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GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Lecture 06

Business Informatics 2 (PWIN)
WS 2019/20

Communication Systems II
Wired and Wireless Communication

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Agenda

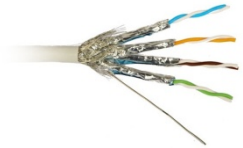
- Wired Communication
  - Basic Cable Types and Topologies
  - Types of Wired Communication
    - Ethernet, Digital Subscriber Line (xDSL), Fiber to the x (FTTx)
    - Connecting Computer Peripherals
- Wireless Communication
  - GSM
  - UMTS
  - LTE
  - 5G
  - WiMax
  - Wireless LAN (Wi-Fi)
  - Bluetooth
  - Near Field Communication (NFC)

Wired Communication Overview

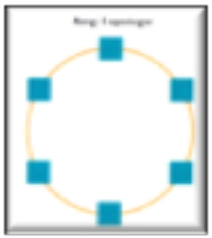
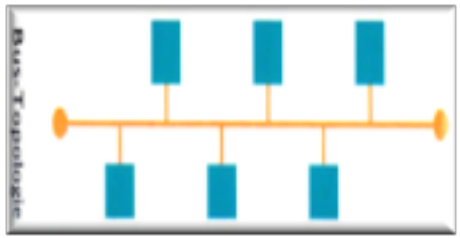
- Wired communication denotes data transmission using physical wires, e.g. for
  - Telephone networks
  - Cable television/Internet access
  - Fiber-optic networks
- Main challenges in wired communication
  - Coping with the distance between two endpoints
  - Provision of the appropriate bandwidth

Basic Wired Networks

- Wired networks
  - Use different types of conductors to build a network
    - Coaxial cable, twisted pair wire, optical fibre, …


  - Make use of different topologies
    - E.g. ring, bus, star topology

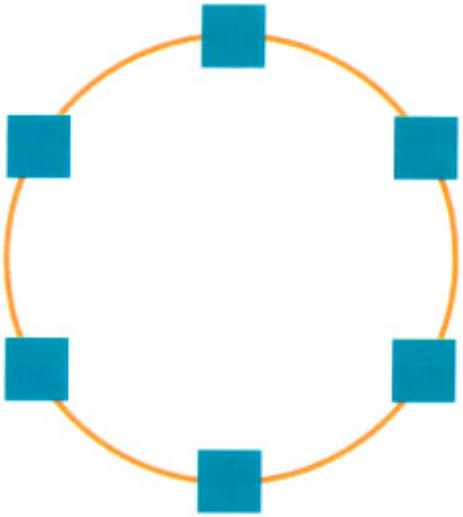



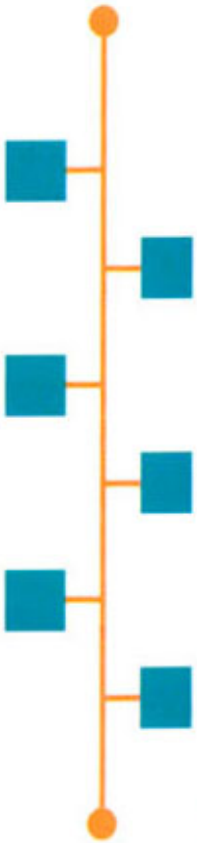
  - Provide different transfer rates
    - 10 / 100 / 1000 Mbit / 1 Gbit / 10 Gbit and more...

Source: Laudon, K.C., Laudon, J.P., Schoder, D. (2010), p. 346.

Wired Network Topologies

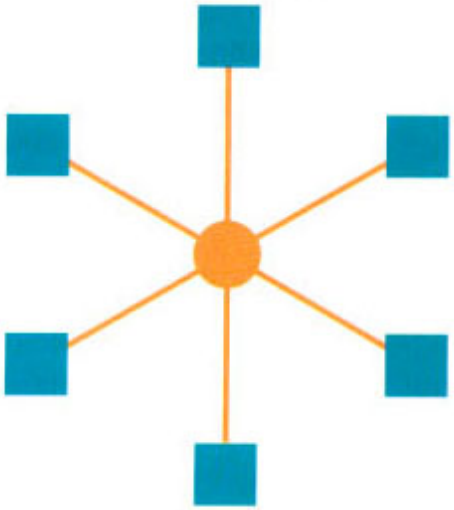
Ring Topology





Bus Topology

Star Topology



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Ethernet

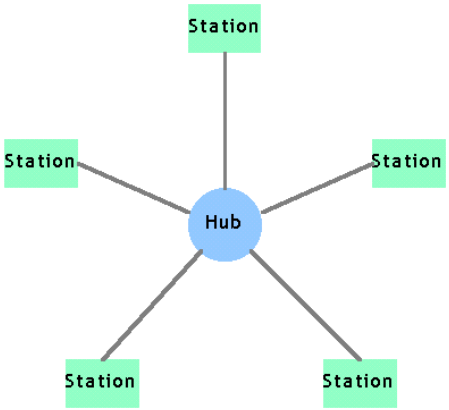
- Definition of wiring and signalling standards for local area networks (LAN)
- Developed in the beginning of the 1970s by Xerox and from 1980 continued by DEC, Intel and Xerox (DIX group)
- Implementation of an access method called Carrier Sense Multiple Access/Collision Detection (CSMA/CD), an enhancement of the Aloha concept, which was previously developed at the University of Hawaii
- Thus, Ethernet is a product name by Xerox, DEC and Intel, in which the product itself had not been compatible to the IEEE specification 802.3 for years.

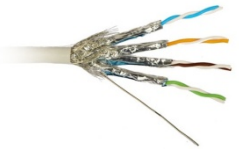
Source: Tanenbaum, A. (2006)

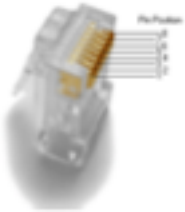
Ethernet Transfer Rate Evolution

1990 1999 2006 2016

- 10Base-T (10 Mbit/s transfer rate)
  - This version of Ethernet was the first to permit **structured cabling** in buildings using copper cables (multiple twisted pairs).
  - Topology: Star
  - Uses 2 twisted pairs in a **Category 5** cable
- 100Base-TX (100 Mbit/s transfer rate)
- 1000Base-T (1 Gbit/s transfer rate)
  - 5 twisted pairs in a **Category 5e** cable
- 10GBase-T (10 Gbit/s transfer rate)
  - Requires **Category 6a** cable
- 25GBase-T (25 Gbit/s transfer rate)
  - 4 twisted pairs in a **Category 8** cable
- 40GBase-T (40 Gbit/s transfer rate)
  - 4 twisted pairs in a **Category 8** cable
- 100GBase-x (100 Gbit/s transfer rate)
- 200GBase-x and above forthcoming



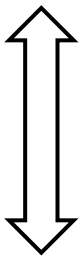




Source: Tanenbaum, A. (2006), IEEE (2016)

Digital Subscriber Line (xDSL)

- Digital Subscriber Lines (xDSL) use **existing copper wires** of a telephone network
- DSL communication is enabled by a connection between **DSL modem** (user) and a **Digital Subscriber Line Access Multiplexer (DSLAM)** (provider).
- DSL download bandwidth typically higher than upload (asymmetric DSL)
- Bandwidth also depends on distance between DSL modem and DSLAM
- Most widely used DSL types
  - Asymmetric DSL (ADSL/ADSL2)
    - ADSL max. Downstream 12 MBit/s ADSL, max. Upstream 1.8 MBit/s
    - ADSL2+ max. Downstream 24 MBit/s, max. Upstream 1.3 MBit/s
  - Very High Speed DSL (VDSL and VDSL2)
    - 55 and 300 MBit/s Downstream, 3 and 100 MBits/s Upstream
  - Symmetric DSL (SDSL), often named Single-Pair High-Speed DSL (SHDSL)
    - 2.36 Mbit bi-directional (Downstream, Upstream)



Using existing copper wires

Fiber to the x (FTTx)

- In telecommunications, “fiber to the x“ denotes a generic term for any broadband network architecture that uses optical fiber for the so-called “last mile”.

- Optical fiber has significant advantages over existing copper wire in long distances and for high-demand applications.
- However, optical fiber systems are complex and expensive compared to their copper equivalent.
- Reasonable solution is a combination of optical fiber and copper wires, e.g.
  - **FTTN - Fiber-to-the-node** - fiber is terminated in a street cabinet up to several kilometers away from the customer premises, final connection is typically established via copper.
  - **FTTB - Fiber-to-the-building** - fiber reaches the boundary of the building, final connection is typically established via copper.
  - **FTTH - Fiber-to-the-home** - fiber reaches the boundary of the living space.

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  - Bluetooth
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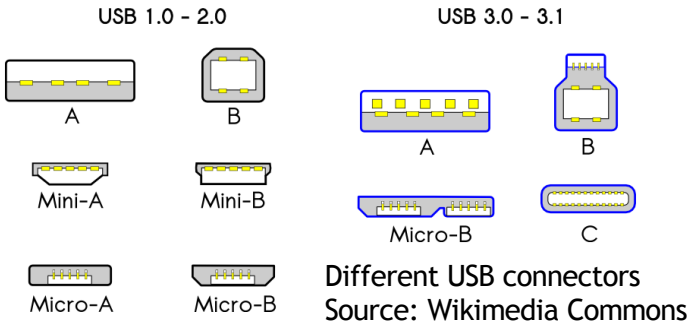
Connecting Computer Peripherals: Universal Serial Bus (USB)

- **Universal Serial Bus** (**USB**) specifies communication between devices and host controllers (e.g. PCs)
- Developed and invented by Ajay Bhatt at Intel
- Different types of connectors specified, e.g. Standard-A, Standard-B. Micro-B, Mini-B 8-pin, Mini-B 5-pin, Standard-C etc.
- Supports transfer speeds up to 20 GBit/s (USB 3.2)



Different USB connectors
Source: Wikimedia Commons

- Other technologies:
  - FireWire (0.8, 1.6, and 3.2 GBit/s)
  - Ethernet (see previous slides)
  - eSATA (PC bus interface for storage devices, max. 1.5, 3.0, 6.0 GBit/s)
  - Thunderbolt 3 (expansion bus for devices including displays, max. 40 GBit/s)

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Wireless Communication Overview

- Unlike wired networks, wireless networks use „air“ as transmission medium.

- Seven selected types of wireless communication types:
  - GSM
  - UMTS
  - 5G
  - LTE
  - WiMax
  - Wireless LAN (Wi-Fi)
  - Bluetooth
  - Near Field Communication (NFC)

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GSM (2G)

- **G**lobal **S**ystem for **M**obile Communications (GSM)

- Originally 1982 driven by "*Groupe Spéciale Mobile*" in order to create a cross national standard contrary to national analogue standards

- European standard by *ETSI* (European Telecommunications Standardisation Institute)

- Worldwide adoption of the standard in more than *212 countries and territories* (most successful mobile radio system up to now)

- Thus, worldwide roaming among different mobile network operators became possible.

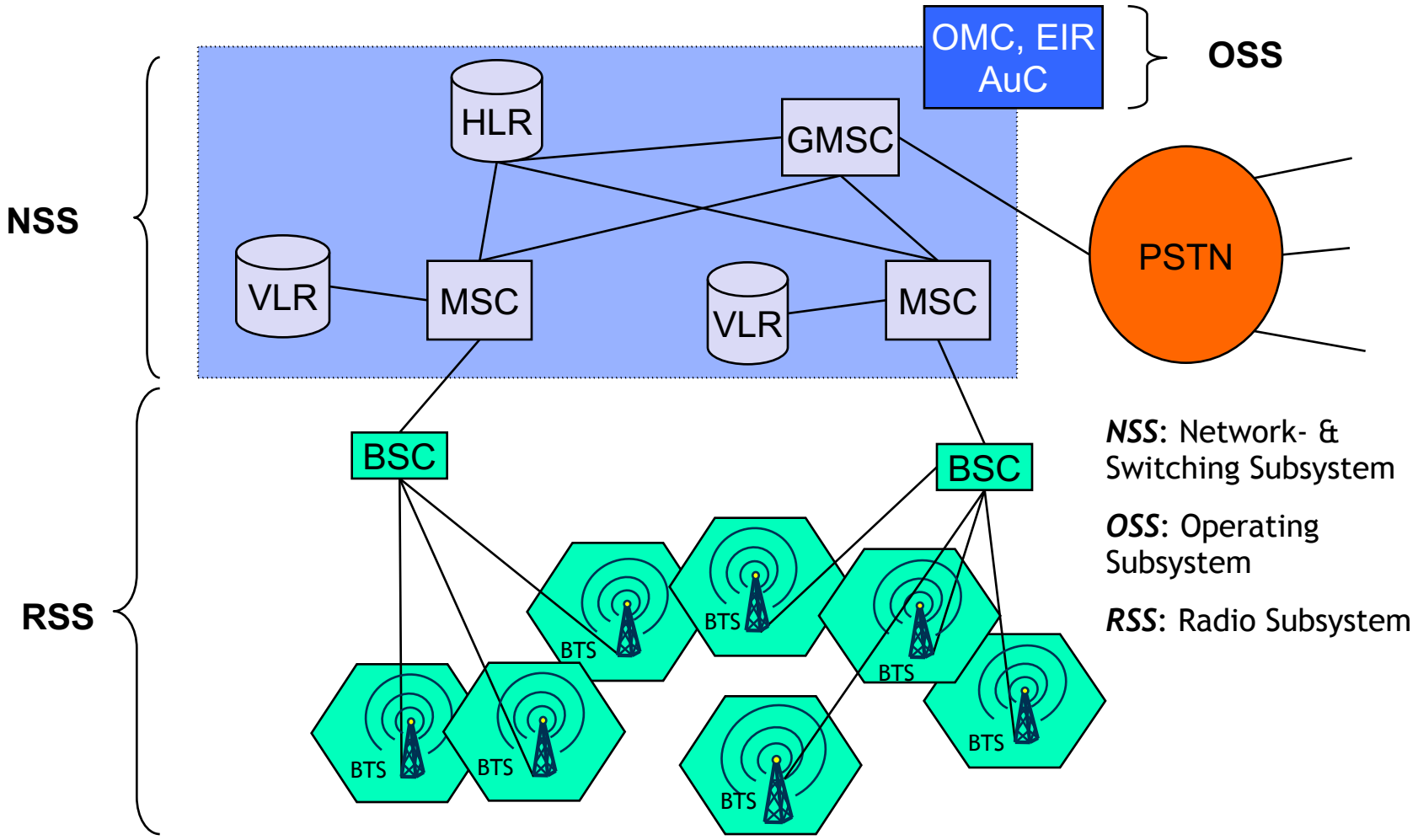
GSM Services

- Carrier services
  - Services to transfer signals over the GSM network:

  →The focus of GSM standardisation was on voice services.
- Telecommunications services
  - Telecommunication services (mainly voice) support the mobile communications among users:

  →Telecommunication services play a central role in the GSM standard.
- Supplementary services
  - GSM provides a number of supplementary services (specific to network operators), such as
    - Caller ID
    - Call redirect
    - Closed user groups (e.g. company-internal network or GSM-R)
    - Teleconferences (up to seven participants).

GSM (2G)
System Architecture



NSS: Network- & Switching Subsystem

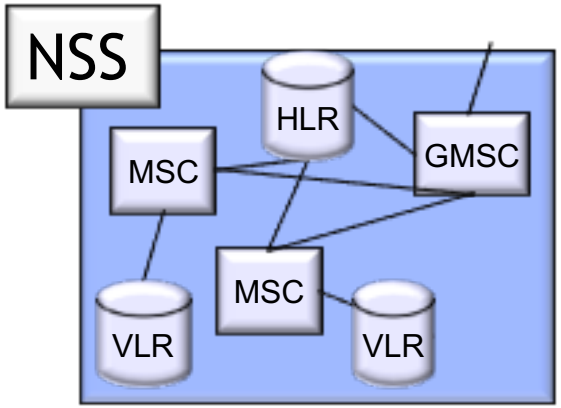
OSS: Operating Subsystem

RSS: Radio Subsystem

Based on [Schiller2003]

GSM – Network & Switching Subsystem (NSS)

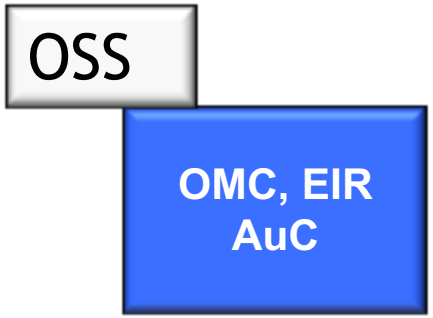
- **Network & Switching Subsystem (NSS)**
  - Connects radio network with conventional networks
  - Locates subscribers and monitors change of location



- Components:
  - **Mobile Switching Centre (MSC):** Switching center for initiation, termination and handover of connections
  - **Home Location Register (HLR):** Central database with subscribers' data (telephone numbers, keys, locations)
  - **Visitor Location Register (VLR):** Database assigned to every MSC with subscribers' data (HLR fraction copy) of active subscribers in the MSC's range
  - **Gateway Mobile Switching Center (GMSC):** Terminates the PSTN (Public Switched Telephone Network) signaling and traffic formats and converts this to protocols employed in mobile networks

GSM – Operation Subsystem (OSS)

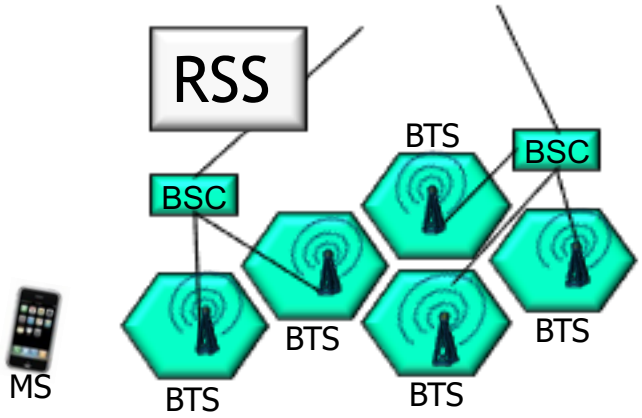
- **Operation Subsystem (OSS)**
  - Supervises operation and maintenance of the whole GSM network



- Components:
  - **Operation and Maintenance Centre (OMC):** Supervises each network component and creates status reports
  - **Authentication Centre (AuC):** Protects identity of participants & data transmission, administrates keys
  - **Equipment Identity Register (EIR):** Database with identification list for devices, e.g. stolen terminals (whitelist, greylist, blacklist)

GSM – Radio Subsystem (RSS)

- **Radio Subsystem (RSS)**
  - System consisting of radio
  - Specific components

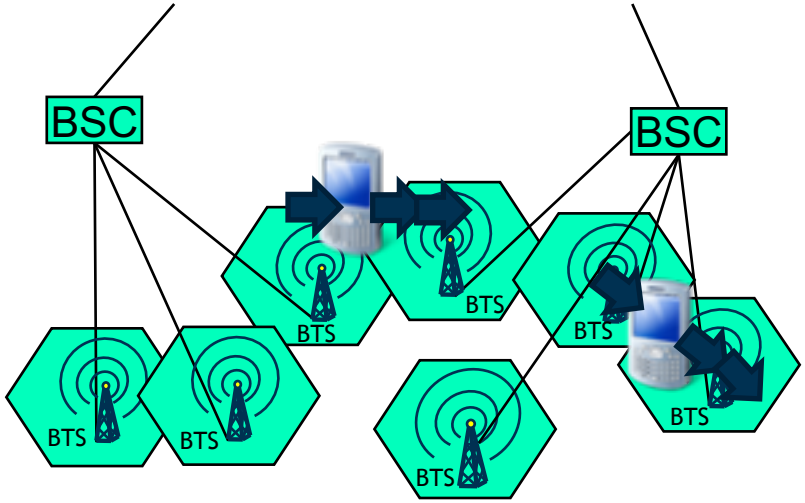


- Components:
  - **Mobile Station (MS):** System of mobile terminal & SIM
  - **Base Transceiver Station (BTS):** Radio facility for signal transfer. A BTS serves one GSM cell (~100m to ~30km radius).
  - **Base Station Controller (BSC):** Administrates affiliated BTS and supervises e.g. frequency allocation and connection handover between cells.

GSM (2G)

System Architecture – Handover

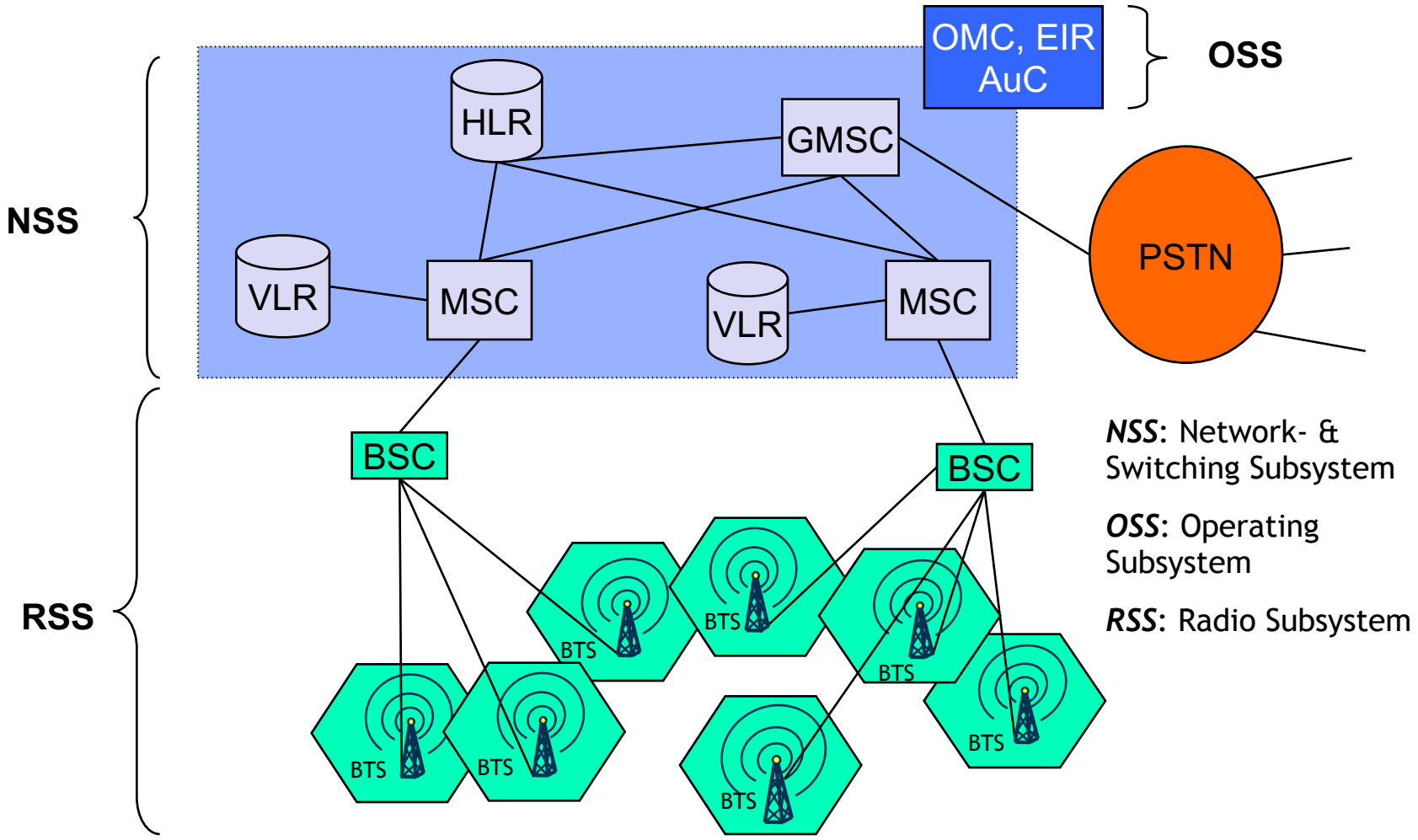
- Transfer of calls or data sessions from one trans-mitting station (in GSM: Base Transceiver Station, BTS) to another.



- Term **handover** common in British English
  - In international and Europe based organisations, e.g. ITU-T, IETF, ETSI and 3GPP
- Equivalent term **handoff** in American English
  - In IEEE and ANSI publications

GSM (2G)

System Architecture – Handover



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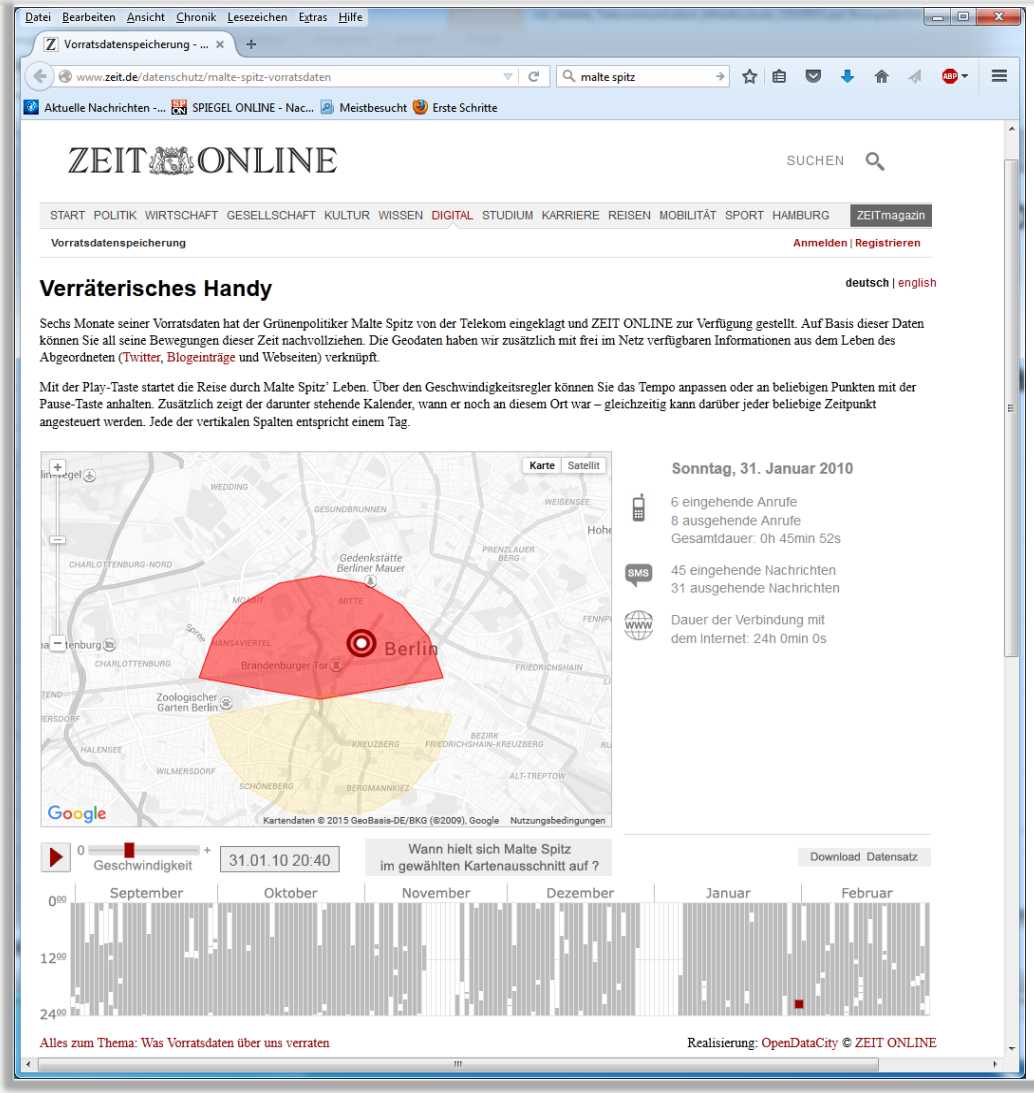
Based on [Schiller2003]

Data Retention of Cell-Based Location Data



[www.zeit.de/datenschutz/malte-spitz-vorratsdaten]

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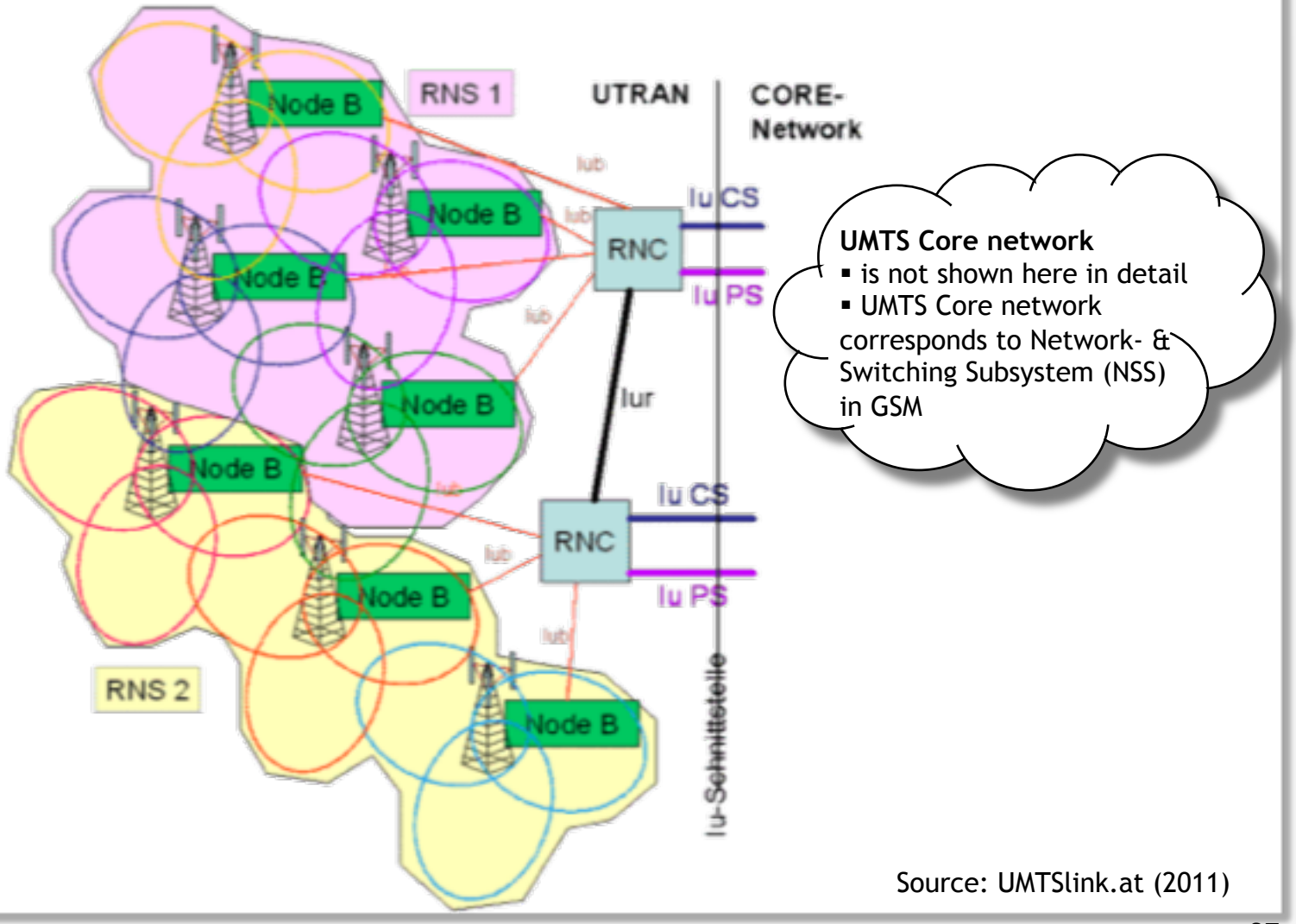
UMTS (3G)

- Universal Mobile Telecommunications System (UMTS):
  - **Status of 2G-Networks:** Different standards in some different continents inhibit worldwide roaming.
  - **Demand for 3G-Networks:** Globally uniform standard

➲ Voting of regional & national regulation offices (e.g. ETSI, ARIB, ANSI) via the International Telecommunication Union (ITU)

UMTS (3G) System Architecture

- ***UTRAN:*** UMTS Terrestrial Radio Access Network
- ***RNS:*** Radio Network Subsystem
- ***RNC:*** Radio Network Controller (controls the Node Bs)
- ***Node B:*** UMTS base stations (equivalent to base transceiver stations (BTS) in GSM



Source: UMTSlink.at (2011)

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Next Generation Networks (4G) and Long Term Evolution (LTE)

4th Generation Networks

- 4G networks integrate a wide range of different wireless technologies, including technologies from existing 3G networks

  - **Long Term Evolution (3.9G, "4G")** standard allows for 300 Mbit/s downlink and 75 Mbit/s uplink speeds
    - First commercial LTE network launched in Scandinavia in December 2009
    - LTE was originally not named a "4G network" due to stricter naming requirements *)
    - The technology can be named either 3.9G or 4G network today.

  - **LTE Advanced (4G)** makes use of the frequency spectrum more efficiently, resulting in higher data rates (towards 1 Gbit/s) and lower latency. It remains backward compatible with LTE, uses same frequency bands.

www.3gpp.org/LTE

www.3gpp.org/LTE-Advanced

*) A 4G service was originally defined as meeting the *IMT-Advanced* requirements issued by the ITU-R. For more information see [Parkvall2008].

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5th Generation Networks (5G) Concept & Requirements

- Two initial views of 5G:
  View 1 – The hyper-connected vision
  View 2 – Next-generation radio access technology
- Standardisation process ongoing (3GPP, ITU)
- Commercial availability expected from 2020 onwards
- 5G technology requirements
  - 1 millisecond end-to-end round trip delay (latency)
  - 1-10 Gbps connections to end points in the field (i.e. not theoretical maximum)
  - 1000 x bandwidth per unit area
  - 100 billion connected devices worldwide
  - 99.999 % availability
  - 90 % reduction in network energy usage
  - Network slicing: multiple logical networks created on top of a common shared physical infrastructure
- "We should consider 5G rather as a business model than a technology" – Börje Ekholm, CEO Ericsson

www.3gpp.org

[GSMA14], [heise17]

Potential 5G Use Cases

- Autonomous driving/Connected cars
- Machine-to-machine connectivity (M2M)
  - vehicle telemetric systems (a field which overlaps with Connected cars above)
  - ‘connected home’ systems (e.g. smart meters, smart thermostats, smoke detectors)
  - consumer electronics and healthcare monitoring.
- Virtual Reality/Augmented Reality/Immersive or Tactile Internet
- Wireless cloud-based office / Multi-person videoconferencing

[GSMA14]

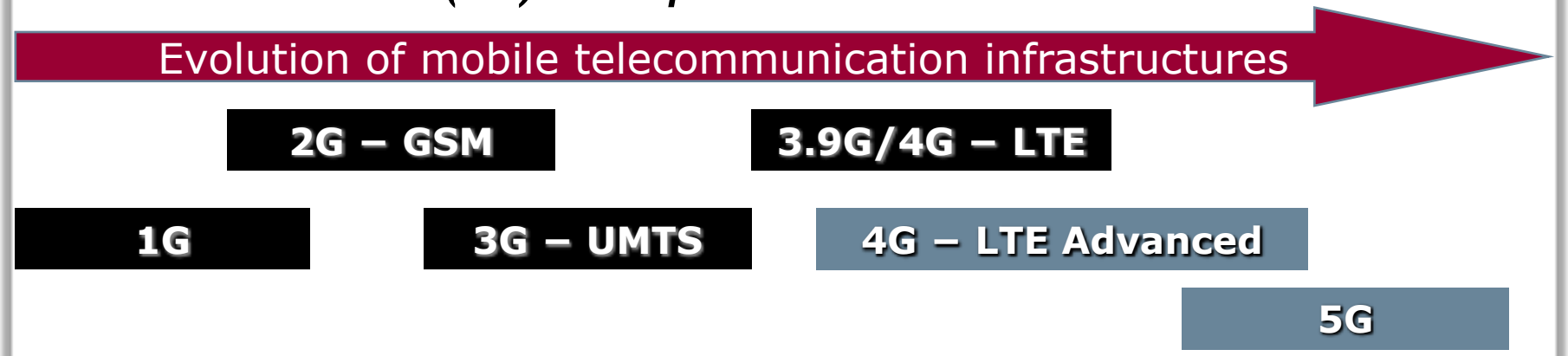
5G Challenges

- Identification of new services, market segments and business models to unlock the 5G opportunity and to optimise cost of network investment
- Pro-investment and pro-innovation regulatory framework required given high network expenses
- Spectrum availability (sub 1 GHz, 1-6 GHz, above 6 GHz) will influence the business case behind 5G.
- Technological breakthroughs needed for e.g. spectral efficiency, low latency and network design
- Successful standardisation to minimise industry fragmentation in spectra, technologies, and operator services

[GSMA17]

Mobile Voice & Data Communication Services

- *1st Generation (1G) - Analogue networks*
- *2nd Generation (2G) - GSM networks*
  Global System for Mobile Communications
- *3rd Generation (3G/3.5G) - UMTS/HSPA/HSPA+*
  Universal Mobile Telecommunications System
  High Speed Packet Access / Evolved HSPA = HSPA+
- *3.9G or 4G - LTE*
  Long Term Evolution
- *4th Generation (4G) - LTE Advanced*
- *5th Generation (5G) - Ubiquitous Internet*



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WiMAX

- **WiMAX** (Worldwide Interoperability for Microwave Access)
- IEEE standard 802.16
- Establishes mobile (broadband) Internet access of up to 40 Mbit/s downlink.
- Services once available e.g. in the USA, Japan, Korea, Taiwan, Russia, Mexico, Middle East, Africa

- In 2015 Sprint Corporation began closing its WiMAX network.
- Since 2015: WiMAX Networks phased out in favour of LTE in Nigeria

- LTE is replacing WiMAX in most countries. However, due to the simplicity and cost-effectiveness of WiMAX, it will likely endure as a niche alternative in some countries.

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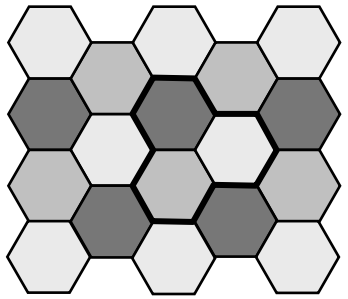
Wireless Local Area Network (Wi-Fi) Basics

- Short-range wireless communication technology with cell-based architecture
- Possible extension to a wired Local Area Network (LAN)
- One Wi-Fi cell serves a circular area in which PCs, laptops, and other connected devices can move freely.

Wireless LAN (Wi-Fi) Basics

- The basic module of a wireless LAN is a radio cell.
- A radio cell covers a circular area that PCs or laptops and other connected devices are able to use.



Wireless LAN (Wi-Fi) Components

- Components (802.11b)
  - Access Point (AP)
    Sender and receiver station that allows the connecting of multiple receiving stations

  - Stations
    End-systems that establish a wireless connection for instance by using an access point (e.g. a notebook with built-in wireless LAN)

Wireless LAN (Wi-Fi) Beacon Frame

- **Beacon Frame (SSID)**
  - The access point is transferring a periodical beacon. A beacon communicates the service set identifier (SSID) and other important operational parameters (channel, …).
  - A wireless LAN client sends a probe request. The access point answers with a probe response. If there is an agreement, the wireless LAN client starts the communication over the access point.
  - A more detailed description of beacon frames can be found in Sauter (2008).

Wireless LAN (Wi-Fi)
Standard IEEE 802.11 – Examples

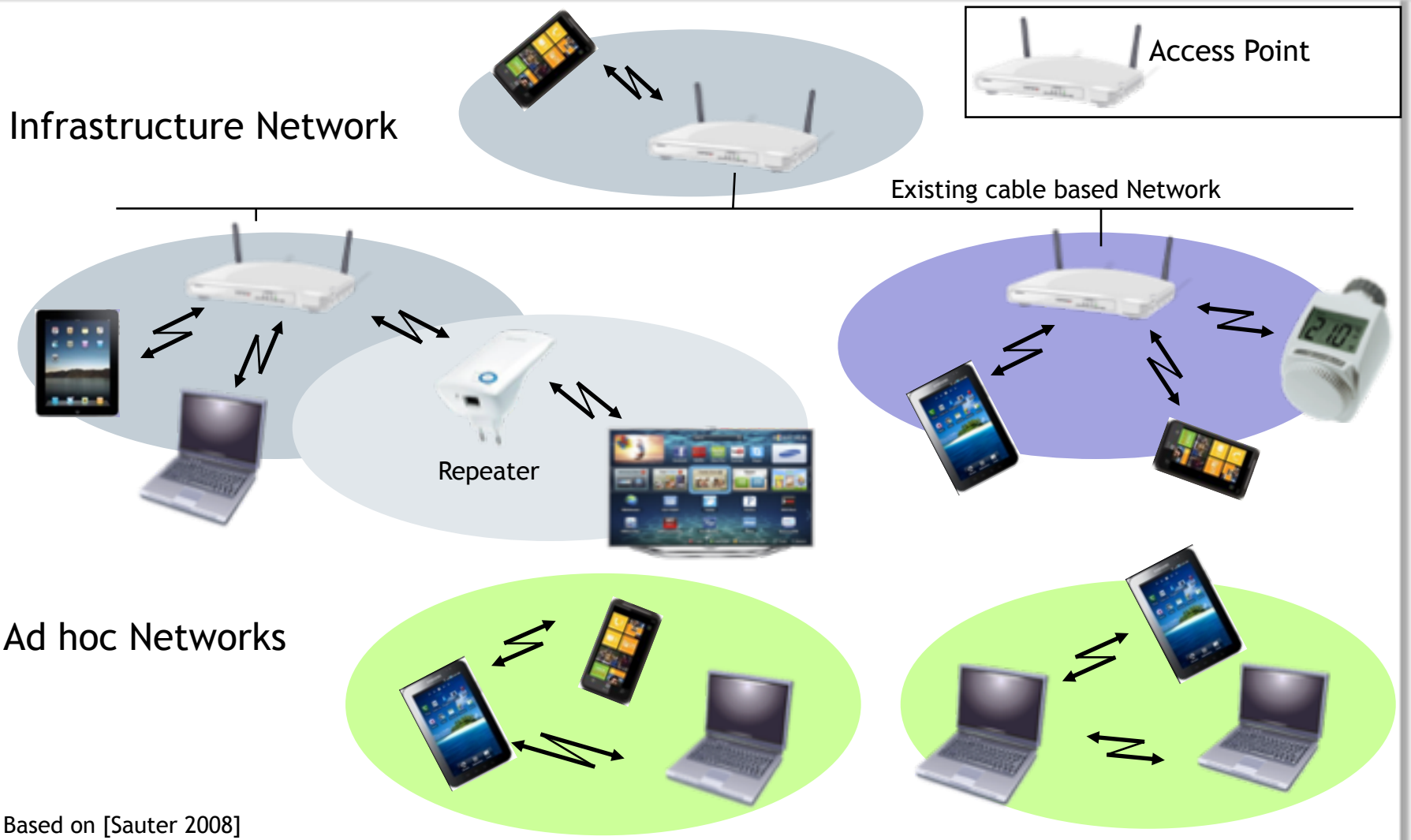
Standard	Description
802.11	Protocol for transmission methods for wireless networks, defined in 1997 for 2 MBit/s at 2,4 GHz
802.11a	Wireless LAN **up to 54 MBit/s** at 5 GHz
802.11b	Wireless LAN **up to 11 MBit/s** at 2,4 GHz
802.11f	Roaming between access points of different manufacturers (published in 2003 and withdrawn by IEEE in 2006) [IEEE2010]
802.11g	Wireless LAN **up to 54 MBit/s** at 2,4 GHz
802.11i	Extended security features: AES, 802.1x, TKIP
802.11n	Wireless LAN **up to 450 MBit/s** when using 3 spatial streams (3x 150 Mbit/s) at 2,4 GHz or 5 GHz *)
802.11r	Fast Roaming/Fast BSS Transition
802.11ac	Wireless LAN using 3 spatial streams at 5 GHz: **Up to 1.3 GBit/s** (3x 433 Mbit/s) or even **up to 2.6 GBit/s** (3x 867 Mbit/s, part of *802.11ac Wave2*) *) **)
802.11ad	Wireless LAN at 60GHz: **Up to 7GBit/s**
802.11ah	Wi-Fi HaLow for Smart Home and connected devices (900 MHz,increased distance, ~1km)

*) 802.11n and 802.11ac data rates depend on the number of antennas and spatial streams ("parallele räumliche Inhaltsströme") supported by the hardware. 802.11ac devices often support 3 streams at most. 802.11n specifies a maximum of 4 streams, 802.11ac a maximum of 8 streams.

**) 802.11ac is a 5 GHz-only standard, so dual-band access points and clients will probably continue to use 802.11n at 2.4 GHz in parallel.

Source: Based on Sauter (2008), IEEE

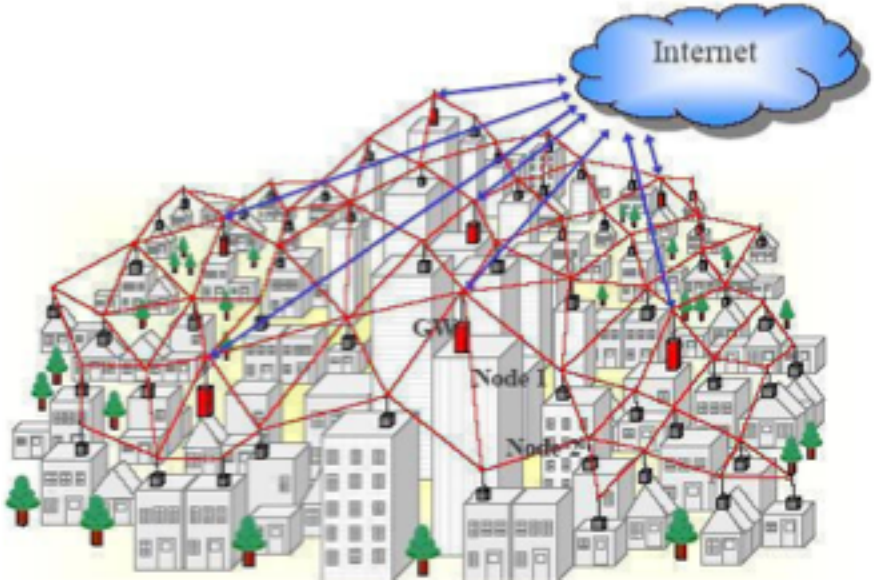
Wireless LAN Infrastructures



Based on [Sauter 2008]

Wireless LAN (Wi-Fi)
Mesh Network Infrastructures

- Access Points
  - Are not connected directly to the Internet
  - Constitute a mesh network, which is inhabited by only a few gateways (GW) providing access to the Internet.



Source: wiredtown.com

Wireless LAN (Wi-Fi) Legal Basics

- The usage of wireless LANs is one of the grey areas of Internet related legislation. The border between legal and illegal is not clearly defined. Most cases the courts decide are precedents.
- What is important?
  - § 202a Strafgesetzbuch
    Spying on data (Ausspähen von Daten)
  - § 88 Telekommunikationsgesetz
    Secrecy of telecommunications (Fernmeldegeheimnis)
  - § 89 Telekommunikationsgesetz
    Ban on eavesdropping (Abhörverbot), receiver operator's confidentiality duty (Geheimhaltungspflicht der Betreiber von Empfangsanlagen)

Wireless LAN (Wi-Fi) State-of-the-Art Encryption

- There are numerous methods for Wireless LAN encryption.
- We are only looking at methods that use a pre-shared key (PSK).
- Most encryption methods are outdated and hence insecure:
  - Wired Equivalent Privacy (WEP) 64-bit
  - Wired Equivalent Privacy (WEP) 128-bit

- WEP 128-bit can be by-passed within minutes.

Source: Heise Online (2007)

Wireless LAN (Wi-Fi) State-of-the-Art Encryption (2)

- **Wi-Fi Protected Access** was developed by the Wi-Fi Alliance Source: Wi-Fi (2010)

- There are two versions of Wi-Fi Protected Access, WPA and WPA2:
  - **WPA** includes most of the 802.11i standard.
  - **WPA2** includes **802.11i** to full extent and also the Advanced Encryption Standard (AES).

mobile business

Agenda

- Wired Communication
  - Basic Cable Types and Topologies
  - Types of Wired Communication
    - Ethernet, Digital Subscriber Line (xDSL), Fiber to the x (FTTx)
    - Connecting Computer Peripherals
- Wireless Communication
  - GSM
  - UMTS
  - LTE
  - 5G
  - WiMax
  - Wireless LAN (Wi-Fi)
  - Bluetooth
  - Near Field Communication (NFC)

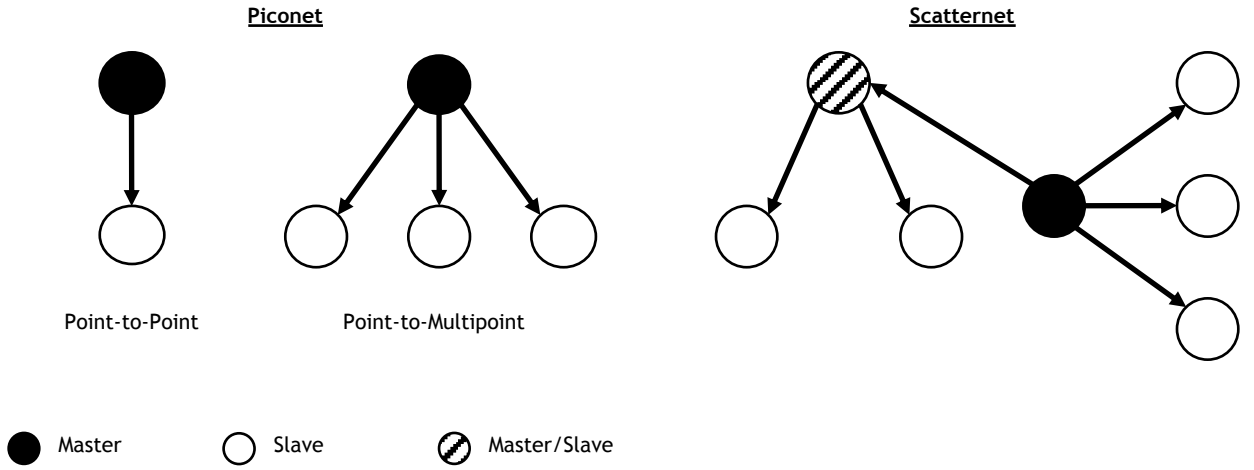
Bluetooth

- Bluetooth is a wireless technology standard for data exchange using small ad-hoc networks called “personal area networks” (PANs)
  - Devices such as laptops, mobile phones, printers, headsets and other periphery-devices can establish a connection.
  - Simple and cheap possibility to set up ad-hoc networks of limited range (up to 10 meters) for spontaneous data exchange
  - Technical specifications for Bluetooth were developed by the Bluetooth Special Interest Group (SIG).
  - Findings were added to the IEEE 802.15 standard.

Source: Wiegleb, M. (2005)

Bluetooth Networks

- There are different types of Bluetooth networks



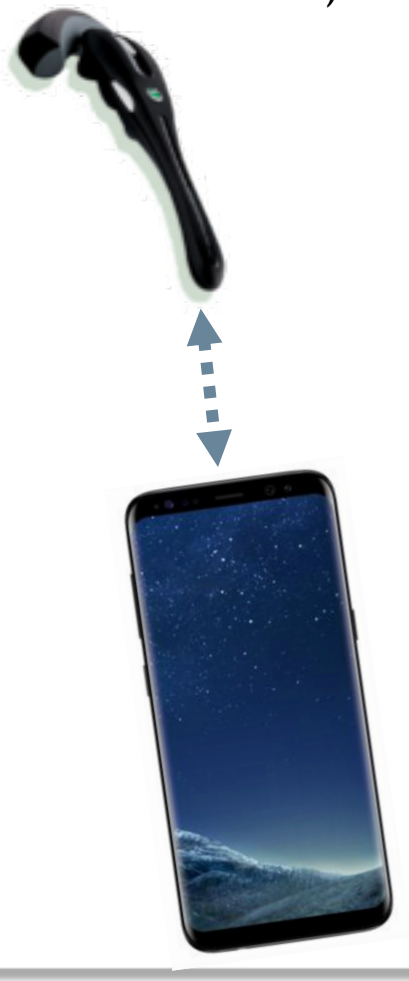
  - A piconet is a connection of one device with another device (point-to-point) or multiple devices (point-to-multipoint).
  - A scatternet is the combination (connection) of two or more piconets.

Source: Wiegleb, M. (2005)

Bluetooth
Popular Applications

Sound transmission (to earphones, headphones or Hi-Fi equipment)

Wireless connections between devices (Bluetooth-headset)



mobile business

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  - Wireless LAN (Wi-Fi)
  - Bluetooth
  - Near Field Communication (NFC)

Near Field Communication (NFC)

- NFC is a short-range (< 4 cm) wireless technology
  - Communication mode of a device can be active or passive
  - Magnetic induction between two loop antennas
  - Application domains
    - Mobile payment / mobile wallet
    - Mobile marketing
      (e.g. redemption of digital coupons)
    - Mobile ticketing
    - Access control (e.g. e-Key)
    - Mobile data user exchange
    - ...

Source: techtickerblog.com (2011)

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Appendix
UMTS (3G)

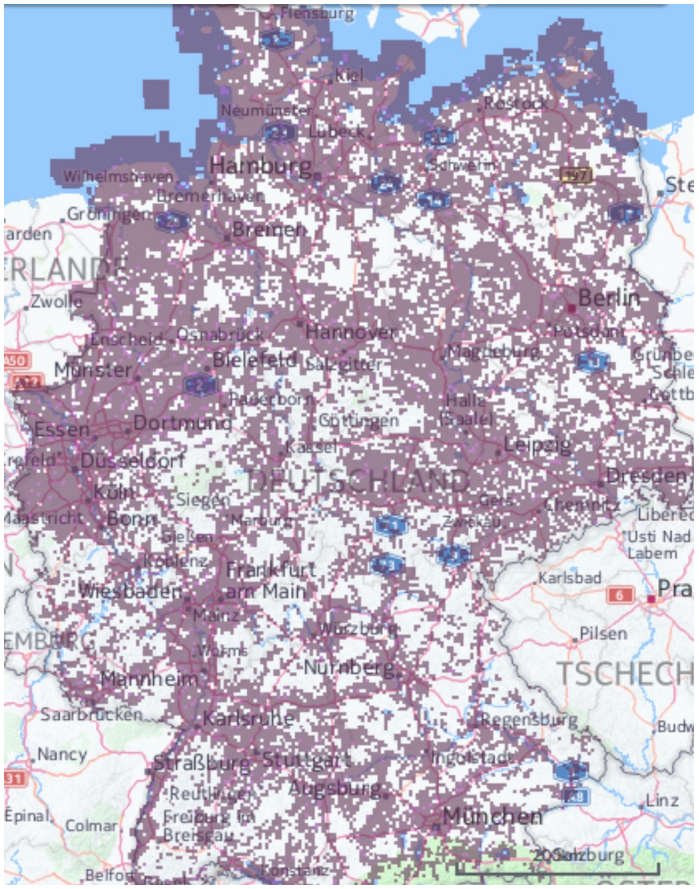
- The UMTS standard includes the following features:
  - Multilateral Security (with regard to authentication)
  - High Speed Downlink Packet Access (HSDPA)
  - …
- 3G UMTS/HSPA/HSPA+ bandwidths
  - **UMTS**: up to 384 kbit/s downlink/uplink
  - **High Speed Packet Access (HSPA)** provides up to 14.2 MBit/s downlink speed and up to 5.7 MBit/s uplink speed.
  - **HSPA+** provides up to 56 MBit/s and up to 11.5 Mbit/s uplink speed.
- But: Available bandwidth per user decreases if terminal is moving or if there are many participants in one radio cell.

UMTS (3G)

3G Network Coverage in Germany

T-Mobile

Vodafone



Source: T-Mobile & Vodafone (2017)

LTE (4G)

4G Network Coverage in Germany

T-Mobile

Vodafone

Source: T-Mobile & Vodafone (2017)