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GOETHE UNIVERSITÄT FRANKFURT AM MAIN

Lecture 12

Information & Communication Security (WS 2020/21)

Network Security II

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Agenda

- Introduction
- Infrastructure Security Components
- Security Protocols
- Application Layer Security
- Wireless / Mobile Security
  - Wireless Internet Security
    - Wireless LAN (WLAN)
    - Mobile IP
  - “Telco” Networks
    - GSM Security
    - GPRS Security
    - UMTS Security
    - LTE Security
    - 5G Security
  - Wireless Application Protocol (WAP)
  - Personal Area Networks

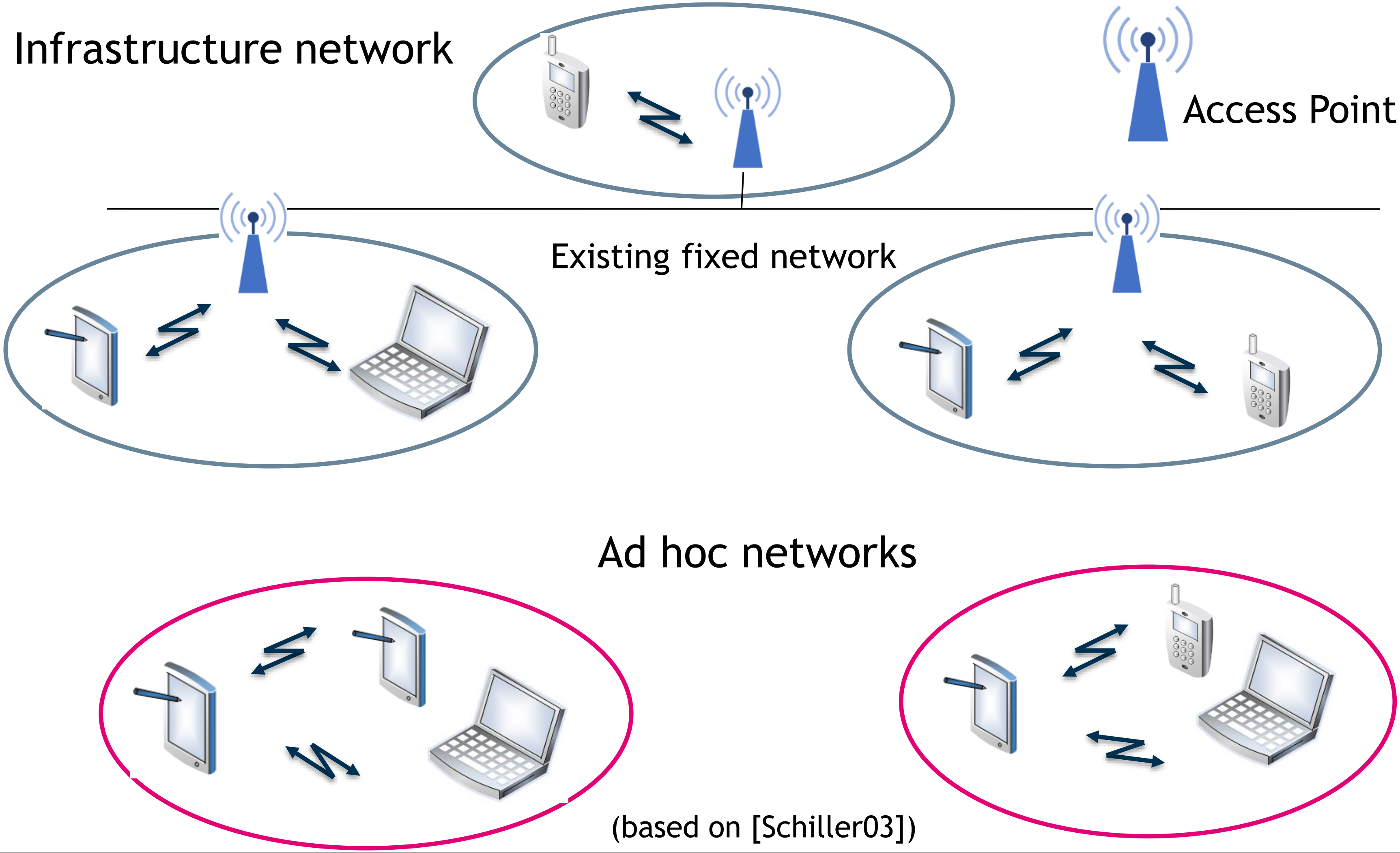
Wireless LAN Basics (WLAN)

- Wireless communication based on radio as transport medium
- Cell based architecture
- Possible extension to a (wired) LAN
- One cell serves a circular area in which PCs, laptops, and other connected devices can move freely.

- **Access Point (AP):**
  Transmitting and receiving station which allows multiple devices to connect

- **Stations:**
  Terminals, used by AP for building a wireless network connection (Example: PCMCIA-WLAN Card in Laptops)

Wireless LAN Basics
Infrastructure and ad hoc networks



(based on [Schiller03])

Wireless LAN Basics
802.11 Standard

Standard	Release date	Description
802.11	1997	Protocol for transmission methods for wireless networks, defined in 1997 for 2 MBit/s at 2,4 GHz
802.11a	1999	Wireless LAN **up to 54 MBit/s** at 5 GHz
802.11b	1999	Wireless LAN **up to 11 MBit/s** at 2,4 GHz
802.11g	2003	Wireless LAN **up to 54 MBit/s** at 2,4 GHz
802.11i	2004	Extended security features: AES, 802.1x, TKIP
802.11ad	2012	Wireless LAN at 60GHz: **Up to 7GBit/s**
802.11ac	2013	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*) *) **)
802.11ah	2016	Wi-Fi HaLow for Smart Home and connected devices (900 MHz, increased distance, ~1km)
802.11ax	2017	This amendment defines modifications for high efficiency operation in frequency bands between 1 GHz and 7.125 GHz.
802.11ay	Est. March 2021	Upcoming Standard extending 802.11ad by defining a new physical layer for 802.11 networks to operate in the 60 GHz spectrum
802.11ba		Amendment of IEEE 802.11 enabling energy efficient operation for data reception without increasing latency
802.11be	-	Potential next amendment likely be designated Wi-Fi 7 building upon 802.11ax

*) 802.11n and 802.11ac data rates depend on the number of antennas and spatial streams 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.

[IEEE] [IEEE17]
[Sauter 2008]

IEEE 802.11-1997 (1): Overview

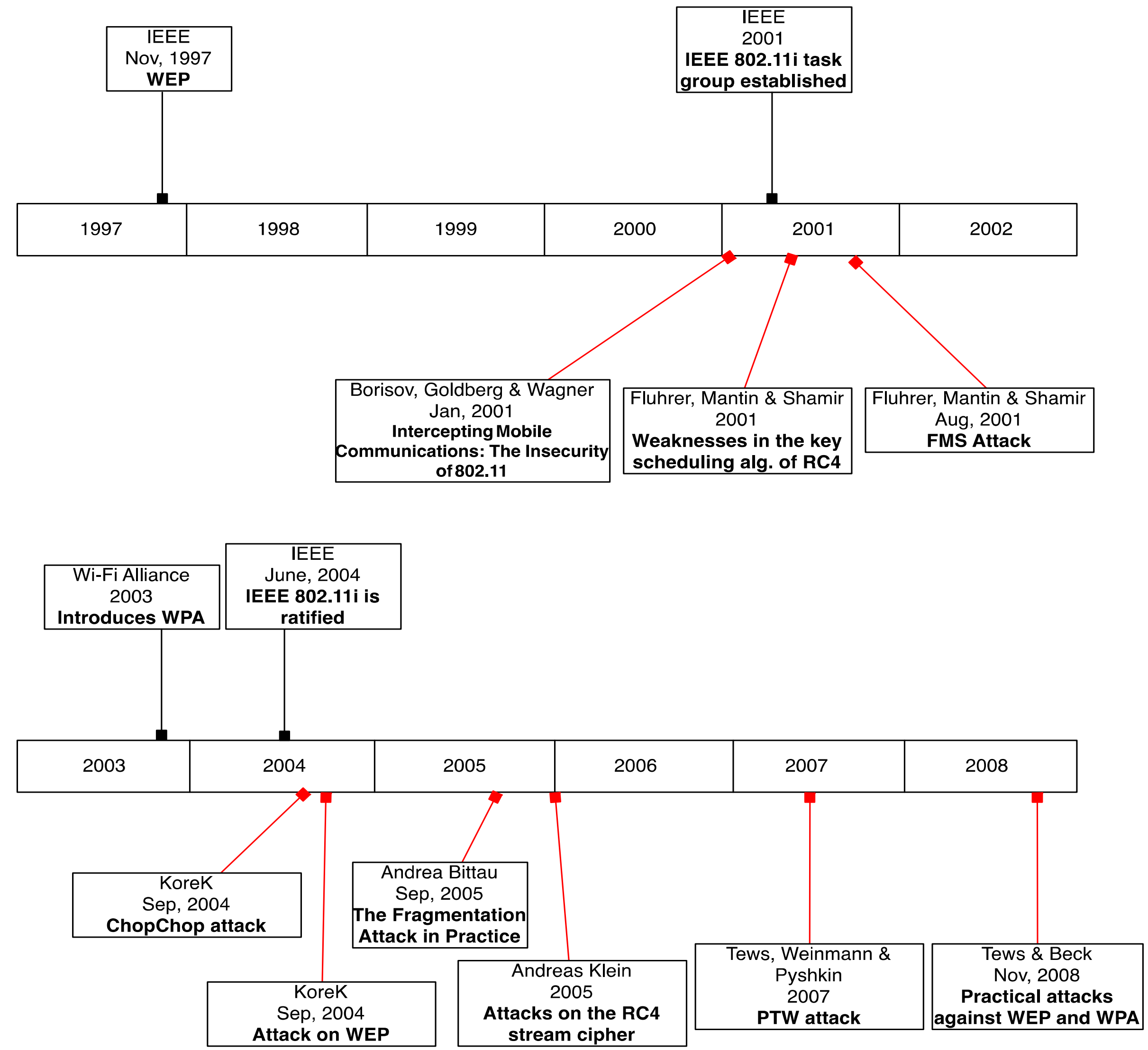
- How IEEE 802.11-1997 aimed to provide security for Wireless LAN:
  - SSID (Service Set Identifier)
    - Name of the network
  - MAC (Media Access Control)
    - Rule based access control
  - WEP (Wired Equivalent Privacy)
    - Encryption mechanism

Wireless LAN (In)Security
IEEE 802.11-1997 (2): Vulnerabilities

- Primitive access control
  - Cumbersome and easy-to-fake by use of MAC address of network card
  - No user authentication
  - Better solution: VPN on top of WLAN
- Weak encryption
  - Problems with entry parameter of RC4 algorithm
  - Challenge-response can be used to retrieve the shared key
  - Weak linear integrity check
- Cumbersome key management
  - WEP does not have a centralized key management.
  - Manual key distribution -> difficult to change keys
  - Single set of shared keys for all nodes

Wireless LAN (In)Security

IEEE 802.11-1997 (3): Discovery of vulnerabilities



[Halvorsen09]

- Standard for authentication server:
  - Remote Authentication Dial-In User Service (RADIUS)
  - In the beginning quasi-standard developed by one company (Livingston Enterprises)
  - Since 1997 supported by The Internet Engineering Task Force (IETF) as Requests for Comments (RFCs)

Wireless LAN Security
WPA

- Improved security by WiFi Protected Access (WPA)
  - Access control
    - Extensible Authentication Protocol (EAP)
    - RADIUS enables individual user authentication.
    - New Message Integrity Check (MIC) algorithm - "Michael" - (to avoid MAC spoofing)
  - Encryption
    - RC4 is kept, but with increased size of the initialization vector.
    - Updated initialization algorithm to avoid using weak keys
  - Key management
    - Dynamic key exchange – TKIP (Temporal Key Integrity Protocol)
    - Derived session keys instead of a shared master key
    - Authentication key different from encryption key
- Interim solution by the WiFi Alliance (manufacturer consortium) till availability of IEEE 802.11i-2004

[Jain07]

Wireless LAN Security
IEEE 802.11i-2004

- Standardization of security mechanisms for 802.11 through IEEE
- Available since the end of 2004 as 802.11i
- Commercially labelled “WPA2”
- Robust Secure Network Association (RSNA)
  - New Cryptographic Mechanisms
    - AES (instead of RC4) => requires hardware support
    - CCMP (Counter Mode Cipher Block Chaining Message Authentication Code Protocol) (instead of TKIP)
  - Key Management
    - RADIUS, EAP, 802.11X
- Transition Security Network (TSN)
  - Uses TKIP instead of CCMP
  - Backwards compatibility for devices not supporting CCMP-AES

Example: Wireless technology at Goethe University

- Eduroam and Flughafen
  - Both WPA and WPA2 supported
  - RADIUS enables individual user authentication (university credentials used).
  - Eduroam supports the authentication method of participating institutions.
- Freiflug
  - Unencrypted connection
  - Login via an https-secured webpage

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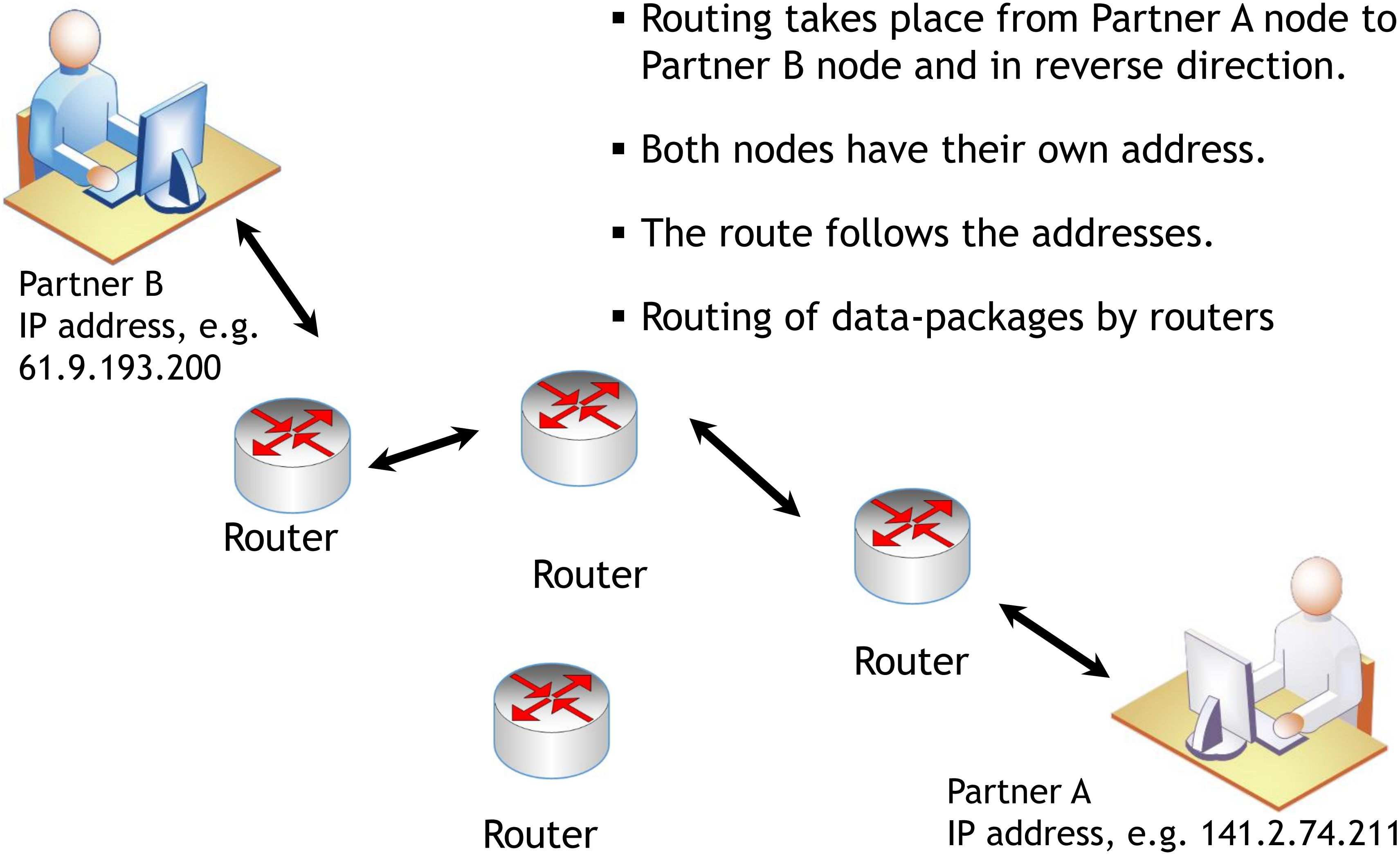
Mobility with TCP/IP

Situation today

- Separate IP-addresses in the office and at home
- DHCP – dynamic IP assignment
- Dial-up with dynamic IPs
  - Continuous accessibility via one IP is not guaranteed.
  - Connection interruptions during access point switches

Routing in TCP/IP

- Routing takes place from Partner A node to Partner B node and in reverse direction.
- Both nodes have their own address.
- The route follows the addresses.
- Routing of data-packages by routers



Updating Domain Names

- In the **Domain Name Service** a domain-name belongs to a fixed IP-address (e.g. www.m-chair.de = 188.138.95.94).
  - **Changing** these addresses requires an update-time of several hours $\Rightarrow$ this is no usable solution.
- **Better solution: Dynamic DNS**
  - Modification time: 15 minutes.
  - Problem: applications resolve a name just once and do not query possible address changes thereafter.

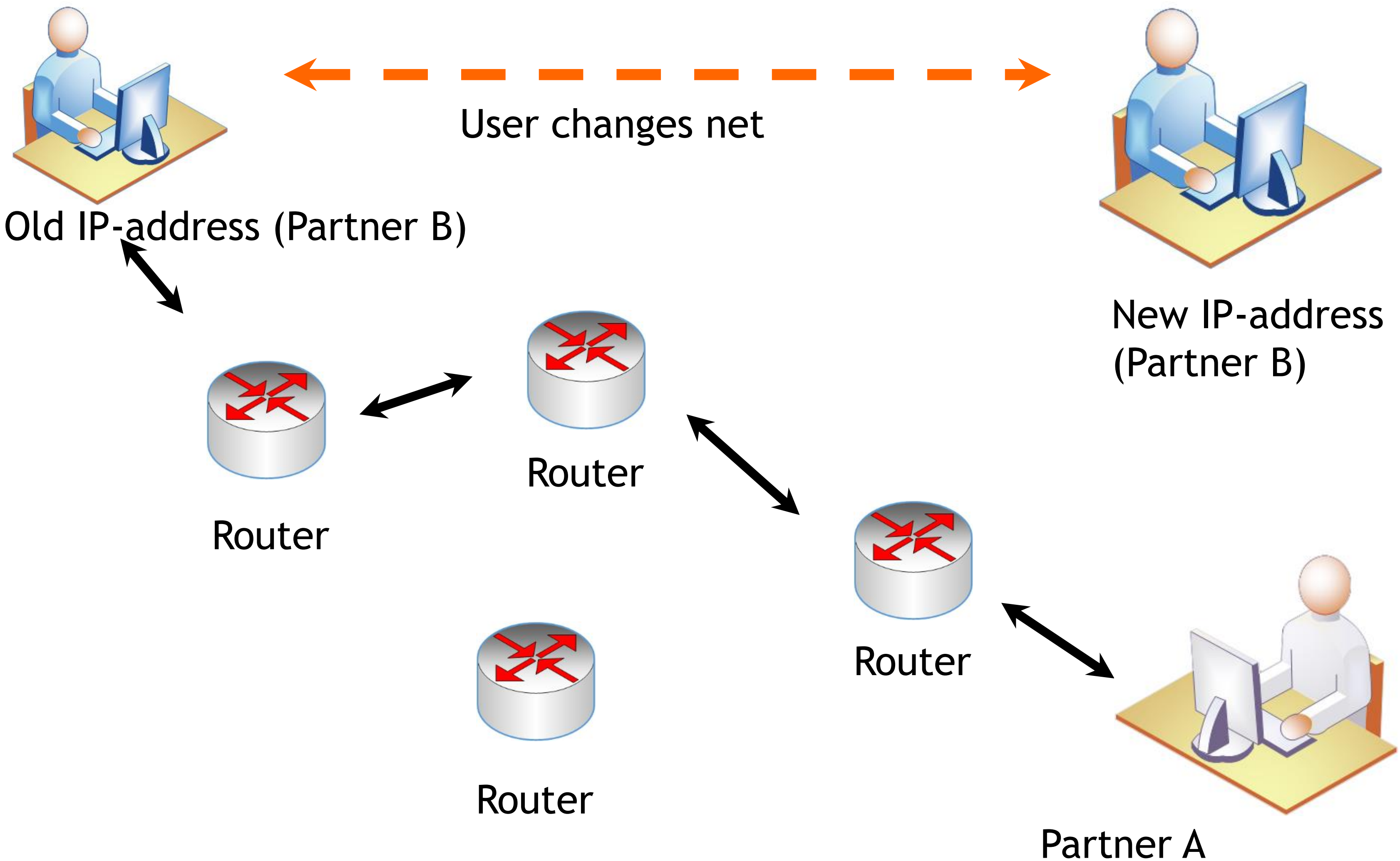
Addressing of mobile devices

- Standards
- Internet Engineering Task Force (IETF)

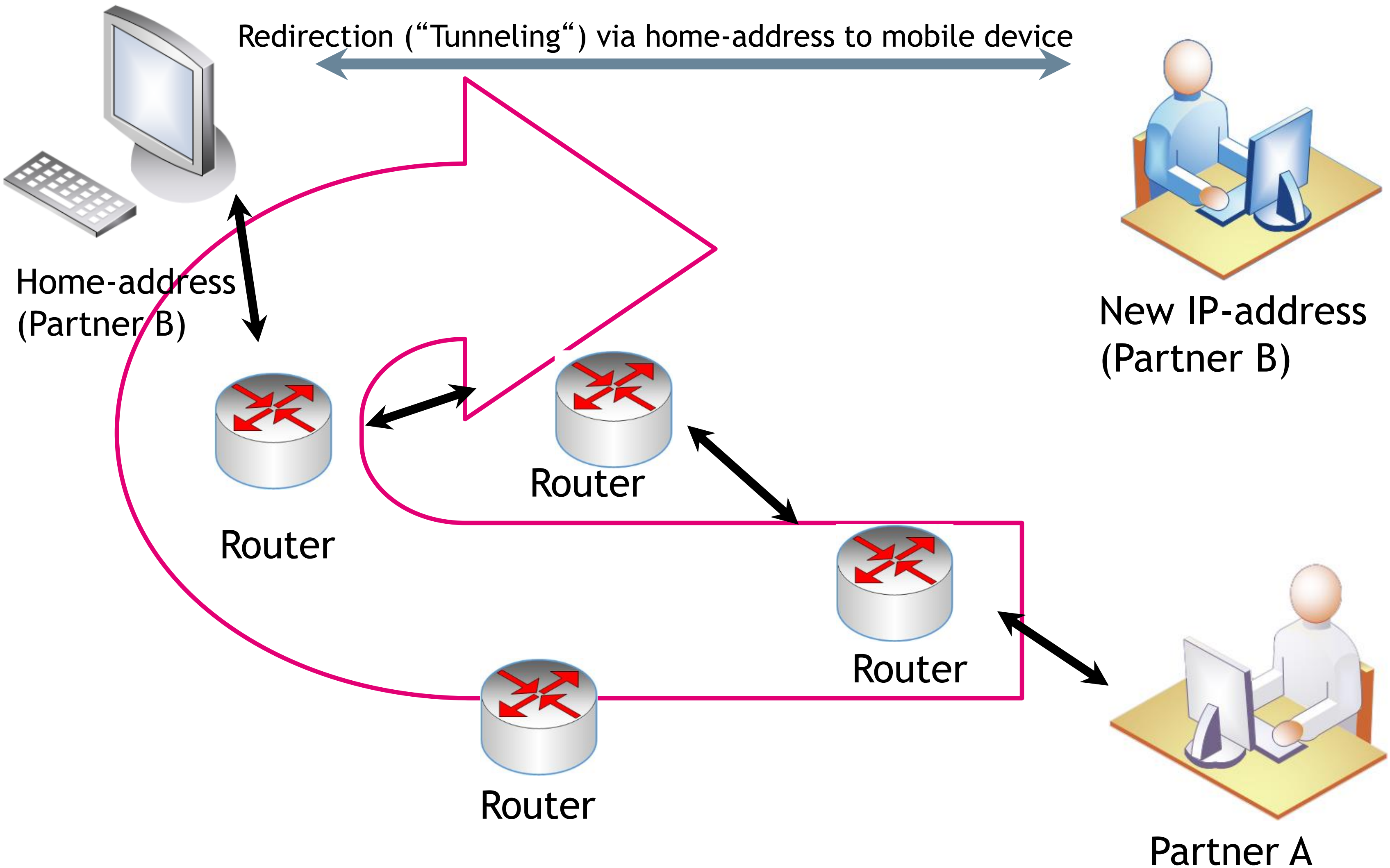
- RFC 2002, 3220: IP Mobility Support
- RFC 2977: Mobile IP Authentication, Authorization, and Accounting Requirements

[MIP02]

Roaming problem



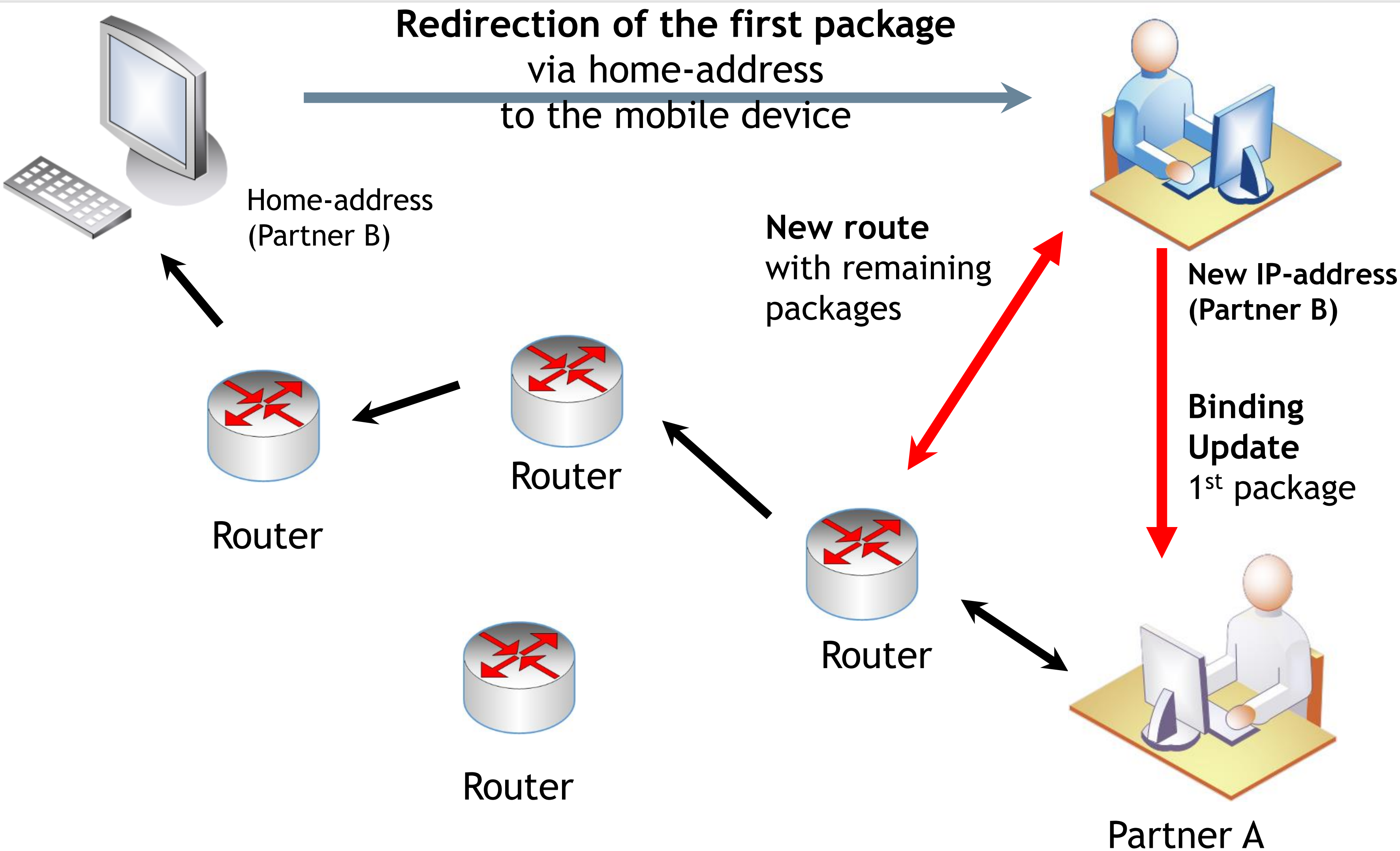
Roaming solution Layer 3



Roaming solution Layer 3

- **But** redirection implies
  - A longer route than before
  - Higher runtime
  - Avoidable usage of resources

Roaming solution
Binding Update



Security for Mobile IP

- Possible attack with illegitimate binding update:
  - **Capture the route** and redirect the TCP/IP-session.

⇒ **Therefore, authentication** of BU-messages and address check is required.

- Further possible attack: **Observation** of user movements through their binding updates!

⇒ Anonymous communication-channels are necessary to protect privacy.

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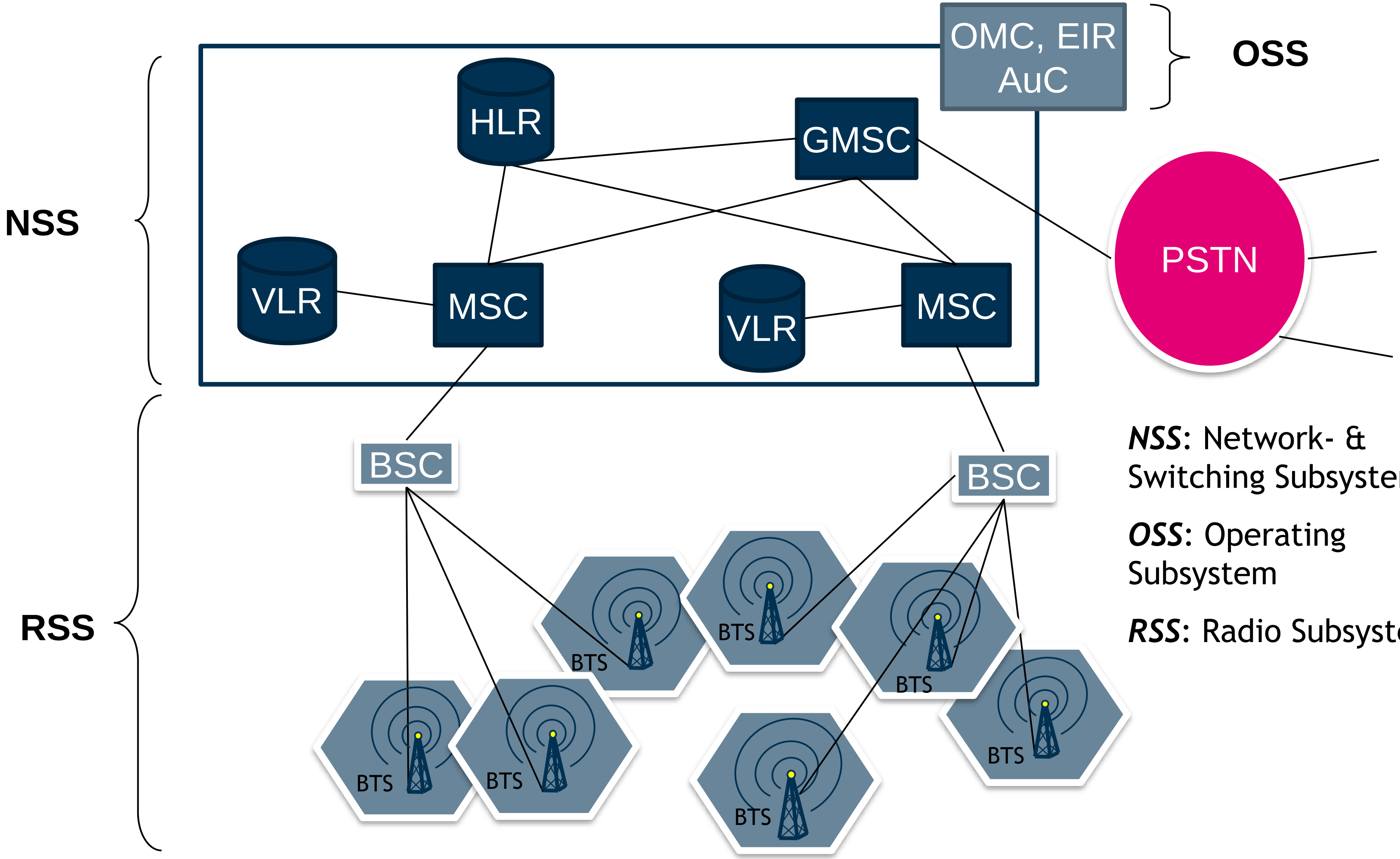
GSM

- GSM (**G**lobal **S**ystem for **M**obile Communications)
- 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 100 countries (most successful mobile radio system up to now)

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

[ETSI00]

GSM (2G)
System Architecture



NSS: Network- & Switching Subsystem

OSS: Operating Subsystem

RSS: Radio Subsystem

Based on [Schiller03]

GSM Security Model

The GSM system offers several “security services“:

Access control and authentication:

Authentication of the subscriber to the SIM by input of a PIN and to the GSM network by Challenge-Response-Procedure

Confidentiality:

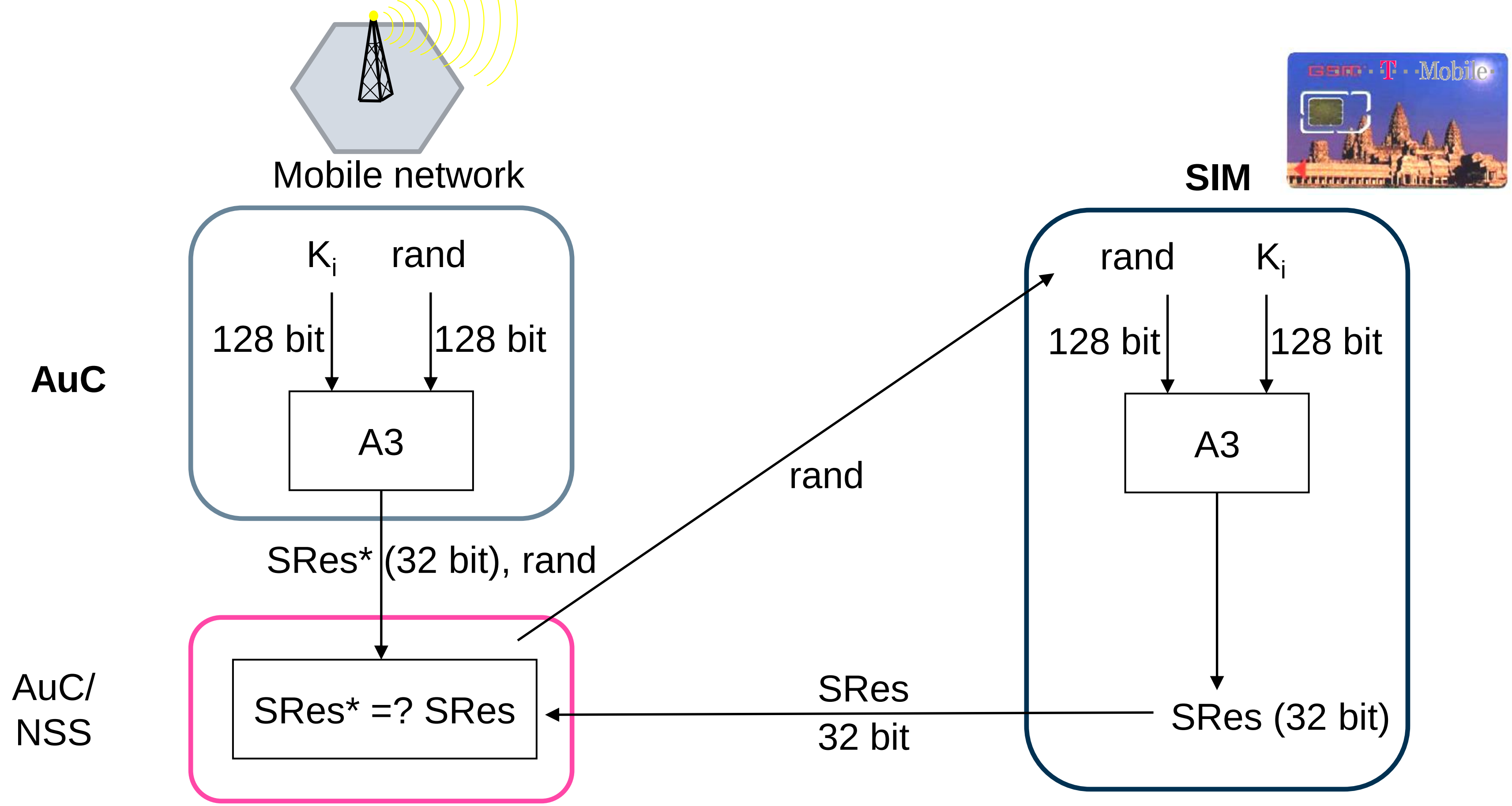
Data & voice transferred between mobile station and BTS are encrypted.

(Partial) Anonymity:

No transfer of data which can identify the subscriber via radio, instead temporary identification (Temporary Mobile Subscriber ID, TMSI)

SIM based subscriber authentication

Challenge response protocol



K_i: individual subscriber authentication key
A3: („secret“) authentication algorithm

SRes: signed response

Based on [Schiller03]

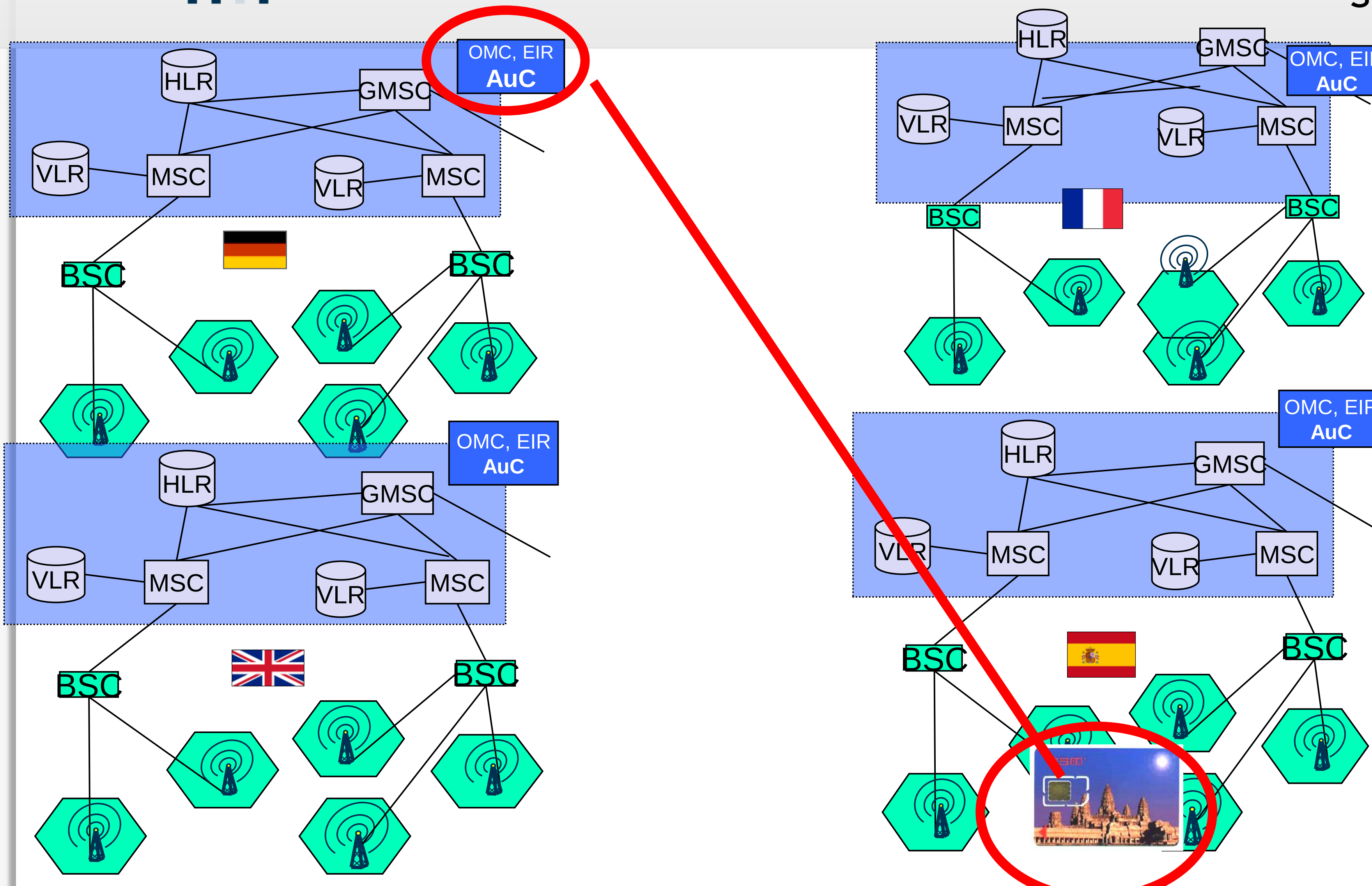
SIM based subscriber authentication

- Challenge-Response-Procedure
- Authentication is based on the individual key K_i, the subscriber identification IMSI, and a secret algorithm A3.
- K_i and A3 are stored on the SIM and in the AuC.

1. AuC creates random number *rand*.
2. AuC encrypts rand and Ki via A3 (->SRes*).
3. AuC transfers rand and SRes* to NSS.
4. NSS transfers *rand* to SIM.
5. SIM computes with “own” K_i and A3 Signed Response SRes.
6. The SRes computed by the SIM is transmitted to the NSS and is compared with SRes*.
7. If SRes* and SRes are equal the subscriber is authenticated successfully.

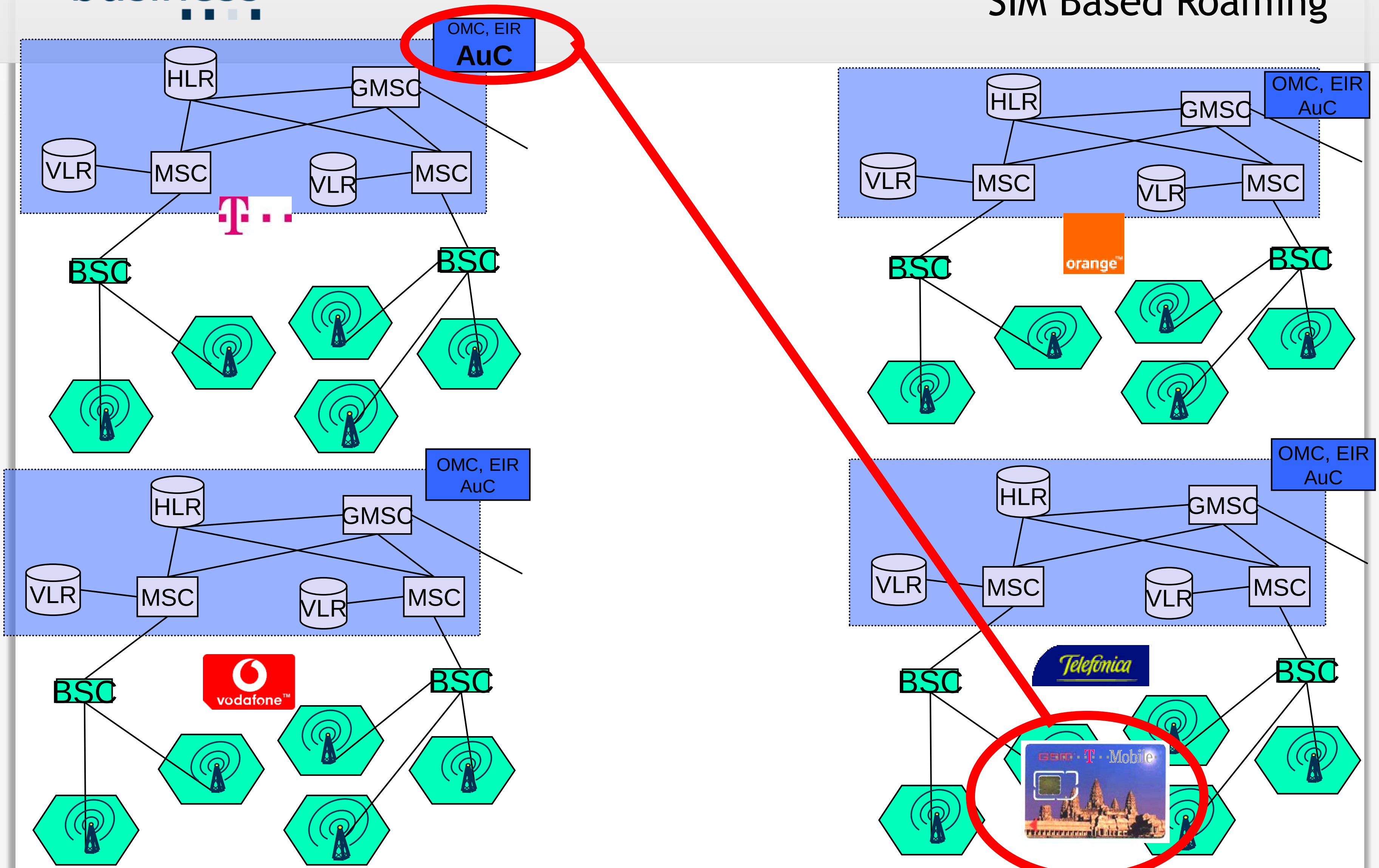
Roaming

SIM Based Roaming

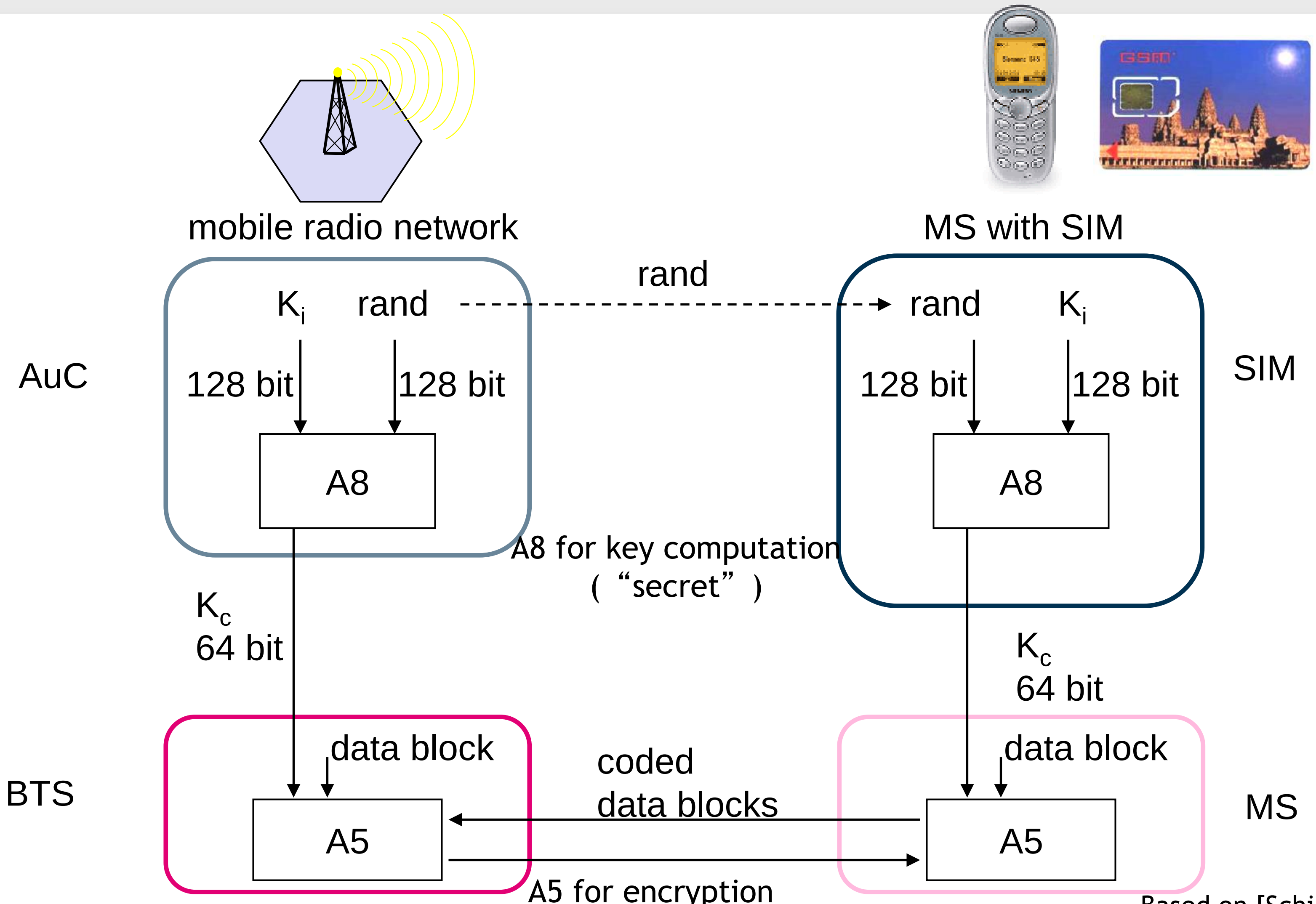


Roaming

SIM Based Roaming



Content Encryption



Based on [Schiller03]

Content Encryption

- GSM provides encryption of voice and data transferred via the air interface:

1. AuC creates random number *rand*.
2. AuC generates the key K_c for the encryption of the transferred data using *rand*, K_i and A8.
3. AuC sends *rand* to SIM.
4. SIM locally computes key K_c using *rand* received, as well as (local) K_i and A8.
5. Mobile station (MS) and mobile radio network (BTS) use K_c and algorithm A5 for encryption and decryption of sent and received data.

Partial Anonymity

- In order to guarantee the anonymity of the users temporary subscriber identification (TMSI) is used.
- TMSI is updated automatically from time to time or on demand.
- Data which identify users are not transmitted.
- Anonymous charging is (technically) possible via prepaid card.

GSM Security Model Shortcomings (1)

- Authentication only by the terminal/subscriber towards the GSM network. The network does not authenticate itself.
  - Assumption that the network is trustworthy per se
  - Security model was developed at a time with a provider monopoly.
- Subscriber positioning is almost exclusively controlled by the network.
  - Centralized movement tracking is possible.
  - To avoid positioning the subscriber must switch off the terminal.

GSM Security Model Shortcomings (2)

- Security model bases partly on secret encryption algorithms.
  - A3 and A8 were published without authorization.
  - Some operators use non-standard algorithms.
- No encryption from terminal to terminal but only over the air interface
  - Encryption deactivation by the network possible
- Encryption comparatively “weak” because of key length (64 bit)
  - Sometimes the real key length is shorter.

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General Packet Radio Service (GPRS)

- First packet-based data service
- Employment of time multiplex procedure for data services
- Dynamic allocation of radio channels among the subscribers in a radio cell
- Channels are only blocked when data is actually transferred.

➲ Packet orientation implies the introduction of new billing methods.

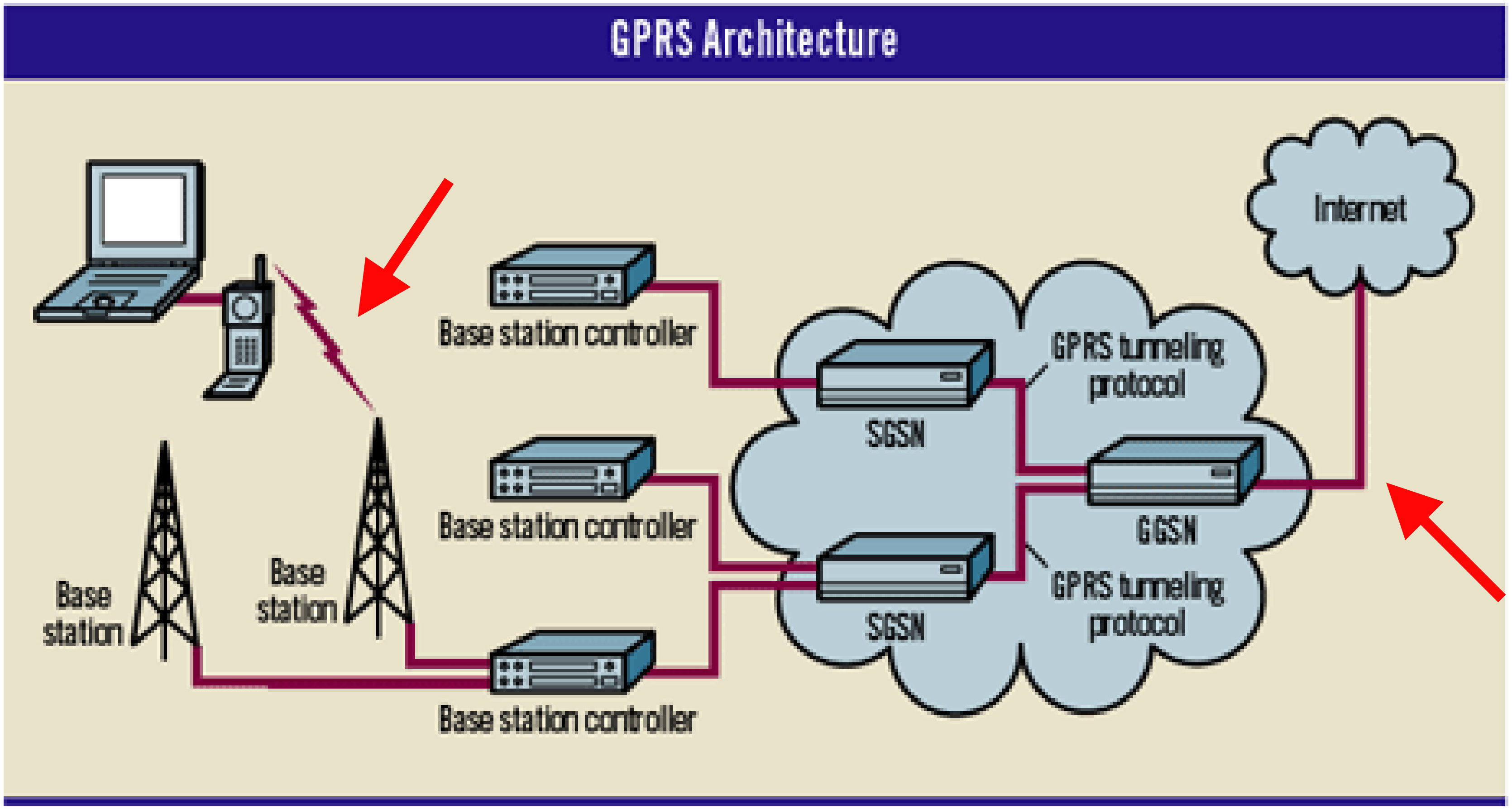
GPRS Implementation

- Up to 8 time slots can be occupied per time frame (at the moment 4 in practice).
- In contrast to HSCSD the GPRS data service requires an extensive upgrade of the GSM architecture with new network components.
- In spite of better network utilization and volume based billing at the beginning the data transfer costs were much higher than those of connection oriented data services (c't 9/2002, p.100).
- The data transfer costs of GPRS data services have been lowered through new price models (especially free volume with higher basic charge).

GPRS (In)Security

- Authentication possible via SIM
- Mobile device is „always on“ and connected directly to the Internet without specific protection (e.g. firewall)
- Encryption algorithm is analog to GSM.
- Encryption can be disabled by the GSM/GPRS-Network.

GPRS
Architectural Security Issues



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UMTS

- Universal Mobile Telecommunications System (UMTS):
  - ***Status of 2G-Networks***: Different standards in some different continents avoid 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)

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UMTS Implementation

- Common approach: worldwide reservation of frequencies in the 2GHz range
- Competing technologies: Existing national networks and installed network technologies in different regions compete for the standard.

➲ The specification of 3G-Networks, introduced by the ITU, leaves room for national, partly incompatible implementations.

UMTS Security

UMTS complements the security mechanisms known by GSM:

- Enhanced participant authentication (EMSI)
- Network authentication
- Integrity protection of data traffic
- Transferred security keys are also encrypted in the fixed network (e.g. between HLR and VLR).
- Increased key length
- End-to-End encryption is possible.

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Long Term Evolution (3.9G, 4G) Overview

- **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.

http://www.3gpp.org/LTE

http://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].

Characteristics of LTE Security

- Re-use of UMTS Authentication and Key Agreement (AKA)
- Use of USIM required (GSM SIM excluded)
- Extended key hierarchy
- Possibility for longer keys
- Greater protection for the link between the core network subnet works.
- Integrated interworking security for legacy and non-3GPP networks

[Dionisio11]

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5th Generation (5G) The Concept

Two views of 5G

- **View 1** – The hyper-connected vision
- **View 2** – Next-generation radio access technology

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
- 10-100 x number of connected devices
- 99.999 % availability
- 100 % geographical coverage
- 90 % reduction in network energy usage
- Up to ten year battery life for low power, machine-type devices

[GSMA5G]

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5th Generation (5G) Security I

Security and privacy requirements

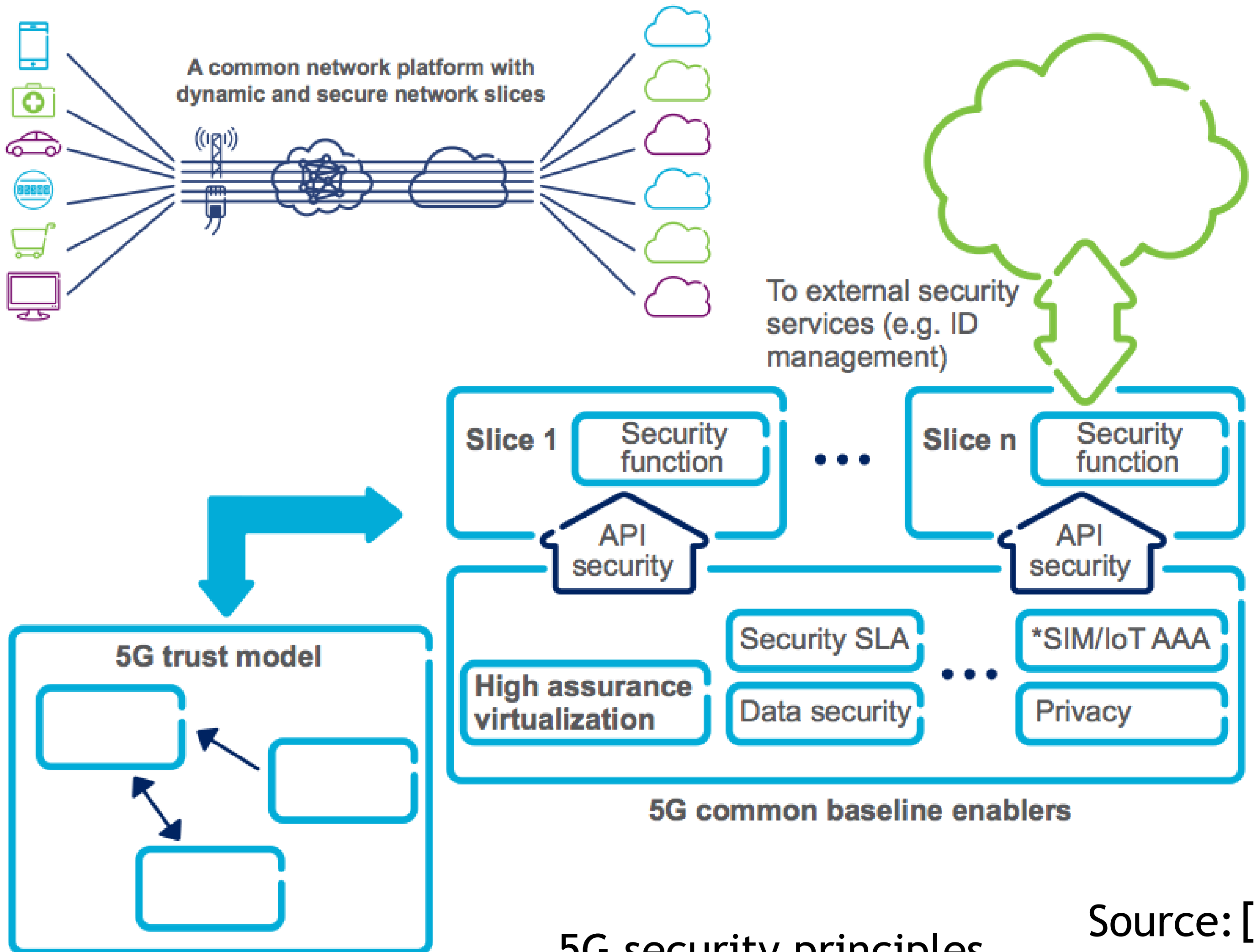
- New trust model
- Security for new service delivery models
- Evolved threat landscape
- Increased privacy concerns

Core 5G security concepts

- Security assurance
- Identity Management
- 5G radio network security
- Flexible and scalable security architecture
- Energy-efficient security
- Cloud security

[5Gsec]

5th Generation (5G) Security II



5G security principles

Source: [5Gsec]

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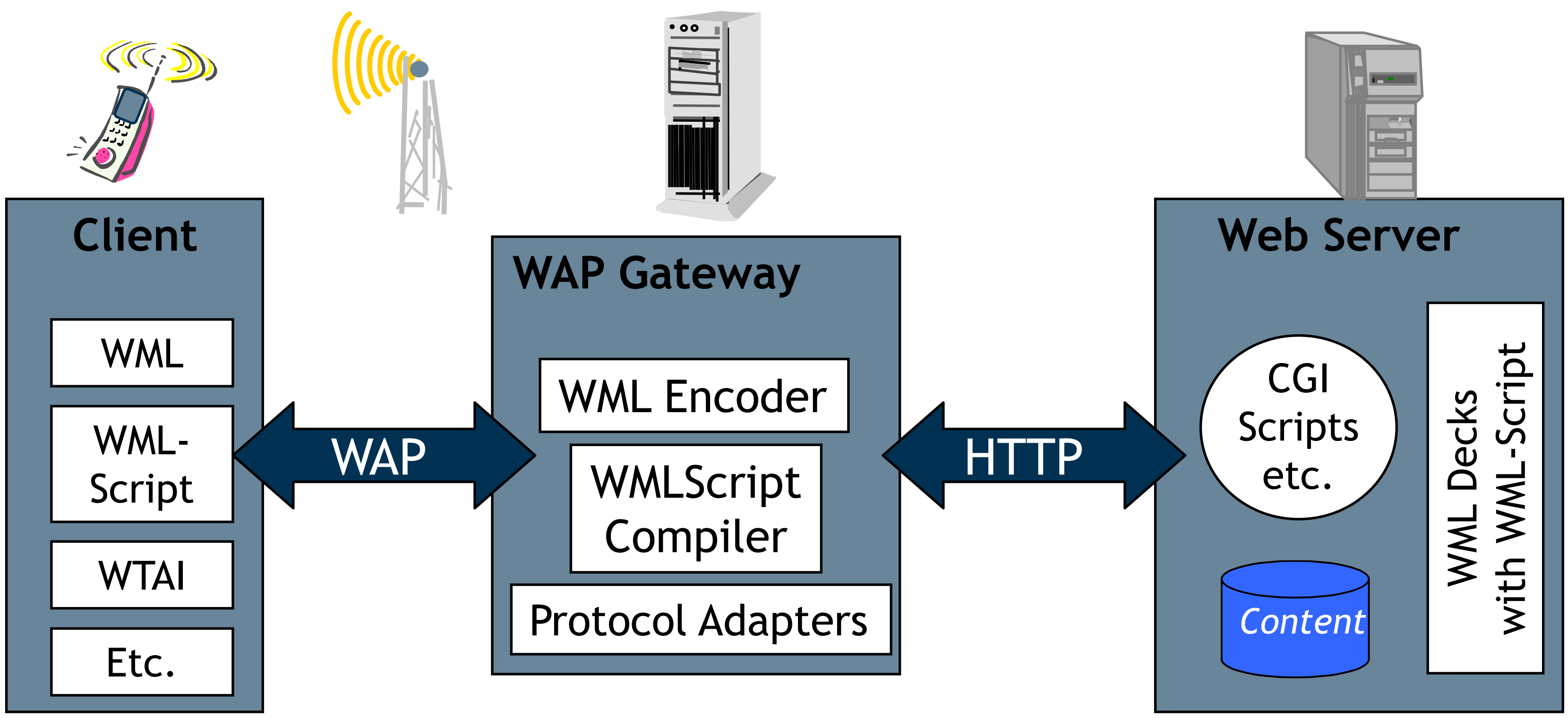
Wireless Application Protocol (WAP)

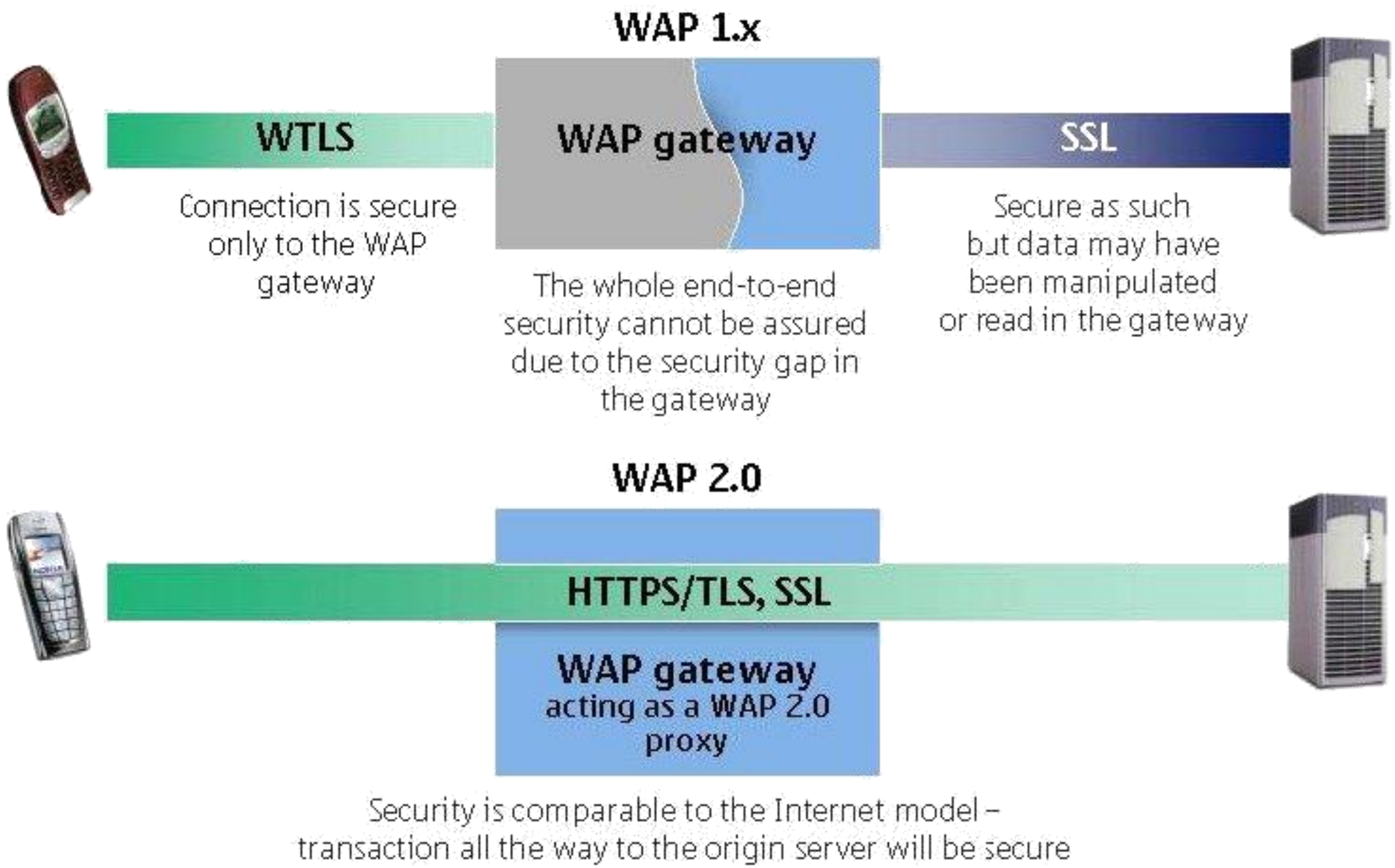
- In 1997, Ericsson, Motorola, Nokia and Unwired Planet founded the WAP-Forum.
- The WAP-Forum is a non-profit-organization with the objective to establish an open standard (protocol) for wireless data-communication.
- More than 300 members worldwide: Manufacturers, software industry, computer and telecommunication companies & network-operators
- Meanwhile consolidated into the Open Mobile Alliance (OMA)

[OMA10]

Application environment WAP Gateway



Comparison of Infrastructures WAP 1.x vs. WAP 2.0



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Personal Area Networks

- “PAN“: Personal Area Network
- Personal environment, short range
- Purpose: Connection of devices in short range, for example PDAs and printers (IrDA, Bluetooth)
- Replaces cable-connections

Infrared Transmission

- IrDA: Infrared Data Association (1993):
- Standardized infrared protocols
- IrDA Version 1.3: asynchronous, serial connection up to 1 Mbps
- Point-to-Point
- Protocol-family for various purposes
- New specification: up to 4 Mbit/s

- Exemplary applications:
  - Transmission of mobile business cards
  - Sales data extraction from cigarette vending machines
  - Connection between mobile and laptop
  - Wireless printing
  - Using smartphones as remote controllers for TVs

Infrared Transmission

- Attributes:
  - Wireless
  - Range up to 10 meters
  - Illumination-angle 15° -30°

- Disadvantages:
  - Sounding: if the infrared-ray misses the target
  - Optical connection required
  - Short interruption of the optical connection e.g. between laptop and mobile phone in the trains leads to complete network-interruption

Bluetooth

- Frequency range of 2.4 GHz
- Simple and cheap possibility to set up ad-hoc networks of limited range (up to 10 meters)
- No official standard, but de-facto-standard
- Consortium: Ericsson, Intel, IBM, Nokia, Toshiba, etc.
- Broadly supported by industry

Bluetooth
Popular applications

File exchange between mobile devices

Wireless extension of device features (headset for mobile)

Bluetooth Security

- „Bonding“ of devices:
  - Exchange of IDs (48 bit, globally unique (!), public)
  - Agreement on key for protected communication
- Access control for devices and singular services possible (3 security modes)
- **Sufficient** for „**own**“ devices when they are introduced to each other in a secure environment
- **Problematic** when ad hoc networks are initiated in unknown environments
- **Dangerous** when devices are configured to
  - Search (“inquire”) for other devices and connect
  - Be open and detectable for other devices

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