAN_PERIOD_MS = 10000;
Handler handler =
  new Handler(Looper.getMainLooper());
```

*See coming slide.

Asking for location permission (again)

```
String[] permissions = new String[]{
  Manifest.permission.ACCESS_FINE_LOCATION
};
ActivityCompat.requestPermissions(
  MainActivity.this, permissions, 0);
```

```
@Override
public void onRequestPermissionsResult (…) {
  scan();
}
```

Starting a scan

```
void scan() {
  handler.postDelayed(new Runnable() {
    @Override
    public void run() {
      scanner.stopScan(scanCallback);
    }
  }, SCAN_PERIOD_MS);
  scanner.startScan(scanCallback);
}
```

Getting scan results

```
ScanCallback scanCallback = new ScanCallback(){
  @Override
  public void onScanResult(
    int callbackType, ScanResult result) {
    super.onScanResult(callbackType, result);
    Log.d(TAG, result.getDevice());
  }
};
```

Hands-on, 15': Android BLE scanner

Build and run the MyBleScannerApp example code.

Check the Logcat output with filter "MainActivity".

If it works, you should see BLE devices around you.

Test the app by disabling Bluetooth, location, etc.

Done? Add a button to the UI to start a scan.

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.

Base UUID for registered services

For a custom service UUID we define all 128-bits, e.g.
`0x6E400001-B5A3-F393-E0A9-E50E24DCCA9E`

For well known, registered services the *base UUID* is*
`0x00000000-0000-1000-8000-00805F9B34FB`

A 16-bit service "UUID", e.g. `0x180D` corresponds to:
`0x0000180D-0000-1000-8000-00805F9B34FB`

*See Bluetooth spec v5.1, Part B, p. 2034 ff.

Connecting to discover GATT services

```
final BluetoothGattCallback gattCallback =
  new BluetoothGattCallback() {
  @Override
  public void onConnectionStateChange(…) { … }
    gatt.discoverServices();
  } …
};
BluetoothGatt gatt = device.connectGatt(
  this, /* reconnect */ true, gattCallback);
```

Reading a GATT characteristic

```
final BluetoothGattCallback gattCallback =
  new BluetoothGattCallback() { …
  @Override
  public void onServicesDiscovered(…) { …
    BluetoothGattCharacteristic characteristic
      = gattService.getCharacteristic(uuid);
    gatt.readCharacteristic(characteristic);
  } …
};
```

Getting a GATT characteristic value

```
final BluetoothGattCallback gattCallback =
  new BluetoothGattCallback() { …
  @Override
  public void onCharacteristicRead(…) { …
    if (characteristic.getUuid().equals(…)) {
      byte[] value = characteristic.getValue();
    }
  } …
};
```

Writing a GATT characteristic

```
final BluetoothGattCallback gattCallback =
  new BluetoothGattCallback() { …
  @Override
  public void onServicesDiscovered(…) { …
    BluetoothGattCharacteristic characteristic
      = gattService.getCharacteristic(uuid);
    characteristic.setValue(value, format, 0);
    gatt.writeCharacteristic(characteristic);
  } … };
```

Getting GATT characteristic write status

```
final BluetoothGattCallback gattCallback =
  new BluetoothGattCallback() { …
  @Override
  public void onCharacteristicWrite(…) { …
    if (characteristic.getUuid().equals(…)) {
      Log.d(TAG, "write, status = " + status);
    }
  } …
};
```

Enabling GATT char. notifications

```
@Override
public void onServicesDiscovered(…) { …
  gatt.setCharacteristicNotification(…, true);
  UUID configUuid = UUID.fromString("2902");
  BluetoothGattDescriptor descriptor =
    characteristic.getDescriptor(configUuid);
  descriptor.setValue(BluetoothGattDescriptor.
    ENABLE_NOTIFICATION_VALUE);
  gatt.writeDescriptor(descriptor);
}
```

Getting GATT characteristic notifications

```
final BluetoothGattCallback gattCallback =
  new BluetoothGattCallback() { …
  @Override
  public void onCharacteristicChanged(…) { …
    if (characteristic.getUuid().equals(…)) {
      byte[] value = characteristic.getValue();
    }
  } …
};
```

Hands-on, 10': Android BLE central

Build and run the MyBleCentralApp example code.

Also, a nRF52840 with HRM BLE peripheral code.

Check the Logcat output with filter "MainActivity".

If it works, you should see heart rate measurements.

Done? Read the Android app source code in detail.

What's missing in the example code

BLE related code should be moved into a Service.

Starting a scan should be triggered by the user*.

Discovered devices should be presented in a list.

Read, write, etc. operations should be queued.

*On API level 26+, try companion device pairing.

Hands-on, 10': Android BLE issues

It looks easy, but BLE on Android has many issues.

Read some of the tips how to make it actually work.

Also check this list of issues to get an impression.

iOS BLE seems more stable. Why could that be?

Done? Find some stats about the Android OS.

BLE libraries from 3rd parties

Writing robust apps based on the BLE API is hard.

There are a number of 3rd party libraries to fix this:

The Nordic Android BLE library is written in Java.

RxAndroidBle library uses the RxJava framework*.

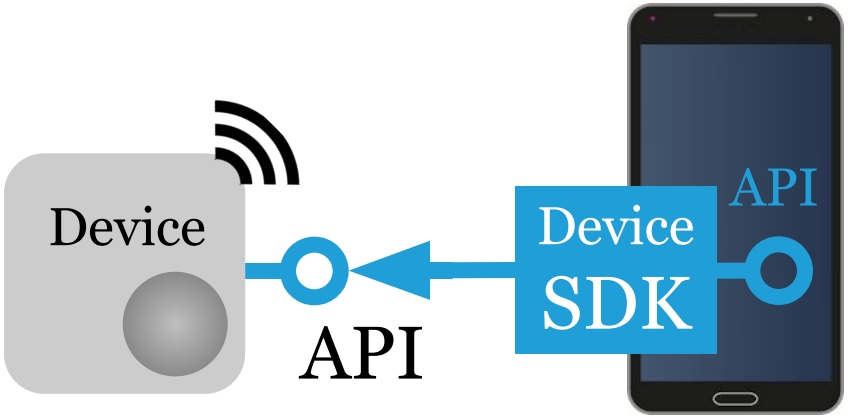
*For more see this Android BLE guide.

Device API vs. SDK

A *device API* specifies how to talk to the device, from any client (here via BLE).

A platform specific *device SDK* simplifies integration.

E.g. *iOS device SDK* to talk to a device API from iOS.




```
Battery Service
  Battery Level [R]
vs.
p = ble.conn(addr);
b = sdk.getBatt(p);
x = b.getLevel();
```

Hands-on, 30': nRF Toolbox Plugin

The nRF Toolbox app allows to write new plugins.

Build and run the nRF Toolbox app source code.

Write a plugin for a custom SHT30 BLE service.

Done? Create a custom icon for your service.

Summary

The Android BLE API allows to implement a central.

Scan, read, write and notify operations use callbacks.

Service and characteristic UUID define the interface.

3rd party libraries can help to write robust BLE code.

Feedback or questions?

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Or email thomas.amberg@fhnw.ch

Thanks for your time.