7. 3rd generation mobile communication: UMTS

Acknowledgements

Several slides of this subsection are taken from material of guest lectures that have been performed by **Nokia Research Center Bochum** in earlier lectures of Mobile Communication/Computer Networks II (Rechnernetze II) in summer terms 2001 – 2005.

Credits go to

- Dr. Paul James
- Oliver Lüert
- Ulrich Müller

The slides are marked in the lower left corner.

Once again:

Several slides in this chapter are very much **based on Jochen Schiller's work.**
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Further information on Prof. Schiller's work, including his excellent books, is available at
http://www.jochenschiller.de

7.1. UMTS - Universal Mobile Telecommunication System

UMTS – European contribution to third generation mobile communication (3G)
driven by ETSI, Technical Sub-Committee (STC) SMG 5 (Special Mobile Group)

3GPP - Third Generation Partnership Project
(founded in 1997 by ETSI)

Global cooperation for 3G mobile communication

3GPP **foundation members**:

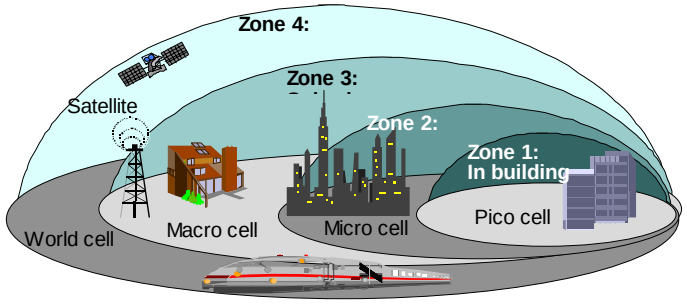
- ARIB Association of Radio Industries and Businesses, Japan
- ETSI European Telecommunications Standards Institute, Europe
- Committee T1 Standards Committee T1 Telecommunications, USA
- TTA Telecommunications Technology Association, South Korea
- TTC Telecommunication Technology Committee, Japan

UMTS Forum in 3GPP since end of 1998

UMTS is part of the family of IMT-2000:
ITU International Mobile Communications at 2000 MHz
World-wide coordination of 3G activities.

Online-Info:
www.etsi.org
www.3gpp.org
www.umts-forum.org
www.itu.int

UMTS/IMT 2000 is universal



(Abb.quelle: Report No. 6 from the UMTS Forum, www.umts-forum.org)

- **Global System**: national terrestrial components and global (world-wide) satellite technology
- Multi-mode and multi-band technology includes systems of second generation (2G, 2.5G)

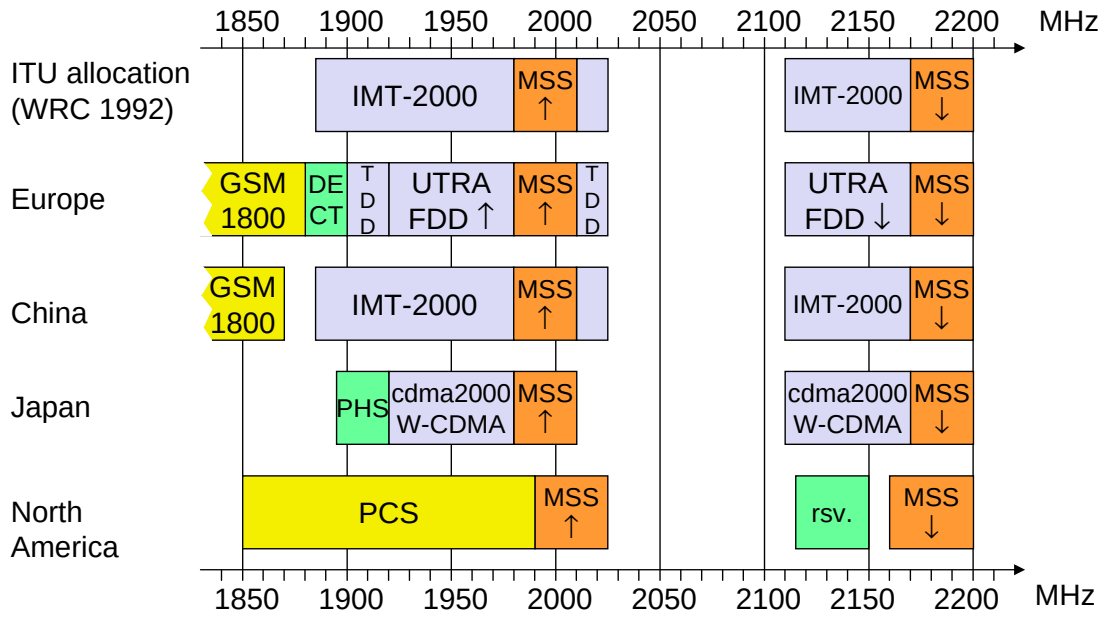
- First goal: **Personal communication, roaming without limitations**:
  - private network(s)
  - Pico (building) or Micro (regional) public cellular networks
  - Macro/Wide Area Network
  - Global world-wide satellite technology

- Second goal: **Consistent "Look and Feel"** independent of location and network
  - "Virtual Home Environment" VHE

UMTS and IMT-2000 *JS*

- Proposals for IMT-2000 (International Mobile Telecommunications)
  - UWC-136, cdma2000, WP-CDMA
  - UMTS (Universal Mobile Telecommunications System) from ETSI
- UMTS
  - UTRA (was: UMTS, now: Universal Terrestrial Radio Access)
  - enhancements of GSM
    - EDGE (Enhanced Data rates for GSM Evolution): GSM up to 384 kbit/s
    - CAMEL (Customized Application for Mobile Enhanced Logic)
    - VHE (virtual Home Environment)
  - fits into GMM (Global Multimedia Mobility) initiative from ETSI
  - requirements
    - min. 144 kbit/s rural (goal: 384 kbit/s)
    - min. 384 kbit/s suburban (goal: 512 kbit/s)
    - up to 2 Mbit/s urban

Frequencies for IMT-2000 *JS*

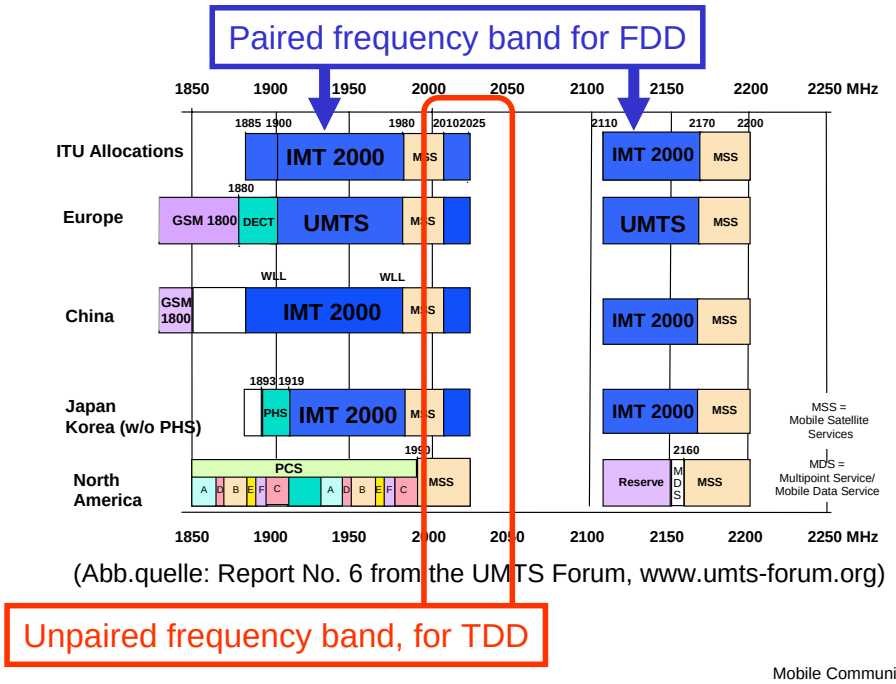


MSS = mobile satellite services

Duplex with UMTS ?

Duplex – separation of uplink and downlink

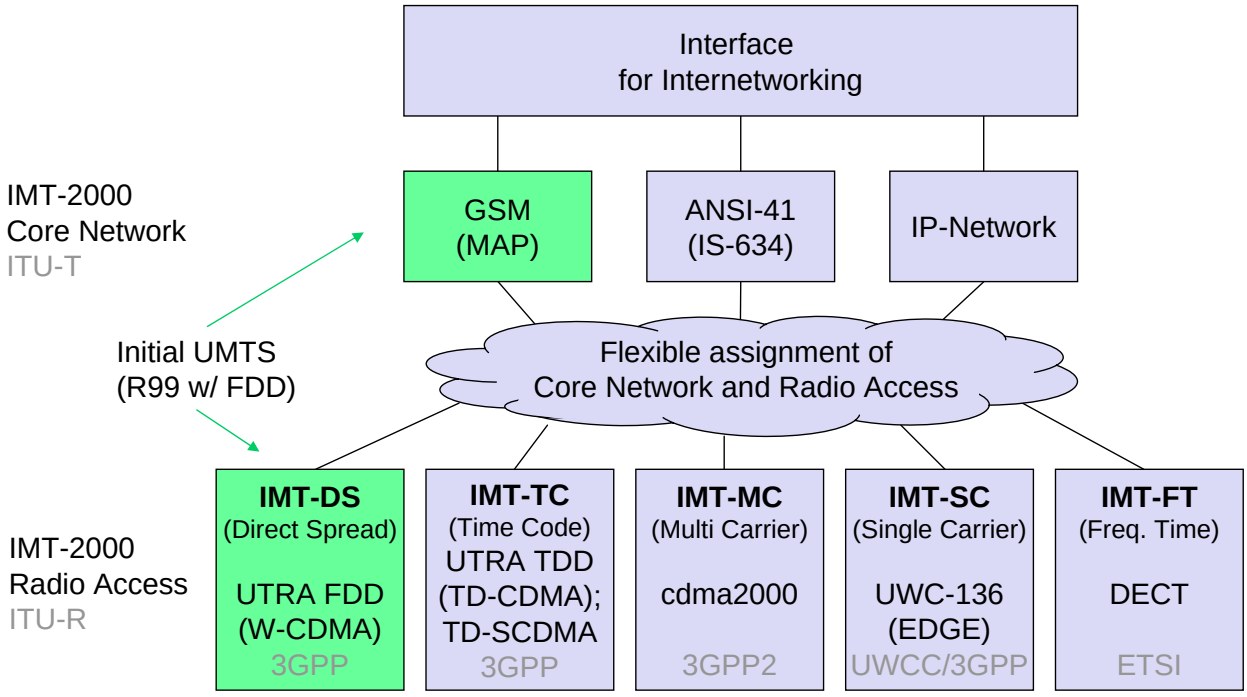
Both concepts are used:
- FDD: Frequency Division Duplex, use pair of frequencies/spectrum in parallel (same as GSM)
- TDD: Time Division Duplex, unpaired frequencies/spectrum, time division of Downlink/Uplink



(Abb.quelle: Report No. 6 from the UMTS Forum, www.umts-forum.org)

IMT-2000 family

JS

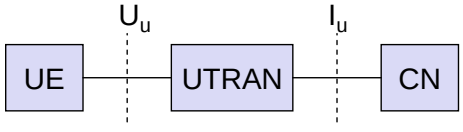


GSM and UMTS Releases JS

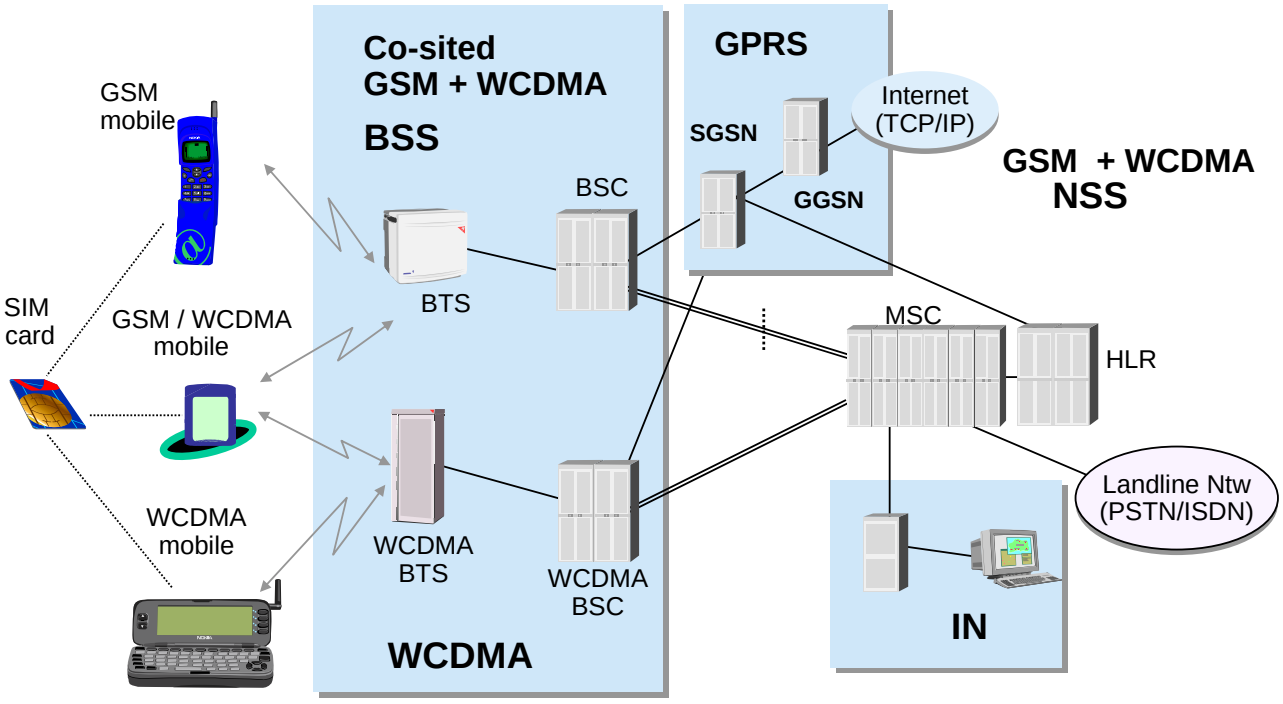
GSM/EDGE Release	3G Release	Abbreviated name	Spec version number	Freeze date (indicative only)
Phase 2+ Release 8	Release 8	Rel-8	8.x.y	Stage 1 freeze Mar. 2008 (stage 2,3 open)
Phase 2+ Release 7	Release 7	Rel-7	7.x.y	Stage 3 freeze Dec. 2007
Phase 2+ Release 6	Release 6	Rel-6	6.x.y	December 2004 - March 2005
Phase 2+ Release 5	Release 5	Rel-5	5.x.y	March - June 2002
Phase 2+ Release 4	Release 4	Rel-4	4.x.y	March 2001
-	Release 2000	R00	4.x.y	Renaming…
Phase 2+ Release 2000	-		9.x.y	
-	Release 1999	R99	3.x.y	March 2000
Phase 2+ Release 1999	-		8.x.y	
Phase 2+ Release 1998	-	R98	7.x.y	early 1999
Phase 2+ Release 1997	-	R97	6.x.y	early 1998
Phase 2+ Release 1996	-	R96	5.x.y	early 1997
Phase 2	-	Ph2	4.x.y	1995
Phase 1	-	Ph1	3.x.y	1992

7.2. UMTS Architecture (Release 99 used here!) JS

- UTRAN (UTRA Network)
  - Cell level mobility
  - Radio Network Subsystem (RNS)
  - Encapsulation of all radio specific tasks
- UE (User Equipment)
- CN (Core Network)
  - Inter system handover
  - Location management if there is no dedicated connection between UE and UTRAN

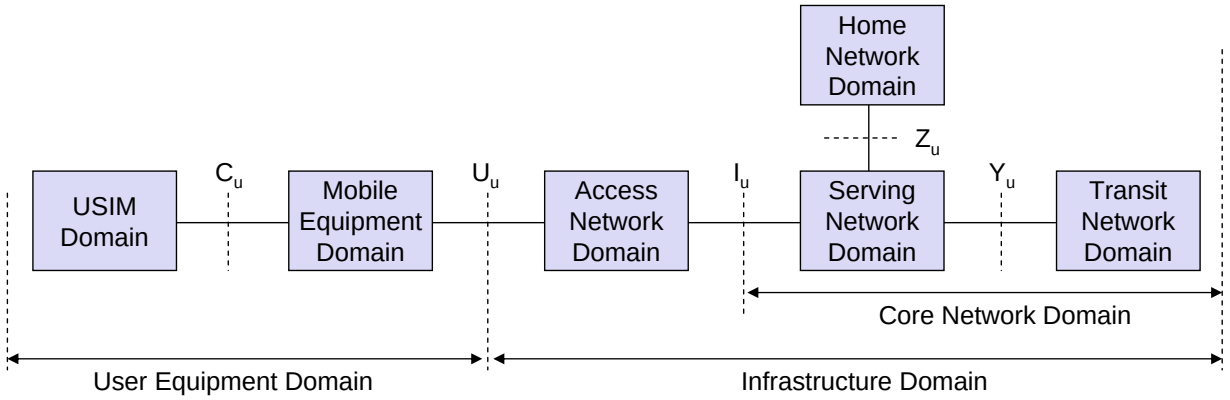


UMTS architecture (2)



Multi-mode/Multi-band using several radio access network technologies.

UMTS domains and interfaces I *JS*



- 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 II *JS*

- Universal Subscriber Identity Module (USIM)
  - Functions for encryption and authentication of users
  - Located on a SIM inserted into a mobile device
- 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

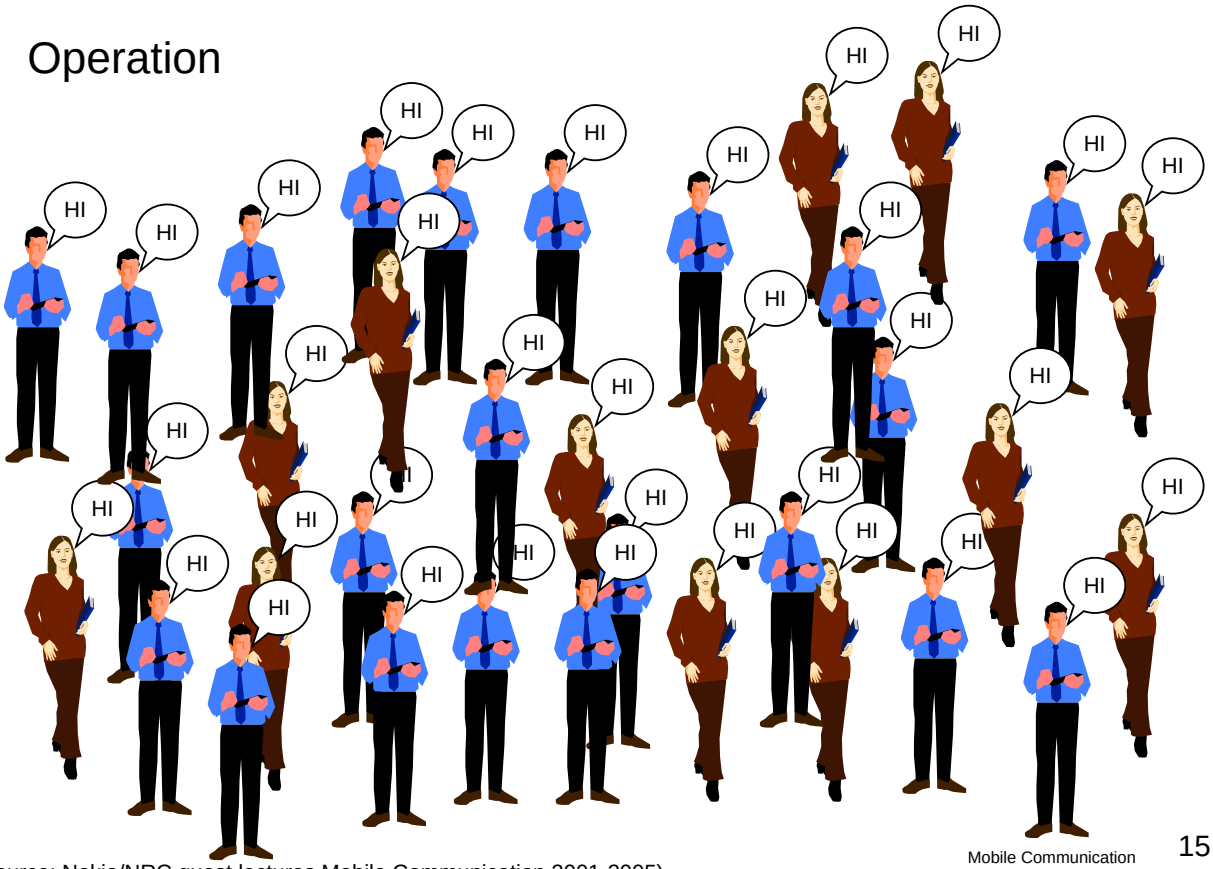
7.3. WCDMA Principle(I) : Spread Spectrum

WCDMA – Wideband CDMA (Code Division Multiple Access)

- WCDMA is a spread spectrum transmission where the users signal is broadcast over the entire frequency spectrum along with signals from other users.
- This is similar to a situation at a party where everyone is talking simultaneously. The brain picks out the conversation listened to from all of the other simultaneous conversations.
- WCDMA works in a similar way such the transmission/reception hardware can extract one particular transmission from all the others by 'tuning' the receiver to a particular transmission using a special coding technique.
- This is simultaneously performed for all of the transmissions in a cell

(Slide source: Nokia/NRC guest lectures Mobile Communication 2001-2005)

WCDMA Principle (II) : Spread Spectrum



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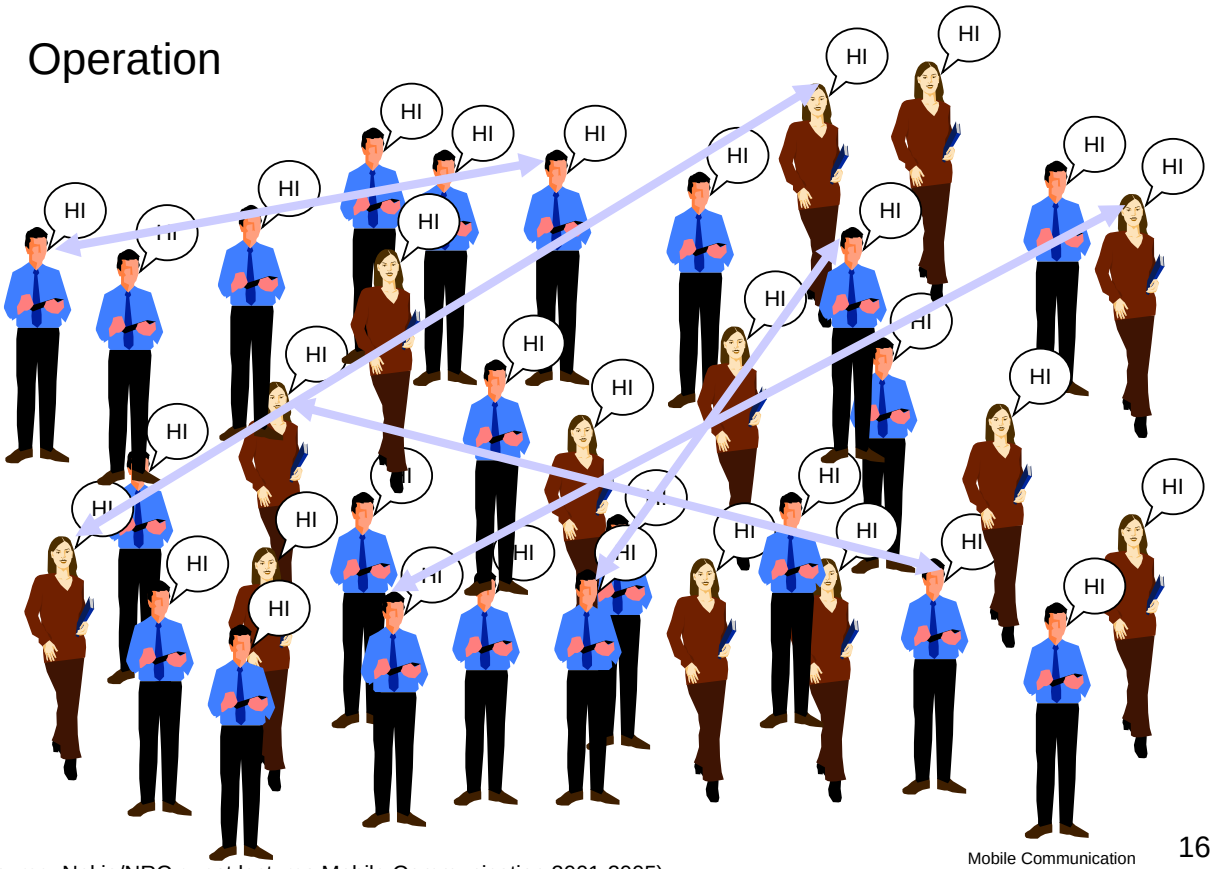
WCDMA Principle (III) : Spread Spectrum



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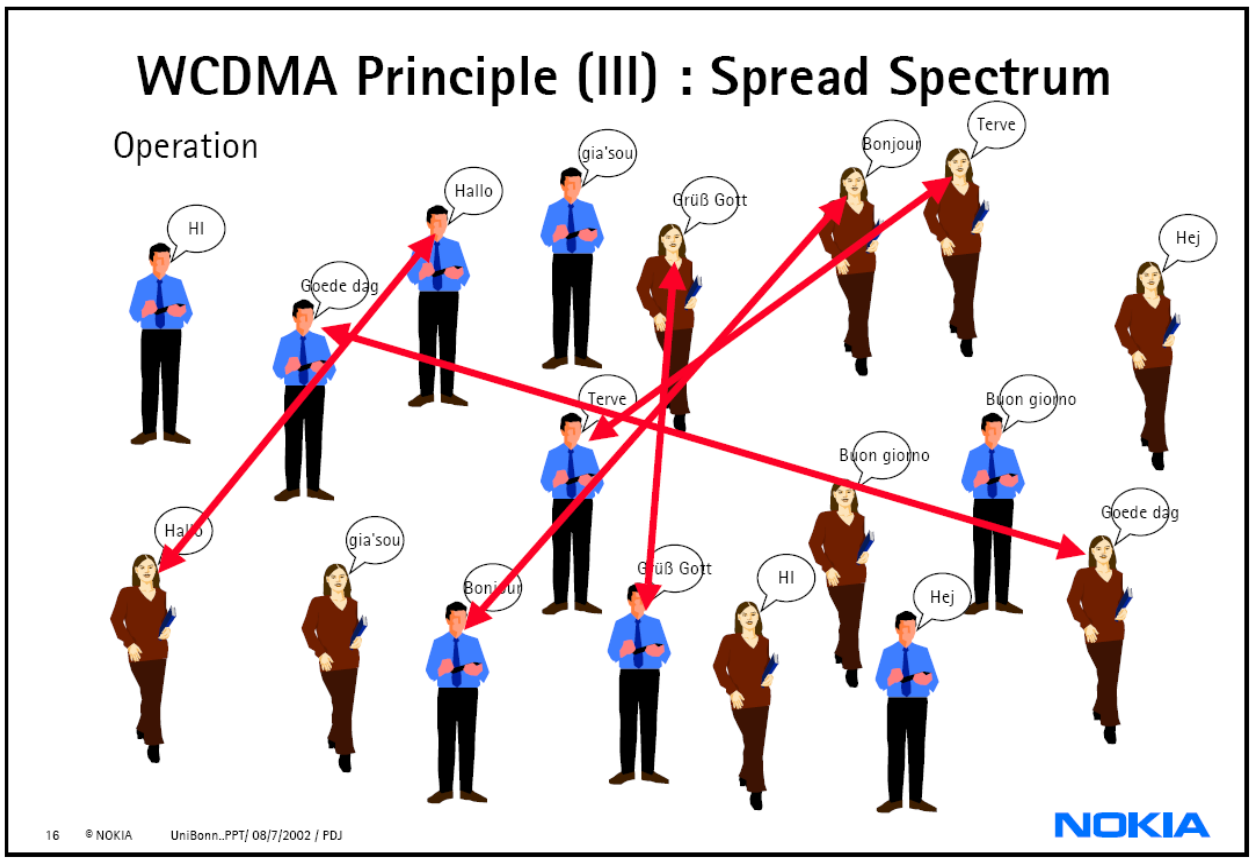
Code division = different languages



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Multiple Access with CDMA

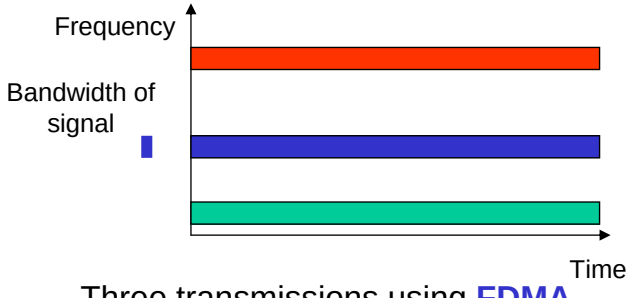
=> cf. subsection 3. Wireless Communication Basics

CDMA - Code Division Multiple Access

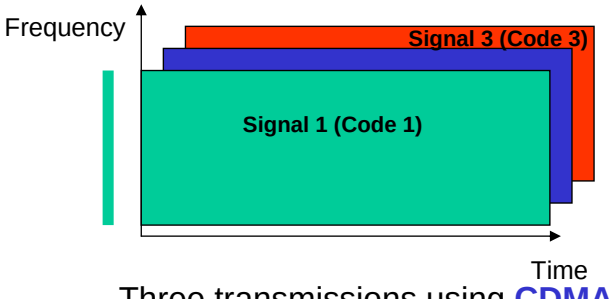
Fixed channel size with GSM (combination of FDMA and TDMA) :
Division of frequencies, each channel division into cyclic time-slots

Idea of CDMA:
- uses the whole bandwidth all the time
- channels are separated by "codes"
- a radio signal (e.g. voice data) with a narrow band will be transmitted using a multiple of the necessary bandwidth (signal spreading)
- broadband signals of several channels will be added on the medium "air"

- different channels use "orthogonal" codes
- the receiver is able to filter out a specific channel with its code

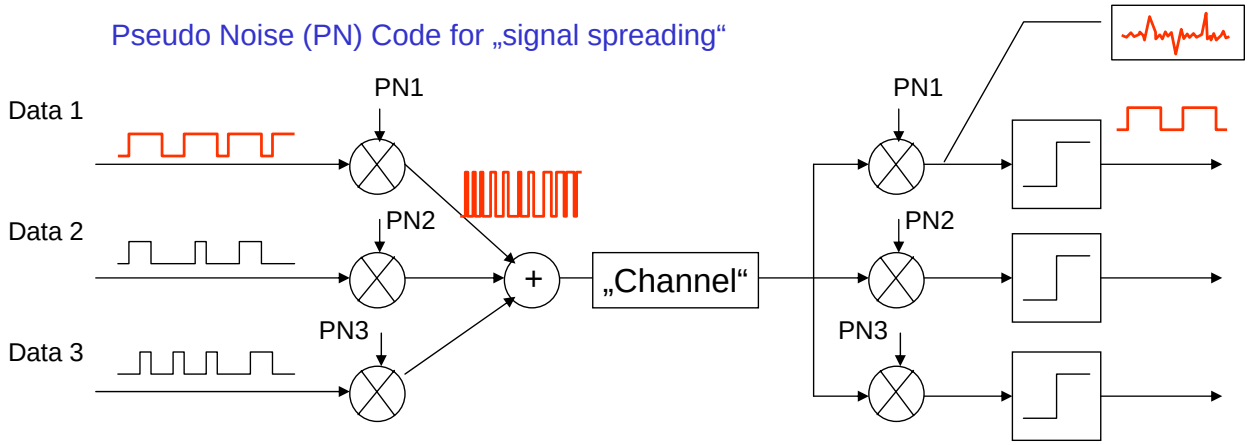


Three transmissions using **FDMA**



Three transmissions using **CDMA**

Coding and Decoding with CDMA



Narrow band user signal

„Spreading“ with code sequence (multiplication)

Multiplication of necessary bandwidth

Superposition of broadband signals in the shared medium „air“

Attenuation Interference

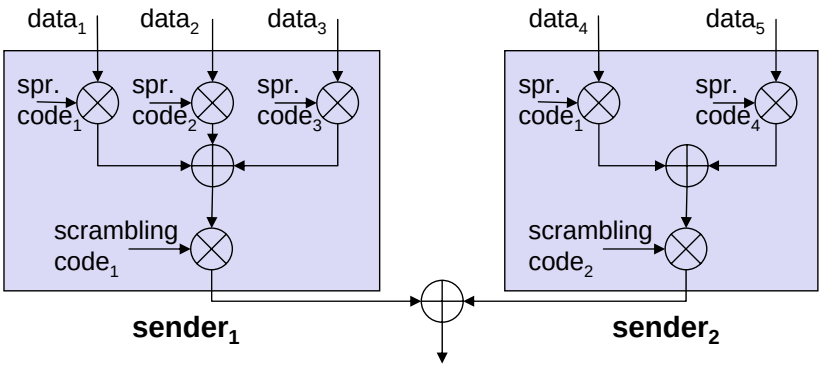
Second multiplication with PN-code sequence (filter)

„Comparator“ decides between 0 and 1 (original user signal)

=> cf. subsection 3. Wireless Communication Basics

Spreading and scrambling of user data *JS*

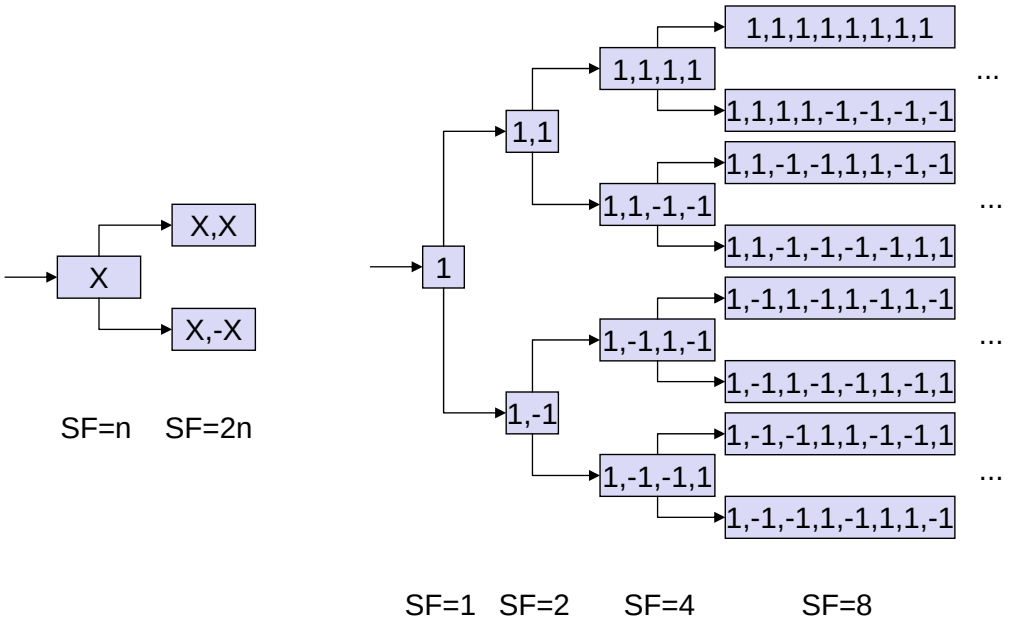
- Constant chipping rate of 3.84 Mchip/s
- Different user data rates supported via different spreading factors
  - higher data rate: less chips per bit and vice versa
- User separation via unique, quasi orthogonal scrambling codes
  - users are not separated via orthogonal spreading codes
  - much simpler management of codes: each station can use the same orthogonal spreading codes
  - precise synchronisation not necessary as the scrambling codes stay quasi-orthogonal



OVSF coding

JS

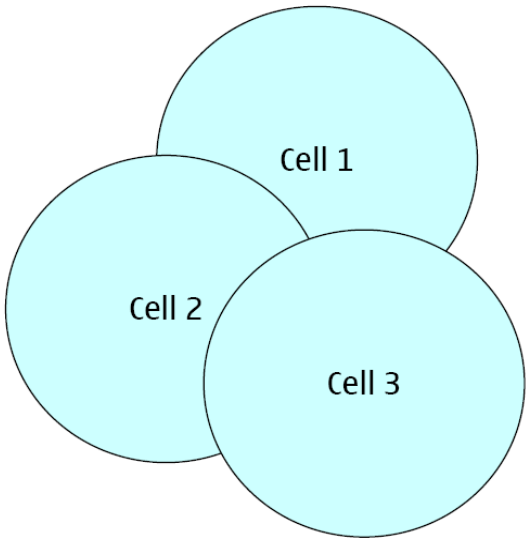
OVSF = Orthogonal Variable Spreading Factor (3G UMTS coding scheme)



Channelization Codes

Limitation of Channelization Codes

- Channelization codes are sufficient for multiplexing within a cell
- How to handle cell overlapping?
- Solution: cell separation by scrambling codes



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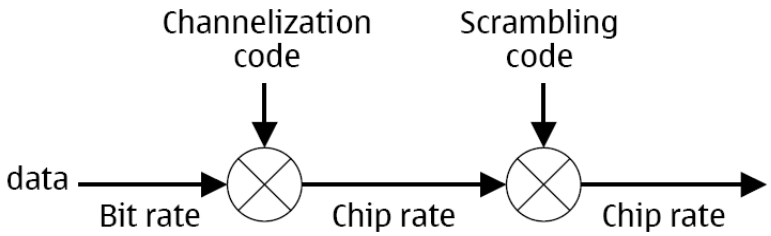
Scrambling Codes

Scrambling Codes

- Scrambling is used to differentiate between several transmitters on same frequency
- Scrambling converts signal into pseudo random noise
- A transmitter can only be “understood” by applying the proper scrambling code



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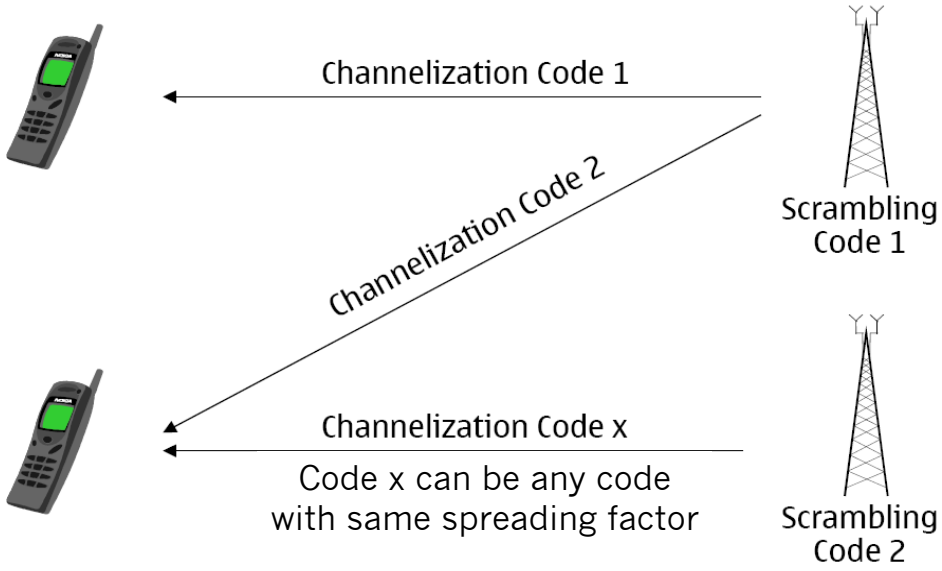
Codes in Downlink

Codes in Downlink



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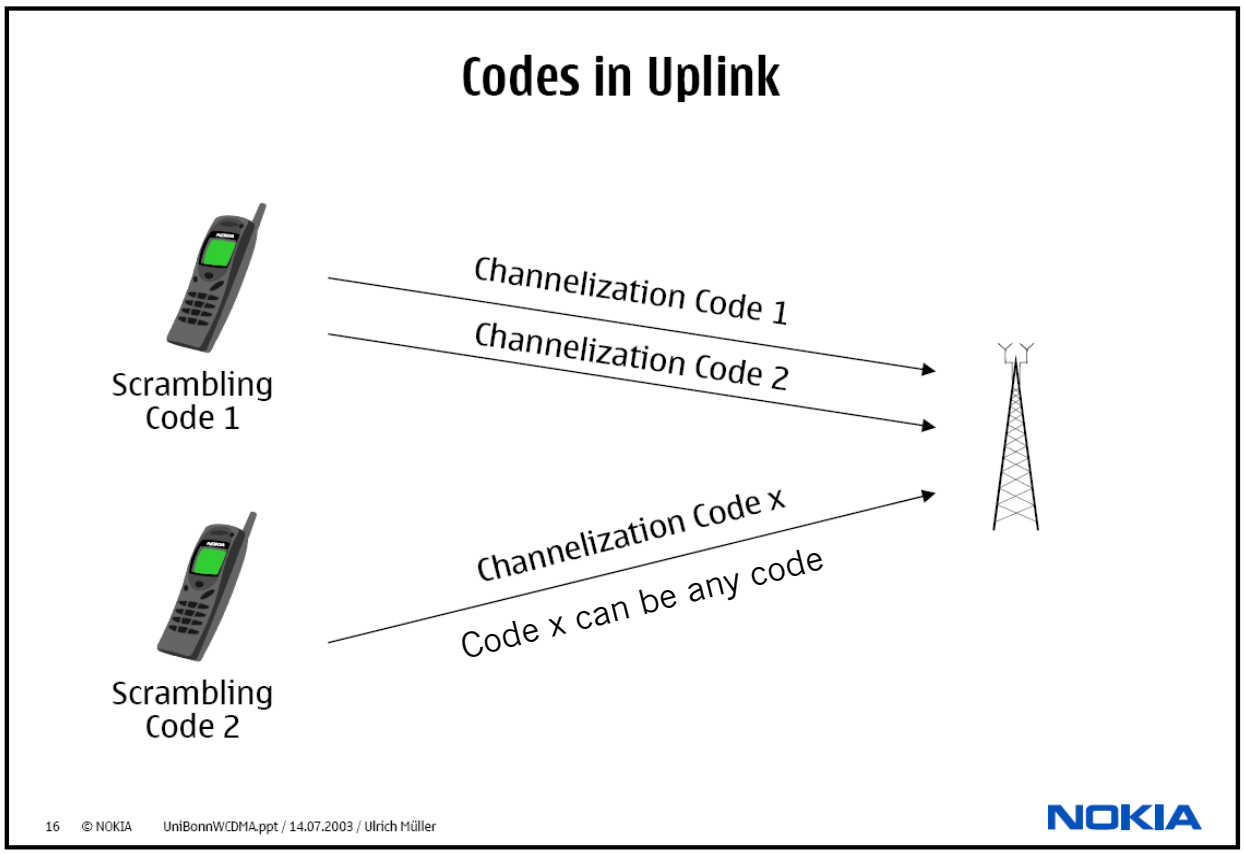
Codes in Uplink



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Overview Channelization vs. Scrambling

Channelization Code vs. Scrambling Code

	Channelization Code	Scrambling Code
Usage in Downlink	Separation of connections to different user within a cell	Separation of cells
Usage in Uplink	Separation of channels from same user	Separation of terminals
Length	4-512 chips in downlink, 4-256 chips in uplink	38400 chips (10 ms)
Number of codes	(see code tree)	512 for downlink, 2^{24} for uplink
Spreading	Code increases transmission bandwidth	Code does not affect transmission bandwidth

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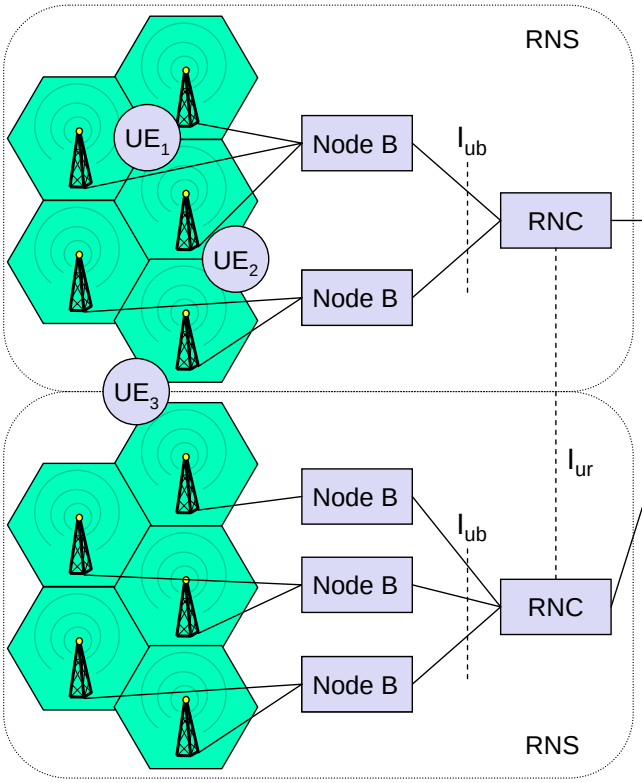
7.4. UTRAN Architecture JS

(UTRAN = Universal Terrestrial Radio Access Network)



RNC: Radio Network Controller

RNS: Radio Network Subsystem

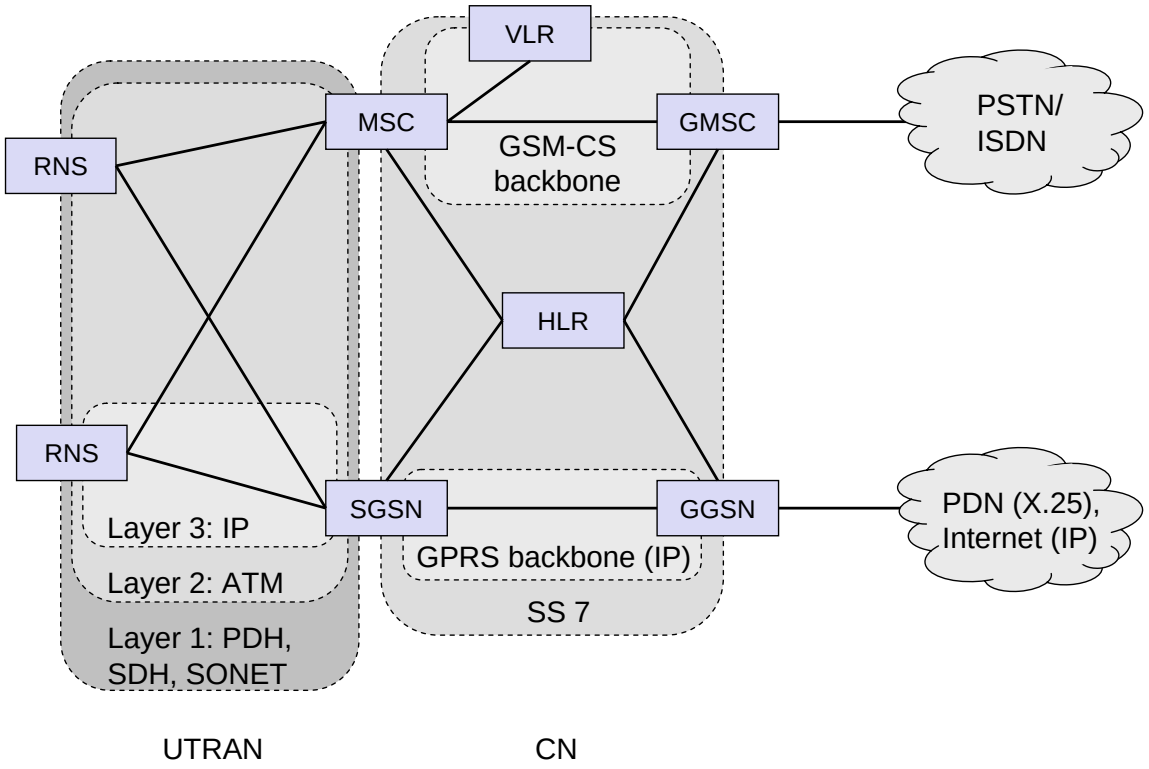
- UTRAN comprises several RNSs
- Node B can support FDD or TDD or both
- RNC is responsible for handover decisions requiring signalingto the UE
- Cell offers FDD or TDD

UTRAN functions JS

- Admission control
- Congestion control
- **System information broadcasting**
- Radio channel **encryption**
- **Handover**
- SRNS moving (Serving RNS)
- Radio network configuration
- **Channel quality measurements**
- **Macro diversity**
- Radio carrier control
- **Radio resource control**
- Data transmission over the radio interface
- Outer loop power control (FDD and TDD)
- **Channel coding**
- Access control

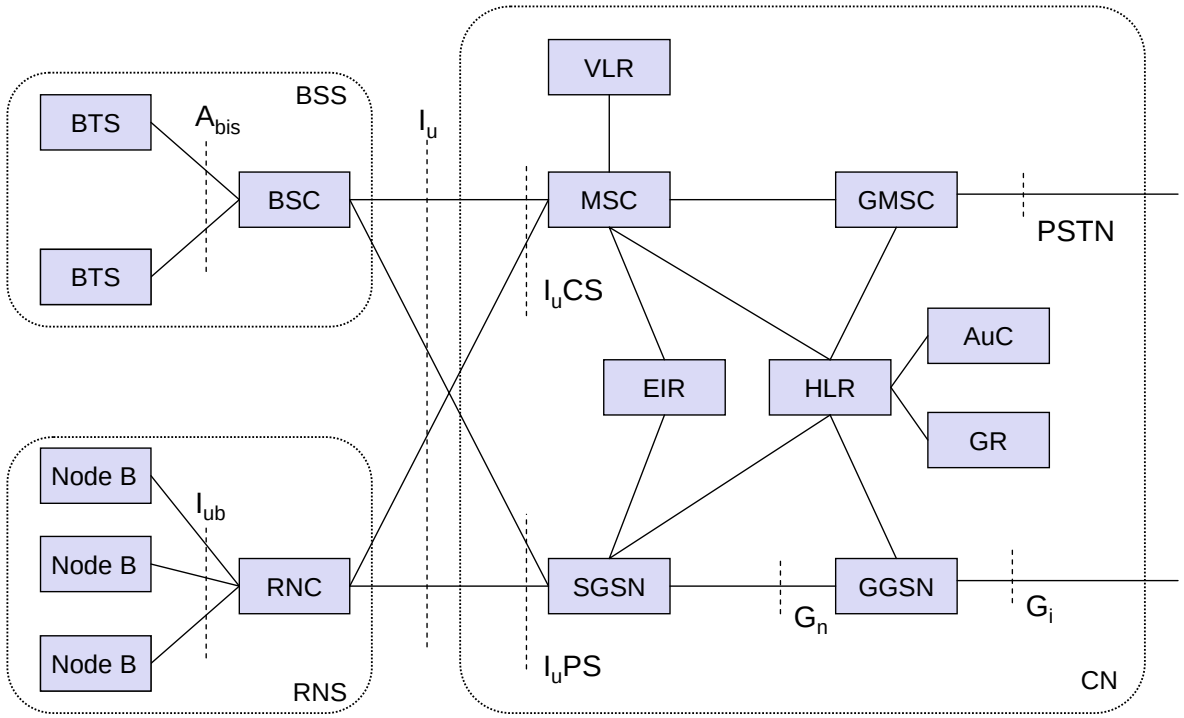
Core network: protocols

JS



Core network: architecture

JS



Core network

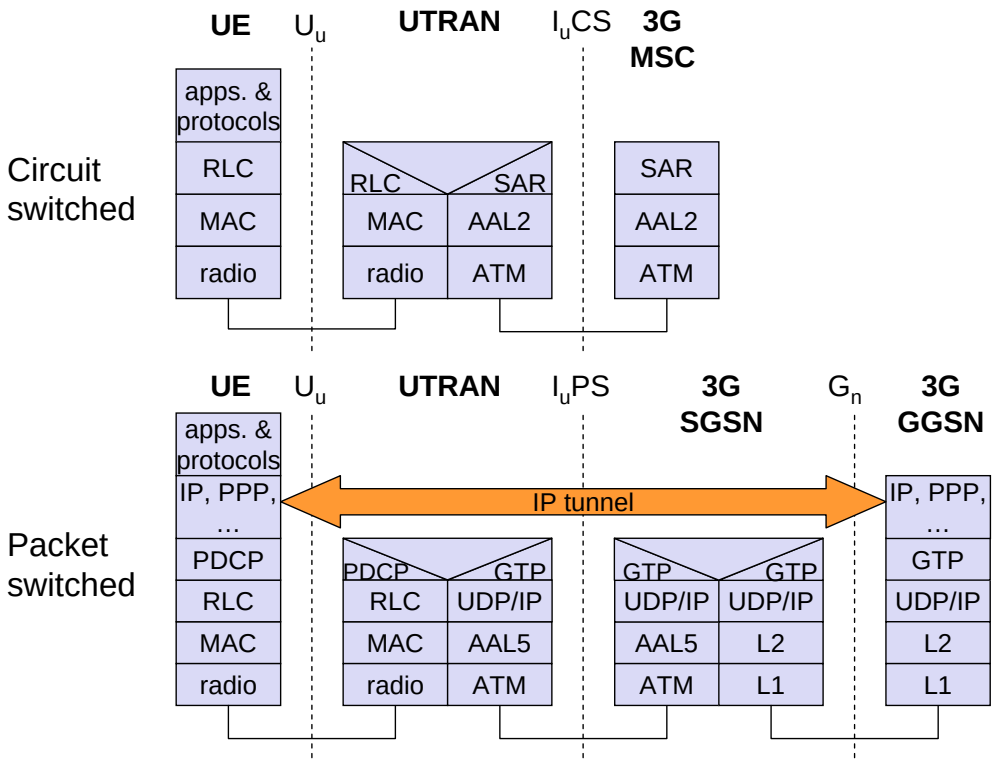
JS

- The Core Network (CN) and thus the Interface I_u, too, are separated into two logical domains:
- Circuit Switched Domain (CSD)
  - Circuit switched service incl. signaling
  - Resource reservation at connection setup
  - GSM components (MSC, GMSC, VLR)
  - I_uCS
- Packet Switched Domain (PSD)
  - GPRS components (SGSN, GGSN)
  - I_uPS

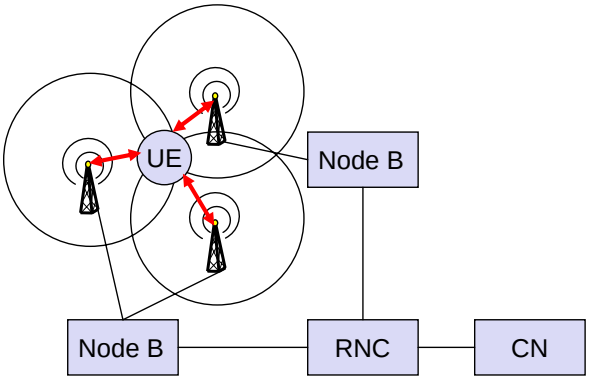
- Release 99 uses the GSM/GPRS network and adds a new radio access!
  - Helps to save a lot of money …
  - Much faster deployment
  - Not as flexible as newer releases (5, 6)

UMTS protocol stacks (user plane)

JS

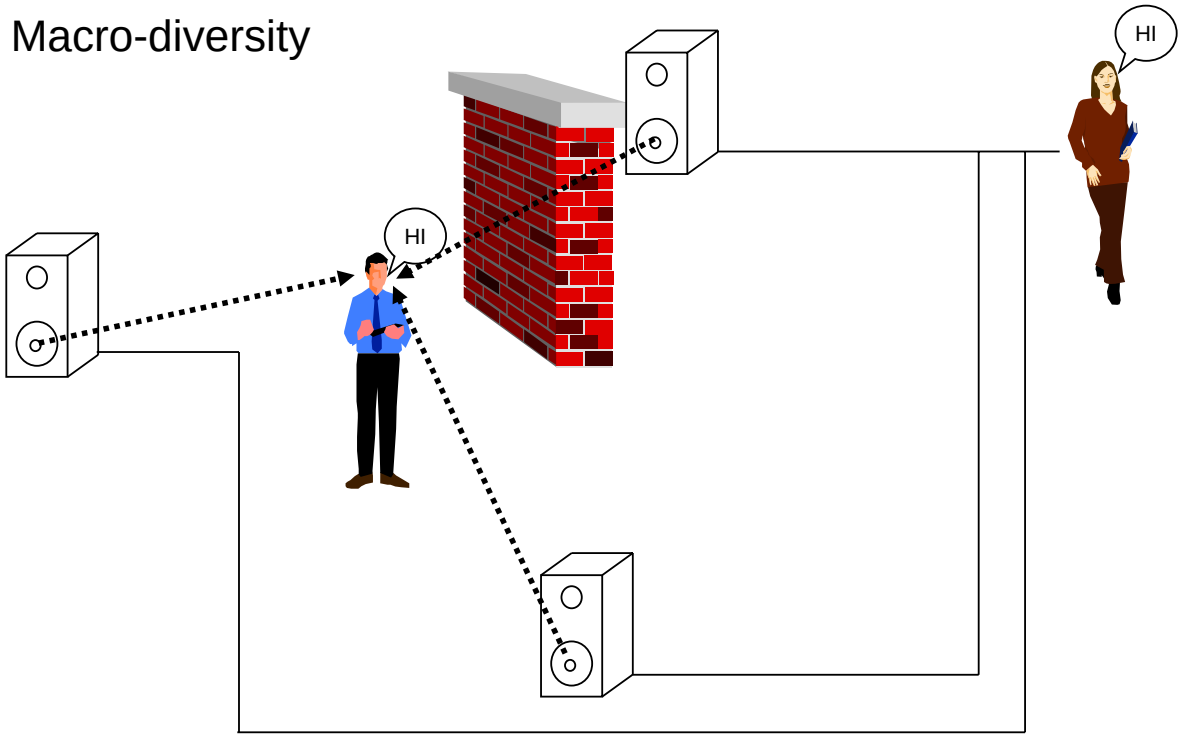


7.5. Support of mobility: macro diversity JS



- Multicasting of data via several physical channels
  - Enables soft handover
  - FDD mode only
- 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

WCDMA Principle: Macro-diversity



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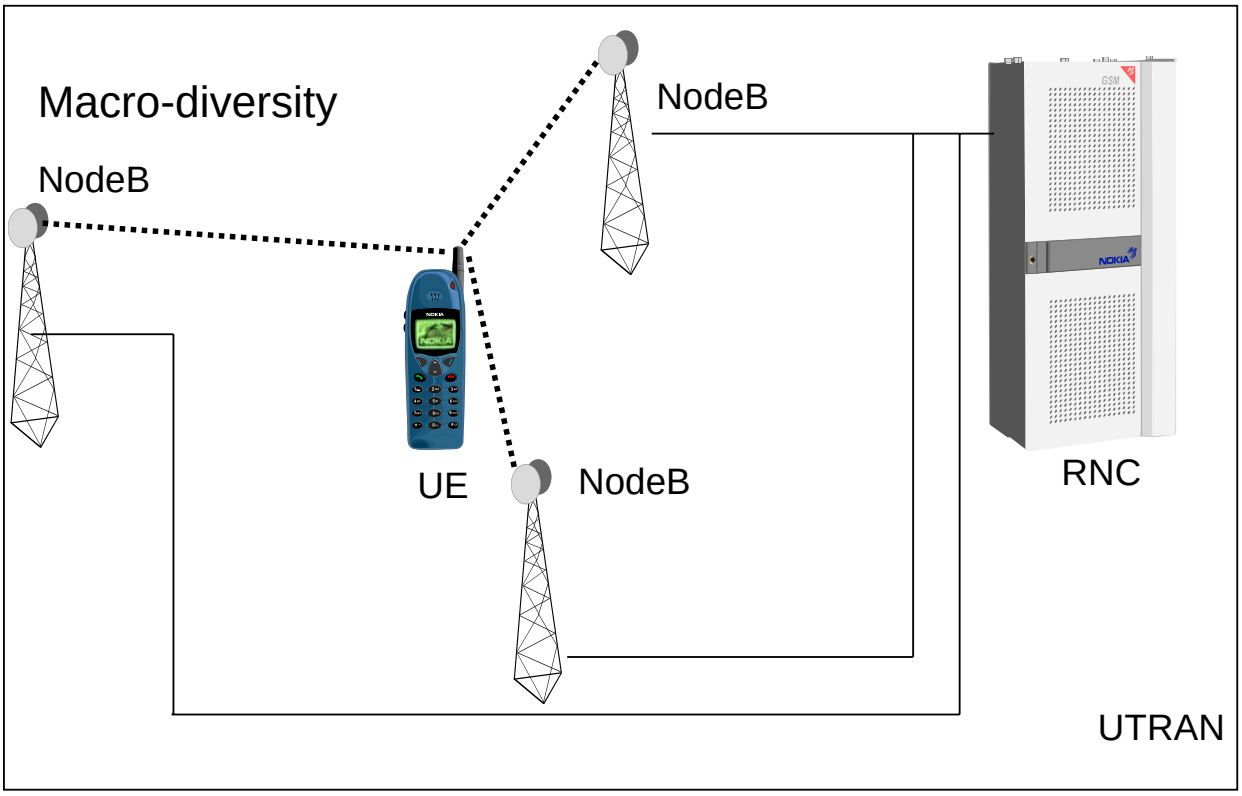
WCDMA Principle: Macro-diversity (2)



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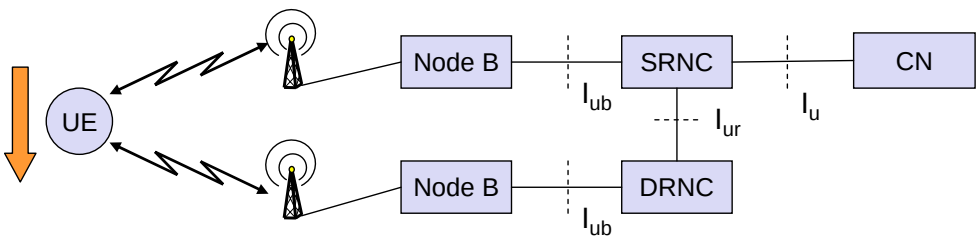
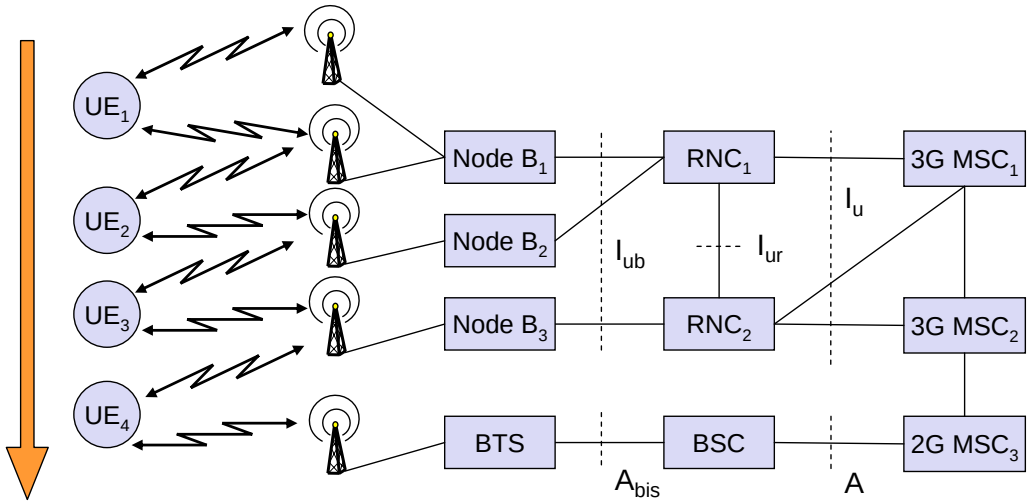
Support of mobility: handover *JS*

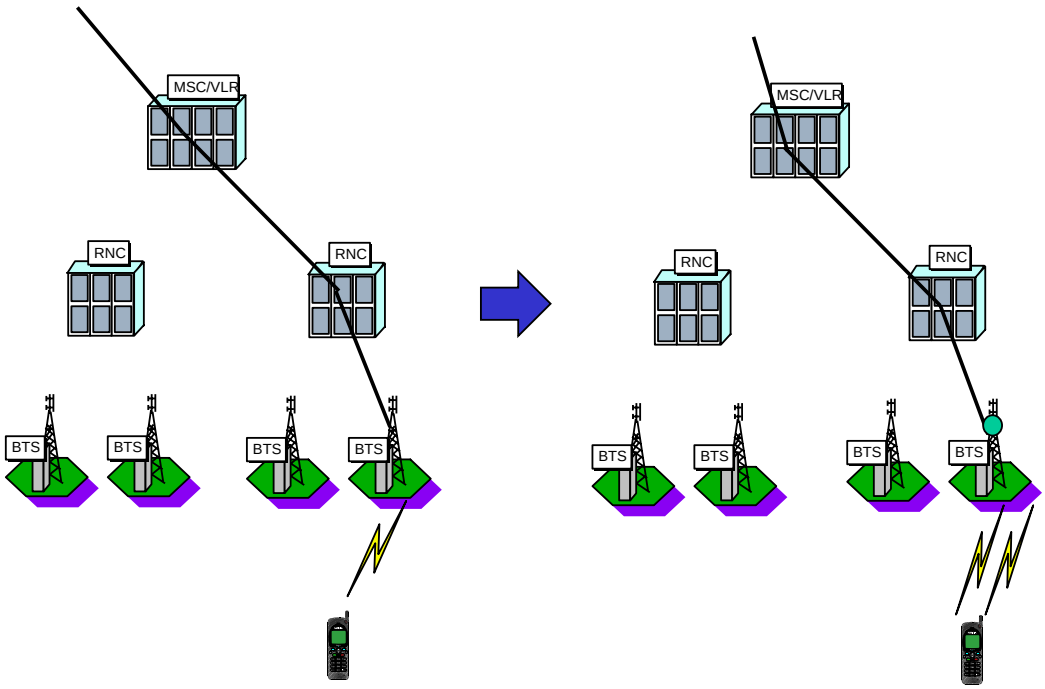
- From and to other systems (e.g., UMTS to GSM)
  - This is a must as UMTS coverage will be poor in the beginning
- RNS controlling the connection is called SRNS (Serving RNS)
- RNS offering additional resources (e.g., for soft handover) is called Drift RNS (DRNS)
- End-to-end connections between UE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



Example handover types in UMTS/GSM *JS*



Macro-diversity Situations: Handover 1/3



Radio Link addition triggered **Resulting Connection**

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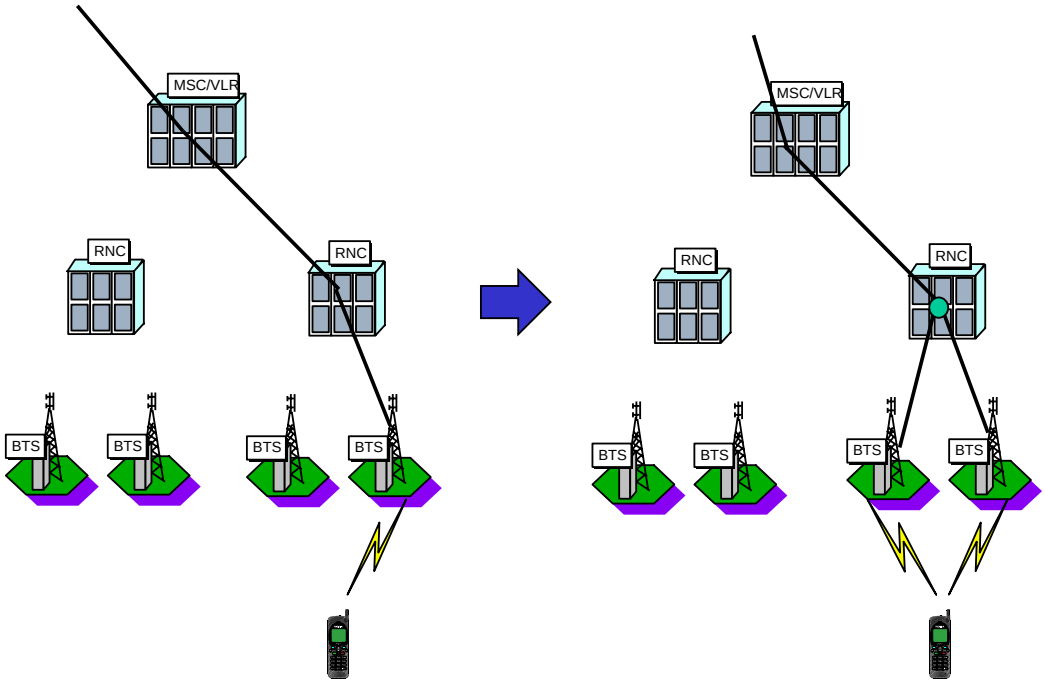
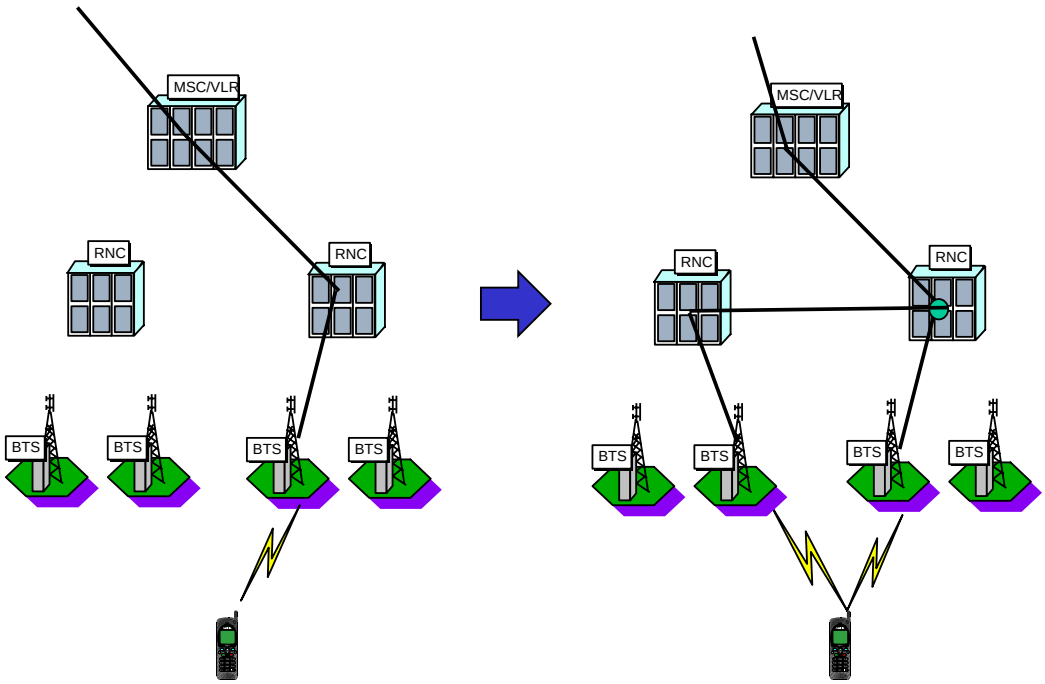
Macro-diversity Situations: Handover 2/3



Radio Link addition triggered **Resulting Connection**

(Slide source: Nokia/NRC guest lectures Mobile Communication 2001-2005)

Macro-diversity Situations: Handover 3/3



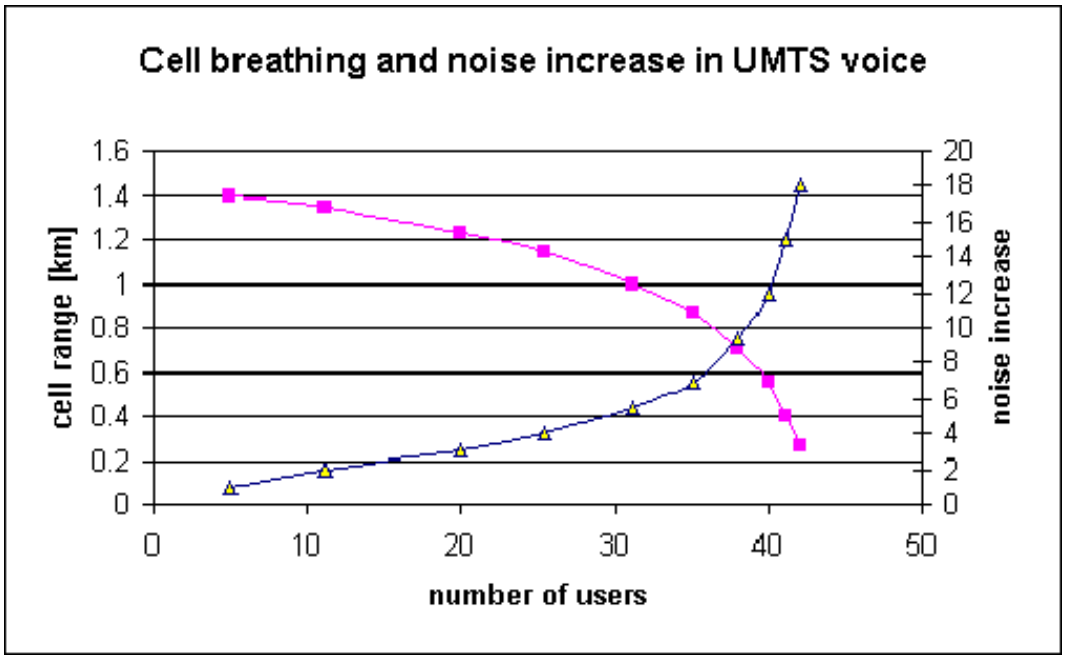
Radio Link addition triggered **Resulting Connection**

(Slide source: Nokia/NRC guest lectures Mobile Communication 2001-2005)

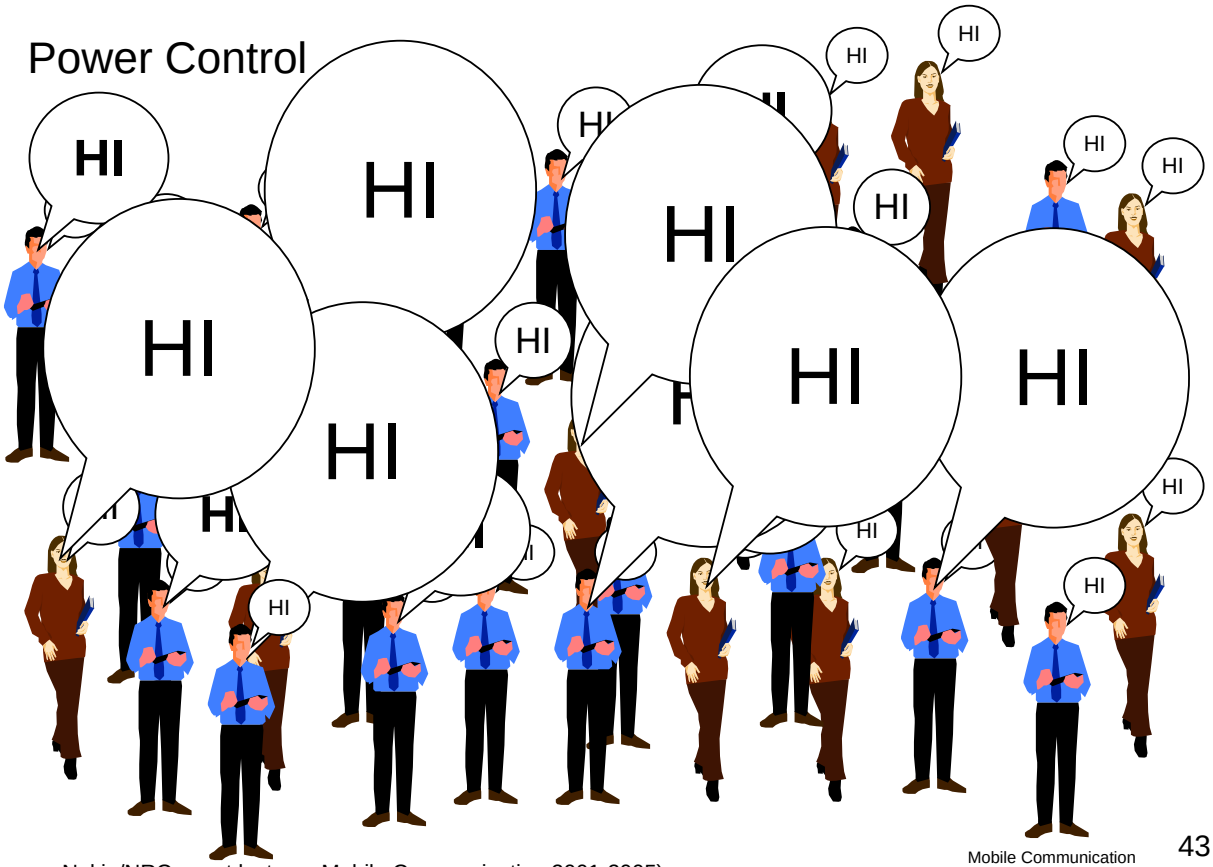
7.6. Breathing Cells JS

- GSM
  - Mobile device gets exclusive signal from the base station
  - Number of devices in a cell does not influence cell size
- UMTS
  - Cell size is closely correlated to the cell capacity
  - Signal-to-noise ratio determines cell capacity
  - Noise is generated by interference from
    - other cells
    - other users of the same cell
  - Interference increases noise level
  - Devices at the edge of a cell cannot further increase their output power (max. power limit) and thus drop out of the cell ⇨ no more communication possible
  - Limitation of the max. number of users within a cell required
  - Cell breathing complicates network planning

Breathing Cells: Example JS



WCDMA Principle: Power Control

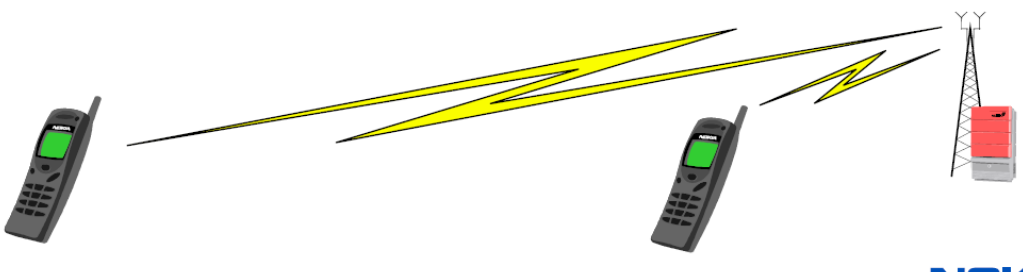


(Slide source: Nokia/NRC guest lectures Mobile Communication 2001-2005)

Power Control: Motivation

Power Control

- Target is to equalize received power per bit of all users
- In downlink base station uses same power level for all users
  - "worst" user determines power level of whole cell
- In uplink all users send on the same frequency:
  Base station needs to receive all signals on same level
  - near users can easily overshout far users (near-far problem)
  - a single over-powered user could block a whole cell



19 © NOKIA UniBonnWCDMA.ppt / 14.07.2003 / Ulrich Müller

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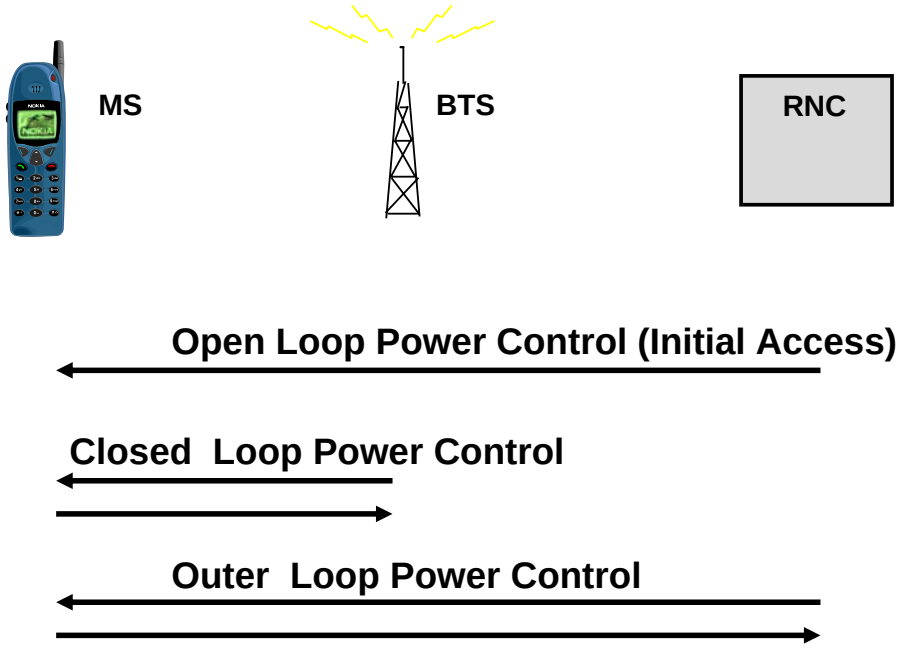
(Slide source: Nokia/NRC guest lectures Mobile Communication 2001-2005)

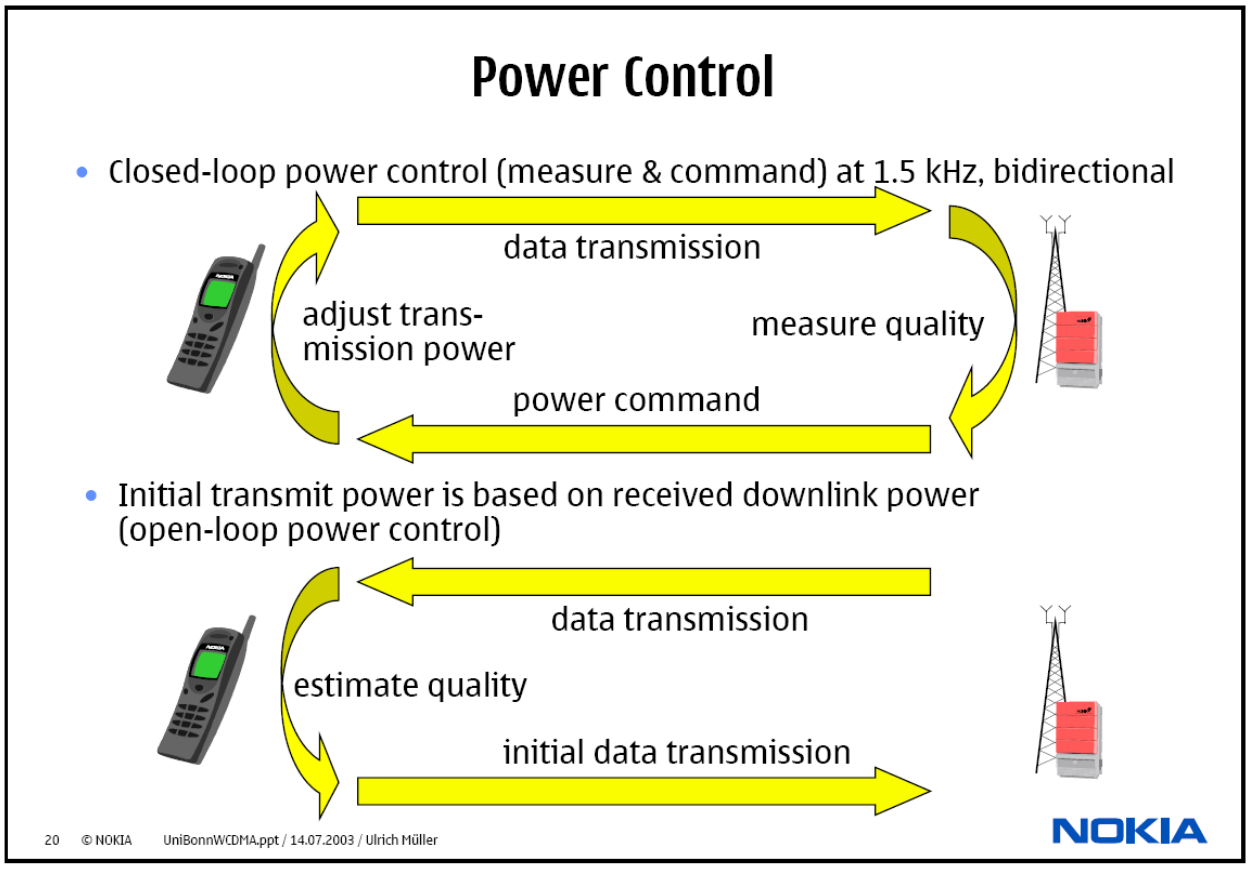
WCDMA Principle: Power Control (2)

Power Control (PC) Loops in WCDMA



(Slide source: Nokia/NRC guest lectures Mobile Communication 2001-2005)

Closed-loop vs. open-loop



(Slide source: Nokia/NRC guest lectures Mobile Communication 2001-2005)

7.7. Some current/further enhancements JS

- GSM
  - **EMS/MMS**
    - EMS: 760 characters possible by chaining SMS, animated icons, ring tones, was soon replaced by MMS (or simply skipped)
    - MMS: transmission of images, video clips, audio
  - **EDGE (Enhanced Data Rates for Global [was: GSM] Evolution)**
    - 8-PSK instead of GMSK, up to 384 kbit/s
    - new modulation and coding schemes for GPRS ➔ EGPRS
      - MCS-1 to MCS-4 uses GMSK at rates 8.8/11.2/14.8/17.6 kbit/s
      - MCS-5 to MCS-9 uses 8-PSK at rates 22.4/29.6/44.8/54.4/59.2 kbit/s
- UMTS
  - **HSDPA (High-Speed Downlink Packet Access)**
    - initially up to 10 Mbit/s for the downlink, later on 20 Mbit/s using MIMO- (Multiple Input Multiple Output-) antennas
    - uses 16-QAM instead of QPSK

Example: EDGE coverage for T-Mobile Germany

EDGE is available in the complete GSM network of T-Mobile.

Source: http://www.t-mobile.de/
URL http://www.t-mobile.de/business/netzabdeckung/0,12565,14540-_,00.html
(used on 18.06.2008)

HSDPA

High Speed Downlink Packet Access

- High Speed Downlink Packet Access (HSDPA)
  - High Speed Data Packet Access channel introduced as an add on for UMTS services (up to 8-14 Mbit/s downlink shared channel)
  - Transmitted within one cell "eating up" certain amount of codes in SF=16
  - New modulation schemes to achieve more bandwidth
  - Priority classes on HSDPA channels allow prioritising certain users within the shared group
- Added to 3GPP Release 5 specifications
  - Support an evolution towards more sophisticated network and multimedia services
  - The main target of HSDPA is to increase user peak data rates, quality of service
  - Generally improve spectral efficiency for downlink asymmetrical and bursty packet data services.

10 © Nokia Future Mobile / 01.07.04 / Oliver Lüert

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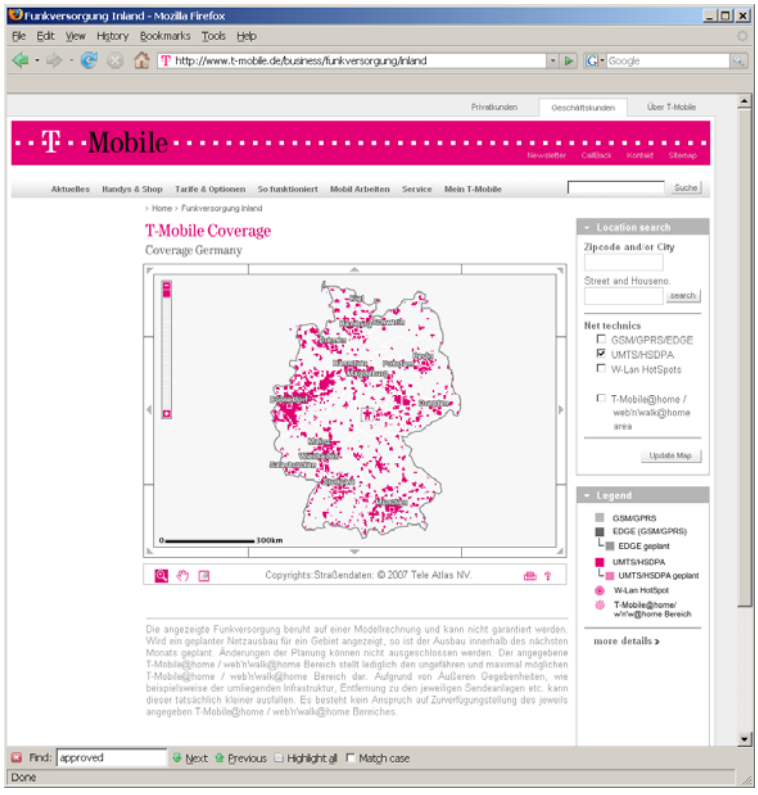
(Slide source: Nokia/NRC guest lectures Mobile Communication 2001-2005)

Example: HSDPA coverage for T-Mobile Germany



HSDPA is available in the complete UMTS network of T-Mobile.

(UMTS available in main metropolitan areas)

Source: http://www.t-mobile.de/
URL http://www.t-mobile.de/business/funkversorgung/inland
(used on 18.06.2008)

7.8. IP Multimedia Subsystem (IMS)

IMS* represents an overlay network on top of cellular networks and provides an all IP service delivery environment for mobile multimedia service provision.

* IMS is the "IP Multimedia System", standardised by the 3rd Generation Partnership Projekt (3GPP), http://www.3gpp.org

- SIP, and SDP for Session Control
- DIAMETER for accounting
- RTP, RTCP for multimedia data transport
- COPS for policy provisioning
- plus many others

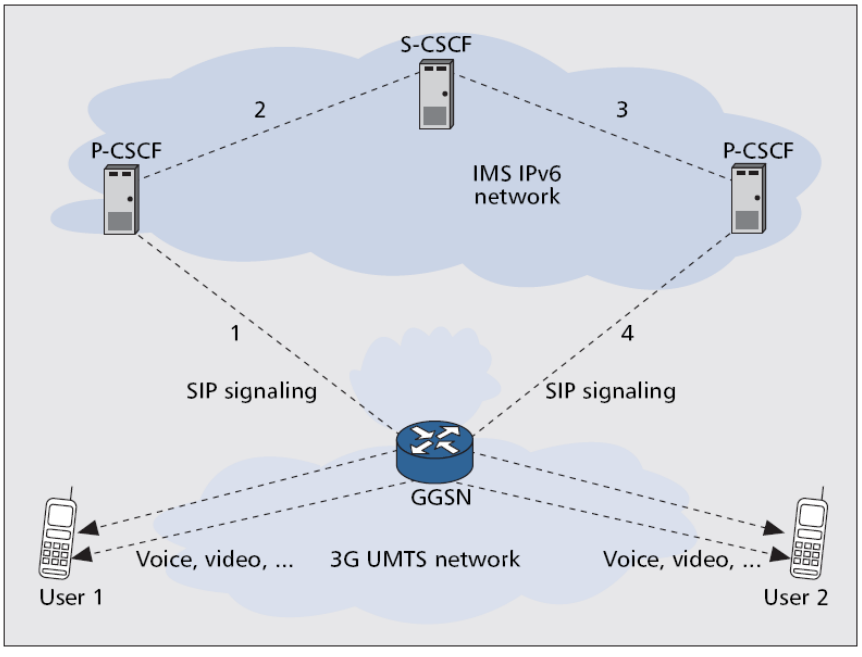
IMS is designed for IPv6, but support for IPv4 has been added in Version 6 of IMS

Why do we *Need* an IMS?

- IMS builds on IETF protocols, to create a robust and complete multimedia system
- IMS defines common interfaces to adopt new and integrated application services
- IMS enhancements and operational profiles provide support for operator control, charging and billing, and security
- IMS provides QoS, single sign-on, subscription, presence, and location

IMS – IP Multimedia Subsystem

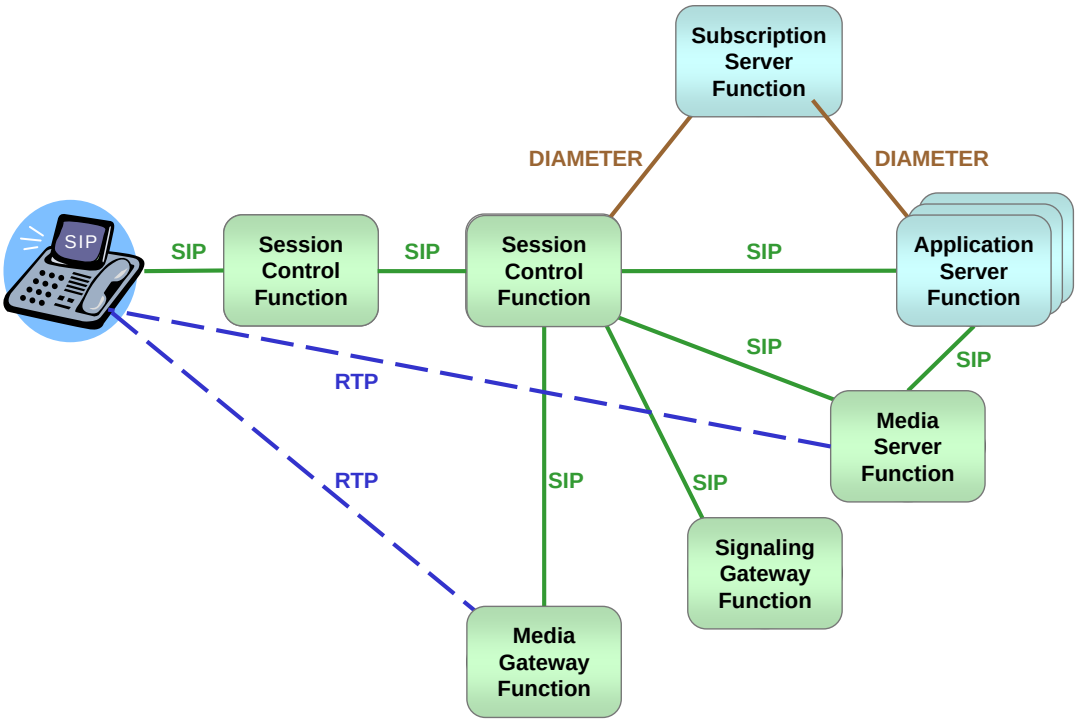
The IMS "service platform" is/was designed by 3GPP (http://www.3gpp.org) to assist and control (multimedia) sessions established between peers. The peers willing to involve IMS in their sessions must us some of the IMS nodes as proxies for their session signaling.



CSCF: Call Service Control Function
P-CSCF: Proxy-CSCF
S-CSCF: Serving-CSCF
SIP: Session Initiation Protocol

Source: IEEE Communications Magazine, August 2006, pp. 75-81

IMS Conceptional Architecture



7.9. Mobile Future: 3.5G … 3.9G … 4G …

3.5 generation of mobile communication:

- HSDPA/HSUPA (D = downlink, U = uplink) extension to UMTS
- Downlink up to 14.4 Mbit/s, Uplink up to 5.7 Mbit/s

3.9 generation of mobile communication:

- UTRAN LTE ("Universal Terrestrial Radio Access Network Long Term Evolution")
- also: "Super 3G"
- Downlink up to 100 Mbit/s, Uplink up to 50 Mbit/s
- 3GPP 3.9G specification approved 2nd half of 2007

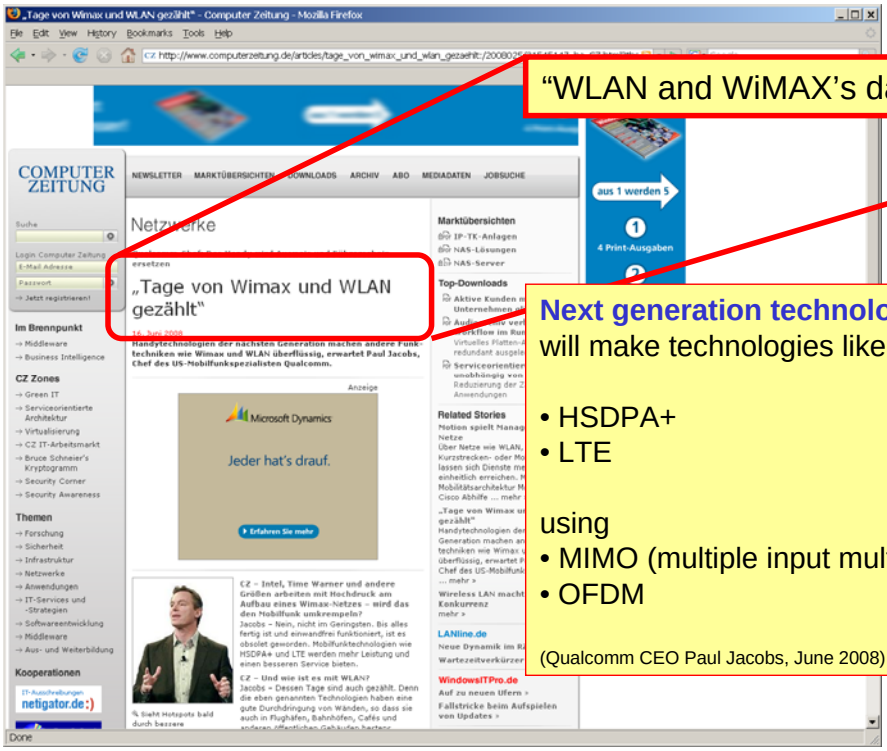
4th generation of mobile communication:

- All-IP based
- NTT DoCoMO (Japan) testing since 1998
- data transfer rates 100 Mbit/s up to 300 Mbit/s

http://www.teltarif.de/ News 10.06.2005
http://www.teltarif.de/arch/2005/kw23/s17412.html

Future statement as of June 2008

More on
http://www.computerzeitung.de/articles/tage_von_wimax_und_wlan_gezaehlt:/2008025/31545147_ha_CZ.html?thes=
or http://www.computerzeitung.de/kn31539662



"WLAN and WiMAX's days are numbered"

Next generation technologies of mobile communication will make technologies like **WLAN, WiMAX, … obsolete**:

- HSDPA+
- LTE

using
- MIMO (multiple input multiple output) antennas
- OFDM

(Qualcomm CEO Paul Jacobs, June 2008)

Annex: Ergebnis Frequenzvergabe für UMTS – FDD (1)
(in German language)

RUNDENERGEBNIS

Versteigerung UMTS/IMT-2000-Lizenzen

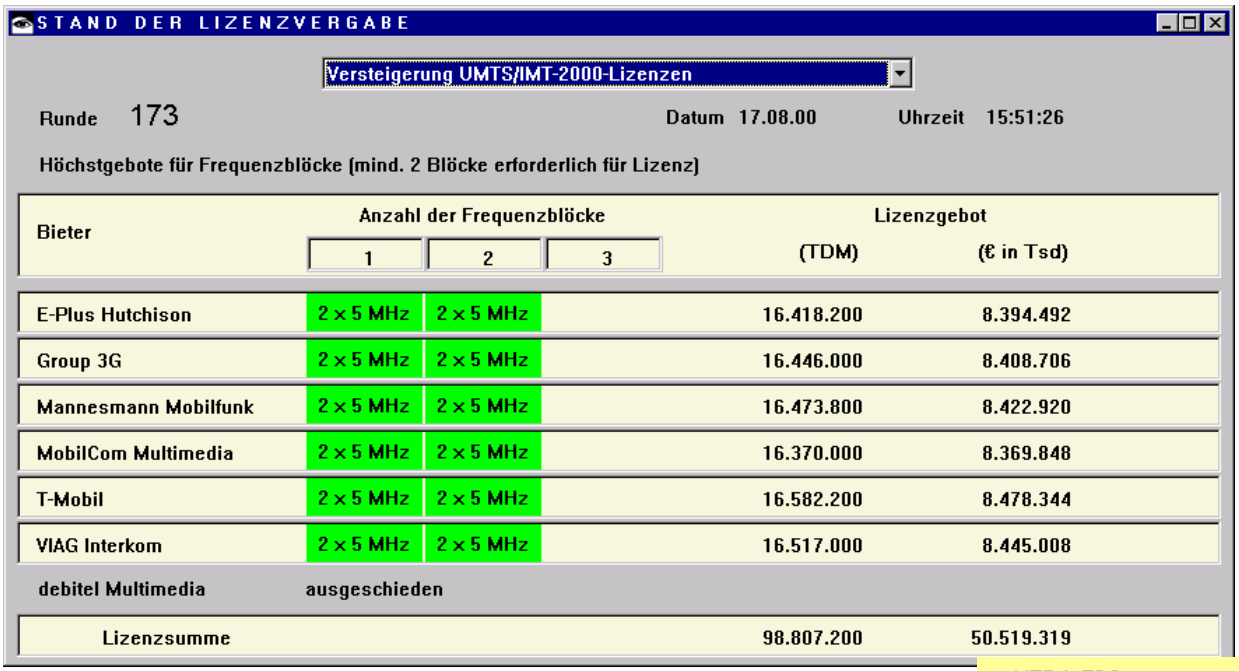
Runde: 173

Lfd. Nr.	Umfang	Höchstbieter	Höchstgebot (TDM)	Höchstgebot* (€ in Tsd)
01	2 x 5 MHz	VIAG Interkom	8.310.400	4.249.040
02	2 x 5 MHz	MobilCom Multimedia	8.170.000	4.177.255
03	2 x 5 MHz	Mannesmann Mobilfunk	8.330.000	4.259.061
04	2 x 5 MHz	Group 3G	8.304.600	4.246.075
05	2 x 5 MHz	MobilCom Multimedia	8.200.000	4.192.593
06	2 x 5 MHz	VIAG Interkom	8.206.600	4.195.968
07	2 x 5 MHz	T-Mobil	8.304.300	4.245.921
08	2 x 5 MHz	E-Plus Hutchison	8.274.300	4.230.582
09	2 x 5 MHz	T-Mobil	8.277.900	4.232.423
10	2 x 5 MHz	E-Plus Hutchison	8.143.900	4.163.910
11	2 x 5 MHz	Mannesmann Mobilfunk	8.143.800	4.163.859
12	2 x 5 MHz	Group 3G	8.141.400	4.162.632
		Summe Höchstgebote	98.807.200	50.519.319

* Eurowerte gerundet

UMTS-Versteigerung Deutschland
14. Tag = 17.08.2000 (bis Runde 173)
Rundenergebnis des Abschnitts 1 (FDD Frequenzblöcke)

Ergebnis Frequenzvergabe für UMTS – FDD (2)



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

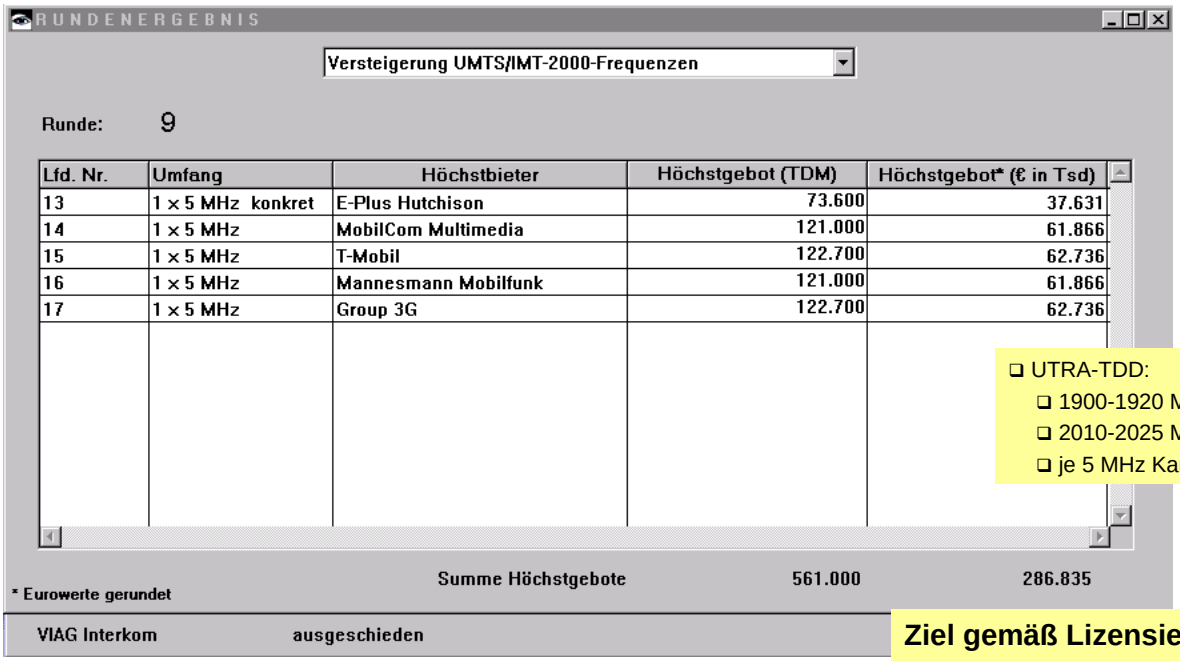
UMTS-Versteigerung Deutschland

14. Tag = 17.08.2000 (bis Runde 173)

Stand der Lizenzvergabe (FDD Frequenzblöcke)

- UTRA-FDD:
  - Uplink 1920-1980 MHz
  - Downlink 2110-2170 MHz
  - Duplexabstand 190 MHz
  - 12 Kanäle zu je 5 MHz

Ergebnis Frequenzvergabe für UMTS – TDD



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-TDD:
  - 1900-1920 MHz,
  - 2010-2025 MHz;
  - je 5 MHz Kanäle

Ziel gemäß Lizensierung:

- Abdeckung: 25% in der Bevölkerung bis 12/2003, 50% bis 12/2005

UMTS-Versteigerung Deutschland

1. Tag = 18.08.2000 (bis Runde 9)

Endergebnis Abschnitt 2 (TDD Frequenzblöcke)