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Lecture 2

Wireless Internet-oriented Infrastructures and Protocols

Mobile Business I (WS 2018/19)

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Overview

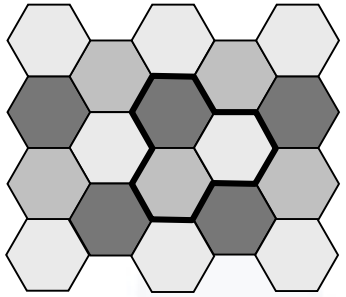
- Wireless LAN
  - Basics
  - Components and Infrastructures
  - State-of-the art Encryption
  - Mobility and Roaming
- Mobile IP – Mobility support for TCP/IP
- IP-based Radio Access Networks

Wireless LAN Basics
General

- Wireless communication based on radio as transport medium
- Cell based architecture
- Extension to a (wire based) LAN
- One cell serves an area in which PCs, laptops, and other connected devices can move freely.
- The term "Wi-Fi“ is
  - used in general English as synonym for a Wireless Local Area Network (WLAN),
  - a trademark owned by the *Wi-Fi Alliance*, a trade association promoting Wi-Fi technology.

Wireless LAN Basics
Radio Cell

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



- A WLAN radio cell can be an add-on for already existing cable-based networks.

Wireless LAN Basics
Beacon Frame

- 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 [Sauter2008].

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Wireless LAN Basics
802.11 Standard

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802.11f	Roaming between access points of different manufacturers (published in 2003 and withdrawn by IEEE in 2006) [IEEE2010]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)
802.11aj	A rebanding of 802.11ad for use in the 45 GHz unlicensed spectrum in some regions of the world (specifically China)
802.11ax	Upcoming Standard operating in the existing 2.4GHz and 5GHz spectrums but incorporating additional bands between 1 and 7GHz. Expected to achieve 4xincrease to user throughput

*) 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.

[IEEE] [Sauter 2008]

Wireless LAN Basics
Bandwidth Volatility

- Wireless LAN bandwidth depends on the **chosen standard**, the **distance** between client and access point, and the construction and quantity of **walls**.

Bandwidth 802.11b	Outside	Inside (Office)	Inside (House)
11 Mbps	~ 160 m	~ 50 m	< 20 m or max. 1 wall
5.5 Mbps	~ 270 m	~ 70 m	< 30 m or max. 2 walls
2 Mbps	~ 400 m	~ 90 m	< 40 m or max. 3 walls
1 Mbps	~ 550 m	~ 115 m	< 50 m or max. 4 walls

[Lanz 2003]

- **802.11b** uses the **2.4 GHz frequency band**. Reach depends even more on local circumstances when using newer IEEE standards together with **5 GHz frequency band**.

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Wireless LAN Components

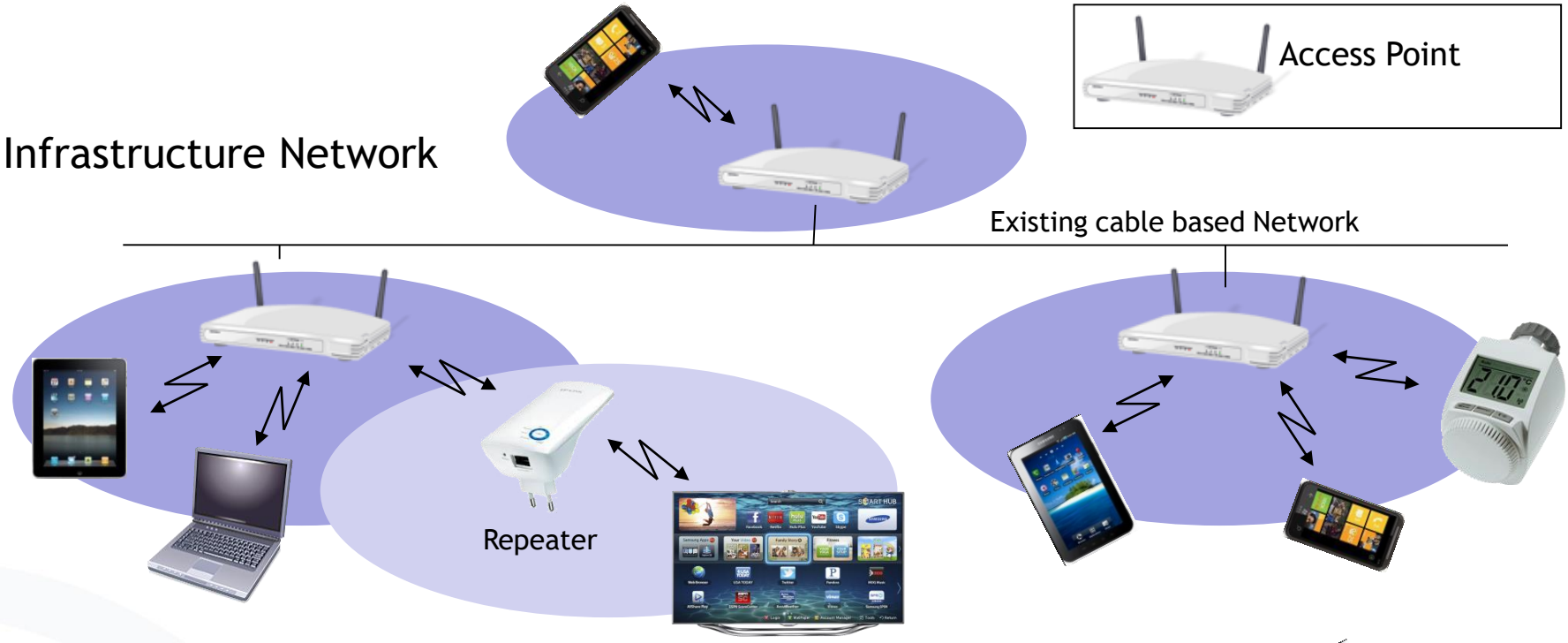
- Components (802.11b)
  - Access Point (AP)

    Sender and receiver station that allows the connecting of many stations

  - Stations

    End-systems that establish a wireless connection e.g. by using an Access Point (e.g. a notebook with built-in Wireless LAN)

Wireless LAN Infrastructures



Based on [Sauter 2008]

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Wireless LAN
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).
- WEP 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. [Heise 2007]

Wireless LAN
State-of-the art Encryption

- **Wi-Fi Protected Access (WPA)** was developed by the Wi-Fi Alliance. [Wi-Fi 2010]

- There are two versions of **Wi-Fi Protected Access**, WPA and WPA2:
  - **WPA** includes most of the 802.11i standard, but is **outdated and insecure** as it has various weaknesses:
    - Vulnerability to dictionary attacks when using a weak PSK
    - Other weaknesses inherited from earlier standards [ArsT 2008]
  - **WPA2** includes **802.11i** to its full extent and also the Advanced Encryption Standard (AES).

Key Reinstallation Attacks (KRACKs) against WPA2

- The attack is mainly against the ***4-way handshake*** of the WPA2 protocol.
- The 4-way handshake protocol is mathematically proven, but it only assures the negotiated key remains secret, and that handshake messages cannot be forged.
- The attack doesn't leak the encryption key, but sensitive information (usernames, passwords, …) can be stolen.
- Discovered by Mathy Vanhoef – a post-doctoral researcher at *KU Leuven*
- *Background material and video on the attack via* https://www.krackattacks.com

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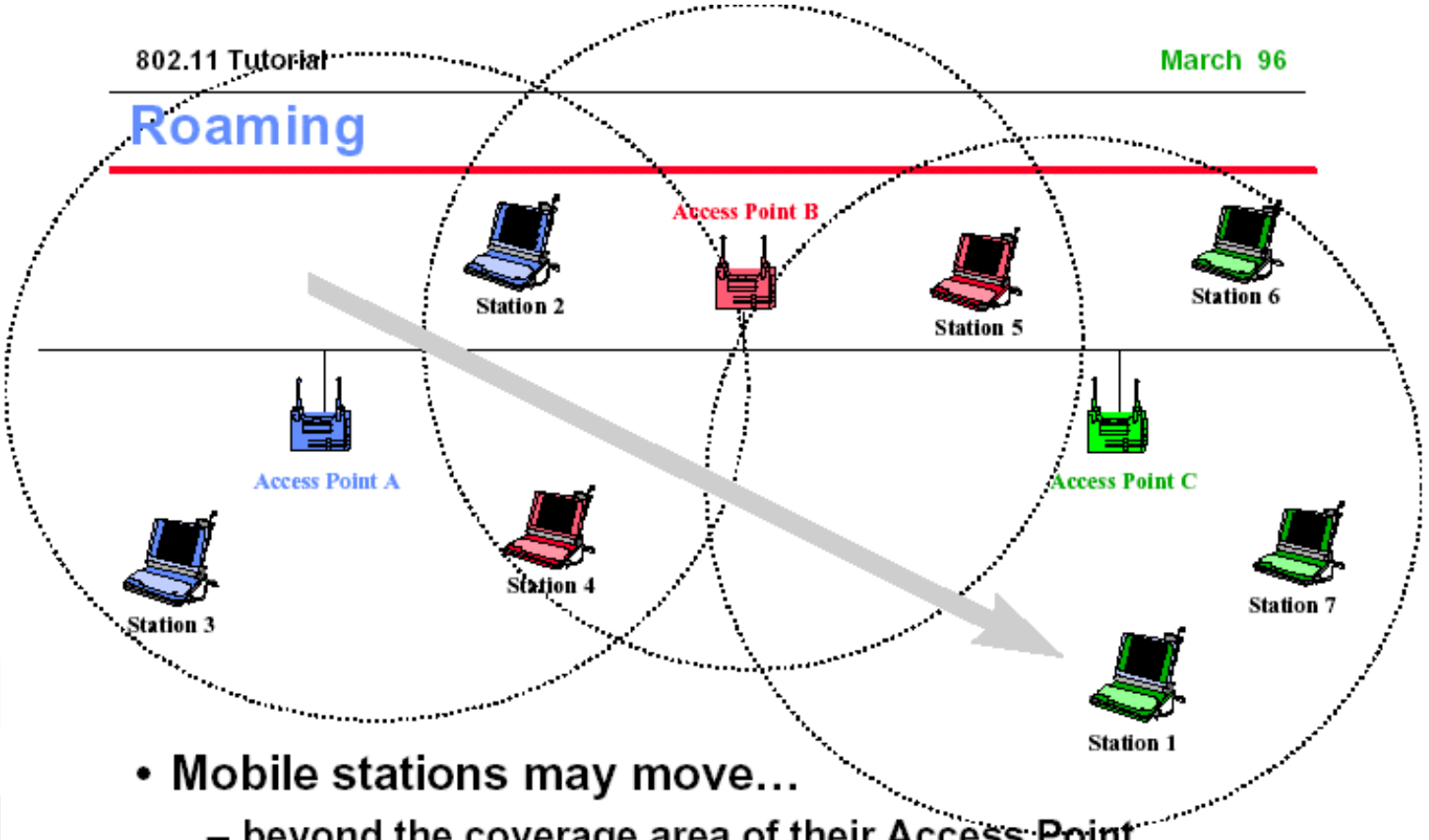
Restrictions of WLAN Mobility

- No existing standard for “handover” or “roaming” between:
  - Access points (AP)
  - Different providers of APs
- Change of AP leads to
  - Connection interrupt
  - New connection/authentication
- Non-uniform accounting / user administration

→ Some of the reasons why WLAN will not replace mobile communication networks

Wireless LAN Mobility Problems



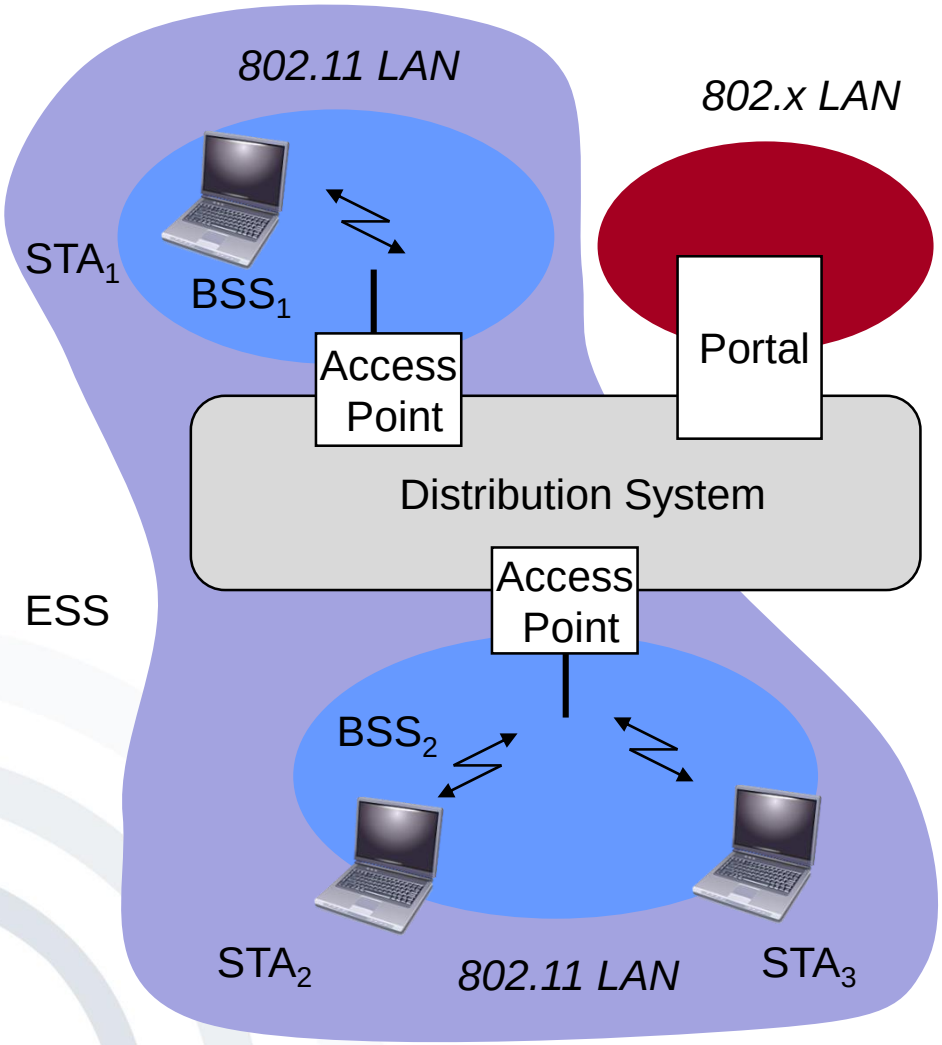
- Mobile stations may move…
  - beyond the coverage area of their Access Point
  - but within range of another Access Point
- Reassociation allows station to continue operation

[IEEE 1996]

Wireless LAN “Roaming”

- Approaches to perform “roaming”
  - By a combination of several access points a so-called distribution system is growing.
  - Every access point covers one radio cell.
  - Upon leaving a radio cell the station starts scanning for other existing access points (which may use the same SSID, but a different transmission channel) and tries to connect.
  - Following the connection to a new access point the distribution system and the access point that was used before will be informed.

Wireless LAN “Roaming”



Station (STA)

- Computer with access to the wireless medium and radio connect to the AP

Basic Service Set (BSS)

- Group of stations, which use the same radio frequency

Access Point

- Station which is integrated into the radio as well as the fixed local area network (distribution system)

Portal

- Transfer into another network

Distribution systems

- Connection of different cells for building a larger network (ESS: Extended Service Set)

Wireless LAN Mobility
Fast BSS Transition (802.11r)

- **BSS = Basic Service Set**.
  A *Basic Service Set (BSS)* is one Wireless LAN access point + all associated stations.
- The client decides which access point to (re)connect to in case the connection to the previous access point is lost (e.g. due to the client moving out of range).
- Wireless security protocols induce interruptions of several seconds during necessary reconnection (problem when using Voice-over-IP telephony connections!).
- Since 2008 a standard for "roaming" between Wireless LAN access points is available:
  IEEE 802.11r = fast roaming and fast BSS transition
  - As of February 2013, no Intel devices support the 802.11r standard. [Intel 2013]
  - For Apple devices iOS 6 introduced support for 802.11r (optimized client roaming on enterprise Wi-Fi networks). [Apple 2012]

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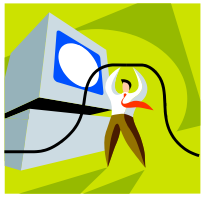
Mobile IP
Mobility with TCP/IP

The situation today:

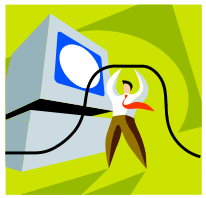
- Separate IP addresses in the office and at home
- DHCP – dynamic IP address assignment
- Dial-up with dynamic IP addresses
  - Continuous accessibility via one IP address is not guaranteed.
  - Connection interruptions during access point switches

Mobile IP
Routing in TCP/IP

Partner B
IP address, e.g.
61.9.193.200



Router



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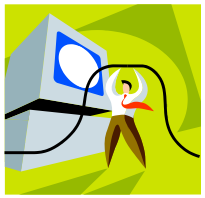

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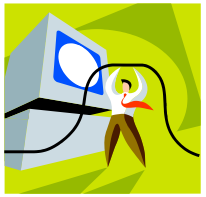


Router

Partner A
IP address,
e.g. 141.2.74.211

- 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 packets by routers

Mobile IP
Addressing of Mobile Devices

Standards

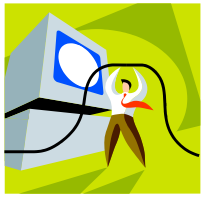
- Internet Engineering Task Force (IETF)
  www.ietf.org
- RFC 2002: IP Mobility Support
- RFC 2977: Mobile IP Authentication, Authorization, and Accounting Requirements

Mobile IP
Mobility problem

Partner B changes network

Old IP address (Partner B)

New IP address (Partner B)



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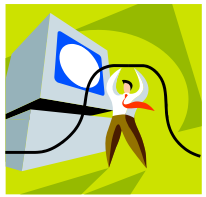

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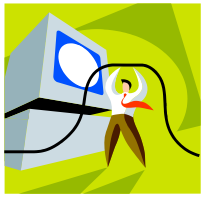
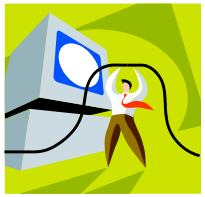


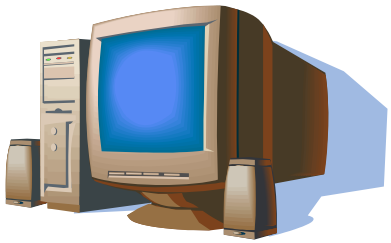
Router



Router

Partner A

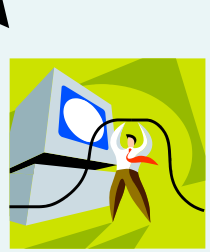
Mobile IP
Mobility solution - Layer 3



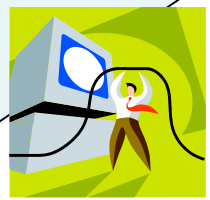
Redirection (“Tunneling“) via home address to mobile device

Home address (Partner B)

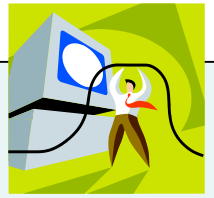
New IP address (Partner B)



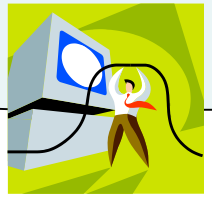
Router



Router



Router



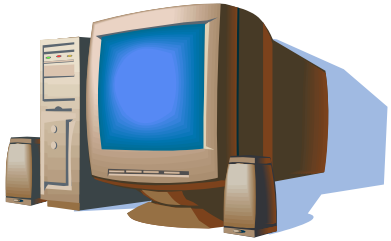
Router

Partner A

Mobile IP
Mobility solution - Layer 3

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

Mobile IP
Mobility solution - Binding Update



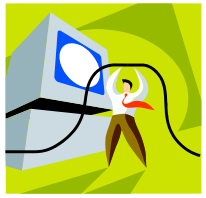
Redirection of the first package
via home address
to the mobile device

New
IP address
(Partner B)

Home address
(Partner B)

New route
with remaining
packets

Binding
Update
1st packet



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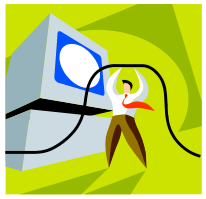

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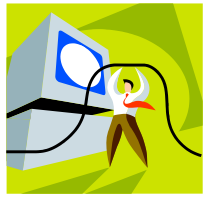

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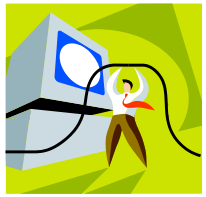

Router

Partner A

Security for Mobile IP

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

  ➲ **Therefore, authentication** of Binding Update (BU) messages and address check is required.

- In addition, **observation** of user movements through their Binding Updates!

  ➲ Anonymous communication-channels are necessary to protect privacy.

Domain Names and Mobile IP

- In the **Domain Name System** a domain-name belongs to a fixed IP address (e.g. www.m-lehrstuhl.de = 141.2.66.180).
  - **Changing** these addresses requires an update-time of several hours ➲ 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.

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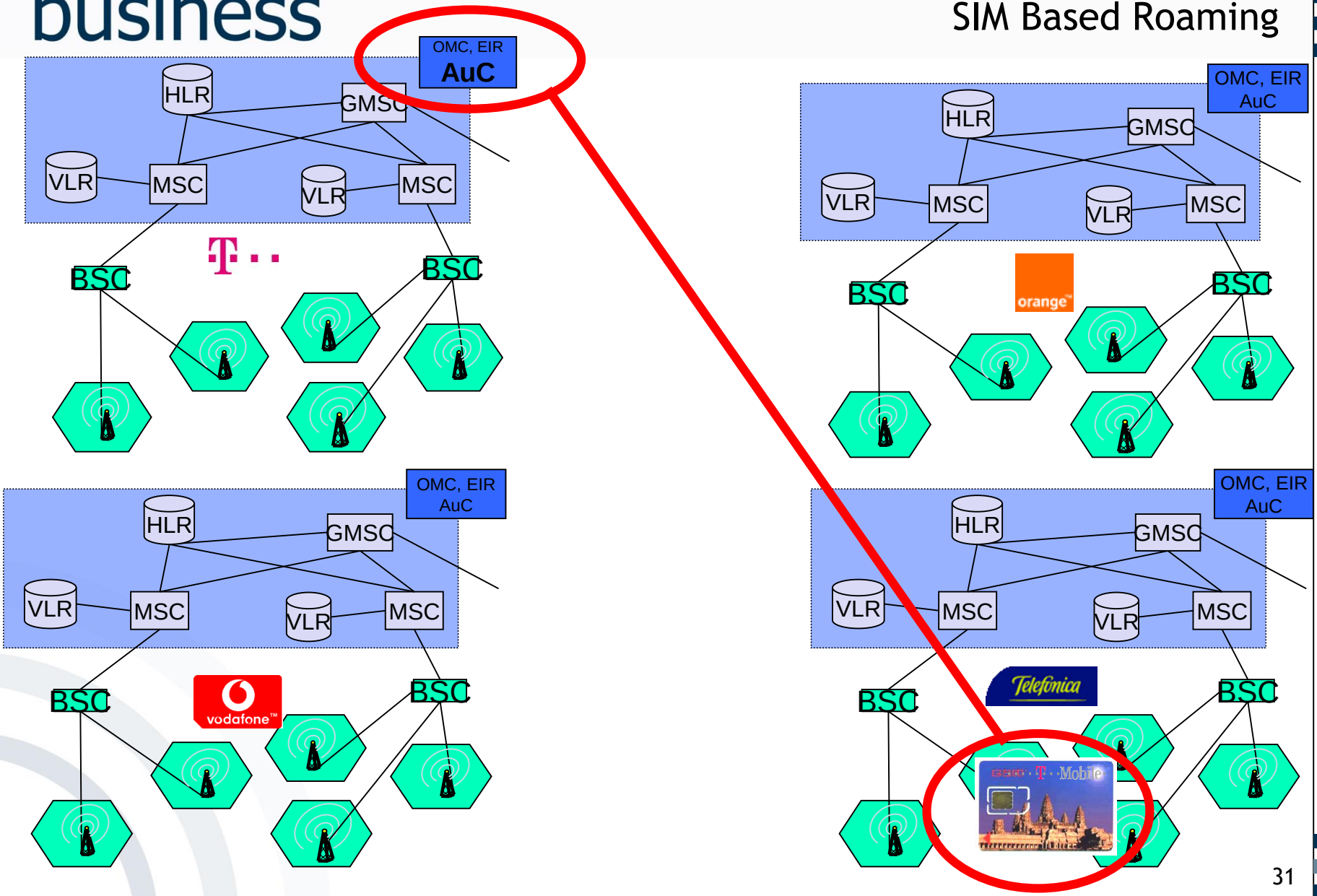
Roaming

SIM Based Roaming



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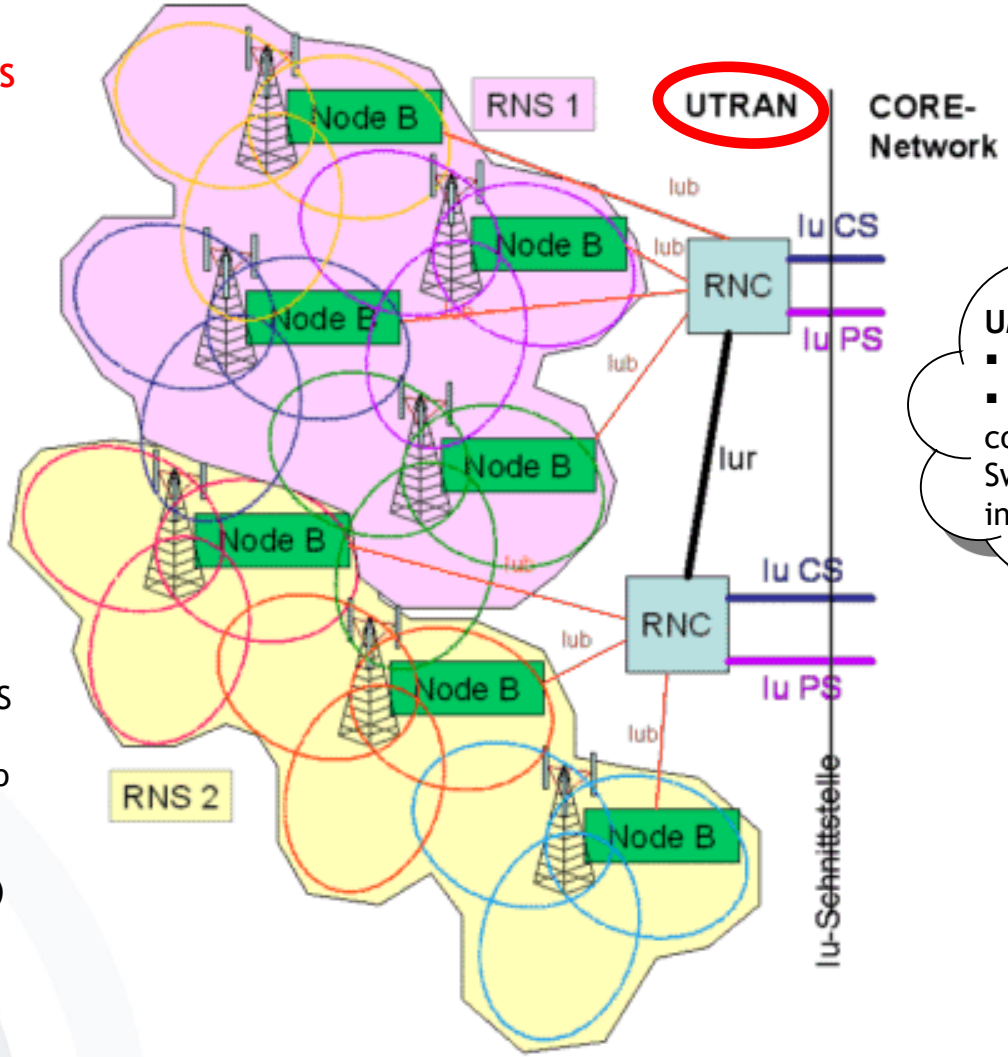
UMTS (3G) System Architecture

- ***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



UMTS Core network
- is not shown here in detail
- UMTS Core network corresponds to Network- & Switching Subsystem (NSS) in GSM

Source: UMTSlink.at (2011)

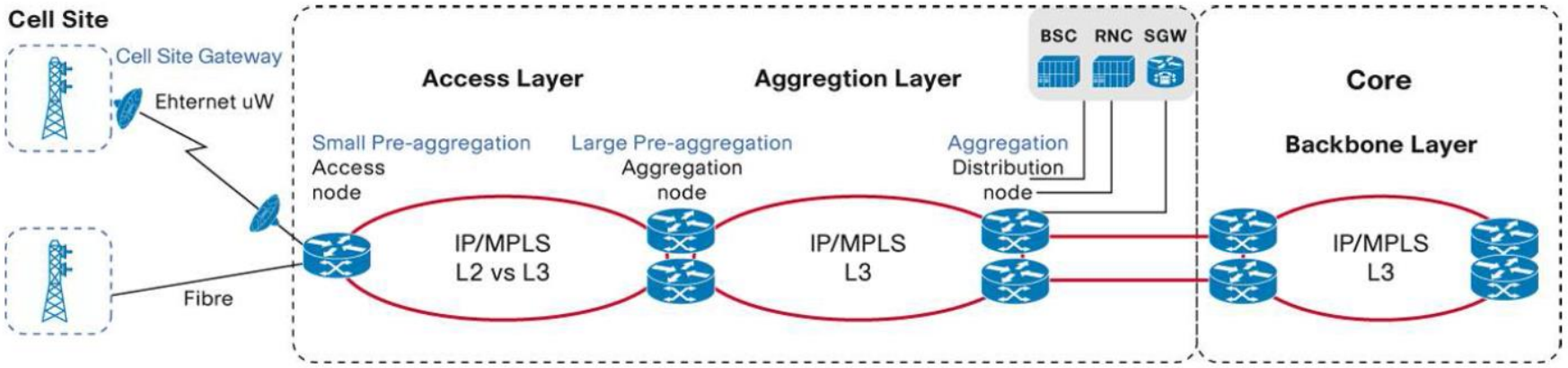
Radio Access Networks (RAN)

- Part of a mobile telecommunication system
- Provides connection between device (phone, computer, or machine) and core network
- Implements certain radio access technologies, e.g. GSM or 3G
- Examples of radio access network types are:
  - **GRAN:** GSM radio access network
  - **GERAN:** essentially the same as GRAN but specifying the inclusion of EDGE packet radio services
  - **UTRAN:** UMTS radio access network
  - **E-UTRAN:** Long Term Evolution (LTE) high speed, low latency radio access network
  - **C-RAN**: Centralized or Cloud-based radio access network
- Some handsets have capability to be simultaneously connected to multiple RANs (dual-mode handsets).

[Wiki 2014]

IP-based Radio Access Networks (IP RAN)

- All different backhaul technologies may be collapsed onto a single IP/MPLS network (MPLS = Multiprotocol Label Switching) → End-to-end IP approach
- Support for legacy services and reduced cost per bit
- 2G, 3G, and 4G radio technologies transparently supported
- Cost savings possible due to alternative transport media (such as Ethernet and DSL)



[Cisco 2011] [Cisco 2014]

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