IMT-2000 and UMTS

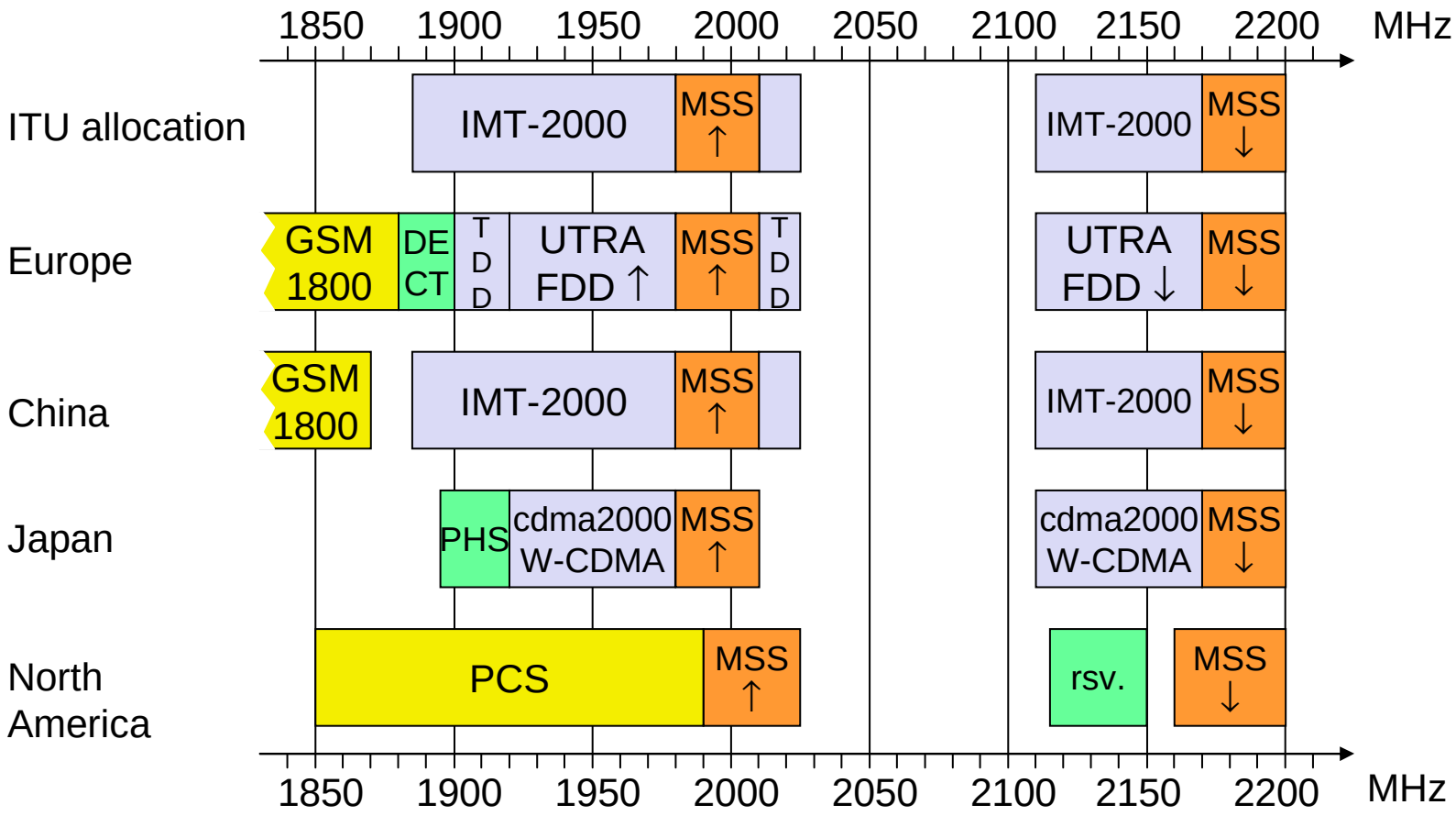
IMT-2000 (International Mobile Telecommunications) was started as activity by ITU to define a world-wide standardized 3G communication system. Lots of proposals were developed:

- UWC-136, cdma2000, WP-CDMA, …
- … and UMTS (Universal Mobile Telecommunications System, ETSI)

UMTS

- … bases on the so-called *UTRA: Universal Terrestrial Radio Access*
- Integration of different mobile, cordless and pager systems into only one radio access network supporting world-wide roaming
- Integration von voice, data, and multimedia data services
- Enhancement of GSM: higher data rates, enhanced service concept, global roaming
- Data rates: 144 kBit/s up to 2 MBit/s
  - min. 144 kBit/s rural (target: 384 kBit/s)
  - min. 384 kBit/s suburban (target: 512 kBit/s)
  - up to 2 MBit/s urban
- Compatibility to GSM, ISDN, ATM, and IP

Frequencies for IMT-2000

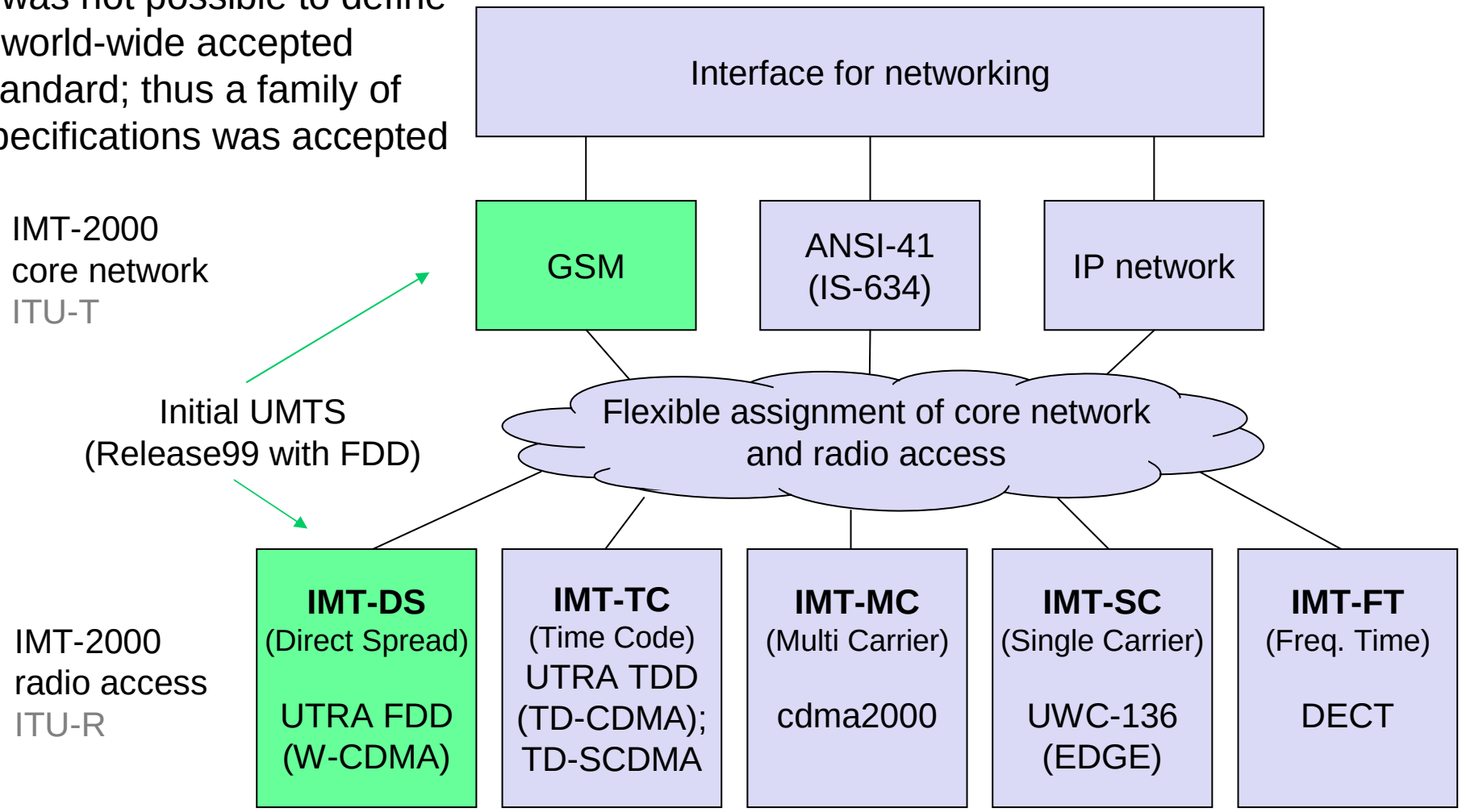


MSS: Mobile satellite services
DECT: Digital Enhanced Cordless Telecommunications
PHS: Personal Handyphone System
PCS: Personal Communications Service (GSM1900)

IMT-2000 Family

IMT-2000 = UMTS ≠ IMT-2000 …

- It was not possible to define a world-wide accepted standard; thus a family of specifications was accepted



Licensing of UMTS in Germany, 18.8.2000

STAND DER LIZENZVERGABE

Versteigerung UMTS/IMT-2000-Lizenzen

Runde 173 Datum 17.08.00 Uhrzeit 15:51:26

Höchstgebote für Frequenzblöcke (mind. 2 Blöcke erforderlich für Lizenz)

Bieter	Anzahl der Frequenzblöcke 1	2	3	Lizenzgebot (TDM)	(€ in Tsd)
E-Plus Hutchison	2 x 5 MHz	2 x 5 MHz		16.418.200	8.394.492
Group 3G	2 x 5 MHz	2 x 5 MHz		16.446.000	8.408.706
Mannesmann Mobilfunk	2 x 5 MHz	2 x 5 MHz		16.473.800	8.422.920
MobilCom Multimedia	2 x 5 MHz	2 x 5 MHz		16.370.000	8.369.848
T-Mobil	2 x 5 MHz	2 x 5 MHz		16.582.200	8.478.344
VIAG Interkom	2 x 5 MHz	2 x 5 MHz		16.517.000	8.445.008
debitel Multimedia	ausgeschieden				
Lizenzsumme				98.807.200	50.519.319

RUNDENERGEBNIS

Versteigerung UMTS/IMT-2000-Frequenzen

Runde: 9

Lfd. Nr.	Umfang	Höchstbieter	Höchstgebot (TDM)	Höchstgebot* (€ in Tsd)
13	1 x 5 MHz konkret	E-Plus Hutchison	73.600	37.631
14	1 x 5 MHz	MobilCom Multimedia	121.000	61.866
15	1 x 5 MHz	T-Mobil	122.700	62.736
16	1 x 5 MHz	Mannesmann Mobilfunk	121.000	61.866
17	1 x 5 MHz	Group 3G	122.700	62.736
		Summe Höchstgebote	561.000	286.835

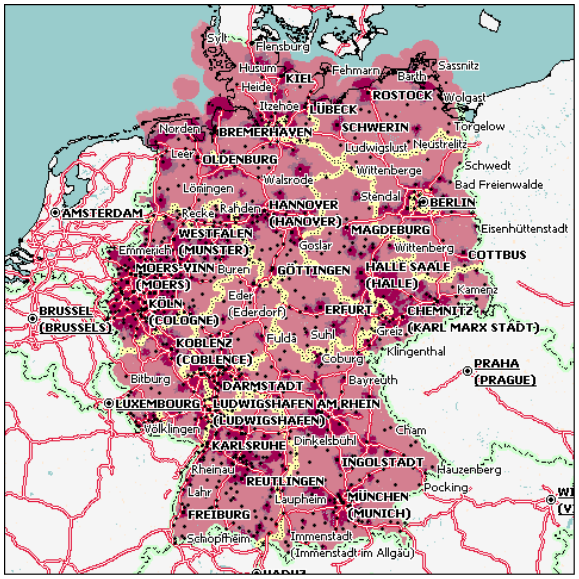
* Eurowerte gerundet

VIAG Interkom ausgeschieden

- UTRA-FDD:
  - Uplink 1920-1980 MHz
  - Downlink 2110-2170 MHz
  - Duplex spacing 190 MHz
  - 12 channels, 5 MHz each
- UTRA-TDD:
  - 1900-1920 MHz
  - 2010-2025 MHz
  - 5 MHz channels
- Planned coverage: 25% of the population till 12/2003, 50% till 12/2005

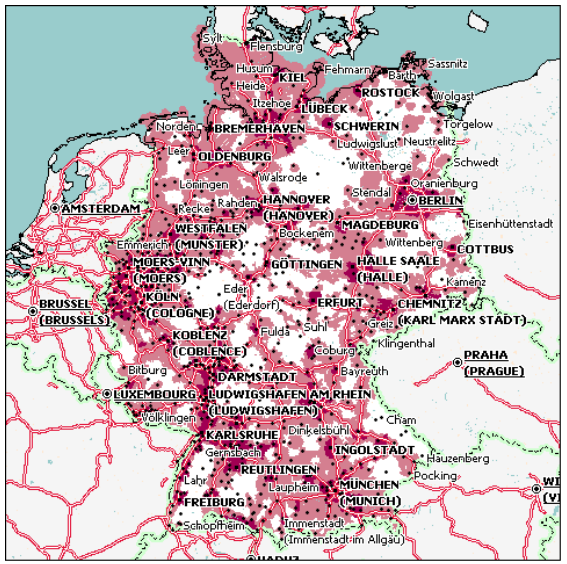
Sum: **50,81 billion €**

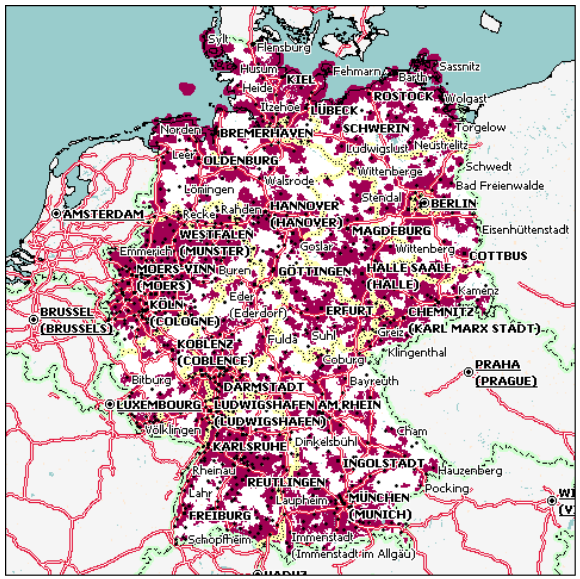
UMTS – End of 2007 (www.gsmworld.com)



ePlus

O_2

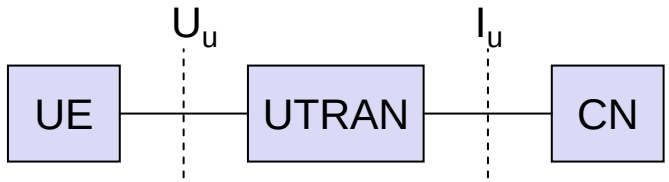




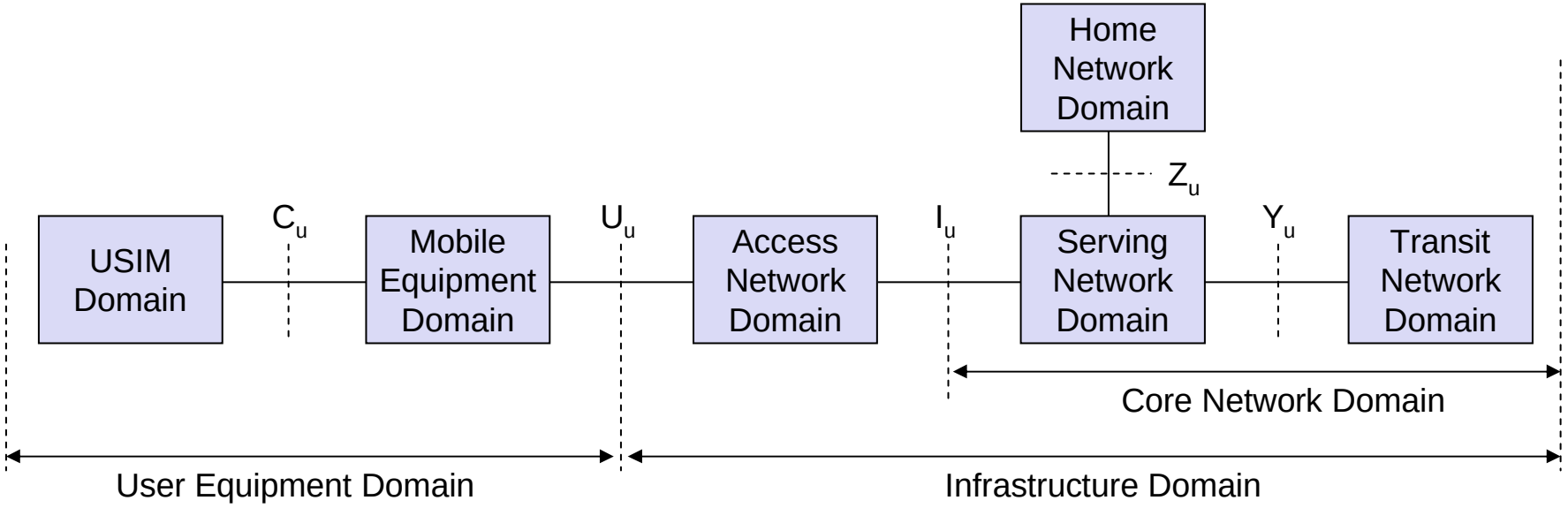
Vodafone

UMTS Architectur (Release 99)

- UTRAN (UTRA Network)
  - Cell level mobility
  - Comprises several Radio Network Subsystems (RNS)
  - Encapsulation of all radio specific tasks
- UE (User Equipment)
- CN (Core Network)
  - Handover between systems
  - Gateways to other systems
  - Location management, if there is no dedicated connection between UE and UTRAN
  - Usage of existing GSM/GPRS infrastructure, change to an IP-based core network with release 5



UMTS Domains and Interfaces

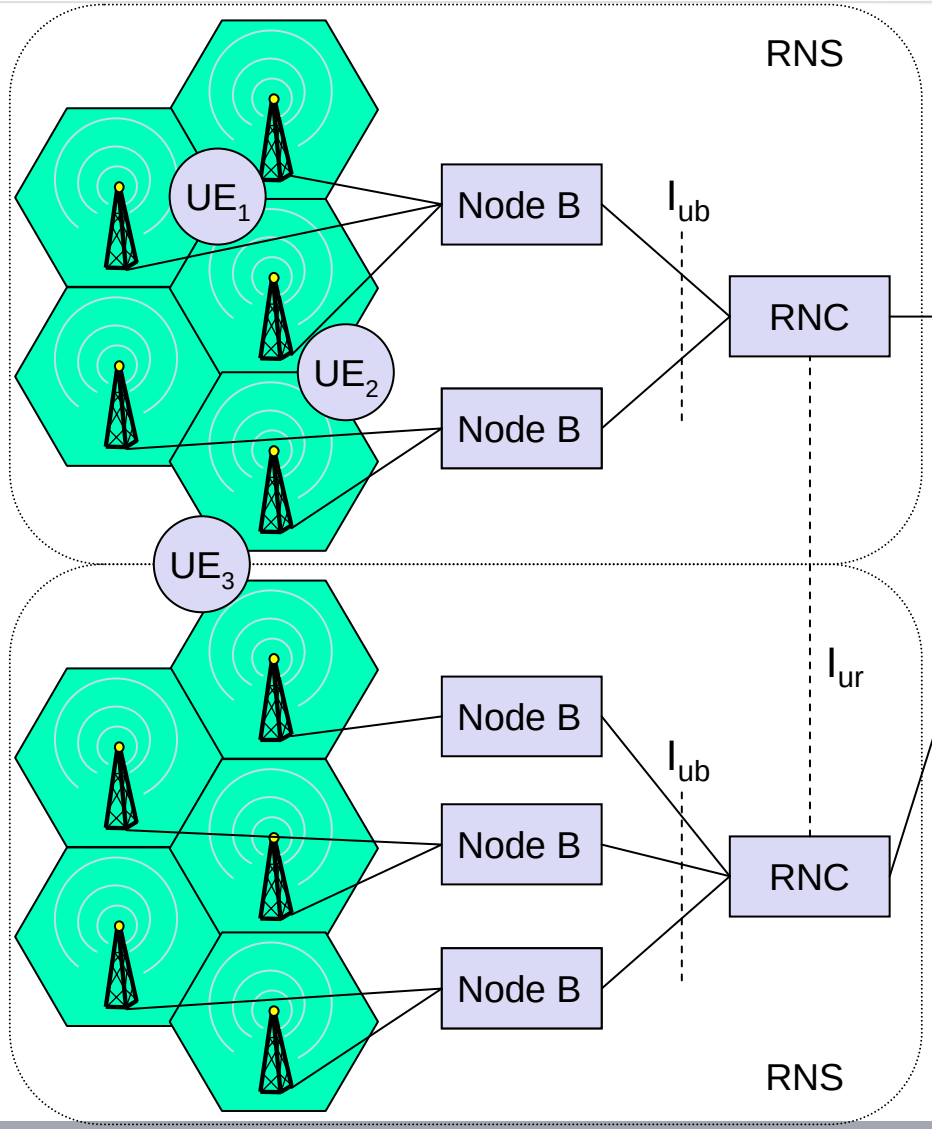


- User Equipment Domain
  - Assigned to a single user in order to access UMTS services
- Infrastructure Domain
  - Shared among all users
  - Offers UMTS services to all accepted users

UMTS Domains and Interfaces

- Universal Subscriber Identity Module (USIM)
  - Functions for encryption and authentication of users
  - Located on the SIM
- Mobile Equipment Domain
  - Functions for radio transmission
  - User interface for establishing/maintaining end-to-end connections
- Access Network Domain
  - Access network dependent functions
- Core Network Domain
  - Access network independent functions
  - Serving Network Domain
    - Network currently responsible for communication
  - Home Network Domain
    - Location and access network independent functions

UTRAN Architecture



RNC: Radio Network Controller

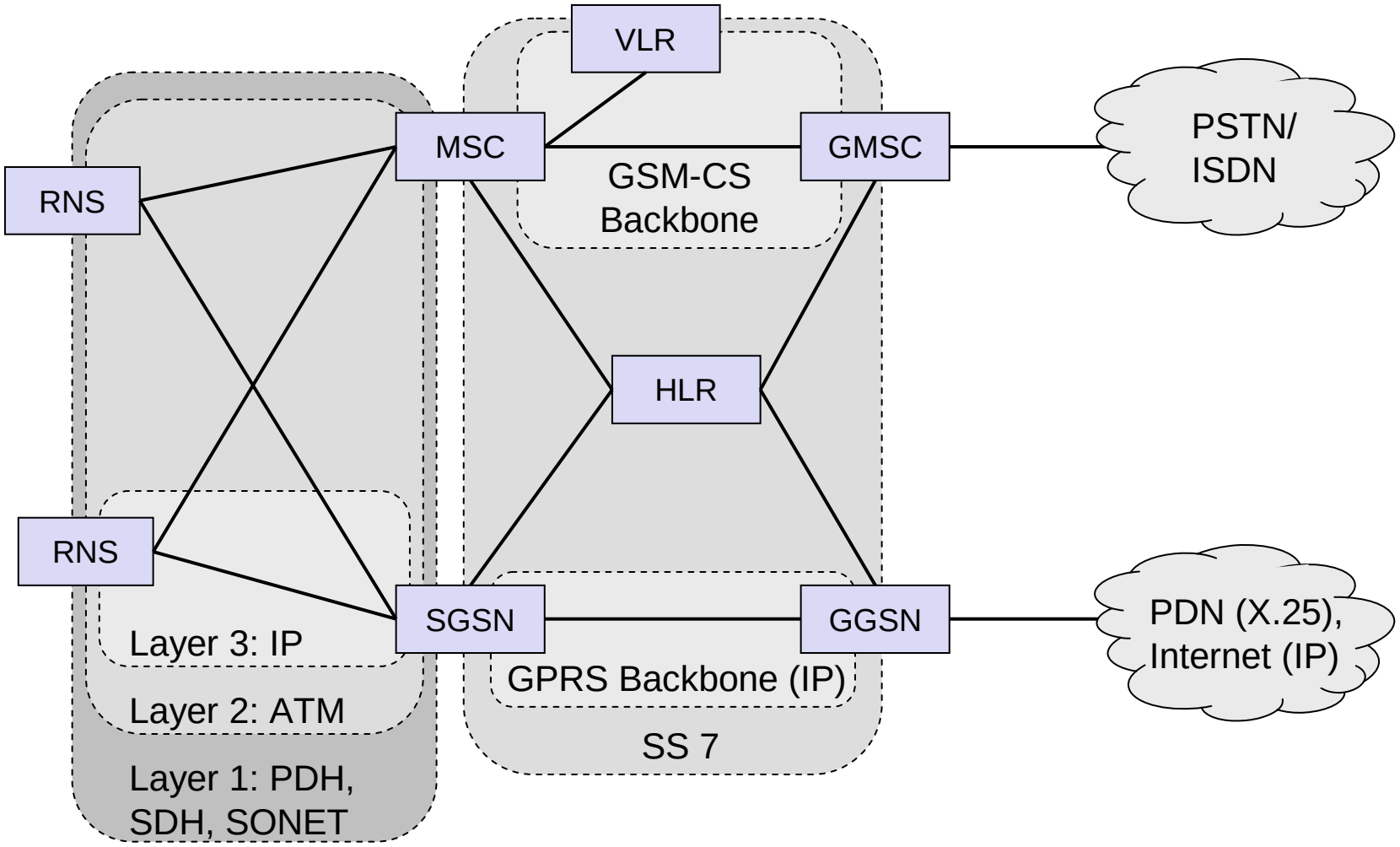
RNS: Radio Network Subsystem

- UTRAN comprises several RNSs
- Node B can support both, FDD or TDD
- RNC is responsible for handover decisions requiring signaling to the UE
- Cell offers FDD or TDD

UTRAN Functions

- Admission Control
- Congestion Control
- System Information Broadcasting
- Radio Channel Encryption
- Handover
- Radio Network Configuration
- Channel Quality Measurements
- Macro Diversity
- Radio Carrier Control
- Radio Resource Control
- Data Transmission over the Radio Interface
- Power Control
- Channel Coding
- Access Control

Core Network: Protocols



RNS can be UMTS RNS or GSM BSS

Core Network

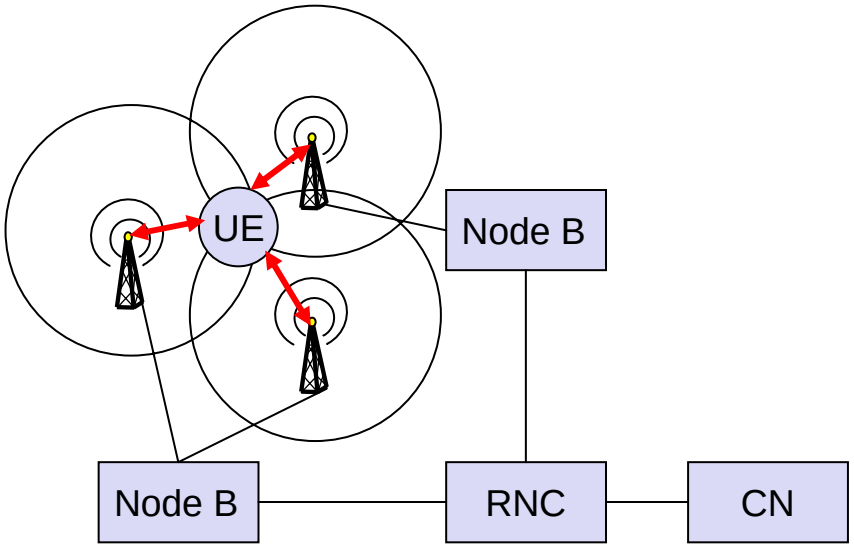
The Core Network and thus also the interface I_u are separated into two logical domains:

- Circuit Switched Domain (CSD)
  - Circuit switched service inclusive signaling
  - Resource reservation at connection setup
  - GSM components (MSC, GMSC, VLR)
- Packet Switched Domain (PSD)
  - GPRS components (SGSN, GGSN)

Release 99 uses the GSM/GPRS network and just adds a new radio access

- Lower costs, faster deployment
- Not as flexible as newer releases since 5 (change to IP based functions, …)

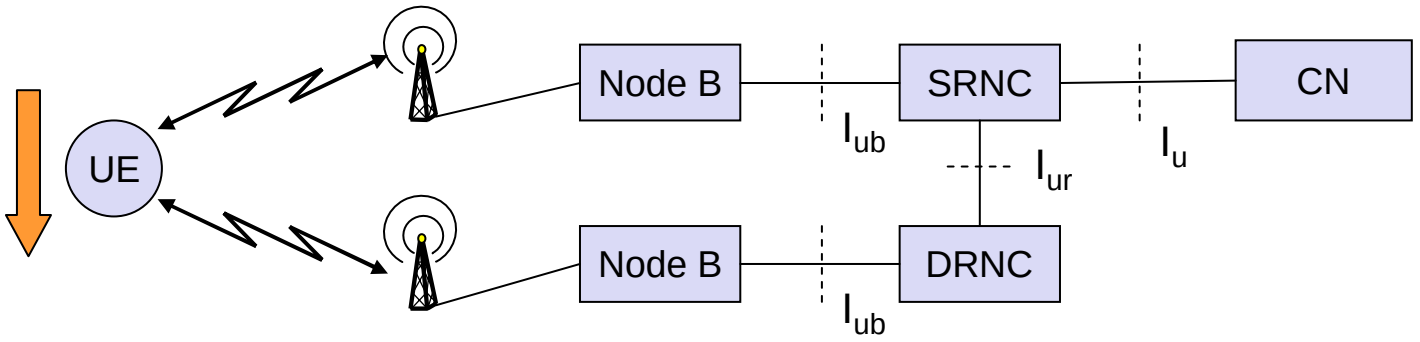
Support of Mobility: Macro Diversity



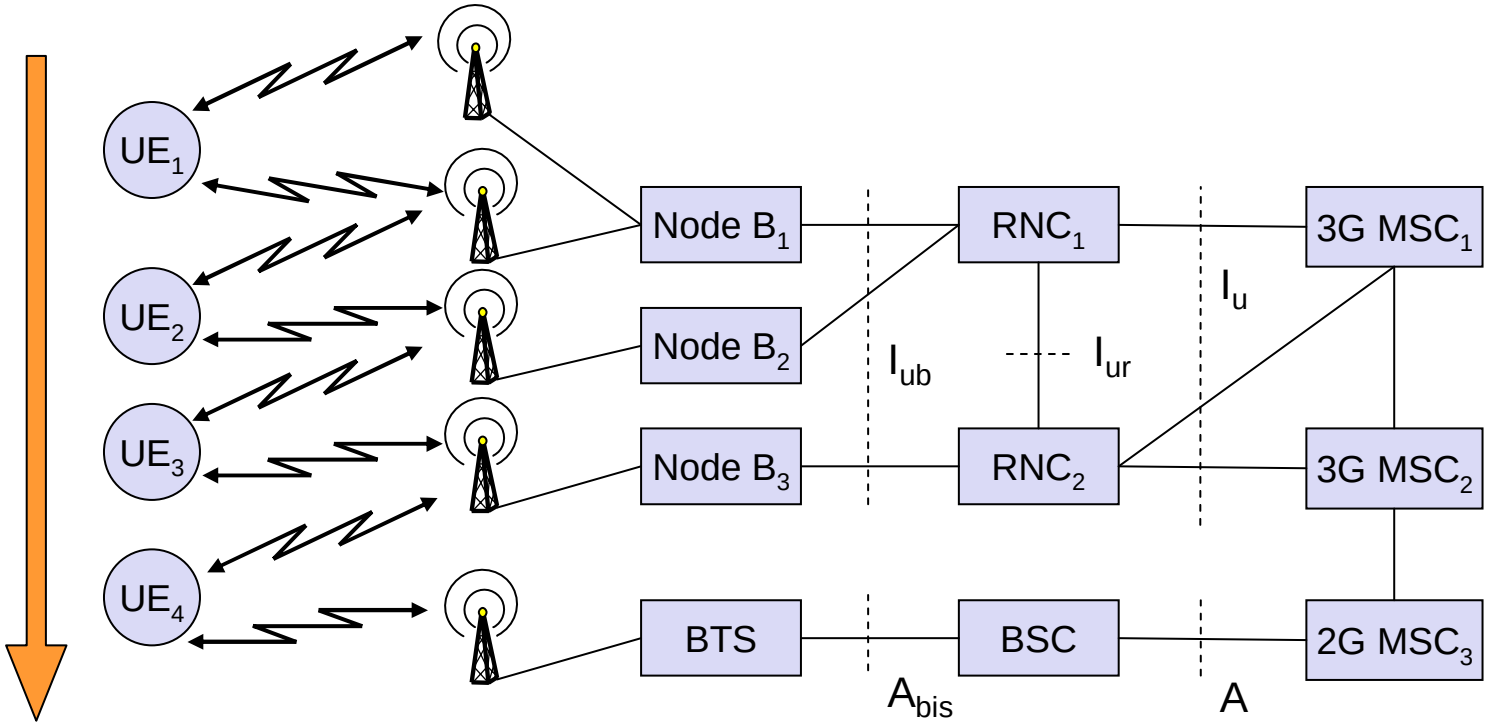
- A device can receive signals over 3 antennas in parallel
- Multicast of data via several physical channels
  - Enables soft handover
  - only in FDD mode
- Uplink
  - Simultaneous reception of UE data at several Node Bs
  - Reconstruction of data at Node B, SRNC or DRNC
- Downlink
  - Simultaneous transmission of data via different cells
  - Different spreading codes in different cells

Support of Mobility: Handover

- From and to other systems (e.g. UMTS to GSM)
  - A must for the beginning when UMTS coverage is poor
- RNS controlling the connection is called SRNS (Serving RNS)
- RNS offering additional resources (e.g.. for soft handover) is called DRNS (Drift RNS)
- End-to-end connections between UE and CN only via I_u at the SRNS
  - Change of SRNS requires change of I_u
  - Initiated by SRNS
  - Controlled by the RNC and CN

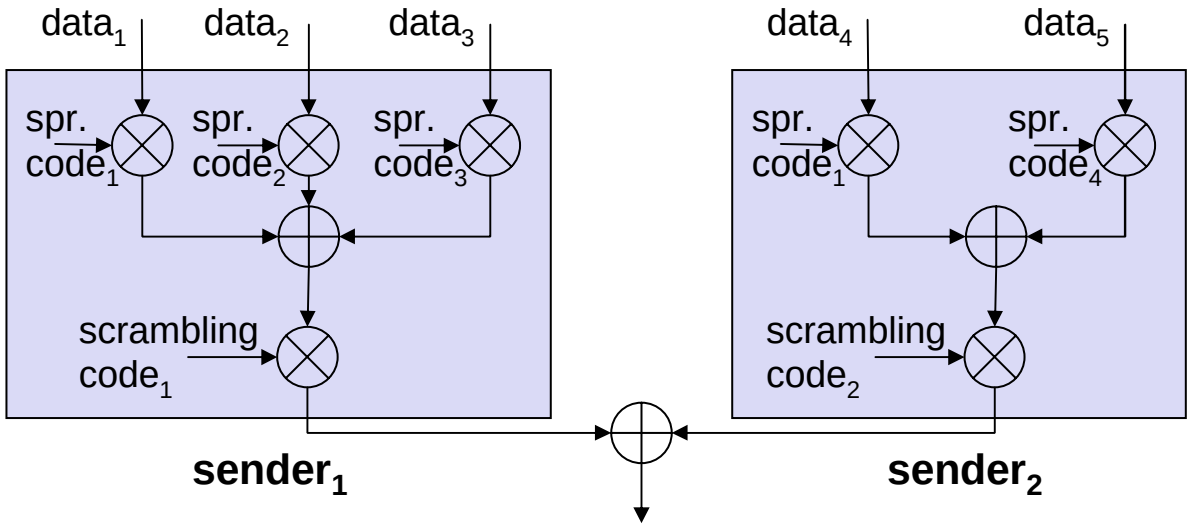


Example Handover Types in in UMTS/GSM



Spreading and Scrambling of User Data

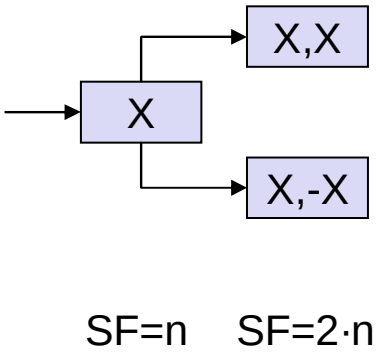
- Constant chipping rate of 3.84 million chip/s in UMTS cells
- Modulation is done using QPSK
- Different user data rates supported via different spreading factors
  - Higher data rate: less chips per bit and vice versa
- Separation of different transmissions is done with a combination of orthogonal spreading codes and quasi-orthogonal scrambling codes
  - Base station manages codes and provides synchronization

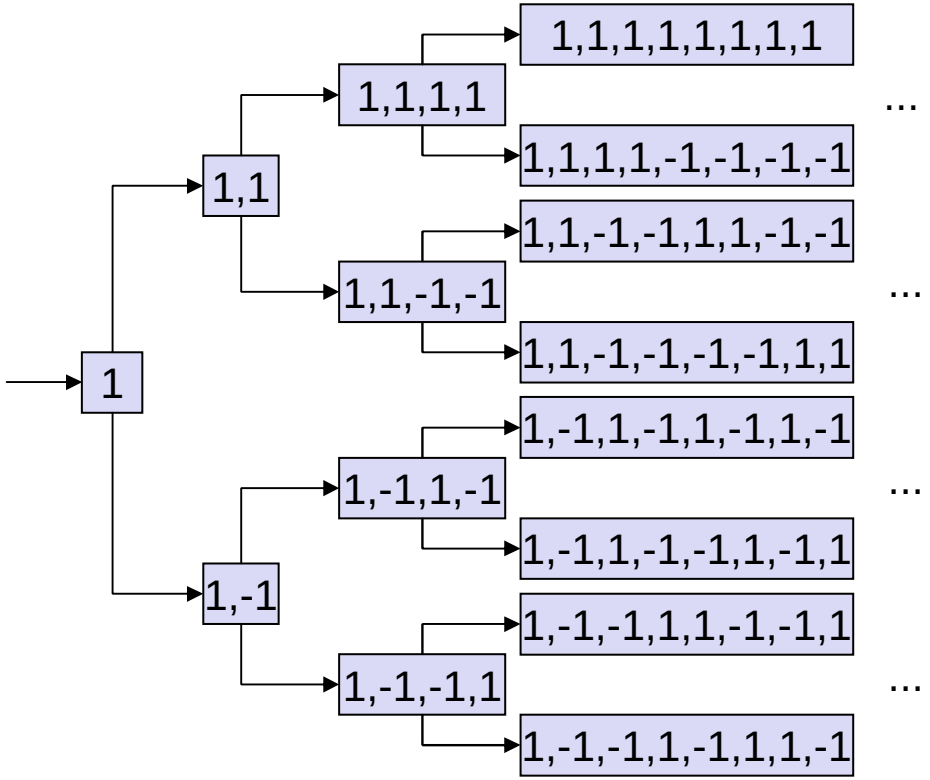


Spreading: OSVF Coding

OSVF: Orthogonal Variable Spreading Factors

- Simple generation of orthogonal chip sequences
- Thus: simple code management
- Code length can be adapted to number of data streams





SF: spreading factor

Scrambling: Gold Codes

As addition to spreading, scrambling is used:

- With linear feedback shift registers, pseudo-random numbers can be generated
- With “good” pseudo-random numbers, the numbers are quasi-orthogonal
- Quasi-orthogonal: only low influence between the codes
- As for Barker codes in WLAN: use codes which also stay quasi-orthogonal if synchronization is not perfect
- Used here: so-called Gold codes

Why to use spreading and scrambling, not only one method?

- Data streams in one station, several mobile stations, base stations in different (overlapping) cells
- Too much synchronization to coordinate everything, especially all base stations in one region!

Usage of Spreading and Scrambling

On the uplink

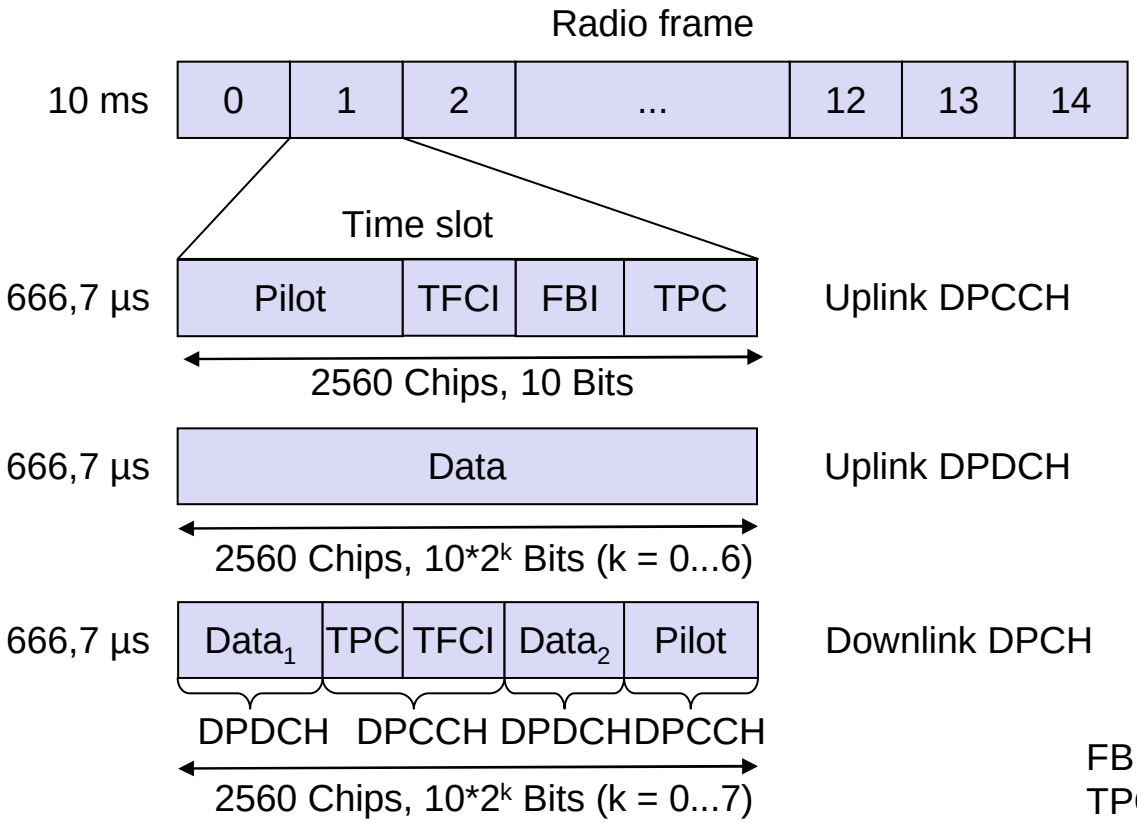
- Use OVSF to generate spreading codes for several transmissions of a mobile station
- Each mobile station generates spreading codes only by itself, depending on the number of own data streams (4 – 256 chips)
- Scrambling codes are assigned by the base station to each mobile station to separate the transmissions of all mobile stations (38400 chips / 256 chips)
- Use of scrambling to separate stations needs less synchronization than spreading

On the downlink

- Use of OVSF by the base station to generate orthogonal codes for the mobile stations – synchronization here is no problem because the base station is overlaying all transmissions before sending (4 – 512 chips)
- Use scrambling codes to scramble spread data streams for separating cells
- Each base station uses on scrambling code, otherwise also cells would have to be synchronized

UMTS FDD Frame Structure

Like in GSM, lots of channels are necessary for data and control purposes, e.g.:



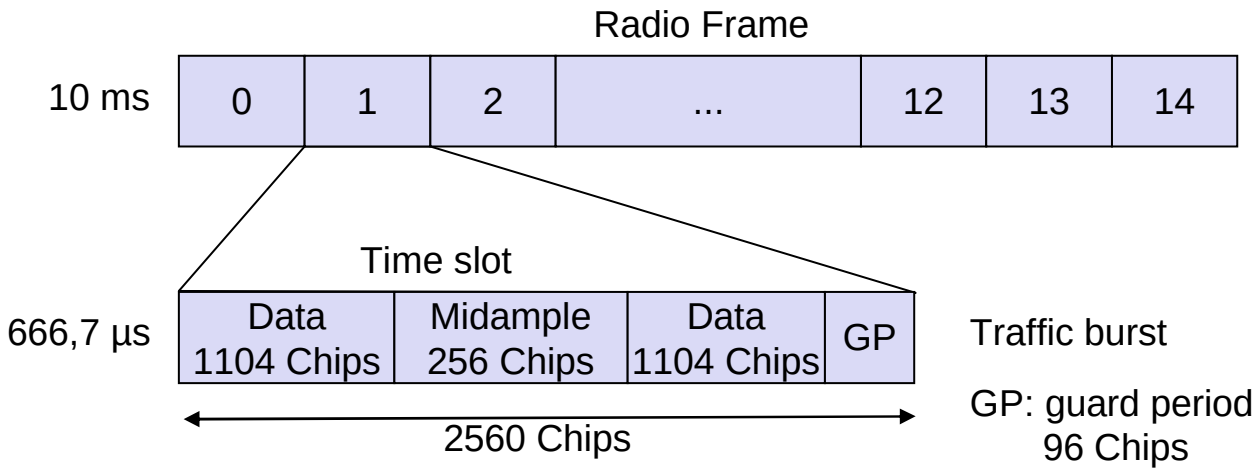
W (Wideband)-CDMA

- 1920-1980 MHz Uplink
- 2110-2170 MHz Downlink
- Chipping rate: 3,840 MChip/s
- Soft handover
- Complex power control (1500 power control cycles/s)
- Spreading factor:
  UL: 4-256; DL: 4-512

Slot structure not for user separation but synchronization!

FBI: Feedback Information (e.g. for handover)
TPC: Transmit Power Control
TFCI: Transport Format Combination Indicator
DPCCH: Dedicated Physical Control Channel
DPDCH: Dedicated Physical Data Channel
DPCH: Dedicated Physical Channel

UMTS TDD Frame Structure



TD-CDMA

- 2560 Chips per slot
- Spreading factor: 1-16
- Symmetric or asymmetric slot assignment to UL/DL (min. 1 per direction)
- Tight synchronization needed
- Simpler power control (100-800 power control cycles/s)

Shown on both slides are only dedicated channels (control / data) for one station – but there are also available all the channels as in GSM, e.g. for random access of new mobile stations.

Cell Breathing

GSM

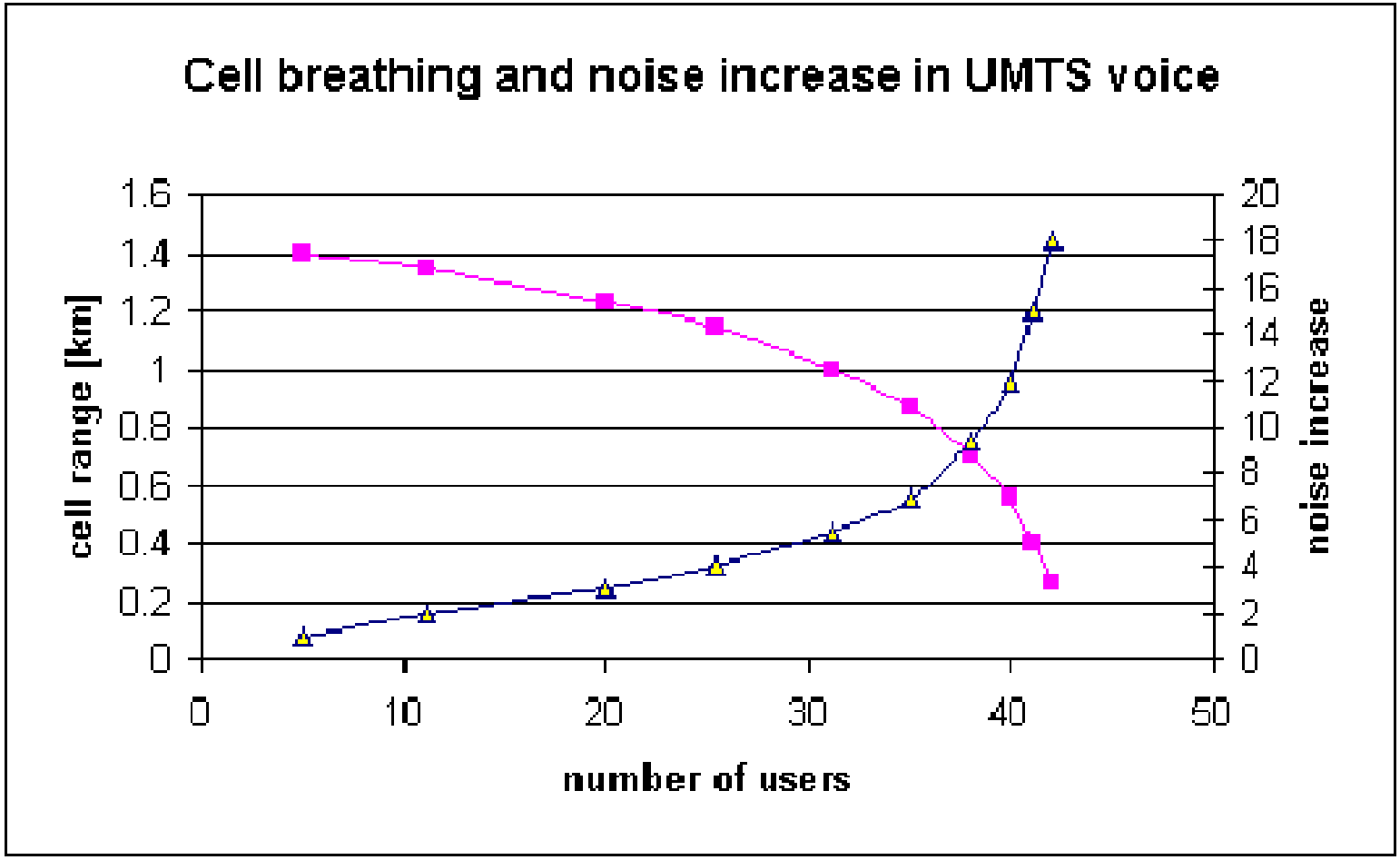
- Device gets adapted power from the base station to send in one slot exclusively
- Number of connected devices has no influence on the cell size

UMTS

- Cell size and number of devices are tightly correlated
- Transmission quality is determined by the Signal-to-Noise-Ratio
- Noise is increased by interference…
  - with other cells
  - with other participants
- If noise is too high, transmit power needs to be increased
- Devices at the cell border are the first which can not furthermore increase the signal strength (power limitation)

  → for too high noise no communication is possible
- Restriction of simultaneous number of users necessary
- Cell breathing makes cell planning complicated

Cell Breathing: Example



UMTS Evolution

UMTS is only one way how to implement IMT-2000. Initial release (Release99):

- Make it cheap: re-use GSM/GPRS in the core network (with small enhancements)
- Define only new CMDA-based radio network (as shown before)

In 2000: definition of release 4 and 5 with some enhancements:

- Almost IP-all based core network for better integration with the Internet
- Integration of IMS (IP Multimedia Subsystem) which should give guarantees in an IP-based network necessary for voice transmission
- Adaptive rate codec for better quality of the transmitted speech
- Integration of “Customized Applications for Mobile Enhanced Logic” (CAMEL) which allows an operator to define services over and above standard GSM services
- First mentioning of beamforming
- High-speed transmission on the radio interface (HSDPA, up to 10 MBit/s downlink)

HSDPA

A higher speed is achieved by improving several details in the data transmission:

- *Hybrid ARQ*: use of a stop-and-wait flow control with ACKs and NACKs. If a received packet is erroneous, a negative ACK is passed back, but the received (damaged) packet is stored. The packet is retransmitted and combined with the damaged version (chase combining) to increase the chance to get a correct packet even if the retransmission also is damaged.
- The *radio frame is shortened* from 10 to 2 ms (equals only 3 slots) to reduce the round trip time
- *Fast packet scheduling*: user devices periodically transmits an indication of the downlink signal quality (500 times per second). Based on this information, the base station decides which users will be sent data in the next 2 ms frame and how much data should be sent for each user (channelization codes).
- *Adaptive modulation and coding*: QPSK and 16QAM are allowed

Result: down-link speeds of 1.8, 3.6, 7.2 and 14.4 Mbit/s.

More recent releases

Release 6

- High-speed uplink (HSUPA) in analogy to HSDPA
- UMTS/WLAN interworking
- Fast cell selection, security enhancements, first mentioning of OFDM, …

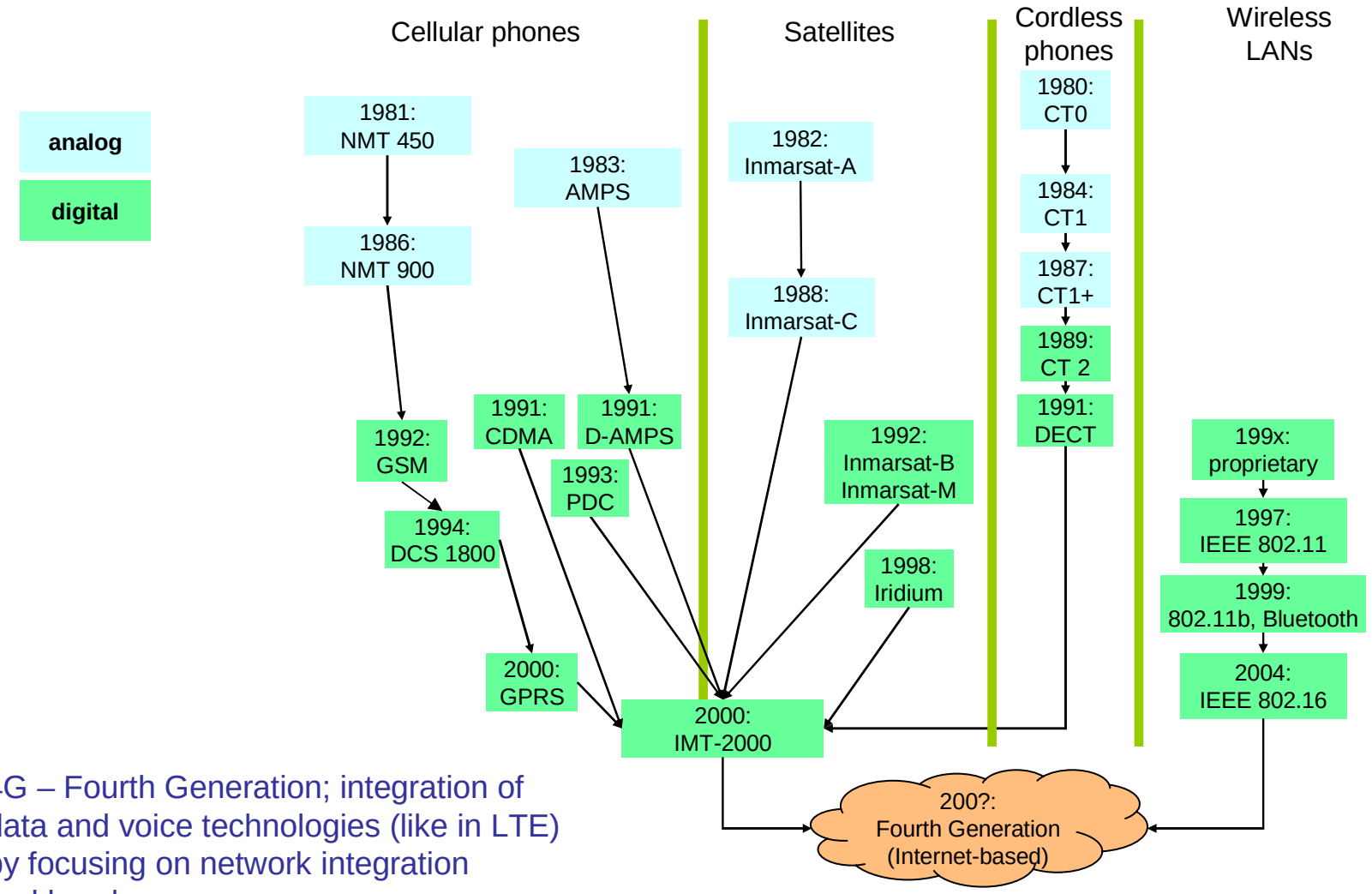
Release 7

- HSDPA improvement by MIMO
- Advanced coding with 64QAM (downlink), 16QAM (uplink)
- QoS on UMTS/WLAN
- New frequency ranges, …

Release 8

- Long Term Evolution (LTE) as HSPA enhancement with 100 MBit/s (downlink) and 50 MBit/s (uplink)
- How? By making use of MIMO/64QAM – and using OFDMA…

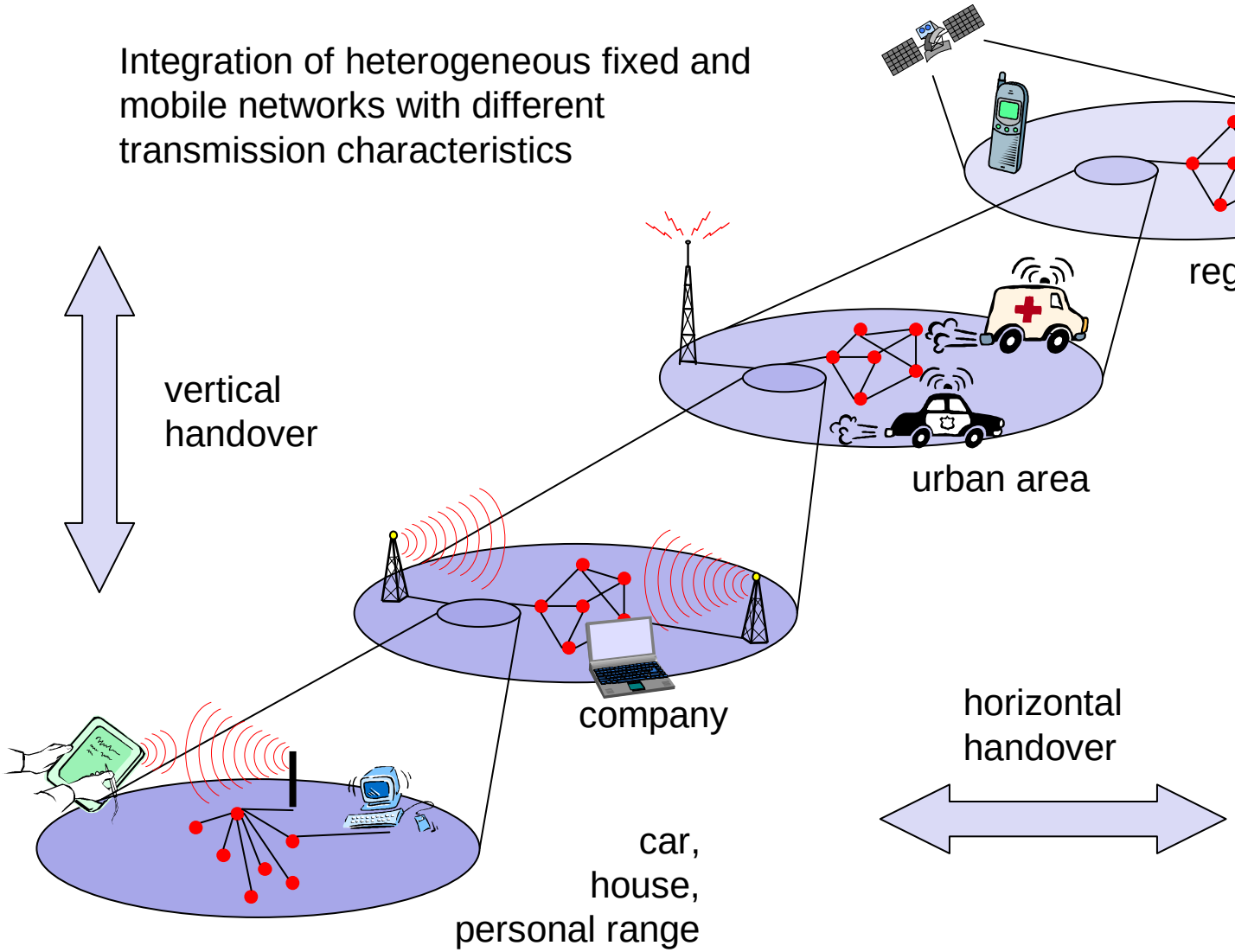
What is Next?



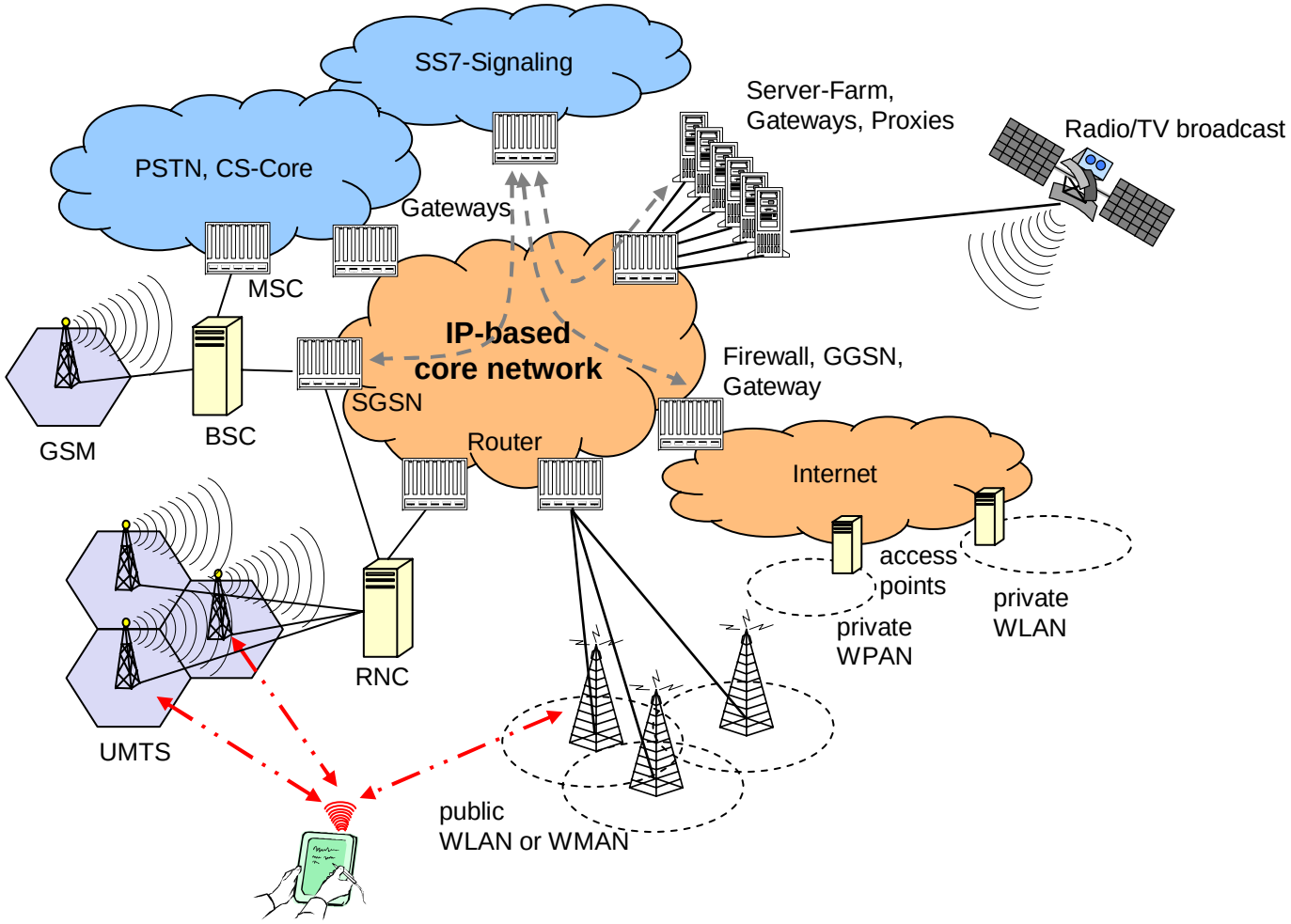
4G – Fourth Generation; integration of data and voice technologies (like in LTE) by focusing on network integration and handover

Overlay Networks – the global Goal

Integration of heterogeneous fixed and mobile networks with different transmission characteristics



Exemplarily IP-based 4G/Next G/... Network



Possible Problems

- Quality of Service
  - The Internet provides best effort data transfer
  - Integrated Services has bad scalability, Differentiated Services have still to be proofed
  - Simplicity of the Internets? DoS attacks auf QoS?
- Internet Protocols are well-known…
  - …also for attackers, hackers, …
- Reliability, maintenance
  - Still an open question if Internet technology is cheaper, when a high reliability is needed (99.9999%) and all demanded services are integrated
- Missing accounting technology
  - Accounting based of technical parameters (data volume, time) makes no sense
  - A content- or application-based accounting is much better
- **Killer Application! There is no single killer application:**
  - The selection of provided services and the seamless access to the services using different access technologies is important