LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Praktikum Mobile und Verteilte Systeme

Connectivity with Android

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Sommersemester 2016

Connectivity with Android

Today:

- Bluetooth
- NFC
- 802.11 & Wifi Direct / P2P

Further Reading:

- Android Developer Guide (http://developer.android.com/guide/topics/connectivity/)

Bluetooth: Introduction (I)

Bluetooth

- Low-cost, radio-based wireless network technology
- Standardized by the Bluetooth Special Interest Group (SIG), a consortium founded in 1998 by Ericsson, Intel, IBM, Nokia, and Toshiba
- Uses the license-free 2.4 GHz band

- Use Cases
  - Wireless internet access
  - Synchronization
  - Wireless headset
  - Data exchange

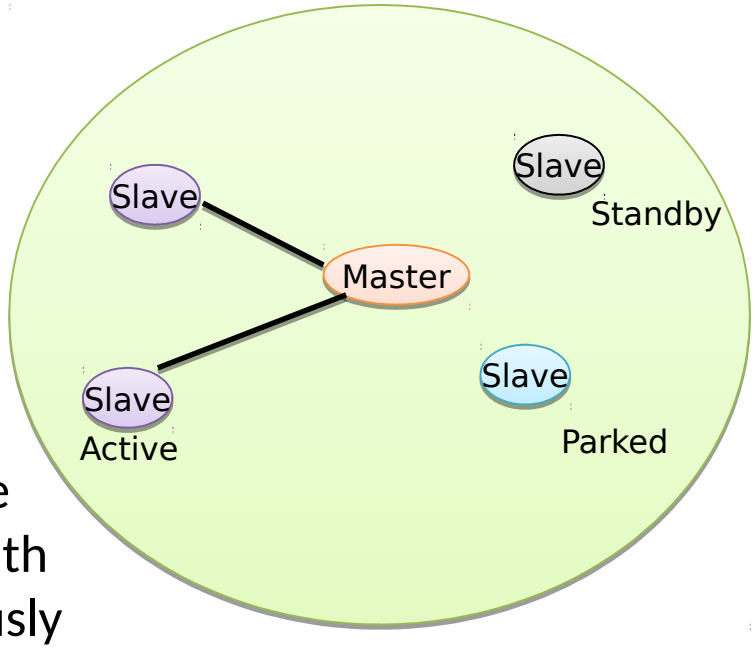
Bluetooth: Introduction (II)

- 2.4 GHz ISM band (2400-2483,5MHz), 79 RF channels, 1 MHz carrier spacing
  - Channel 0: 2402 MHz … channel 78: 2480 MHz
  - Guard bands: Lower Guard Band 2MHz, Upper Guard Band 3,5MHZ
  - G-FSK modulation (1 MSymbol/s), 1-100 mW transmit power
- FHSS and TDD
  - **Frequency hopping** with 1600 hops/s
  - Hopping sequence in a pseudo random fashion, determined by a master
  - **Time division duplex** for send/receive separation
- Voice link – SCO (Synchronous Connection Oriented)
  - FEC (forward error correction), no retransmission, 64 kbit/s duplex, point-to-point, circuit switched
- Data link – ACL (Asynchronous Connection Less)
  - Asynchronous, fast acknowledge, point-to-multipoint, up to 433.9 kbit/s symmetric or 723.2/57.6 kbit/s asymmetric, packet switched
- Topology
  - Overlapping piconets (stars) forming a scatternet

Bluetooth: Piconets

Piconet

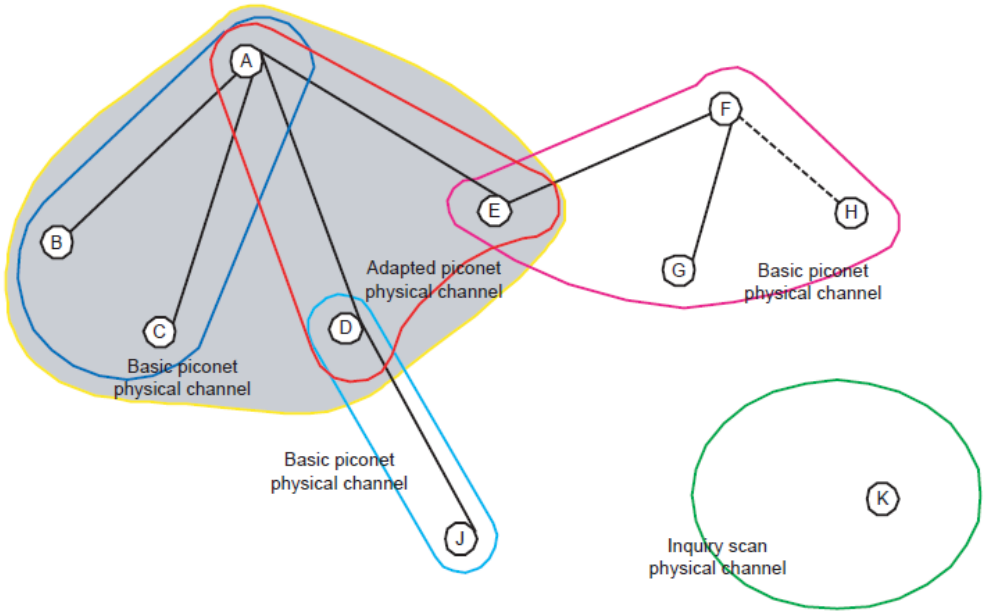
- Basic unit of networking in Bluetooth
- Consists of a master device and up to
- seven slaves
- Master coordinates medium access
- Slave may only communicate with the
- master and may only communicate when
- granted permission by the master
- Only units that have to exchange data share
- the same Piconet, so that many Piconets with
- overlapping coverage can exist simultaneously



Bluetooth: Scatternets

Scatternet

- Group of linked Piconets joined by common devices
- Devices linking the Piconets can be slaves on both Piconets, or a master of one Piconet and a slave of another



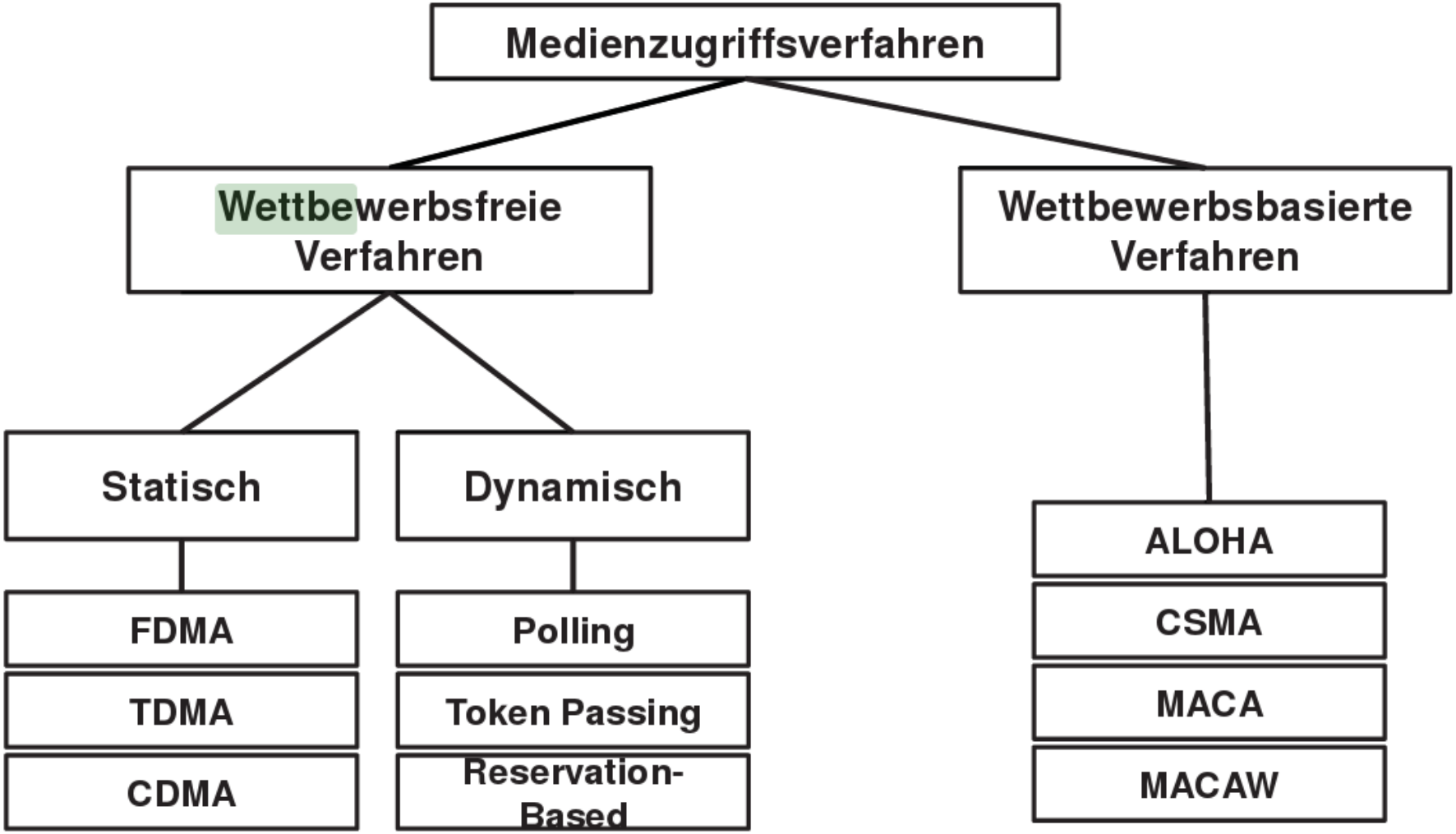
Bluetooth: Multiplexing (I)

Medium access among different Piconets:
FH (Frequency Hopping)-CDMA
(cp. FHSS in 802.11)

- Master coordinates medium access
- Slave can only communicate with the master and can only communicate when granted permission by the master
- Total bandwidth divided into 79 physical channels, each of bandwidth 1 MHz
- **Overlapping Piconets are separated from one another by frequency hopping**
- Frequency hopping occurs by jumping from one physical channel to another in a pseudorandom sequence

- The same hopping sequence is shared by all devices on a single Piconet
- 1,600 hops per second
- Slot length of 625µs (625 bits at 1 Mbps)
- **Hopping sequence is a function of the master's Bluetooth address and clock**
- As the master's address is known to all terminals in a Piconet, all terminals can derive the hopping sequence
- Because different Piconets have different masters, they use different hopping sequences

MAC-Verfahren



Wettbewerbsfreie Verfahren (I)

- Vermeidung von Kollisionen durch Allokation der Ressourcen
- Beispiele für statische Zuweisung
  - **FDMA**: Frequency Division Multiple Access
    - Unterteilung des Frequenzbandes in mehrere Teilbänder, die gleichzeitig genutzt werden können
  - **TDMA**: Time Division Multiple Access
    - Unterteilung in Zeitslots, für welche festgelegt ist, wer senden darf
  - **CDMA**: Code Division Multiple Access
    - Nutzung der gleichen Ressource durch mehrere Nutzer durch Verwendung von Spreizcodes
    - Aus Überlagerung von Signalen unterschiedlicher Codes kann durch Eigenschaften der Codes das Datensignal eines Nutzers wieder isoliert werden

Wettbewerbsfreie Verfahren (II)

- Dynamische Verfahren
  - **Polling**
    - Ein Controller fragt jeden Knoten, ob er etwas zu senden hat. Wenn ein Knoten nicht übertragen möchte, wird der nächste Knoten gefragt.
  - **Token Passing**
    - Ein Token wird zwischen den Knoten herum gereicht. Nur wer das Token hat, darf senden.
  - **Reservation**
    - Knoten nutzt bestimmte Slots, um Zeitslots für zukünftige Übertragung zu reservieren.

Wettbewerbsbasierte Verfahren

- Knoten können zur gleichen Zeit ihre Übertragung initiieren
  - Mechanismen zu Vermeidung und Auflösung von Konflikten nötig
  - **ALOHA**
    - Jeder Knoten sendet, wann er will
    - Erfolgreiche Übertragungen werden mittels ACK bestätigt
    - Bei Kollisionen wartet Knoten bestimmte Zeit (exponential back-off) vor erneuter Übertragung
  - **Carrier Sense Multiple Access** (CSMA)
    - CSMA with Collision Detection (CSMA/CD)
      - Sender prüft zunächst, ob Medium frei ist
      - Wenn Medium belegt, dann stellt Knoten seine Übertragung zurück
      - Erfolgreiche Übertragungen werden mittels ACK bestätigt
  - **CSMA with Collision Avoidance** (CSMA/CA + RTS/CTS)
    - Versucht Kollisionen durch *Four-Way Handshaking* zu verhindern

Bluetooth: Specifications

- Bluetooth 1.1:
- IEEE 802.15, Non-encrypted Channels

- Bluetooth 1.2:
- Adaptive Frequency Hopping (AFH), Enhanced SCO (eSCO), November 2003

- Bluetooth 2.0 + EDR:

  Enhanced Data Rate (EDR), October 2004

- Bluetooth 2.1 + EDR:

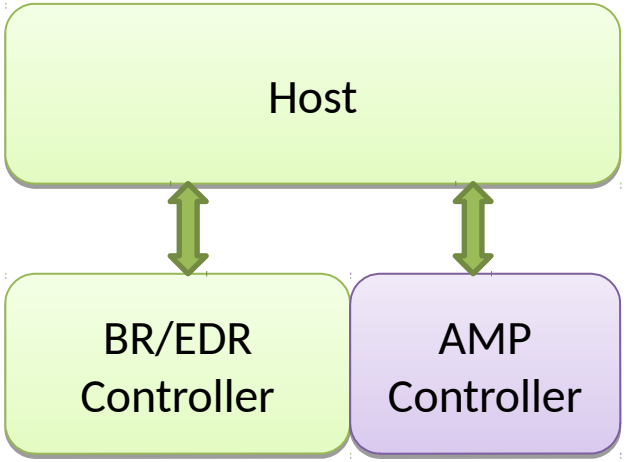
  Secure Simple Pairing, Quality of Service, July 2007

- Bluetooth 3.0 + HS:

  Alternate MAC/PHY (AMP) Controller, April 2009

Bluetooth: Bluetooth AMP (Alternate MAC/PHY)

- Uses 802.11 (WLAN) to transmit at higher data rates (up to 24 Mbit/s)
- Bluetooth radio still used for device discovery
  - AMP Managers can discover the AMPs that are available on the other device
  - If available on both devices: Data traffic is moved from BR/DER Controller to AMP Controller
- AMP consists of Protocol Adaptation Layer (PAL) on top of a MAC and PHY
- PAL responsible for mapping the
- Bluetooth protocols to specific
  - protocols of underlying MAC/PHY



Bluetooth: Low Energy (v4.0)

- Bluetooth Core Specification Version 4.0:
  - Formal adoption in July 2010
  - Hallmark feature: Bluetooth low energy technology
- Key features:
  - Ultra-low peak, average and idle mode power consumption
  - Ability to run for years on standard, coin-cell batteries
  - Low cost
  - Low complexity
  - Multi-vendor interoperability
  - Enhanced range

Bluetooth: Android

- Android supports classical Bluetooth and Bluetooth Low Energy (since API Level 18)
  - Reference: `android.bluetooth`

- Using the Bluetooth API, apps can
  - Scan for other Bluetooth devices
  - Query the local Bluetooth adapter for paired Bluetooth devices
  - Establish RFCOMM channels
  - Connect to other devices through service discovery
  - Transfer data to and from other devices
  - Manage multiple connections

Bluetooth: First steps with Android

- **Bluetooth Permissions**

```
<manifest ... >
  <uses-permission android:name="android.permission.BLUETOOTH" />
  <uses-permission android:name="android.permission.BLUETOOTH_ADMIN" />
  ...
</manifest>
```

- **Setting Up Bluetooth**
  - Check if Bluetooth is supported:

```
BluetoothAdapter mBluetoothAdapter =
BluetoothAdapter.getDefaultAdapter();
if (mBluetoothAdapter == null) {
    // Device does not support Bluetooth
}
```

  - Enable Bluetooth:

```
if (!mBluetoothAdapter.isEnabled()) {
     Intent enableBtIntent = new
     Intent(BluetoothAdapter.ACTION_REQUEST_ENABLE);
     startActivityForResult(enableBtIntent, REQUEST_ENABLE_BT);
     }
```

Bluetooth: Summary

- Bluetooth
  - Low-cost, radio-based wireless network technology
  - Uses the license-free 2.4 GHz band
- Multiplexing
  - Frequency hopping , Time division duplex
- Link types
  - SCO, ACL
- Topology
  - Piconet, Scatternet
- Specifications
  - Classical, EDR, HS, BLE
- Android Bluetooth API

NFC – Introduction (I)

„Near field communication (NFC) is a set of standards for smartphones and similar devices to establish radio communication with each other by touching them together or bringing them into close proximity, usually no more than a few inches.”

Source: http://en.wikipedia.org/wiki/Near_field_communication

- Wireless Short Range Communication Technology
- Based on RFID technology at 13,56 MHz
- Operating distance: up to 10 cm
- Data exchange rate: up to 424 kilobits/s

NFC – Introduction (II)

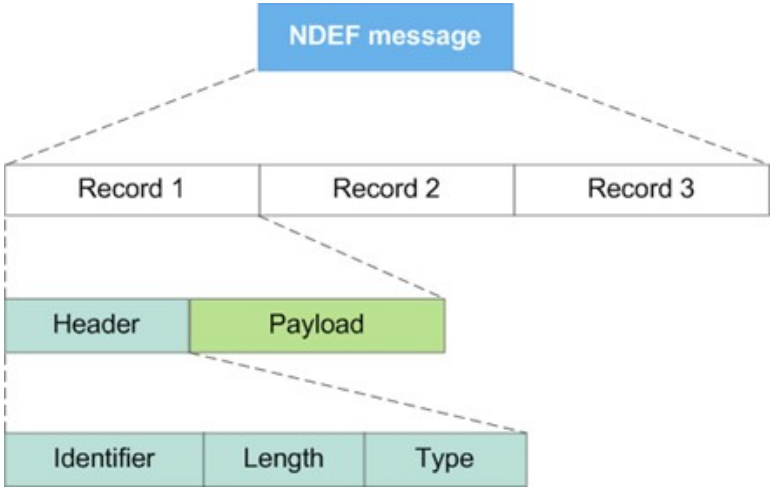
- Advantages
- Intuitive usage; Easy and simple connection
  - method
  - Complementary to Bluetooth and 802.11
  - with their long distance capabilities
  - Works in dirty environment
  - Provides communication method
  - to non-self powered devices

- Use Cases
  - Mobile Ticketing
  - Mobile Payment
  - Smart Posters
  - …

NFC: Android & NDEF

- Android supports NFC since API level 9
  - Since API level 10: comprehensive reader/writer support + foreground NDEF pushing
  - Since API level 14: push NDEF messages to other devices with Android Beam + convenience methods to create NDEF records

- **NDEF** (NFC Data Exchange Format)
- Standard data format to send and
  - receive data in Android
  - Reference:
  - `android.nfc.NdefMessage`,
  - `android.nfc.NdefRecord`
  - Other formats:
  - `android.nfc.tech`

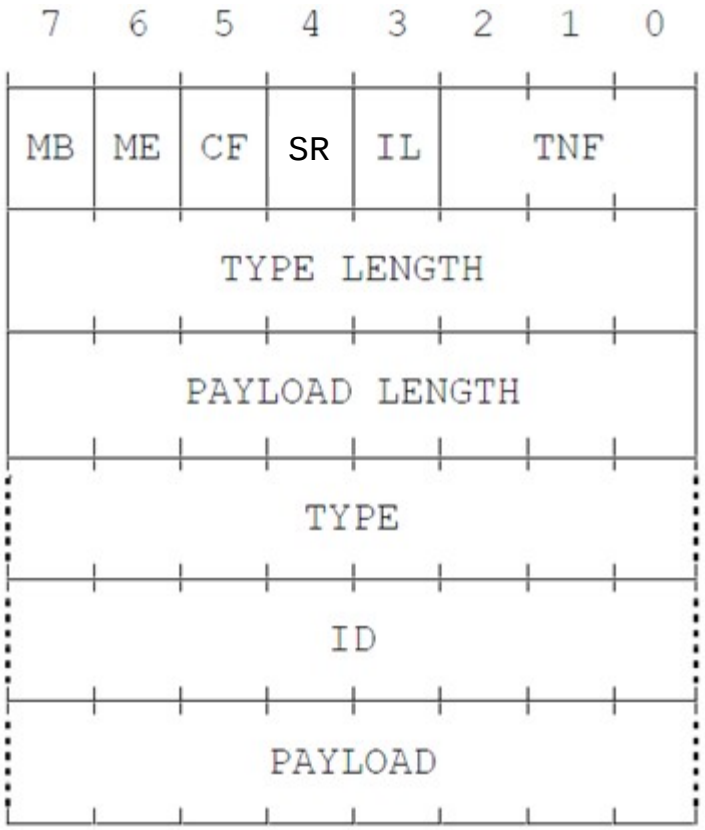


NFC: TLV Blocks

- Tag
  - Single byte to identify the type of TLV block
- Length
  - Contains the size (in bytes) of the value field (either one or three byte format)
  - One byte format: a single byte value from 0x00..0xFF
- Value
  - Only present if the Length Field (described above) is present and not equal to 0x00.
  - Value field contains payload (e.g., an NDEF Message)
- Terminator TLV
  - Last TLV block in the data area
  - Consist of a single byte: 0x0FE

NFC: NDEF example

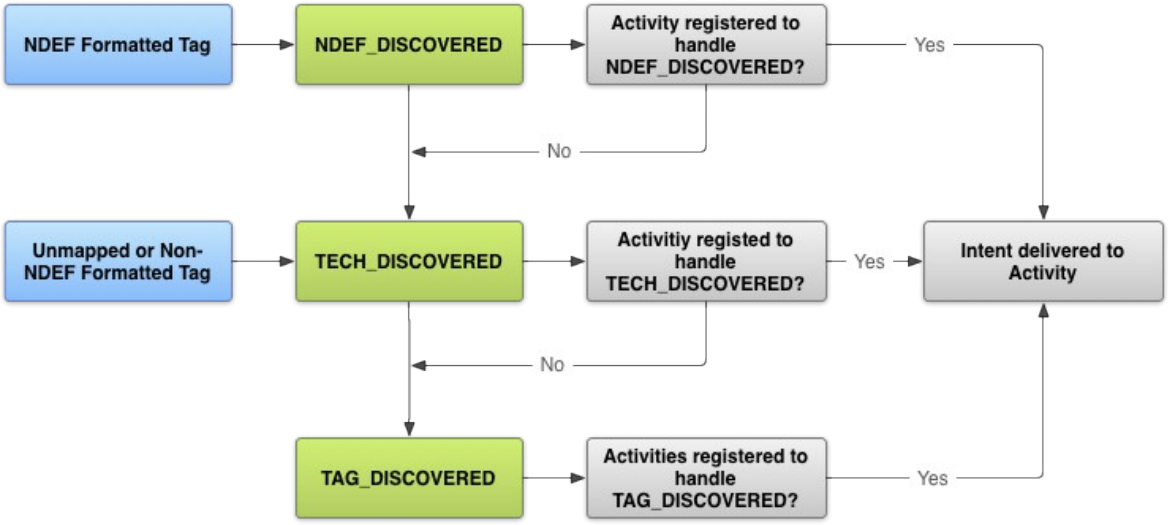
- Payload : „nokia.com“
  - 6e 6f 6b 69 61 2e 63 6f 6d
- Type:
  - URI Record: 55,
  - „http://“: 0x03
- Length:
  - Payload: 0A, Type: 01
- Flags/Identifier:
- MB: 1, ME: 1, CF: 0,
  - SR: 1, IL: 0, TNF: 001
- TLV: Tag: 03, Length: 0e, Terminator: FE



- **Gesamt:** 03 0e d1 01 0a 55 03 6e 6f 6b 69 61

NFC: Tag Dispatch System

1. Parsing the NFC tag and figuring out the MIME type or a URI that identifies the data payload in the tag.
2. Encapsulating the MIME type or URI and the payload into an intent.
3. Starts an activity based on the intent.



NFC: Manifest

- Requesting NFC access:

```
<uses-permission android:name="android.permission.NFC" />

<uses-feature android:name="android.hardware.nfc"
  android:required="true" />

<uses-sdk android:minSdkVersion="10"/>
```

- Filtering for NFC intents:

```
<intent-filter>
  <action android:name="android.nfc.action.NDEF_DISCOVERED"/>
  <category android:name="android.intent.category.DEFAULT"/>
  <data android:scheme="http"
        android:host="developer.android.com"
        android:pathPrefix="/index.html" />
    </intent-filter>
```

NFC: Reading tags

1. Check to see if activity was launched with a NFC intent to ensure that a tag was scanned
2. Obtain the extras out of the intent

```
public void onResume() {
  super.onResume();
  ...
  if (NfcAdapter.ACTION_NDEF_DISCOVERED.equals(getIntent().getAction())) {

    Parcelable[] rawMsgs =
      intent.getParcelableArrayExtra(NfcAdapter.EXTRA_NDEF_MESSAGES);

    if (rawMsgs != null) {
      msgs = new NdefMessage[rawMsgs.length];
      for (int i = 0; i < rawMsgs.length; i++) {
        msgs[i] = (NdefMessage) rawMsgs[i];
      }
    }
  }
  //process the msgs array
}
```

NFC: Summary

- NFC
  - Wireless Short Range Communication Technology
  - Based on RFID technology at 13,56 MHz
  - Operating distance: up to 10 cm
  - Data exchange rate: up to 424 kilobits/s
- NDEF (NFC Data Exchange Format)
- Android Bluetooth API
  - Tag Dispatch System
  - Reading tags

WLAN: IEEE 802.11 Introduction

Standards differ with respect to frequency, multiplexing and modulation scheme

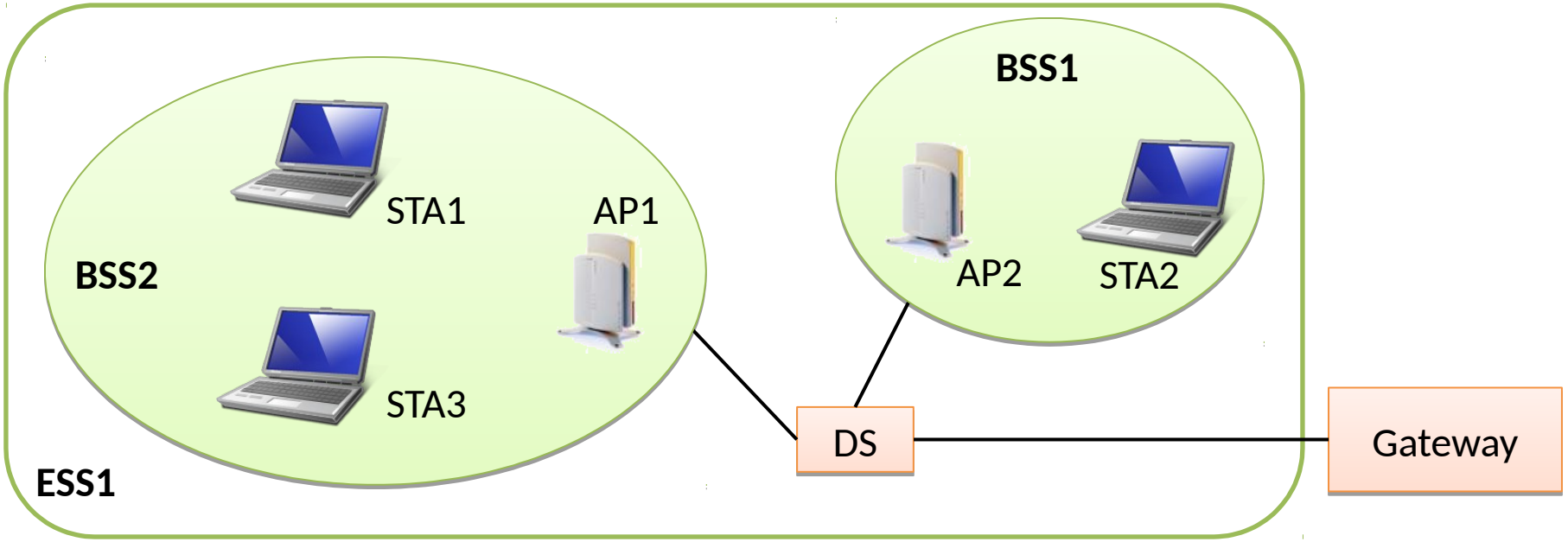
Standard	Speed (MBit/s)	Frequency (Ghz)	Multiplexing	Modulation
802.11	1 - 2	2.4	FHSS/DSSS	FSK
802.11b	1 – 11	2.4	DSSS/CCK	PSK
802.11g	6 – 54	2.4	OFDM DSSS/CCK	PSK
802.11a	6 – 54	5.0	OFDM	PSK
802.11n	6 - 600	2.4 / 5.0	SDM/OFDM	PSK or QAM

- Additional Extensions (e.g.):
- 802.11e: Quality of Service (QoS),
  - Direct Link Protocol (DLP)
  - 802.11f: Information exchange among
  - Access Points (APs)
  - 802.11i: Extensions to security and
  - authentication mechanisms

FHSS: Frequency Hopping Spread Spectrum
DSSS: Direct Sequence Spread Spectrum
OFDM: Orthogonal Frequency Division Multiplexing
CCK: Complementary Code Keying
SDM: Space Division Multiplexing
FSK: Frequency Shift Keying
PSK: Phase Shift Keying
QAM: Quadrature Amplitude Modulation

WLAN: 802.11 System Architecture (I)

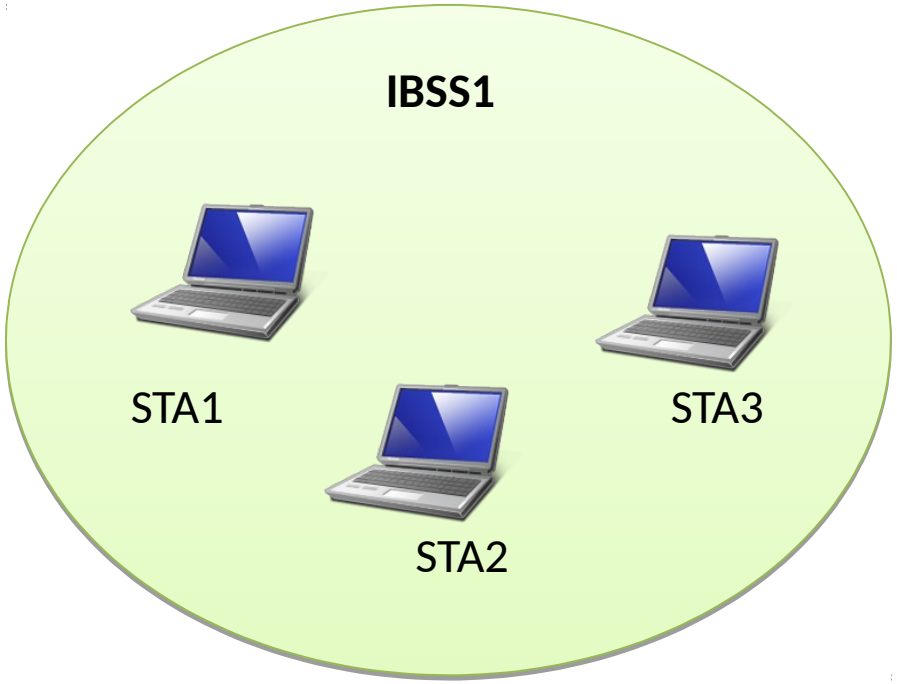
- Basic Service Set (BSS): Incorporates an Access Point (AP) and at least one Station (STA)
- Extended Service Set (ESS): One or more BSSs connected through a Distribution System (DS)



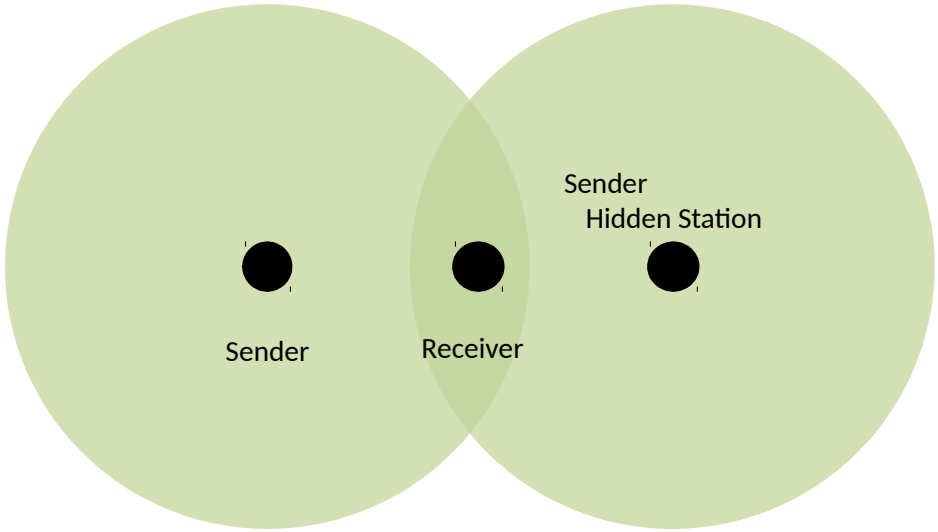
WLAN: 802.11 System Architecture (II)

Independent Basic Service Set (IBSS):

- Wireless Ad-Hoc Network (without AP)



WLAN: 802.11 Hidden Station Problem



- „Hidden Station Problem“
- Solution in 802.11
  - Sender: „Request to Send“ (RTS)
  - Receiver: „Clear to Send“ (CTS)
  - Hidden Station now knows about transmission
  - However, collisions of RTS/CTS frames are possible, frames are just smaller

WLAN: Wi-Fi P2P

- **Wi-Fi Direct**
- Wi-Fi technology enabling Wi-Fi
- devices to connect directly (without
  - an intermediate access point)

- **In Android**: Wi-Fi peer-to-peer (P2P)
  - Since API level 14: `android.net.wifi.p2p`
  - Android's Wi-Fi P2P framework complies with the Wi-Fi Alliance's Wi-Fi Direct™ certification program
- Three main components:
  - **Methods**: discover, request, and connect to peers (`android.net.wifi.p2p.WifiP2pManager`)
  - **Listeners**: Notification of the success or failure of method calls
  - **Intents**: Notification of specific events detected by the Wi-Fi P2P framework

WLAN: Wi-Fi P2P Applications

- Permissions

```
<uses-sdk android:minSdkVersion="14" />
<uses-permission android:name="android.permission.ACCESS_WIFI_STATE" />
<uses-permission android:name="android.permission.CHANGE_WIFI_STATE" />
<uses-permission android:name="android.permission.CHANGE_NETWORK_STATE" />
<uses-permission android:name="android.permission.INTERNET" />
<uses-permission android:name="android.permission.ACCESS_NETWORK_STATE" />
```

- Create and register a broadcast receiver
  - `WIFI_P2P_STATE_CHANGED_ACTION`, `WIFI_P2P_PEERS_CHANGED_ACTION`, `WIFI_P2P_CONNECTION_CHANGED_ACTION`, `WIFI_P2P_THIS_DEVICE_CHANGED_ACTION`
- Discover and connect to peers
  - `android.net.wifi.p2p.WifiP2pManager.discoverPeers`, `android.net.wifi.p2p.WifiP2pManager.connect`
- Transfer data
  - ServerSocket/Socket

WLAN: Summary

- IEEE 802.11
  - System Architecture
  - Medium Access Control
    - Distributed Channel Access / Inter Frame Spacing
    - Point Coordination Function
    - Hidden Station Problem: Request-to-Send / Clear-to-Send
- Wi-Fi P2P