

## 7. 3rd generation mobile communication: UMTS

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## 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.

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Once again:

Several slides in this chapter are very much **based on Jochen Schiller's work**. The copyright of these slides - marked "**JS**" in the upper right corner - is with Jochen Schiller.

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:

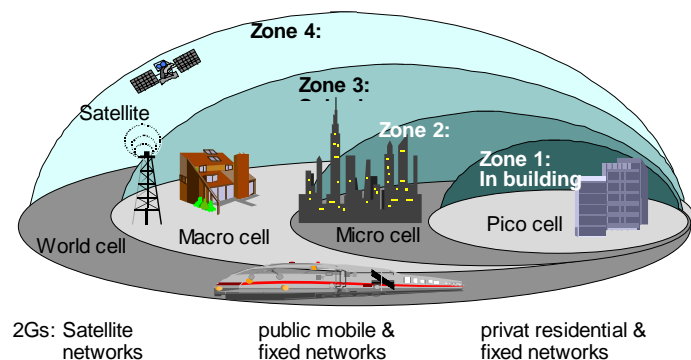
[www.etsi.org](http://www.etsi.org)

[www.3gpp.org](http://www.3gpp.org)

[www.umts-forum.org](http://www.umts-forum.org)

[www.itu.int](http://www.itu.int)

## UMTS/IMT 2000 is universal

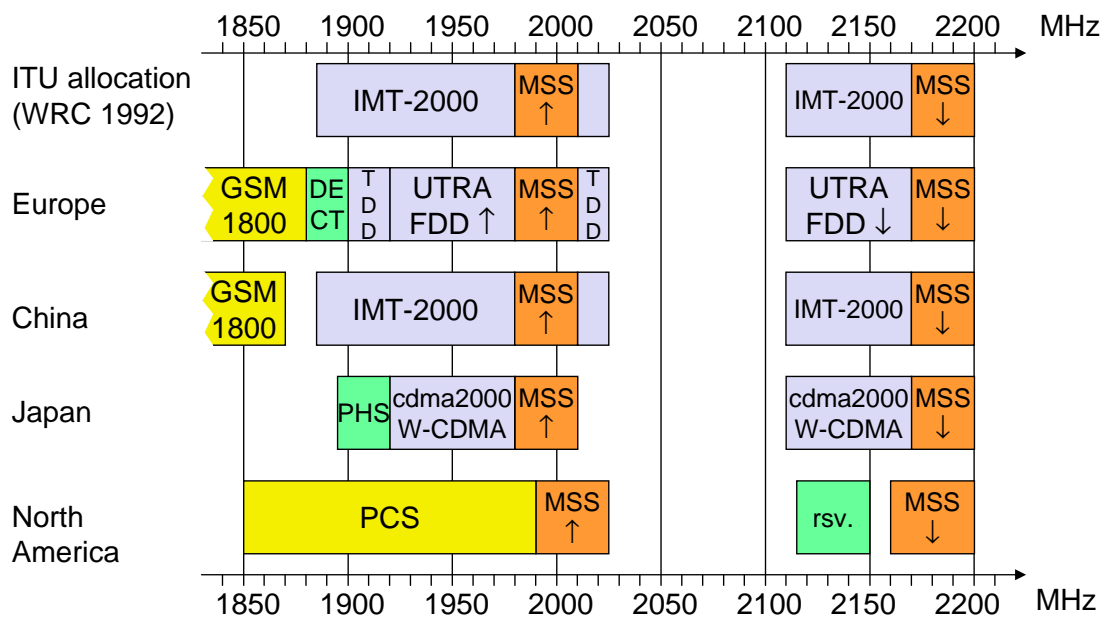


(Abb.quelle: Report No. 6 from the UMTS Forum, [www.umts-forum.org](http://www.umts-forum.org))

- **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

- 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



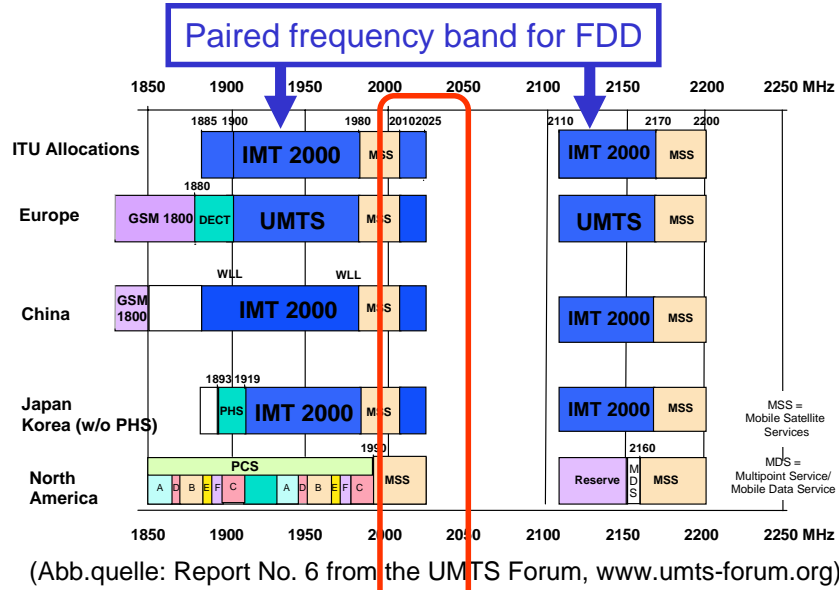
MSS = mobile satellite services

# Duplex with UMTS ?

## Duplex – separation of uplink and downlink

Both concepts are used:

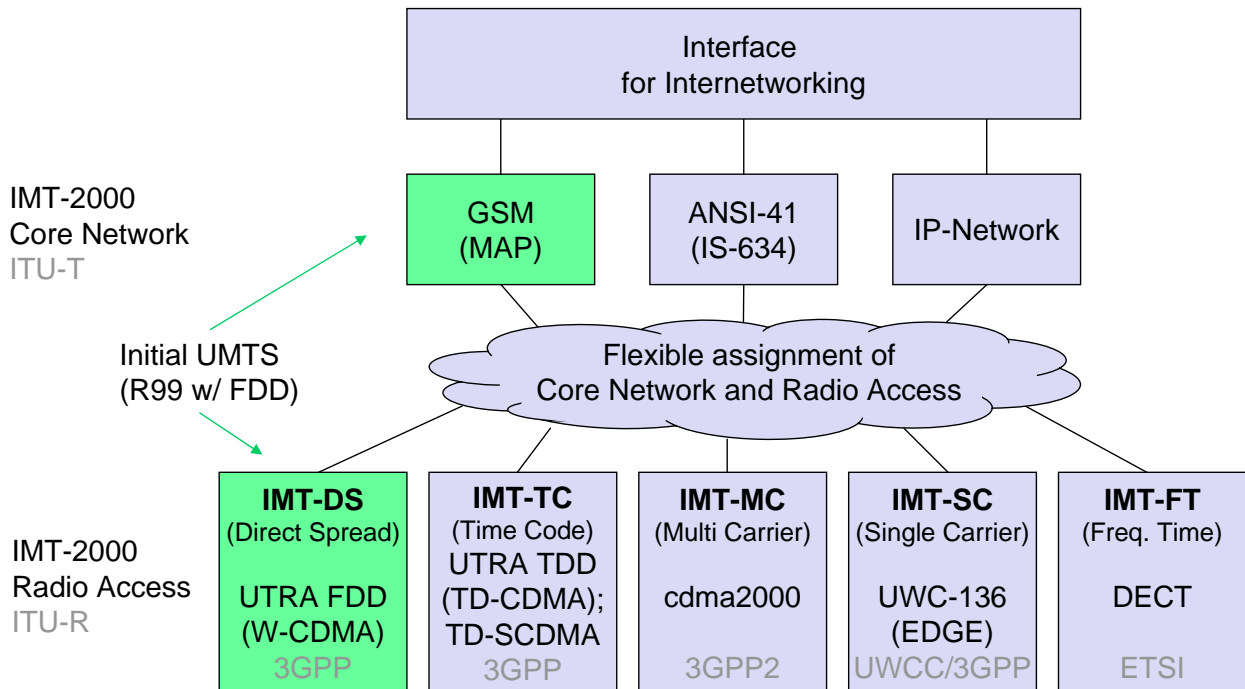
- FDD: Frequency Division Duplex, use pair of frequencies/spectrum in parallel (same as GSM)
- TDD: Time Division Duplex, unpaired frequencies/spectrum, time division of Downlink/Uplink



Unpaired frequency band, for TDD

# IMT-2000 family

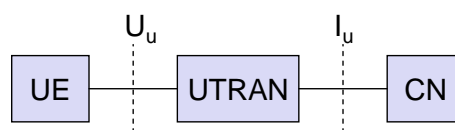
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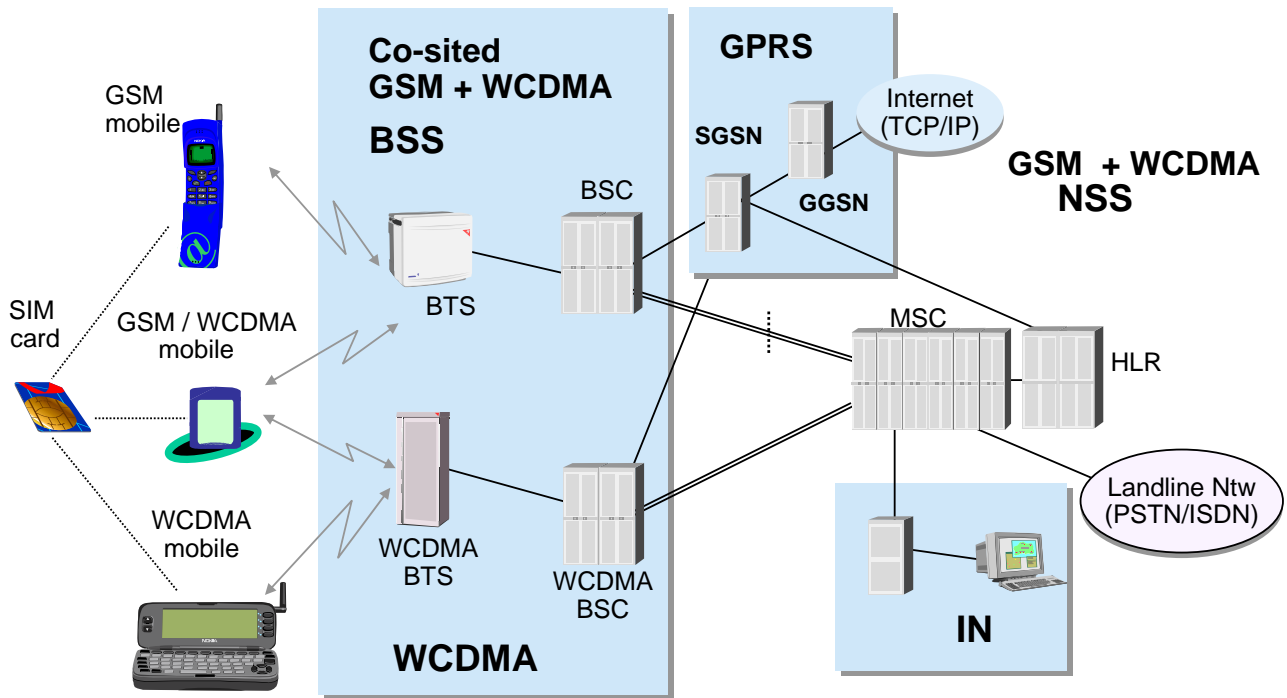
GSM/EDGE Release	3G Release	Abbreviated name	Spec version number	Freeze date (indicative only)
Phase 2+ Release 8	Release 8	Rel-8	8.x.y	Stage 1 freeze Mar. 2008 (stage 2,3 open)
Phase 2+ Release 7	Release 7	Rel-7	7.x.y	Stage 3 freeze Dec. 2007
Phase 2+ Release 6	Release 6	Rel-6	6.x.y	December 2004 - 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!)

- 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



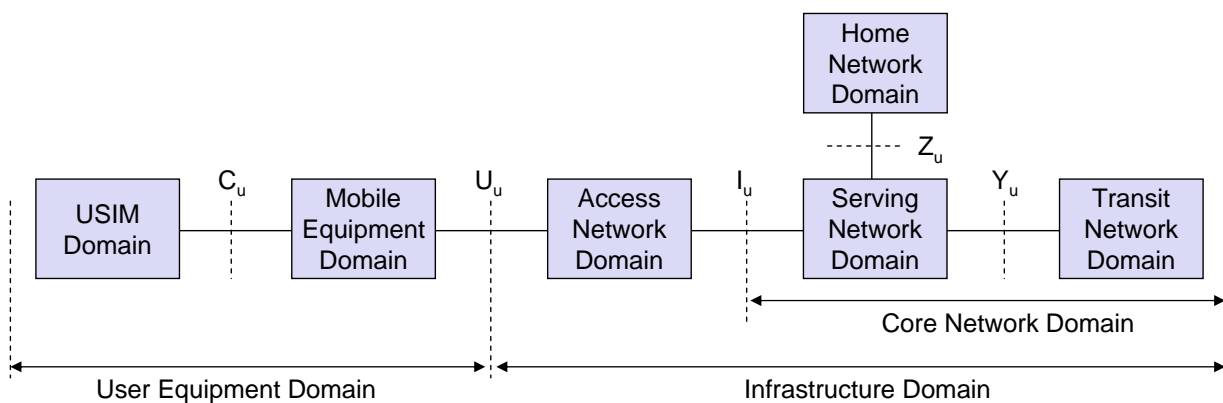
## UMTS architecture (2)



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

## UMTS domains and interfaces I

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- 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

- 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

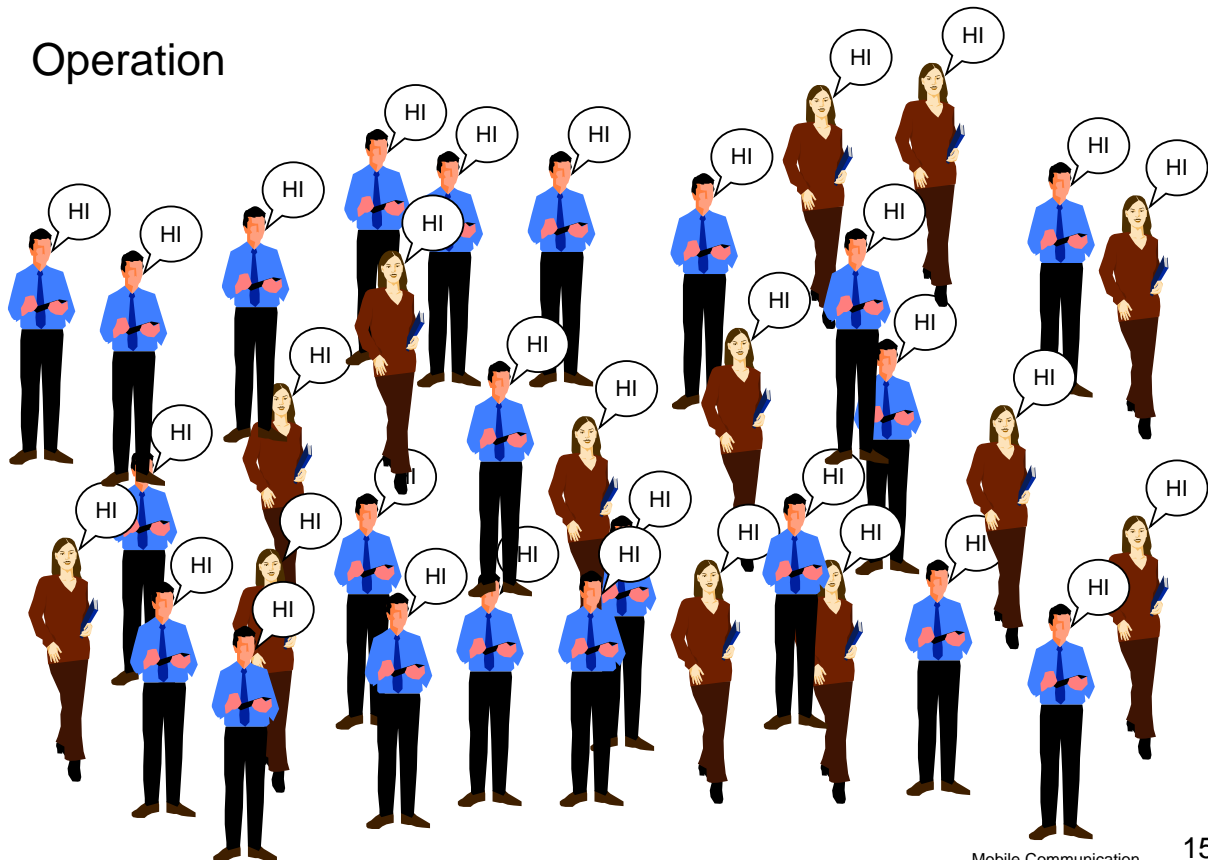
## 7.3. WCDMA Principle(I) : Spread Spectrum

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

## WCDMA Principle (II) : Spread Spectrum

Operation



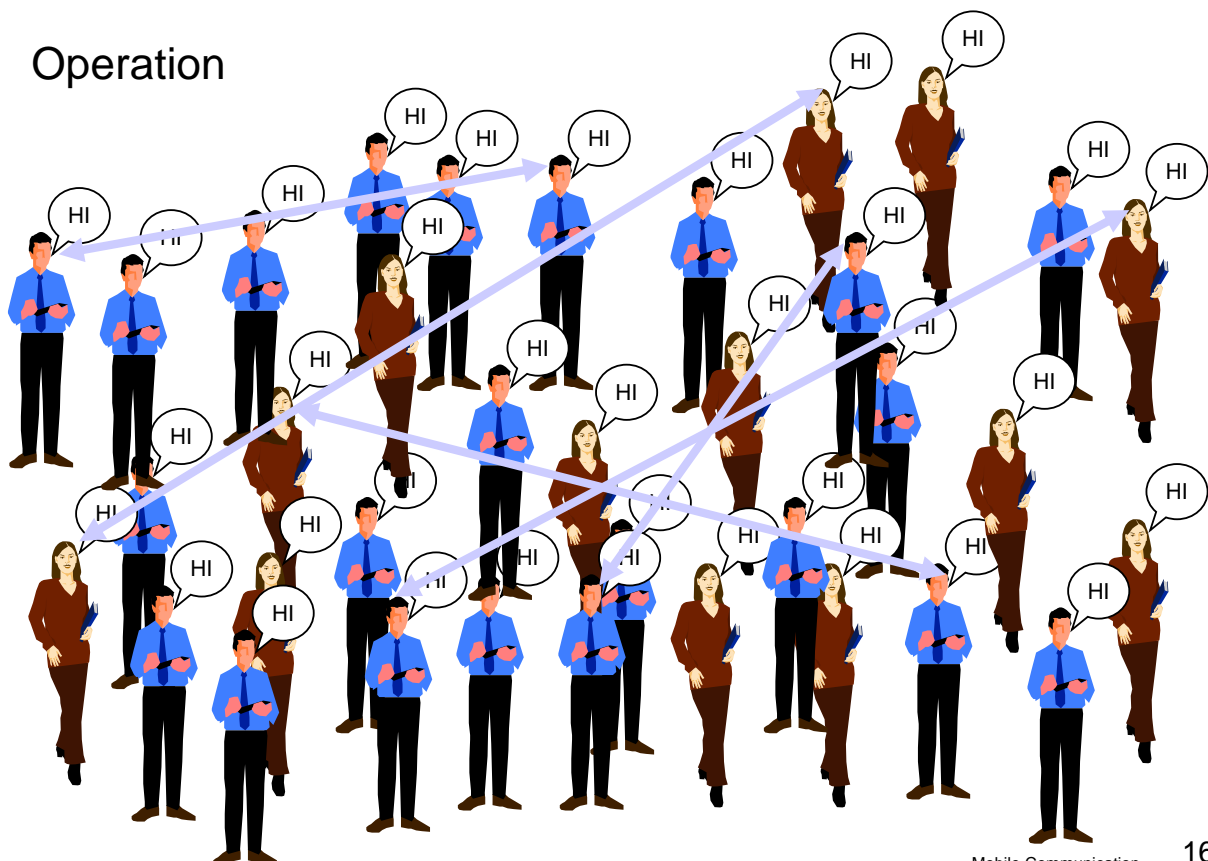
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## WCDMA Principle (III) : Spread Spectrum

Operation



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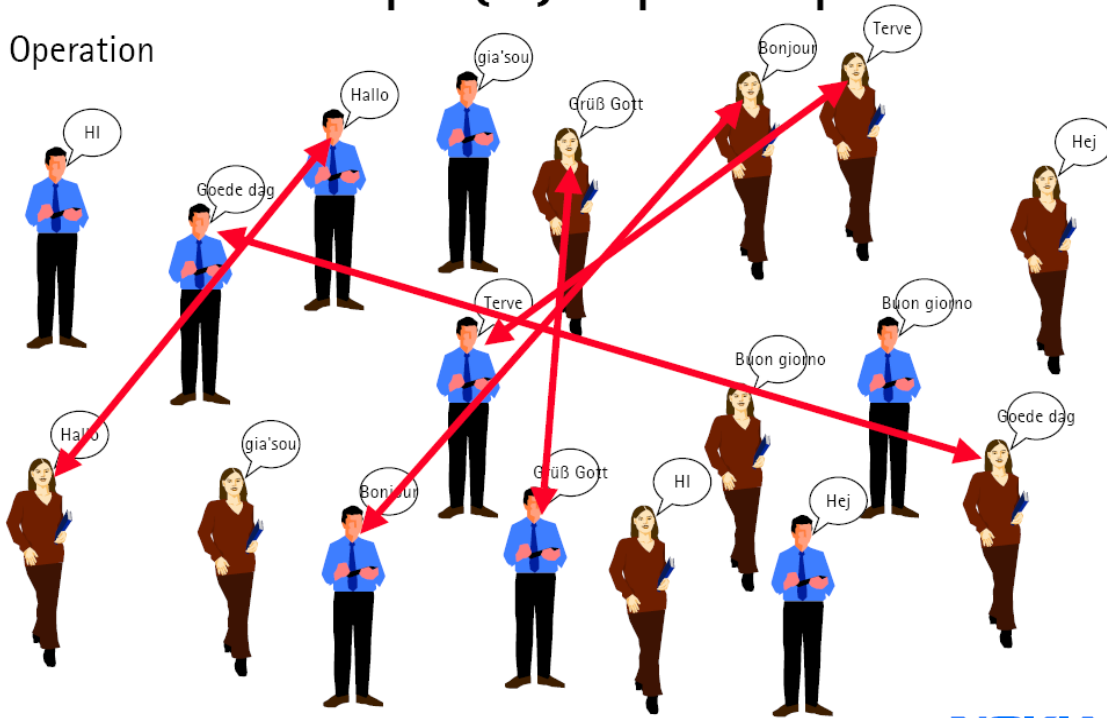
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## Code division = different languages

### WCDMA Principle (III) : Spread Spectrum

Operation



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## Multiple Access with CDMA

### CDMA - Code Division Multiple Access

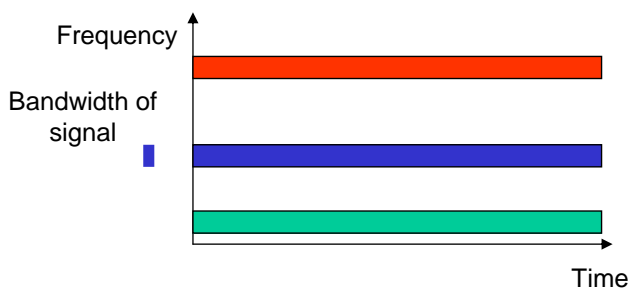
=> cf. subsection  
3. Wireless Communication Basics

Fixed channel size with GSM (combination of FDMA and TDMA) :

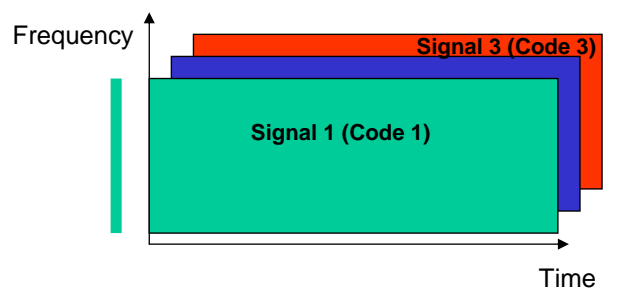
Division of frequencies, each channel division into cyclic time-slots

**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



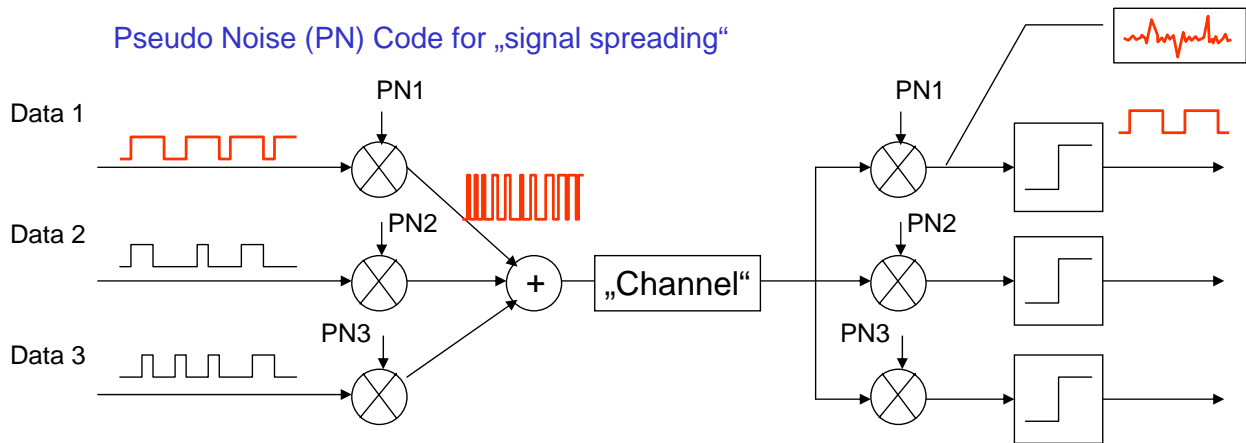
Three transmissions using **FDMA**



Three transmissions using **CDMA**

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# Coding and Decoding with CDMA



Narrow band user signal

„Spreading“ with code sequence (multiplication)  
 Superposition of broadband signals in the shared medium „air“

Second multiplication with PN-code sequence (filter)

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

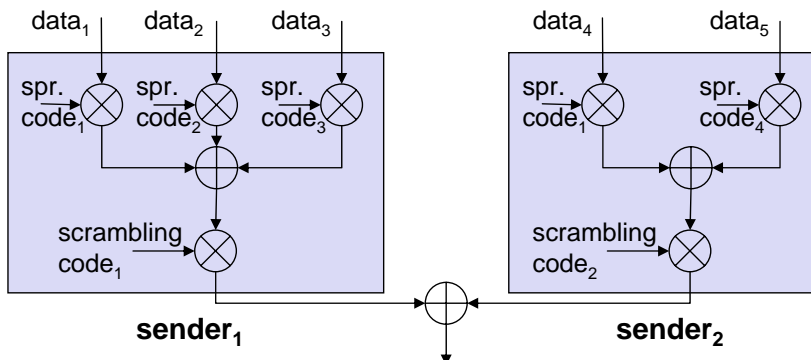
Multiplication of necessary bandwidth  
 Attenuation Interference

=> cf. subsection 3. Wireless Communication Basics

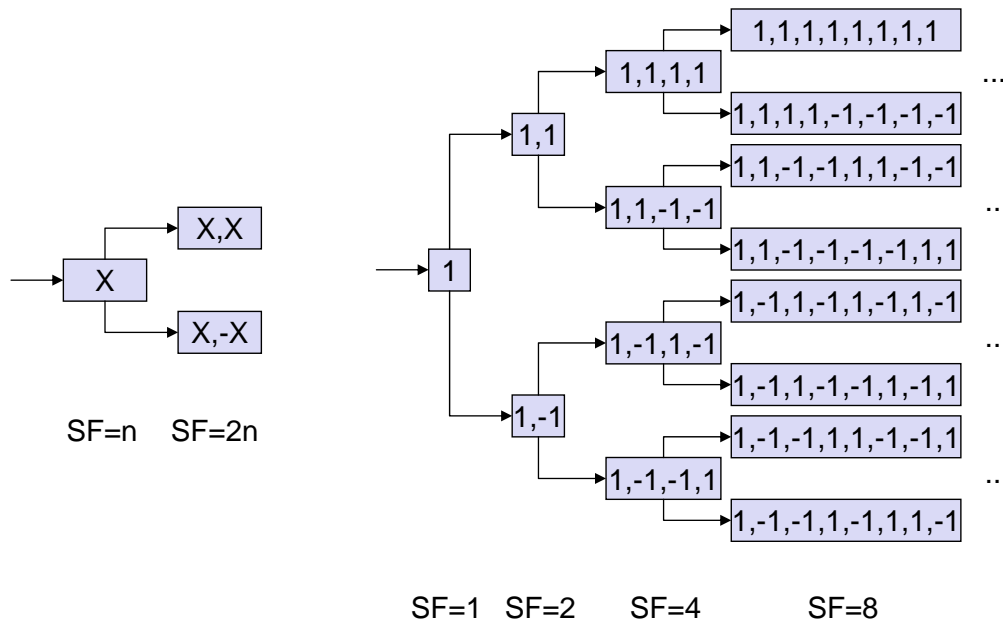
# Spreading and scrambling of user data

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- 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



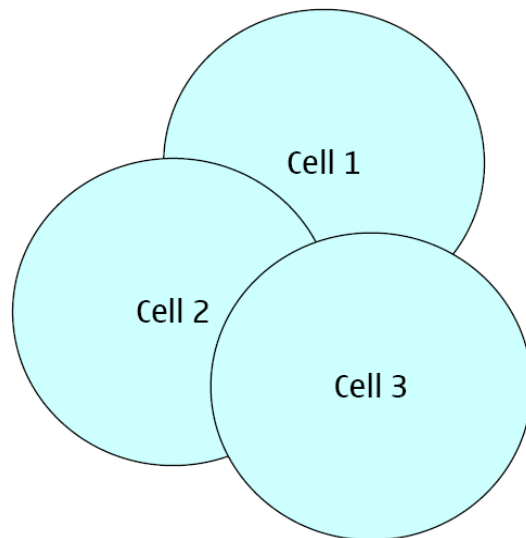
OVSF = Orthogonal Variable Spreading Factor (3G UMTS coding scheme)



Channelization Codes

Limitation of Channelization Codes

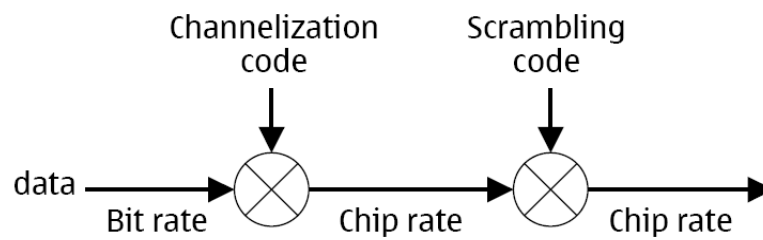
- Channelization codes are sufficient for multiplexing within a cell
- How to handle cell overlapping?
- Solution: cell separation by scrambling codes



## 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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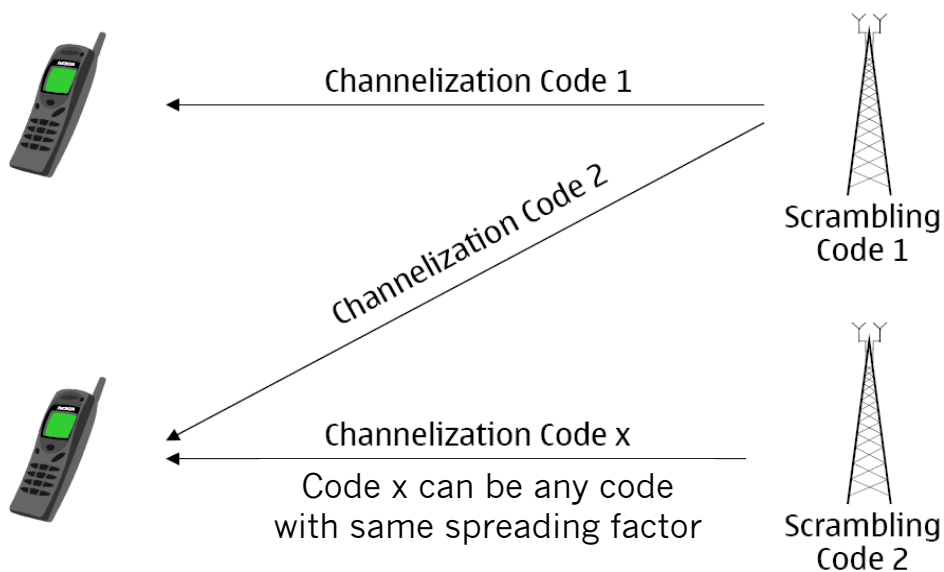
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## Codes in Downlink

### Codes in Downlink



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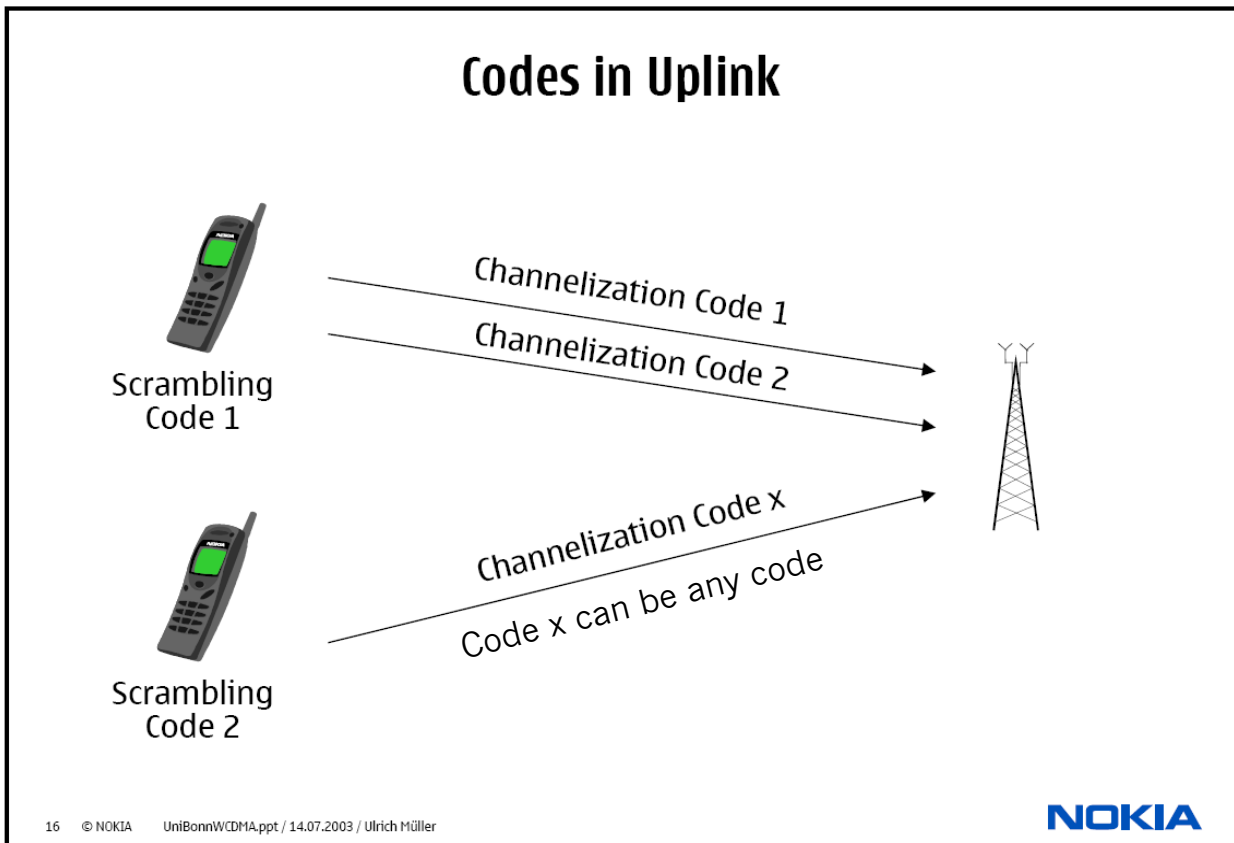
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## Codes in Uplink



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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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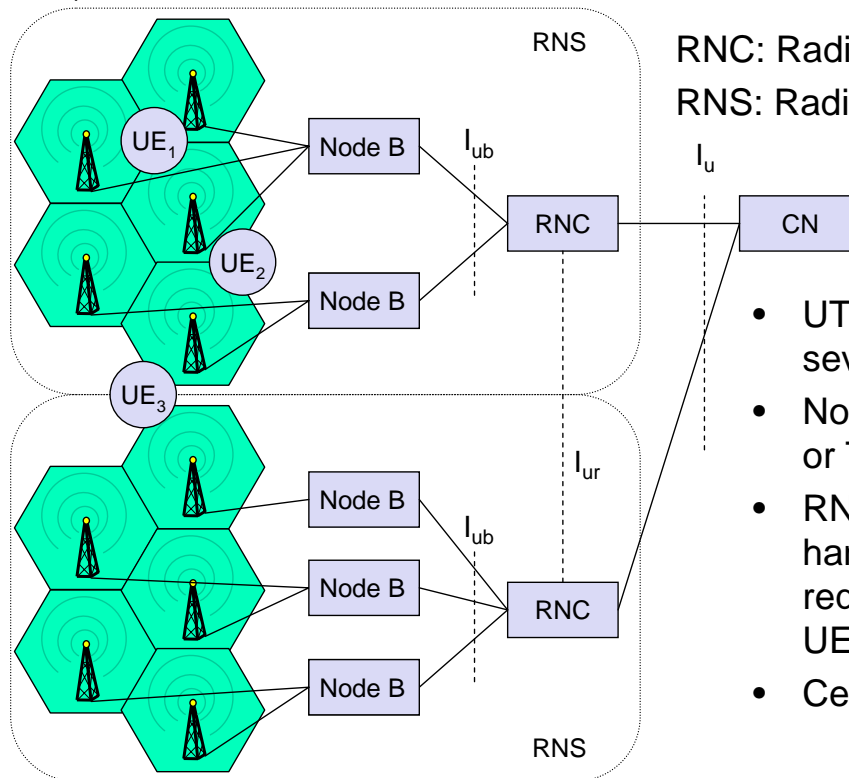
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(UTRAN = Universal Terrestrial Radio Access Network)

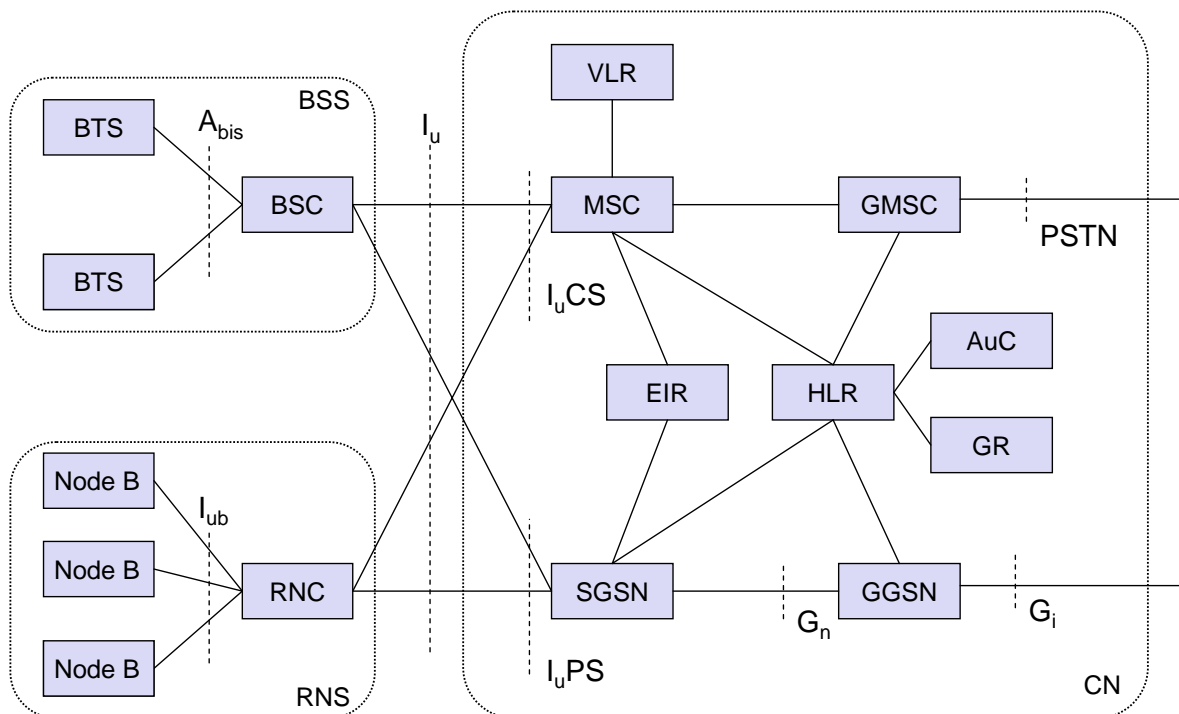
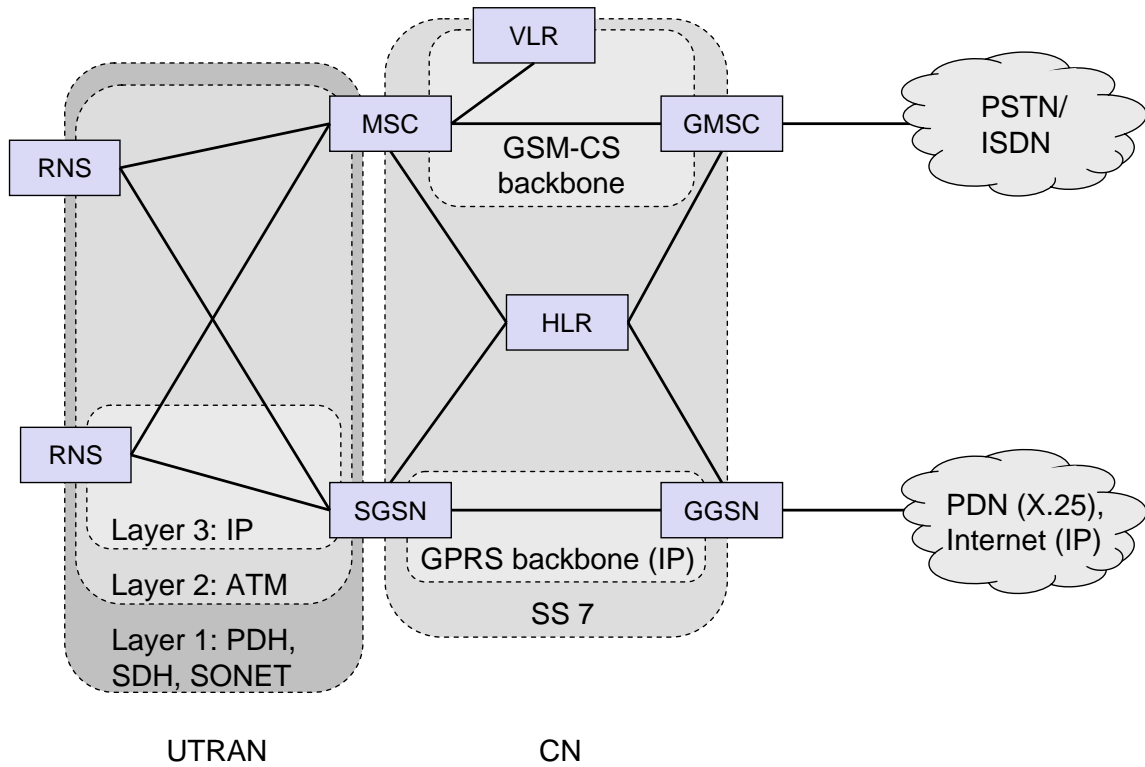


RNC: Radio Network Controller  
RNS: Radio Network Subsystem

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

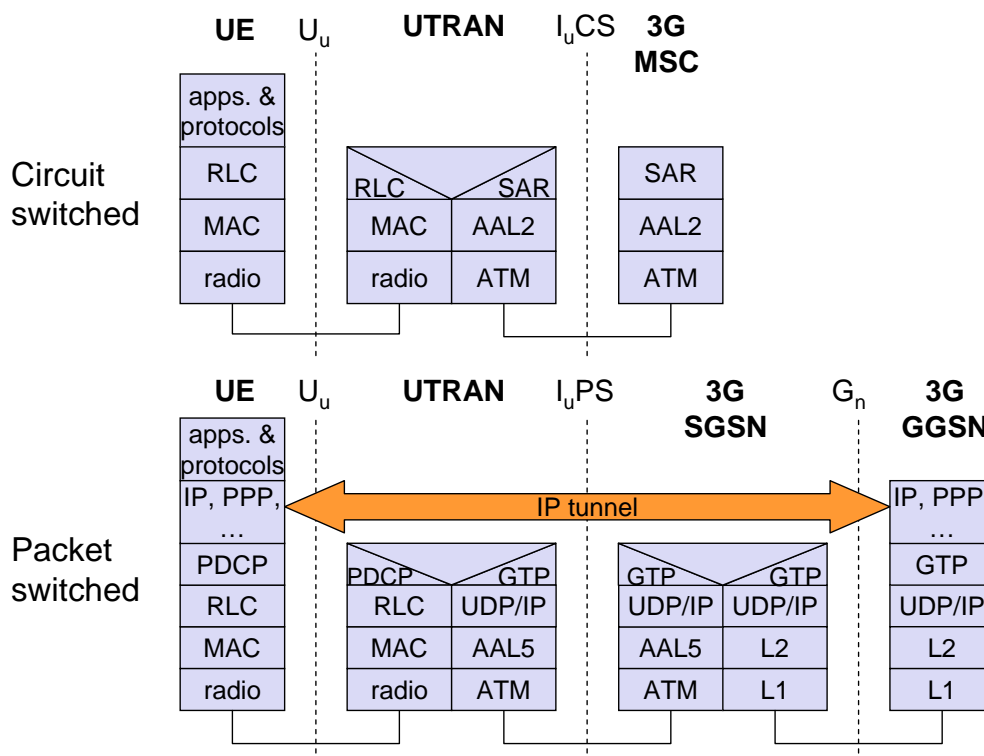
## UTRAN functions

- 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

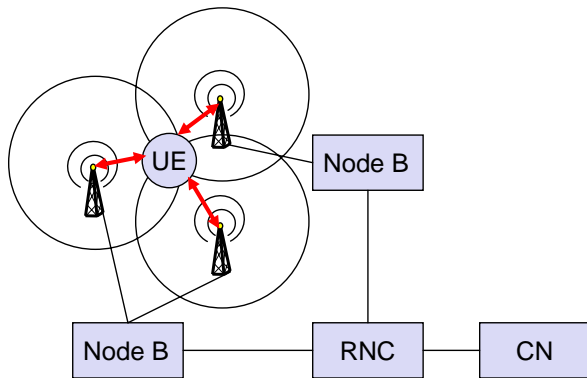


- The Core Network (CN) and thus the Interface  $I_u$ , too, are separated into two logical domains:
- Circuit Switched Domain (CSD)
  - Circuit switched service incl. signaling
  - Resource reservation at connection setup
  - GSM components (MSC, GMSC, VLR)
  - $I_{uCS}$
- Packet Switched Domain (PSD)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



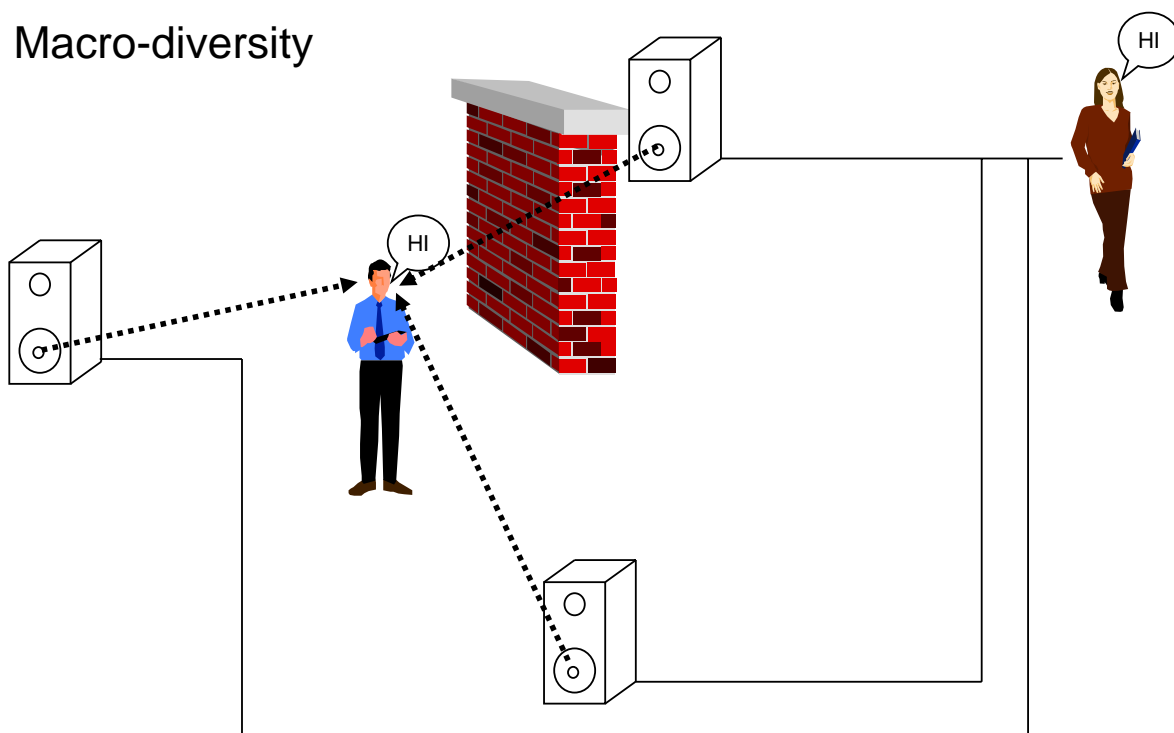




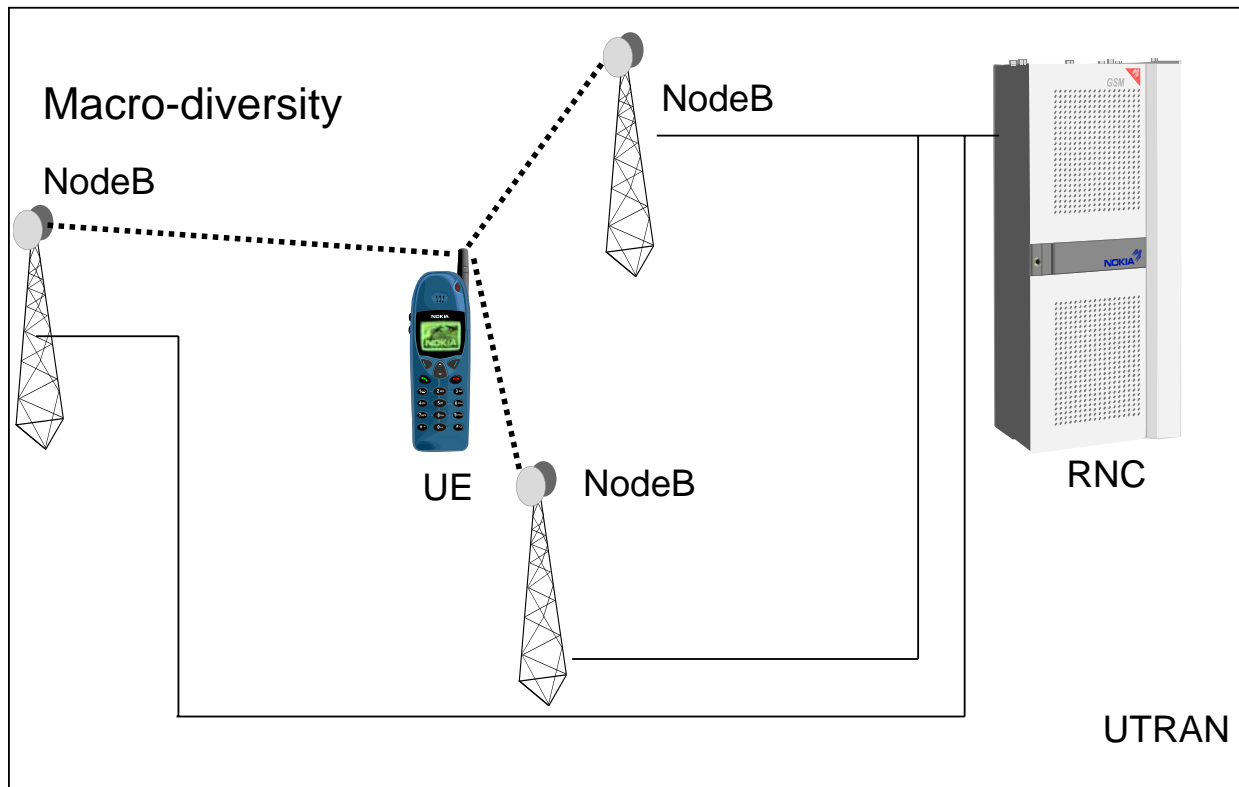
- Multicasting of data via several physical channels
  - Enables soft handover
  - FDD mode only
- Uplink
  - simultaneous reception of UE data at several Node Bs
  - Reconstruction of data at Node B, SRNC or DRNC
- Downlink
  - Simultaneous transmission of data via different cells
  - Different spreading codes in different cells

## WCDMA Principle: Macro-diversity

### Macro-diversity



## WCDMA Principle: Macro-diversity (2)



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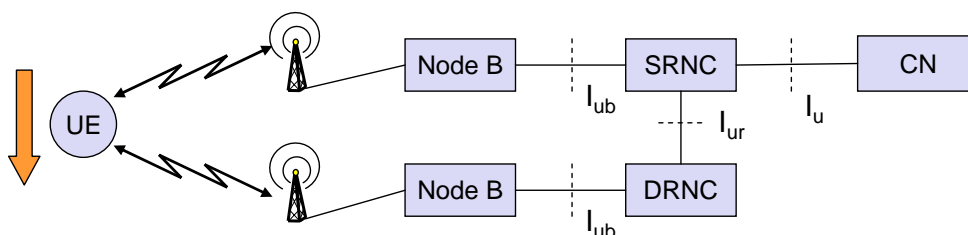
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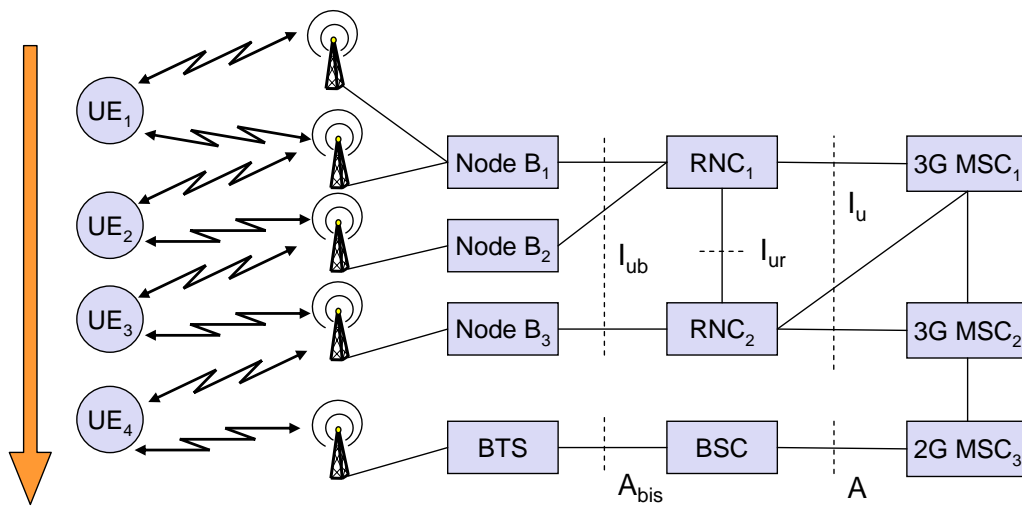
## Support of mobility: handover

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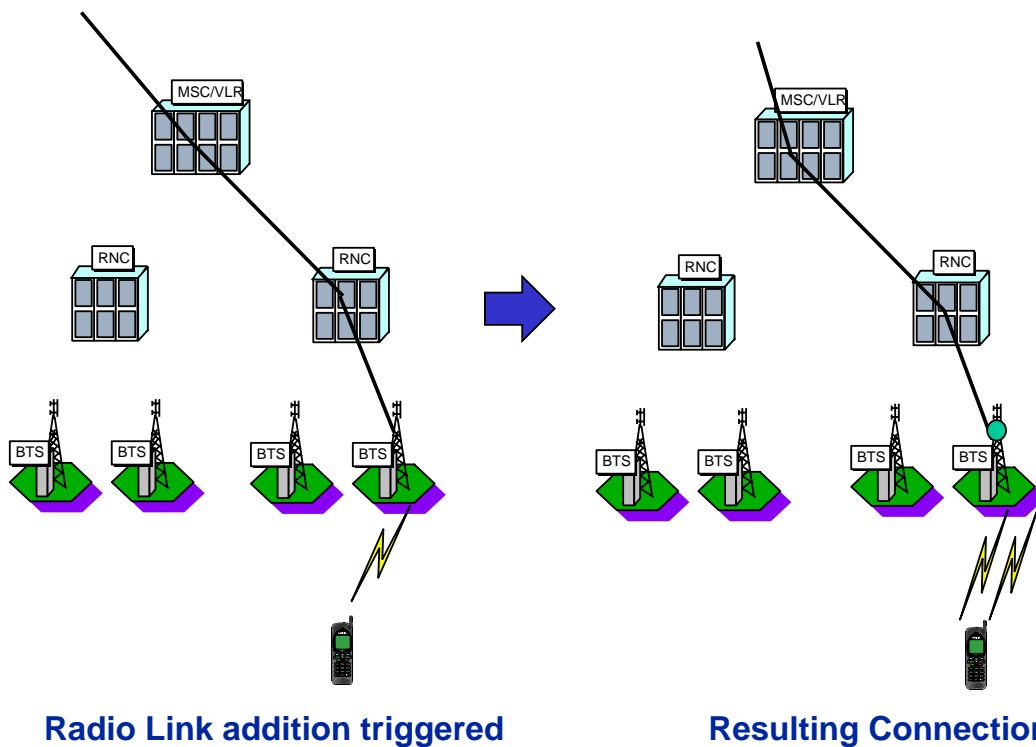
- From and to other systems (e.g., UMTS to GSM)
  - This is a must as UMTS coverage will be poor in the beginning
- RNS controlling the connection is called SRNS (Serving RNS)
- RNS offering additional resources (e.g., for soft handover) is called Drift RNS (DRNS)
- End-to-end connections between UE 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



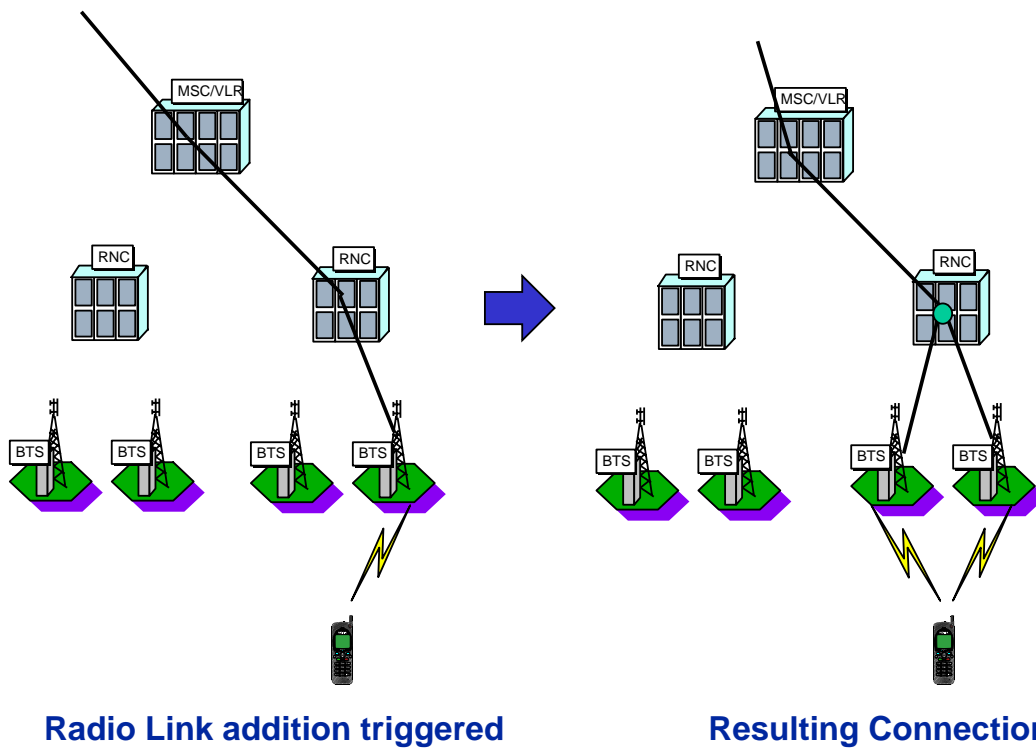
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## Macro-diversity Situations: Handover 1/3



## Macro-diversity Situations: Handover 2/3

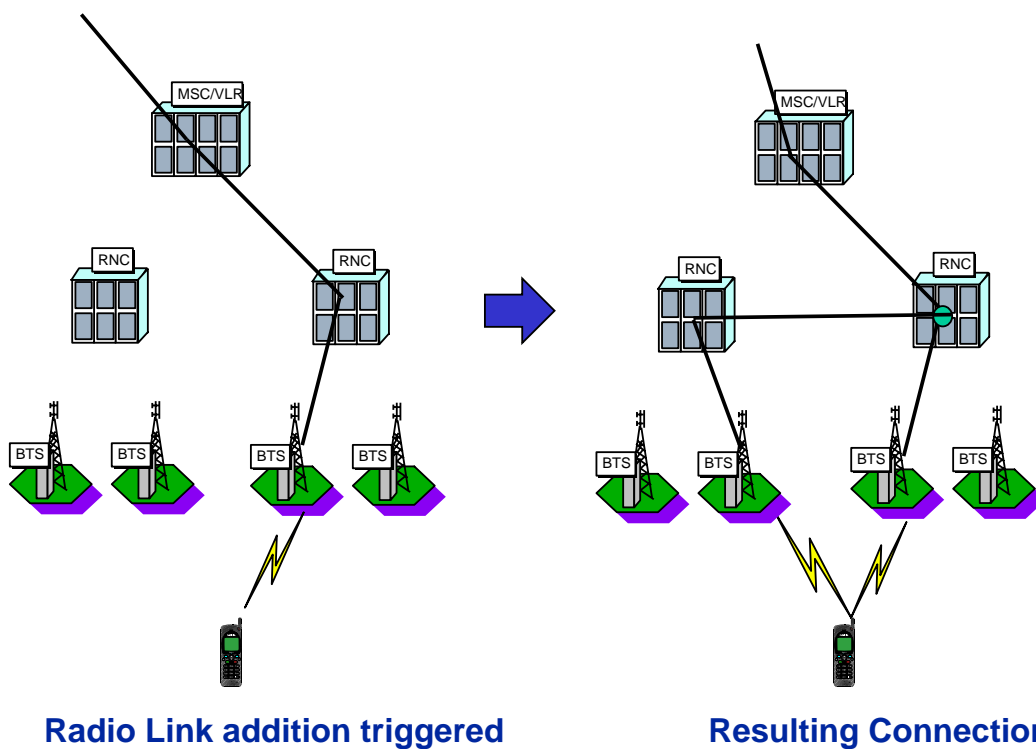


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## Macro-diversity Situations: Handover 3/3



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