Evolution der öffentlichen Mobilfunknetze (3G/4G)
Chapter IV: Physical Layer

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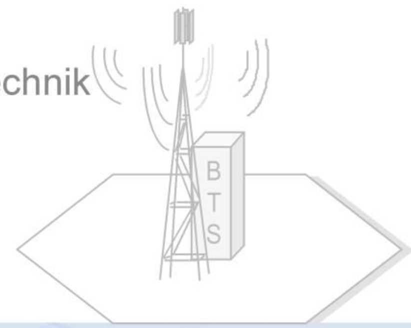

Evolution of public radio networks

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1. Introduction/Overview GSM/UMTS
2. Basics: Radio Transmission
3. Basics: Radio Network Planning
4. Physical Layer
5. Radio Interface Protocols
6. Architecture / Core Network
7. Security
8. UMTS Evolution / LTE
9. Supplemtary Services

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Outline Part IV

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1. Overview Radio Interface: Timing and Codes
2. Codes/ OSVF
3. Data rates – Spreading Factor
4. Coding/ Interleaving
5. Power Control
6. Handover
7. CAC
8. Timing Advance

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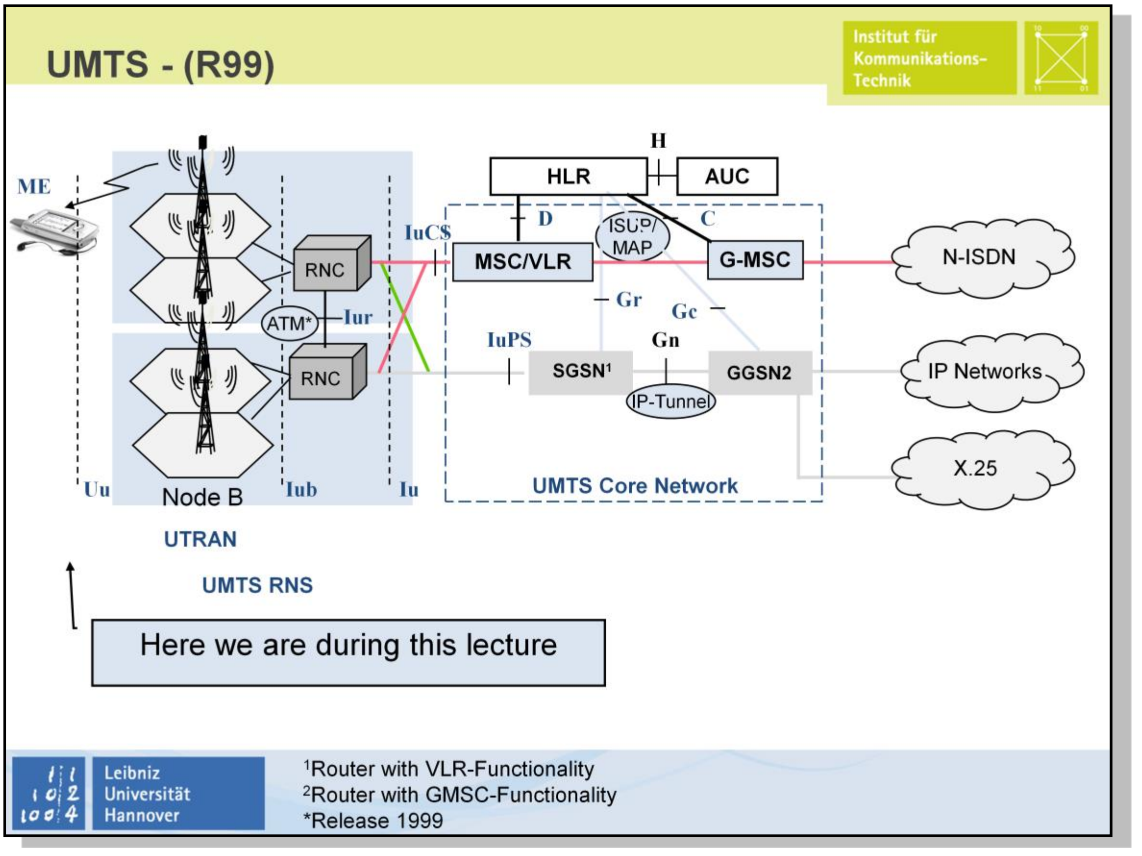

RNS: Radio Network System

RNC: Radio Network Controler

UTRAN: UMTS Terestrial Radio Access Network

UMTS CN: UMTS Core Network

SGSN Serving GPRS Support Node

GGSN Gateway GPRS Support Node

GMSC: Gateway Mobile Switching Centre

HLR: Home Location Register

VLR: Visitor Location Register

Physical Layer - L1 (PHY)

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- Tasks, related directly with the air interface apart the transmission functions:
  - Provision of transport channels and their mapping to physical channels
  - Macro Diversity/ Soft Handover
  - Error protection with CRC, ARQ, FEC und Interleaving
  - Synchronization (frequency and time)
  - Measurement of FER (Frame Error Rate), SIR (Signal to Interference Ratio)
- Realized differently within UTRA-TDD and UTRA-FDD

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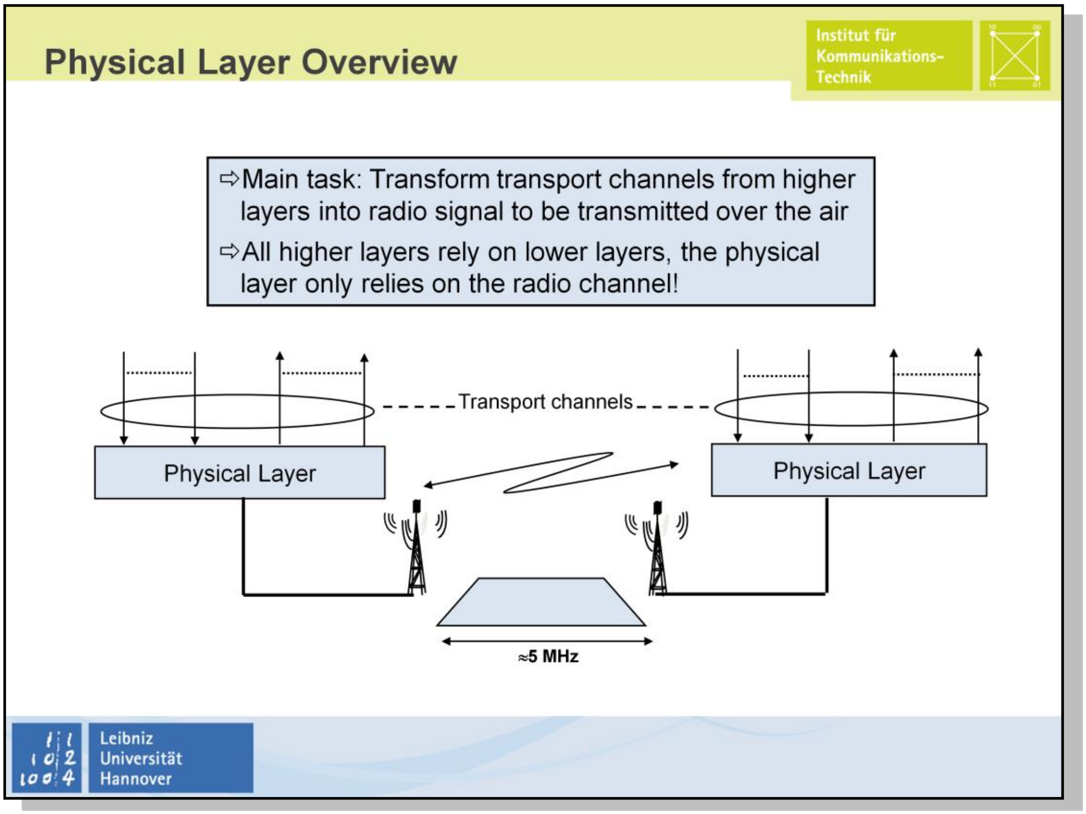
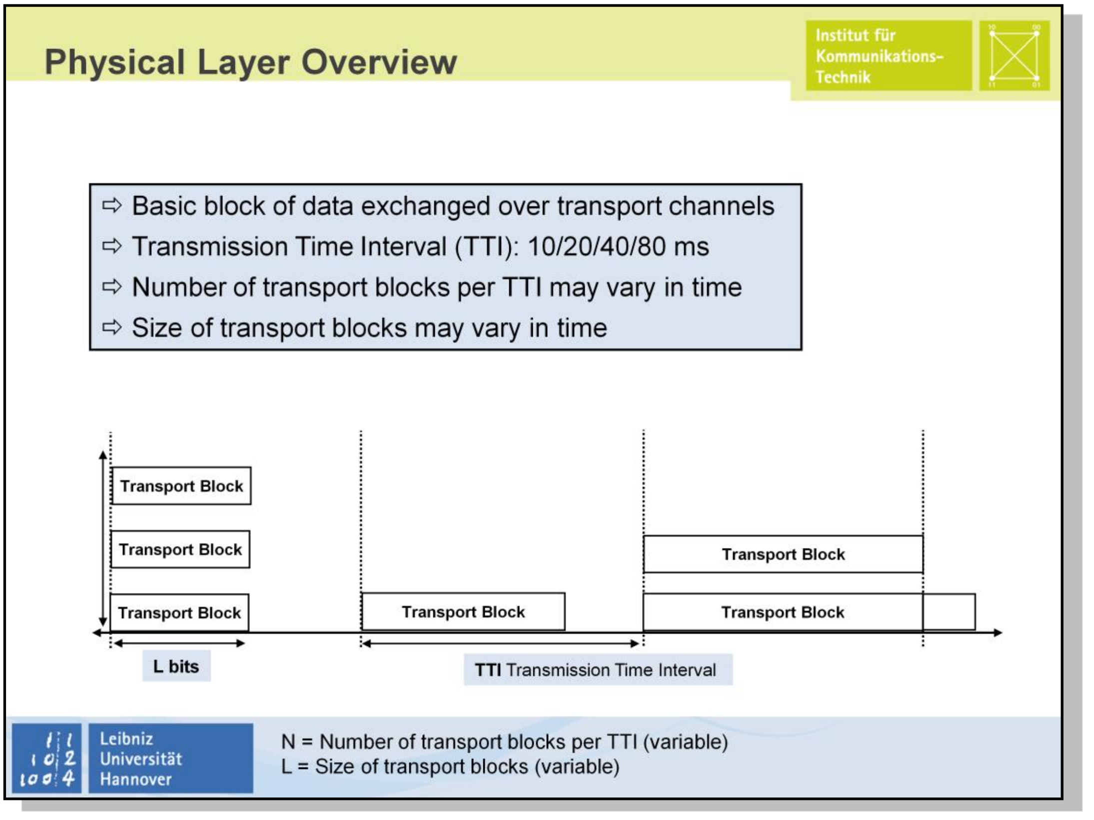


The physical layer

The main task of the physical layer is to „convert“ transport channels delivered from the MAC layer into a (wide-band) radio signal that can be transmitted over the air (from the network to the UE, i.e. in the downlink direction, or from the UE to the network, i.e. in the uplink direction). At the receiver and (UE for downlink, UTRAN for uplink), the physical layer receives the radio signal and processes it to recover the transport channels to be delivered to the receiver MAC layer.



Transport blocks

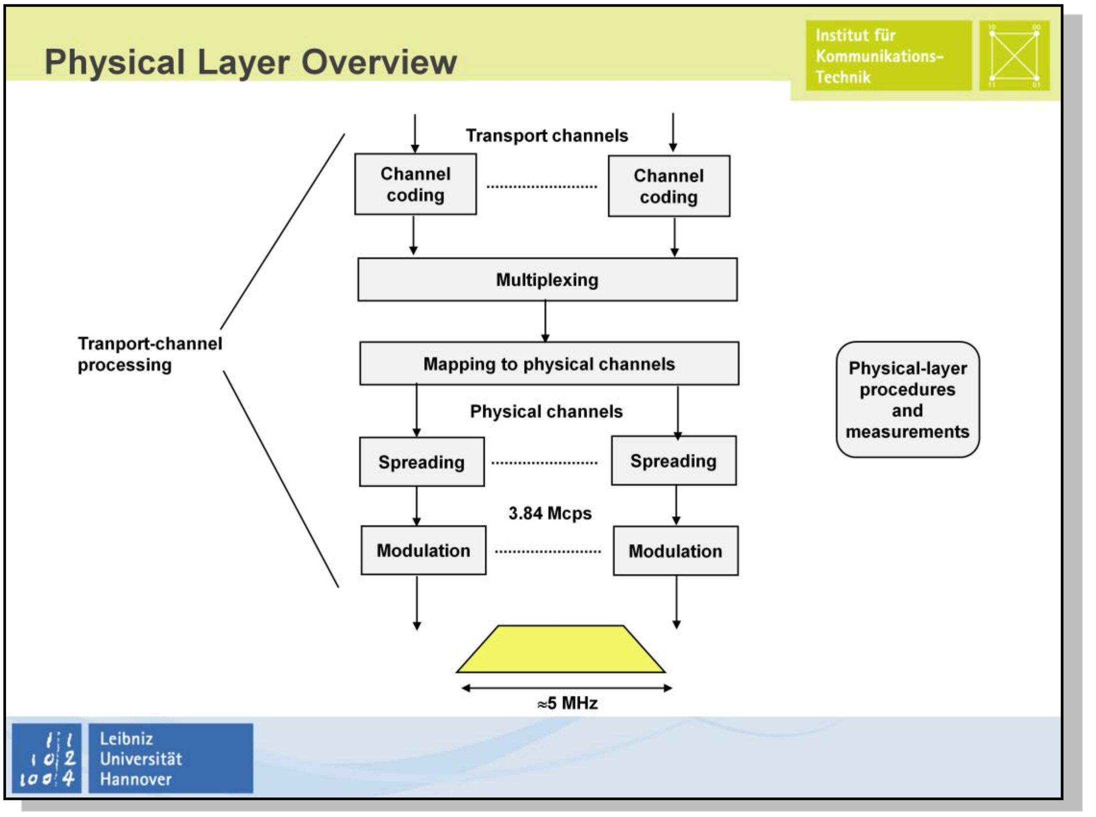
A *Transport Block* is the basic unit exchanged over transport channels, i.e. between the physical layer and the MAC layer.

Transport blocks arrive to or are delivered by the physical layer once every *Transmission Time Interval* (TTI). The TTI is transport-channel specific from the set {10 ms, 20 ms, 40 ms, 80 ms}.

Transport channels support variable-rate transmission in two different ways:

- Number of transport blocks per TTI (N in the figure above) may vary in time.

- Number of bits per transport block (L in the figure above) may vary in time.



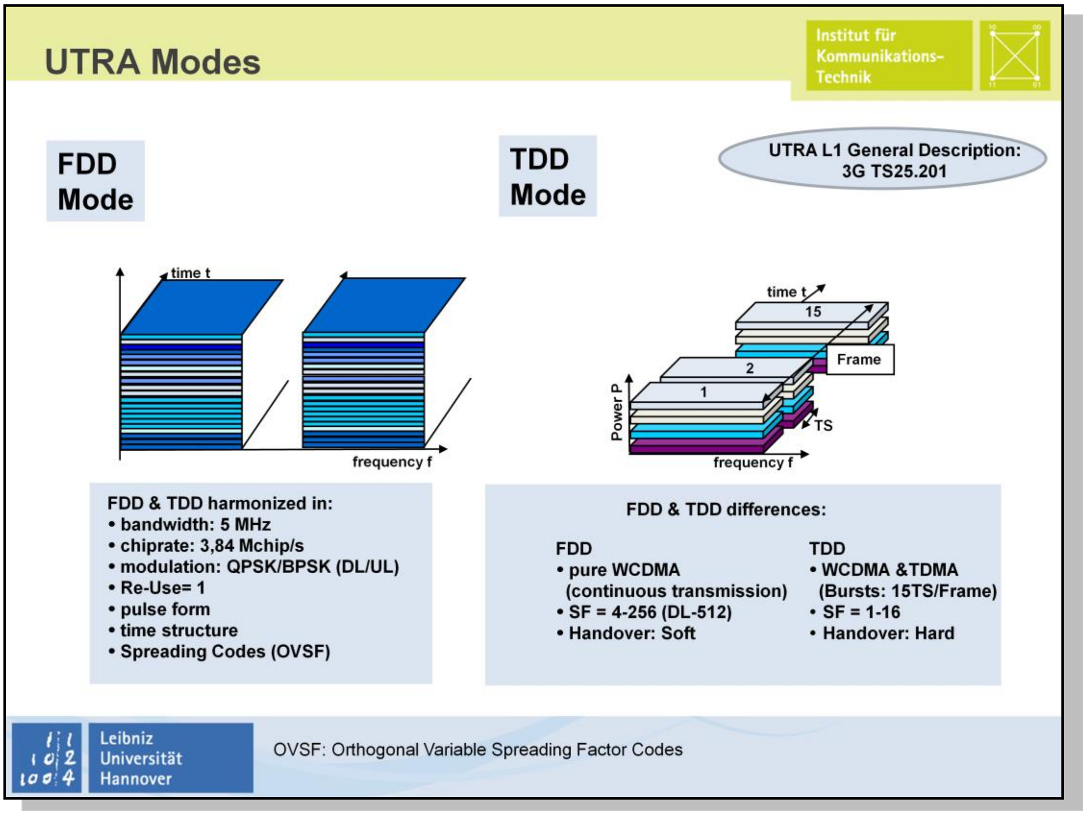
Physical layer overview

The figure illustrates the different processing steps carried out by the physical layer.

Transport channels are basically processed according to the following steps:

- Channel coding (per transport channel)
- Transport-channel multiplexing (in case of multiple transport channels to/from one UE)
- Mapping to physical channels
- Spreading of the physical channels to the chip rate by means of user-specific spreading code. For WCDMA, the chip rate in 3.84 Mcps.
- Modulation of the chip-rate sequence to a radio carrier. For WCDMA, the bandwidth is 5 MHz.

In parallel to the transport-channel processing, the physical layer also carries out some other tasks such as searching for new cells for handover and collection of other measurement data to be delivered to the higher layers.



UTRA TDD / FDD – Common Features

UTRA FDD and TDD modes were harmonized in many central areas – for example::

Bandwidth B =5 MHz (including guard bands)

Chip rate Rc =3.84 Mchip/s

Modulation method: QPSK

Re-use =1 (i.e.,same frequency possible in neighboring cells)

Pulse shape

Timing structure (frame &TS duration – described below))

Spreading codes: based on OVSF (Orthogonal Variable Spreading Factor) codes

UTRA TDD / FDD – Differences

There are also differences in the following central aspects:

FDD uses pure WCDMA (DS-CDMA) for multiplexing. The information is transmitted continuously spread over the entire bandwidth. The shortest duration of a transmission is represented by a frame (10 ms).

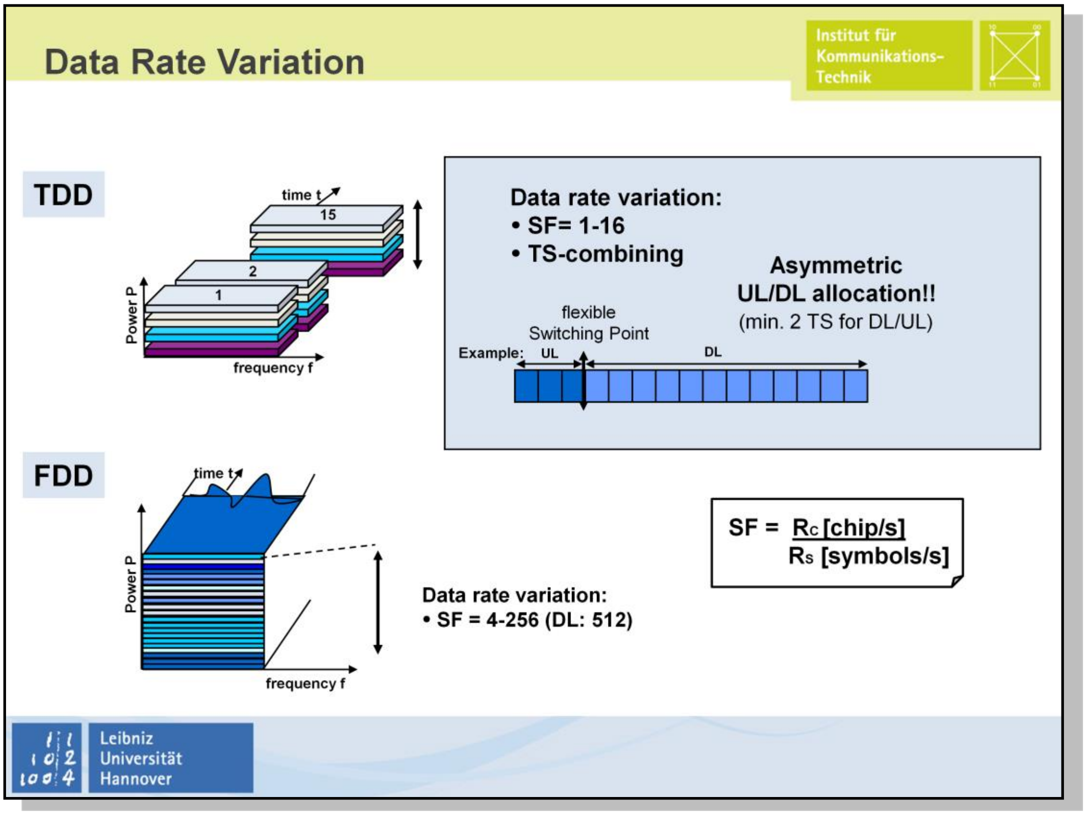
TDD uses a hybrid solution of TDMA and WCDMA (DS-CDMA) as multiplex access.

Like in GSM, the subscriber information is sent in the form of single bursts. A TDMA frame (10 ms) contains 15 timeslots (TS) that can contain bursts from different users (CDMA component).

FDD uses spreading factors of 256 to 4 (UL)or 512 to 4 (DL); TDD uses factors of 16 to 1.

FDD mostly uses soft handover and TDD hard handover (described later).

The 3G TS 25.201 provides an overview of the major common features and differences along with references to individual aspects.



Variation in Data Rate

UMTS allows flexible, dynamic variation of the data rate.The data rate can be varied in different ways in the TDD and FDD modes.

In the FDD mode,the data rate can be varied by SF variation.SF can vary from 256 – 4 ((UL)or from 512 – 4 ((DL). This gives rise to symbol rates from 15 ksymb/s (UL) or 7.5 ksymb(s)(DL) to 960 ksymb/s. This data rate can include the simultaneous transmission of data belonging to different applications of the same subscriber. In other words, multimedia applications are possible.

The data rate can be varied in the TDD mode by SF variation and combination of timeslots (TS). SF can vary from 16 –1, thus yielding symbol rates of 240 ksymb/s to 3.84 Msymb/s. These symbol rates must be regarded under consideration of the 15 timeslots, TS (TDMA component of the TDD mode). In this way, symbol rates from 16 ksymb/s to 256 ksymb/s are available to a subscriber using one TS by varying the SF from 16 to 1. This transmission rate can be increased by combining multiple timeslots in a TDMA frame for one user.

The data rate can also be increased in the TDD and FDD modes by allocating multiple codes to one user (if the UE is capable of doing so). The allocation of multiple codes is useful for different applications belonging to the same user that are served simultaneously. A fine level of granularity of the data rate can be obtained in this way.

Asymmetric Allocation of Frequency Resources

Strongly asymmetric data streams in the UL and DL directions are expected, particularly with regard to the mobile use of the Internet in 3G. Both UTRA modes allow asymmetric transmission of subscriber data. The TDD mode enables network operators to respond in a flexible manner to the asymmetry and to optimise how they use their frequency resources. Different numbers of TS's can be used for UL and DL.

However, at least two of the 15 TS's must remain reserved for UL or DL (for different TDD configuration options, refer to TS 25.221).

UTRA W-CDMA and TD-CDMA - Physical Parameter

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Mode	FDD	TDD
	DS-CDMA	TDMA/CDMA
Chip rate	3.84 MChip/s (Options at 8 and 16 Mchips/s)	HCR: 3.84 Mchip/s LCR: 1.28 Mchip/s (3 frequencies)
Band width	4.4 to 5 MHz (grid of 200 kHz (4,4 to 5MHz)	
Frame duration	10 ms (Adaptation of periodic functions)	
Frame structure	15 slots/frame	HCR: 15 slots/frame (667µs/Slot) LCR: 14 slots/frame (675µs/Slot) + 2 Sync-frames (275µs)
Modulation	QPSK	
Spreading factor	4 - 256 uplink 4 - 512 downlink	1 - 16
Coding	Convolutional codes (1/2, 1/3, 1/4) Turbo-Codes	

2 Mbit/s	384 kBit/s	144 kBit/s
Indoor	Outdoor, Urban	Outdoor, Rural
Low mobility	Medium mobility	High mobility

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Chip: spread symbol

The respective modulation symbol rates vary from 960 k symbols/s to 15 k symbols/s (7.5 k symbols/s) for FDD uplink (downlink), and for TDD the momentary modulation symbol rates shall vary from 3.84 M symbols/s to 240 k symbols/s.

Chiprate:=Symbolrate

Das in UMTS eingesetzte Verfahren zur Realisierung des Codevielfachzugriffs ist das sogenannte Direct Sequence CDMA. Hierbei wird der Nutzdatenstrom (Bits) mit einer teilnehmerspezifischen Codefolge multipliziert. Die Elemente der Codefolge nennt man Chips, um sie von den Bits des Nutzdatenstroms zu unterscheiden.

Unter einem Chip versteht man ein kodiertes binäres Muster, ähnlich dem Bit, nur dass es sich jetzt um ein kodiertes bzw. gespreiztes Signal handelt. Je länger der Code ist, umso größer wird die Datenrate bzw. umso mehr wird dessen Frequenzspektrum „gespreizt“. Das ursprüngliche Bitmuster wird durch die Chips des Codemusters ersetzt, daher spricht man bei kodierten und damit gespreizten Signalen von „Chiprate“. Die Codelänge wird dabei so gewählt, dass das kodierte Signal eine Datenrate von 3.840.000 Chips pro Sekunde hat, was der Chiprate von 3,84Mchip/s entspricht. Diese 3,84Mchip/s ist jene Datenrate, die genau in ein 5MHz-Frequenzband hineinpasst, welches man bei der Frequenzversteigerung erwerben konnte.

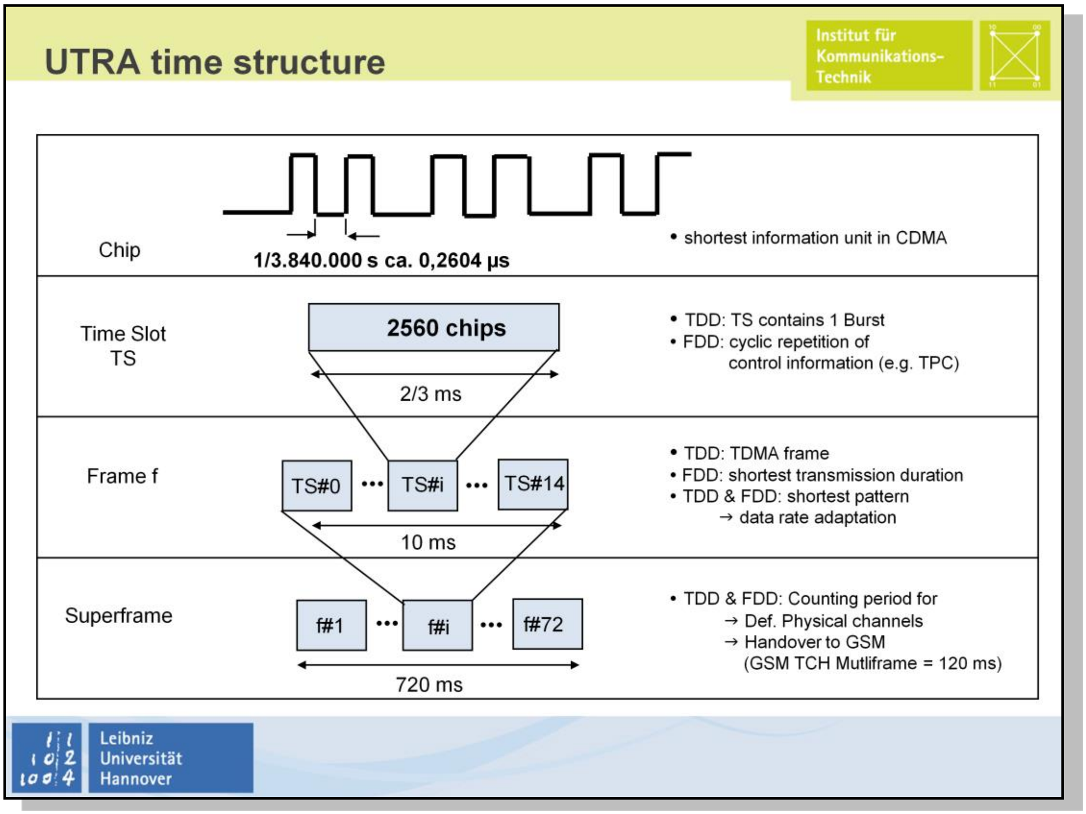
HCR: High Chip Rate

LCR: Low Chip Rate (Frequenzbereich wird in kleinere Bereiche eingeteilt)

Durch geringe Spreizfaktor bei TDD (bis zu 1) wäre eine theoretische höhere Datenrate (FDD:2Mbit/s) möglich, z.B. bei SF=1

$$D_{\max} = 3{,}84\frac{14}{15} = 3{,}584\ MBit/s$$

es können max. 14 von 15 Zeitschlitzen zusammen für Up- bzw. Downlink verwendet werden.



Chip

⇨ The shortest unit of time used in UTRA corresponds to the duration of a chip. Since a chip rate of 3.84 Mchip/s is used, the duration of a chip is about 260.4 pico seconds (ps).

Timeslot (TS)

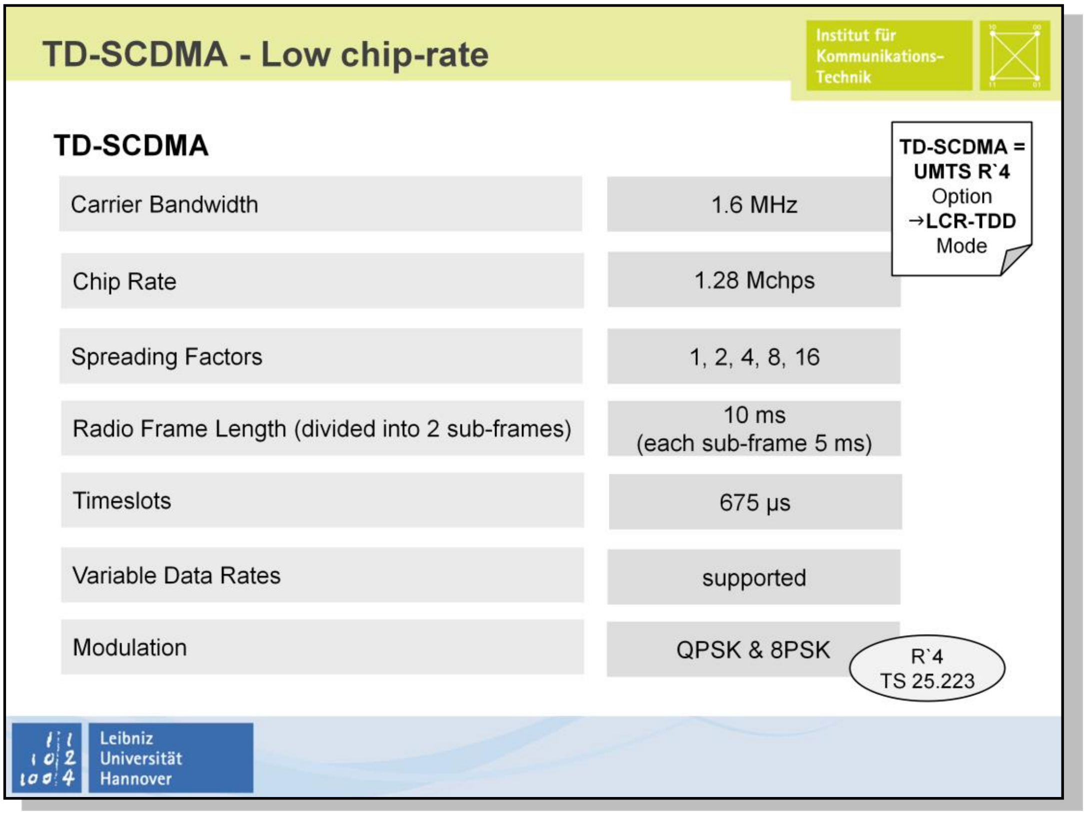
⇨ A UTRA timeslot (TS) is defined as the length of 2560 chips: this corresponds to a duration of 2/3 ms. A timeslot is the shortest repetitive period in UTRA. A timeslot for the TDD mode means the time frame allowed by an HF burst. In the FDD mode specific information is exchanged cyclically between the UE and network. An example of this is the power control information (Transmit Power Control–TPC)).

Frame

⇨ A UTRA frame is defined by the duration of 10 ms. A frame therefore contains 15 timeslots. In the TDD mode, a frame is identical with the TDMA frame – i..e., the cyclical repetitive pattern of the TS's. In the FDD mode, a frame is the shortest possible transmission duration.Short data packets for setting up a connection,for transmission of SMS messages or packet- switched data packets are at least one frame in duration. UTRA is a radio access solution allowing data rates that are not only flexible, but that can also be dynamically adapted. A frame is likewise (for TDD and FDD) the shortest period of time for changing the transmission rate.

Superframe

⇨ A UTRA superframe is defined as the duration of 72 frames – i..e.,720 ms. A superframe is the counting period for defining physical channels. Since it exactly 6 times longer than a traffic channel (TCH)multiframe in GSM (=120 ms), it enables adaptation of the timing patterns between UMTS and GSM – as is essential for inter--system handover between the two systems.



TD-SCDMA / LCR-TDD mode

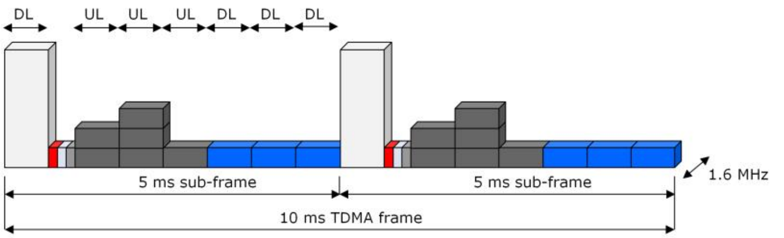
From UMTS Release 4 on, a new RTT option, which has originally been developed by the Chinese SDO CATT, is included into the UMTS standard: Time Division – Synchronous CDMA. TD-SCDMA is included as a second TDD option with a lower chip rate. Therefore, it is called Low Chip Rate TDD mode (LCR-TDD).

The key characteristics of LCR-TDD are:

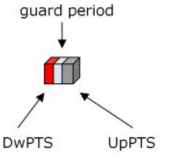
- Bandwidth: 1.6 MHz
- Chip Rate: 1.28 Mchip/s
- Spreading Factor: 1, 2, 4, 8, 16
- Radio Frame Length: 10 ms, subdivided into two 5 ms sub-frames
- Time Slot: 0.675 ms duration; 7 TS per sub-frame
- Data Rate Variation: SF-variation; TS combining; change of modulation; theoretically, a maximum of 2 Mbit/s can be supported
- Modulation: QPSK (Quadrature Phase Shift Keying) and 8PSK (8 Phase Shift Keying)

These key parameters are taken from UMTS R´4 TS 25.223.

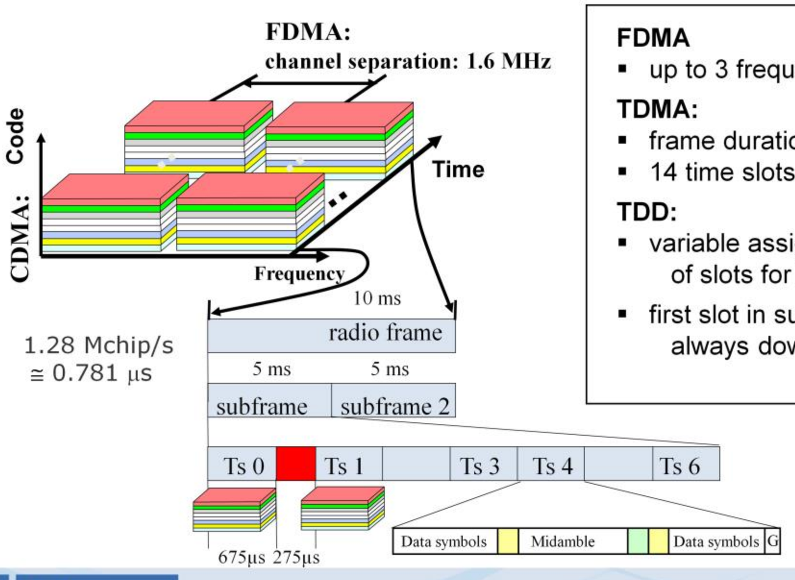
TDD mode, low chip rate option



Multiple access method	CDMA/FDMA/TDMA
Duplex method	TDD
FDMA channel spacing	1.6 MHz
TDMA frame duration	10 ms
TDMA sub-frame duration	5 ms
Timeslots/sub-frame UL	1-6 (of 7)
Timeslots/sub-frame DL	1-6 (of 7)
Modulation rate	1.28 Mchip/s
Modulation	QPSK or 8PSK
Spreading factor UL	1-16
Spreading factor DL	1 or 16



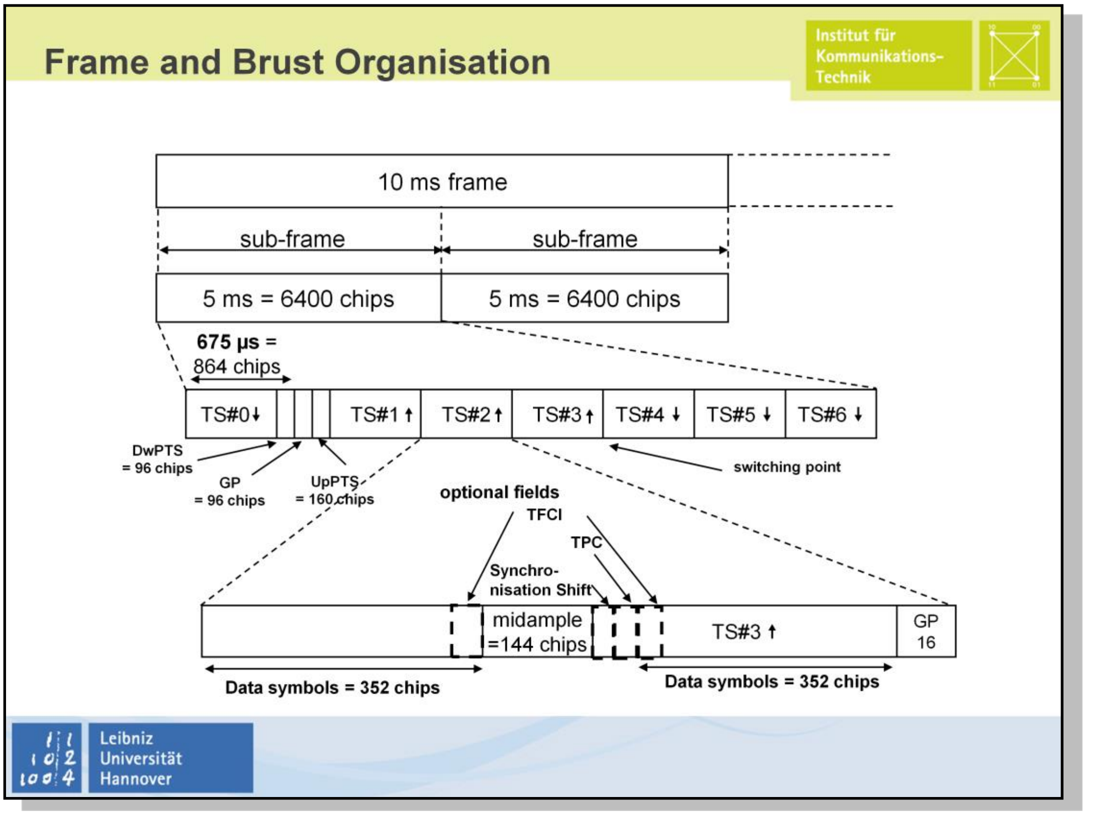
TD-CDMA - low chip-rate



FDMA
- up to 3 frequencies

TDMA:
- frame duration: 10ms
- 14 time slots

TDD:
- variable assignment of slots for DL and UL
- first slot in subframe always downlink



Frame and Burst organization in the TDD low chip rate option

In the TDD low chip rate option, a 10 ms frame is sub-divided into two 5 ms sub-frames. The main reason to introduce the 5 ms sub-frames is to allow.

- a fast update of power control,
- uplink synchronization, and
- smart antenna beamforming

Within a 5 ms sub-frame, 6400 chips are in use. The total number of timeslots, which can be found in a 5 ms sub-frame is 7. Each time slot lasts 864 chips or 675 µs, i.e. the duration of timeslots is not changing in comparison to the high chip rate TDD mode.

TS#0 is always used for downlink, and TS#1 always for uplink. Between TS#0 and TS#1 is therefore one switching point, a point where the direction of the communication is changing. There is only another switching point, which can be dynamically located after TS#1 to TS#6. This is in contrast to the high chip rate TDD mode, where a multitude of switching points are allowed. But given the two switching points in the low chip rate TDD mode, both symmetric and asymmetric traffic can be offered to the subscribers.

Between TS#0 and TS#1, there are three additional fields:

- DwPTS: This field gives the downlink pilot time slot. It`s length is 96 chips. It is used for the air interface synchronization by using a downlink synchronization burst.
- UpPTS: This field is used for the uplink pilot time slot. It lasts 160 chips. It is used for the radio interface synchronization.
- GP: The guard period (GP) is 96 chips long. It therefore supports a cell radius of 11.25 km. As long as the UE is within this cell radius, the UE´s reception of the DwPTS and the UE`s transmission of the UpPTS is not taking place at the same time, i.e. a collision between uplink and downlink is avoided.

There is only type of burst, which is transmitted within the time slot- in contrast to the high chip rate TDD option, where two burst types exist. The burst is logically organized in

- two data symbol fields, each consisting of 352 chips
- one midamble, which consists of 144 chips. The midamble acts like a training sequence in a GSM burst. It is used to determine the middle of the bursts and to adjust the timing advance. Up to 16 different midambles are possible.
- one guard period of 16 chips

Information, which is necessary to manage the radio link, is transmitted within the two data symbol blocks. Hereby, this information is located next the midamble. Three types of radio link management information can be found there:

- TFCI (Transport Format Combination Indicator): The use of the TFCI is negotiated during the call set-up and can be re-negotiated during the call. The TFCI. The TFCI describes, how the media streams where multipliexed for the transmission via the radio interface. For every user, the TFCI information is transmitted only once within a 10 ms frame. It is in use both uplink and downlink.
- TPC (Transport Power Control): When a dedicated channel is established, the TPC is sent both uplink and downlink at least once in one 5 ms sub-frame.
- SS (Synchronization Shift) Symbol: It is provides the possibility of uplink synchronization control (ULSC) within dedicated channels. It is used to command a timing adjustment once per 5 ms sub-frame in the downlink. Every timeslot is controlled independently by an SS command.

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Air-Interface Codes

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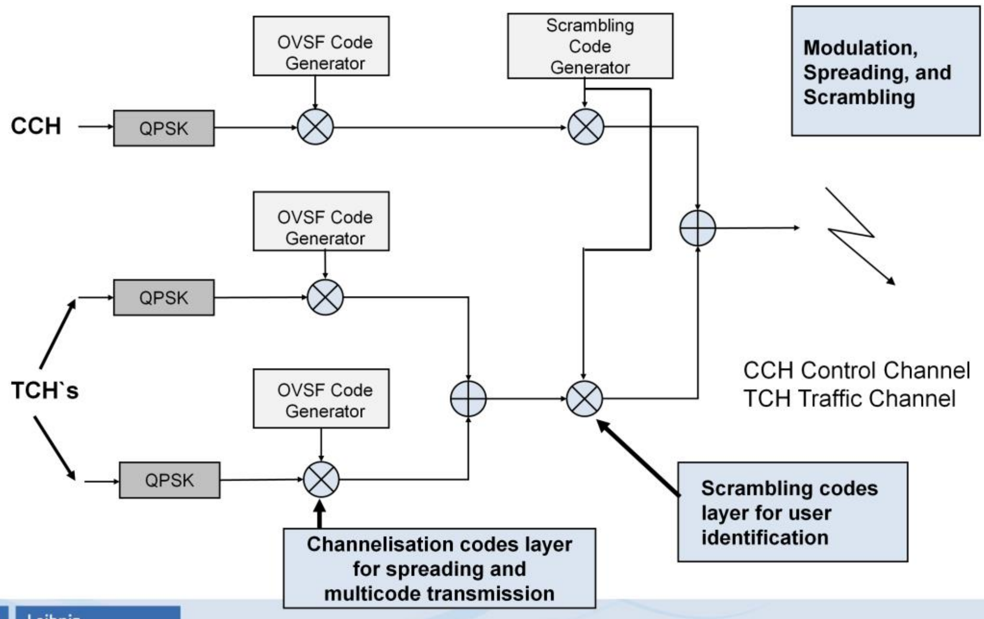

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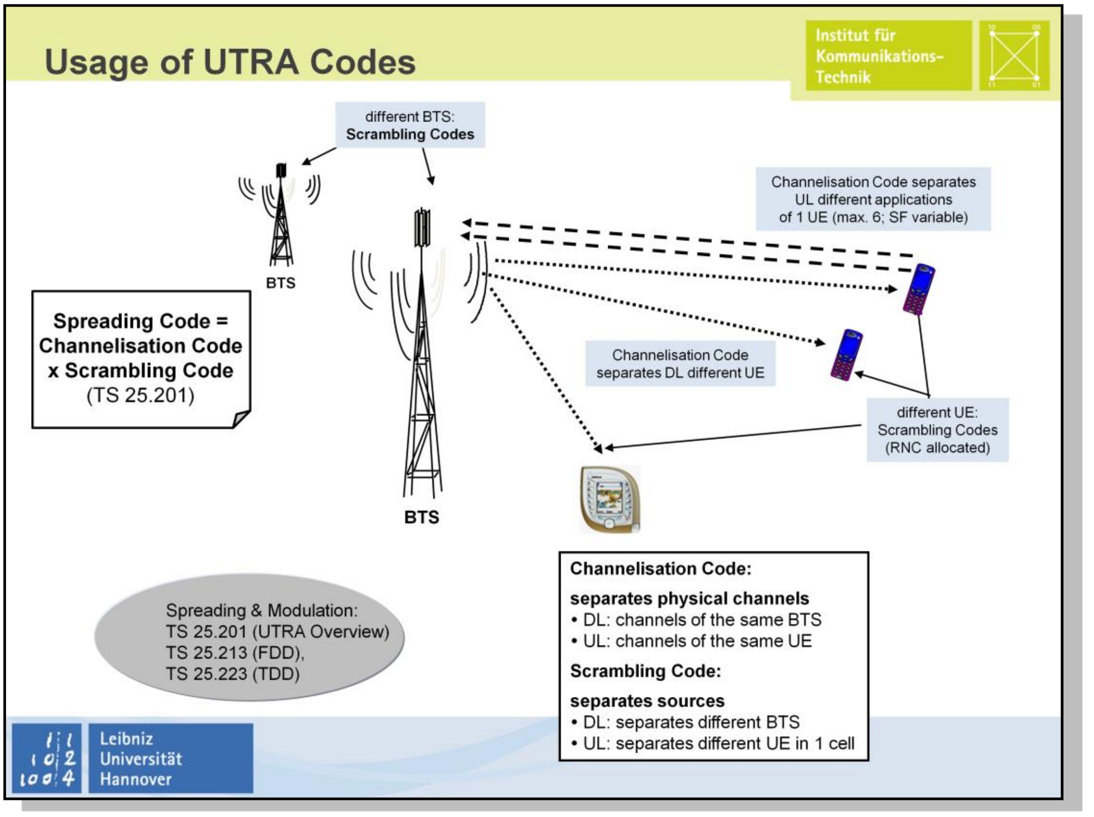


UTRA Codes

The spreading code in UTRA is obtained by multiplying different code types – namely the channelization code and the scrambling code.

Channelization code

Channelization codes are used to separate channels from the same source. For DL this channelization means the separation of different users (or, to take it a step further, different applications of different users)by the BTS. For UL the channelization means the separation of different applications used simultaneously by the same UE.Up to 6 different applications are theoretically possible from individual UE.

The channelization codes for the TDD and FDD modes are Orthogonal Variable Spreading Factor (OVSF)codes and have orthogonal attributes.

Scrambling codes

Scrambling codes are used to separate different sources. For DL this means the separation of different BTS's. Each cell has a scrambling code to allow the UE to distinguish between neighboring cells.The scrambling codes are not globally unique cell codes. For UL the scrambling means the separation of different items of UE in a cell. The scrambling codes are assigned to the UE by UTRAN.

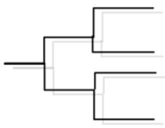
FDD and TDD use different scrambling codes. So-called gold codes 10 ms in length (=38400 chips)are used periodically in FDD. In TDD, sequences of 16 chips are used periodically.

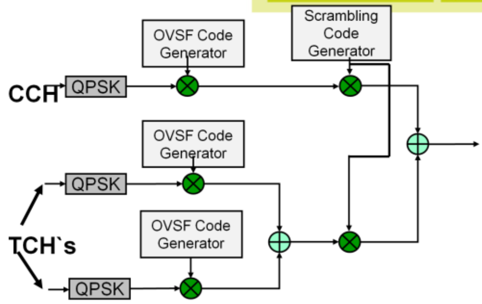
TS 25.201 provides an overview of channelization and scrambling codes. Details on

the channelization and scrambling codes used for FDD and TDD can be found in TS

25.213 and TS 25.223.

Air Interface Codes





Orthogonal Variable Spreading Factor (OVSF) codes used to allow for multicode transmission

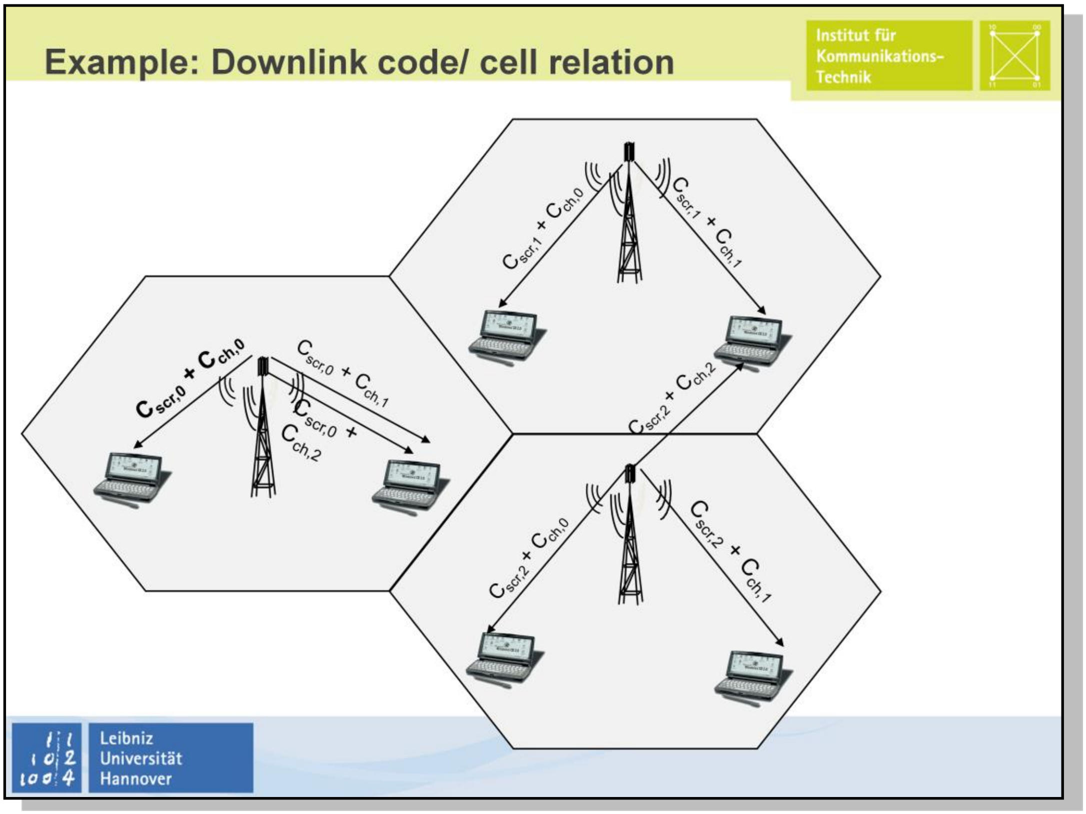
FDD
- Down-link (DL): 4-512 chips
- UP-link (UL): 4-256 chips

TDD
- Up- & down-link: 1-16 chips

Scrambling codes to identify MSs & BSs

FDD
- Short (256 chips) scrambling codes in UL to allow for Multi-User Detection (MUD)
- Long (38400 chips=1 frame) scrambling codes (gold codes) in UL & DL

TDD
- Short (16 chips) scrambling codes to allow MUD in UL & DL



Downlink code/cell relation

In downlink, each cell use different scrambling codes (scrambling codes are reused in a large reuse pattern). Different users within the same cell use different channelization codes. When multi-code transmission ist used, different channelization codes are used for the codes going to one UE.

For users in soft/softer handover, the channelization codes used for the radio links in the different cells are typically different. Also the scrambling codes are different, since the radio links are to different cells.

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Physical Channels

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FDD: spreading code, frequency channel, in UL: phase shift of carrier signal

TDD: spreading code, time slot and frequency channel

Physical Channels

- **Dedicated** Physical Channels (**exclusive use**)
- **Common** Physical Channels (**simultaneous or alternating use**)

Physical Channel:

AICH - Acquisition Indicator Channel
BCH - Broadcast Control Channel
CCPCH - Common Control Physical Channel
CPCH - Common Packet Channel
CPICH - Common Pilot Channel
DCH - Dedicated Channel
DPCH - Dedicated Physical Channel
DPCCH - Dedicated Physical Control Channel
DPDCH - Dedicated Physical Data Channel
PDSCH - Physical Dedicated Shared Channel
PICH - Page Indication Channel
PRACH - Physical Random Access Channel
RACH - Random Access Channel
SCH - Synchronisation Channel

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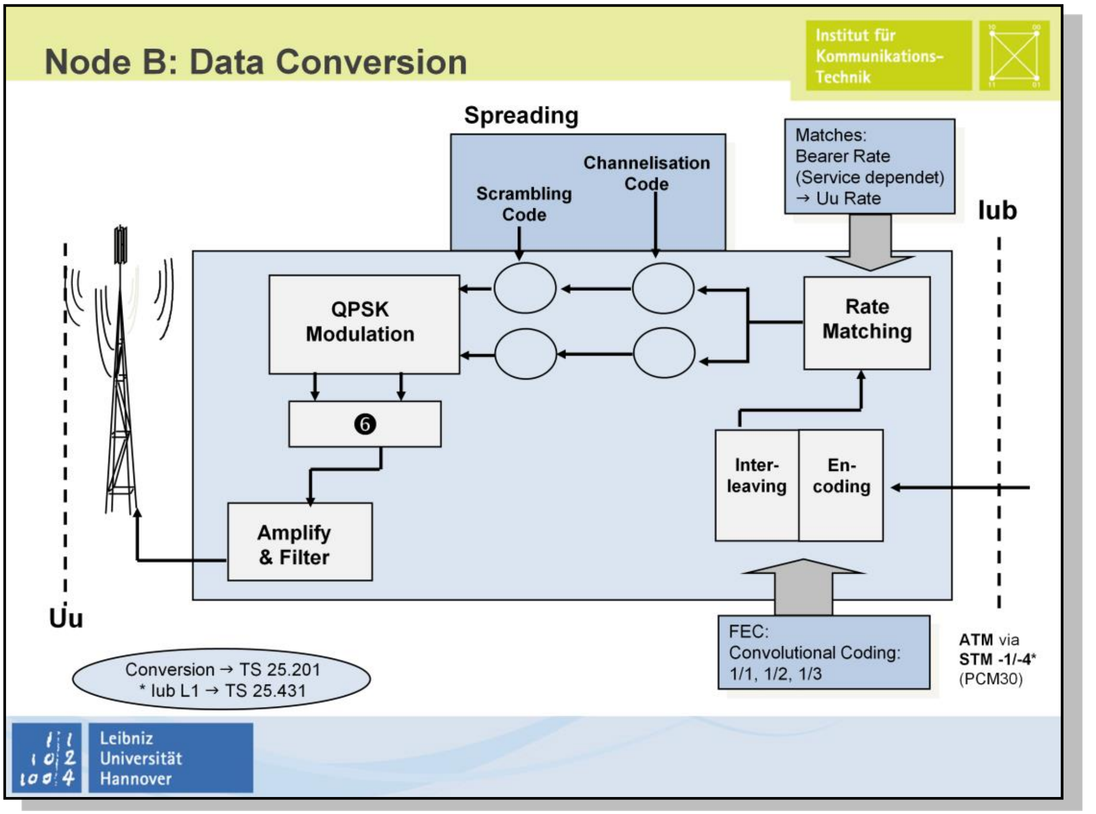


Node B – Data Conversion

A Node B converts user and signalling information received from the RNC via the Iub interface for transport over the radio interface, Uu, and in the opposite direction.

Encoding & Interleaving

This activity includes safeguarding of the data (Forward Error Correction – FEC) for transport over the relatively insecure air interface. The data can be given redundancy – encoding. This is usually accomplished with so-called convolutional coding. The options available in UMTS are 1/1 (no redundancy), 1/2 (each bit redundant) and 1/3 (each bit doubly redundant). In addition, turbo coding is also defined as an option. The redundant information is then de-spread with regard to time – so-called interleaving. The interleaving lengths are between 20 ms and 80 ms according to the data rate used over the Uu.

Rate Matching

After encoding and interleaving, the data rates of the service used must be adapted to the data rates that are possible over the radio interface (the bearer rates). This process is known as rate matching. This adaptation is necessary because only specific data rates are possible for the spreading process.

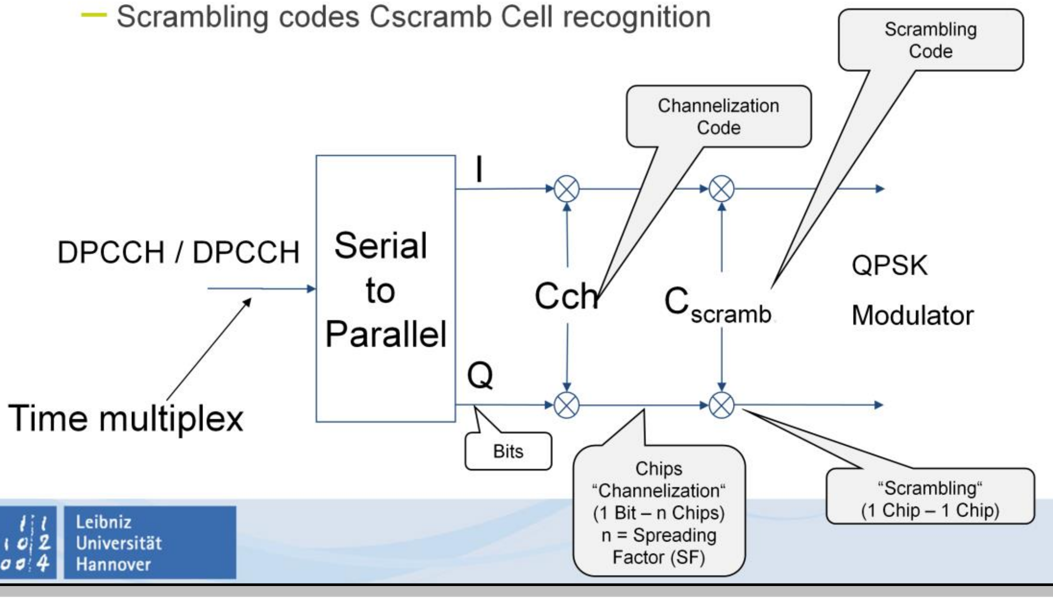
Spreading & Modulation

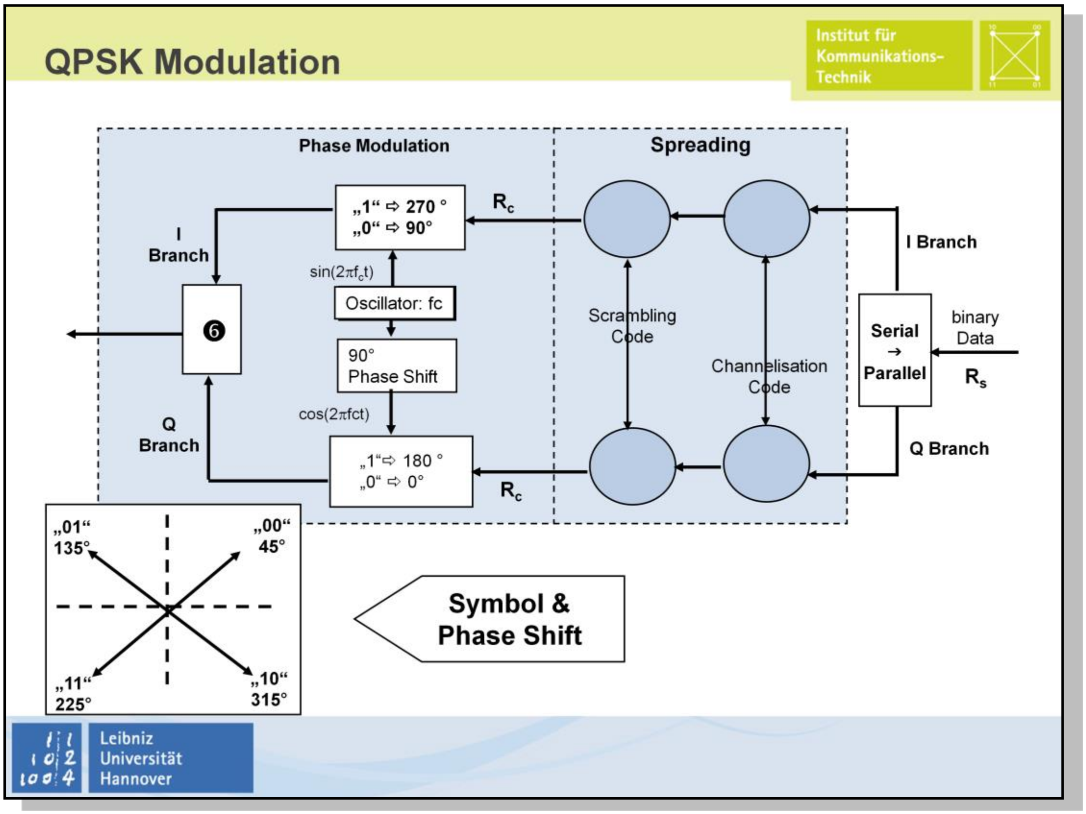
After the rate matching, the data is split into two different branches – an I-branch and a Q-branch. I and Q branches are first separately spread by linking with the channelization and scrambling codes, and are then modulated by QPSK. The resulting HF signals are summed, amplified (under consideration of the power control) and filtered. The HF signal must be filtered in order to prevent interfering sidebands. Interference with other frequency bands should be minimized. 99% of the total radiated power must be contained in the 5-MHz bandwidth of a UMTS frequency band.

For additional details on data conversion for Uu and further references, consult the 3G TS 25.201.

Downlink Channelization and Scrambling (I)

- **Downlink** DPDCH and DPCCH multiplexed
  - Channelization code Cch (OVSF) Rate adaptation
  - Scrambling codes Cscramb Cell recognition





Spreading

⇨ The subscriber data (user data and subscriber signaling data) is split into two different branches (serial – parallel conversion) after the rate matching. The two branches are known as the I- and Q-branches (I for the imaginary, Q for the real part). Both branches are spread with the same spreading code sequences. The channelization code (OVSF code tree) provides the data with its user-specific code.

⇨ The data is adapted to the chip rate of 3.84 Mchip/s. The scrambling code gives the data its BTS-related code. The information can only be reconverted to its original form (de-spreading) by using the same synchronized code in the UE.

QPSK Modulation

⇨ The spreading process is followed by the modulation of the data. UMTS uses Quadrature Phase Shift Keying (QPSK) to modulate. Phase Shift Keying (PSK) means that the information is transmitted in the form of shifts in the phase of the carrier frequency. Quadrature PSK means that a total of four different phase shifting options are available. They each allow a 2-bit pair to be represented as a single information unit: '00', '01', '10' and '11'. The information unit transmitted over the radio interface is known as a symbol. A symbol therefore has 2 bits in the QPSK modulation method used in UMTS.

⇨ The information in the I-branch is represented as the phase shift of a carrier frequency generated by an oscillator. The representation of a '1' results in a phase shift of 270°, the representation of a '0' in a phase shift of 90°. The phase of the carrier wave is shifted by 90° for the Q-branch. The representation of '1' or '0' results in a phase shift of 180° or 0° respectively for this branch. After then adding the I- and Q-branches together, the four possible phase shifts of 45°, 135°, 225° and 315° shown in the phase diagram are obtained. These shifts represent the symbol information '00', '01', '11' and '10'.

⇨ Details on the topics of spreading and modulation can be found in the 3G TS 25.213 and 25.223 (FDD / TDD).

Multicode Transmisson (FDD) Downlink

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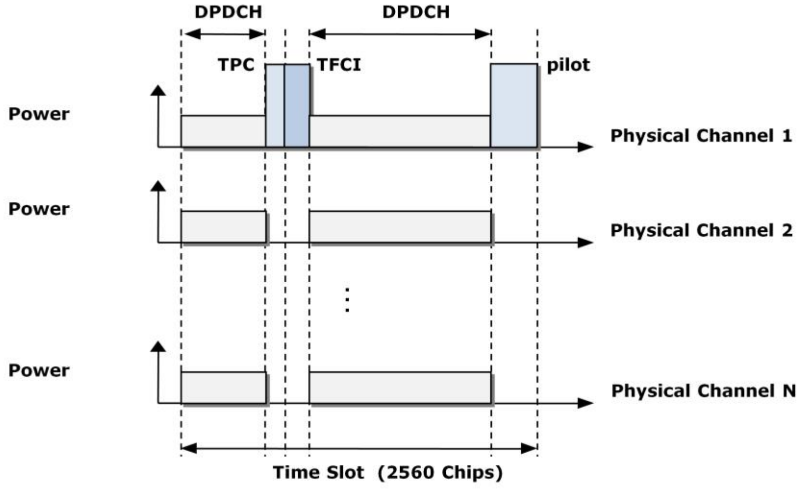

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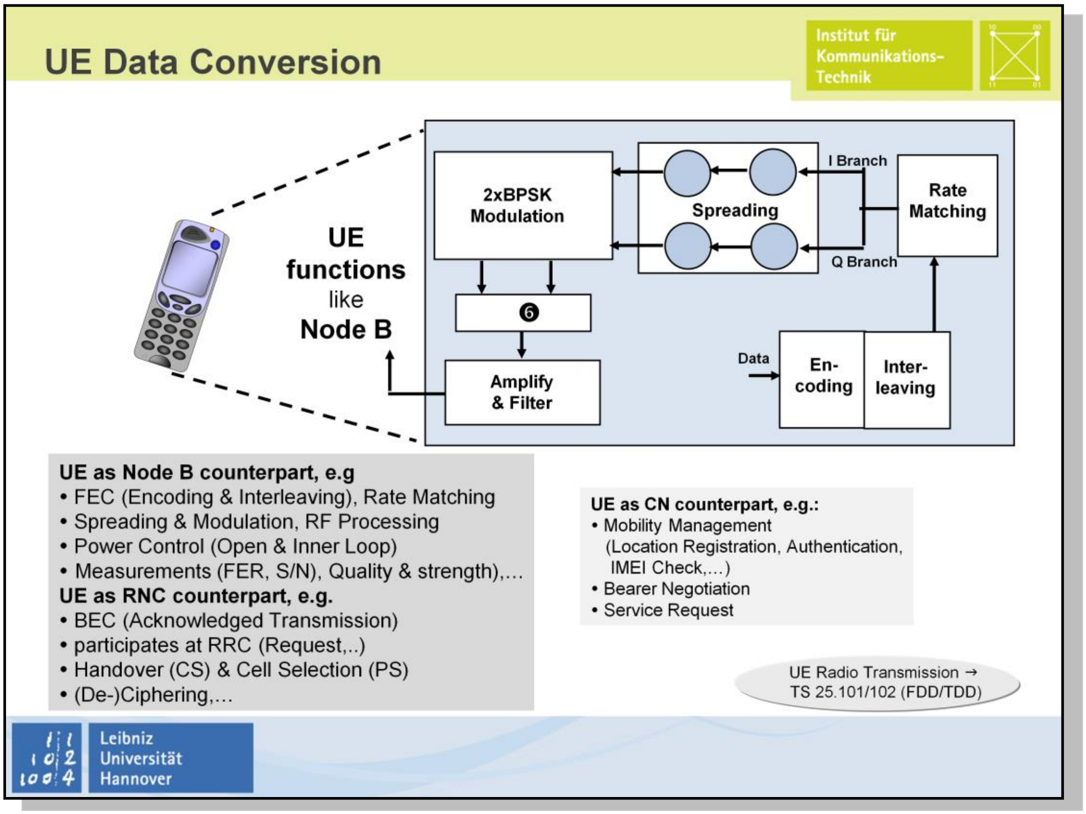


User Equipment (UE) Functions

With regard to functions, UE is a mirror image of the UTRAN and CN. In terms of radio transmission, UE is the opposite of a Node B.

Data for transmission is likewise provided with redundancy and spread using encoding and interleaving processes in order to prevent any loss of data during radio transmission.

In addition, the transmission rate must be adapted in a rate matching process to the data rates possible after the spreading.

The data is split into I- and Q-branches and spread using channelization and spreading codes. Unlike the Node B, the channelization code in UE is used to distinguish different applications of the same UE, while the scrambling code is used to identify the UE. The FDD mode has a particular attribute: user data and user-related signaling data pass separately through the I- or Q-branch and are assigned different channelization codes (different SF's are possible).

The data is modulated by QPSK, summed, amplified, filtered and routed to the UE antenna.

Regarding the power control (PC), the UE is also the counterpart to the Node B. Open and Inner Loop PC's are used for power control of the UE, TPC information is exchanged with the Node B for the Inner Loop PC. The UE receives comparison values for Inner Loop PC from the RNC. Like the Node B, the UE constantly measures the quality and strength of a link, the interference level and also the strength of the near BTS's. The data is sent to the Node B and from there is transmitted together with the Node B measurements to the RNC in a measurement report.

In regard to many of its functions, the UE is the opposite of the RNC. Like the RNC, however, the UE is involved in Backward Error Correction (BEC) for Non-Real Time (NRT) Transmission (Acknowledged Mode).

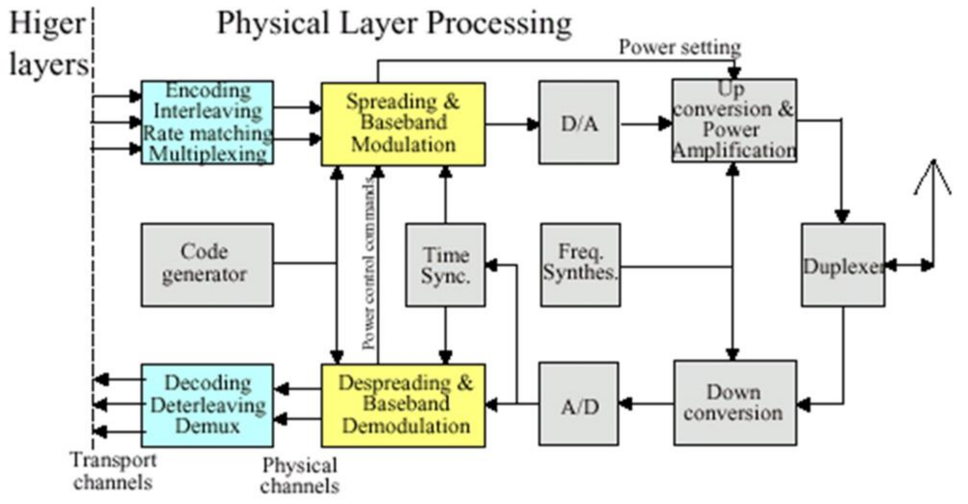
The UE is the counterpart to the RNC in regard to the Radio Resource Control (RRC). It requests allocation of radio resources, plays the opposing role during renegotiations, sets up contact during handovers (at the request of the RNC) to the new BTS's and is alone responsible for cell selection during PS transmission. The UE is also the counterpart during ciphering and deciphering.

The UE is the counterpart to the Core Network (CN) in many of its functions.

The UE participates in Mobility Management, initiates updates to the location information (Location Registration / Update for VLR / SGSN), is the counterpart during authentication and IMEI checks, and does much more.

In addition, the UE communicates directly with the CN to negotiate bearer capacity and to request special services.

UE transceiver structure



Multicode Transmission (FDD) Uplink

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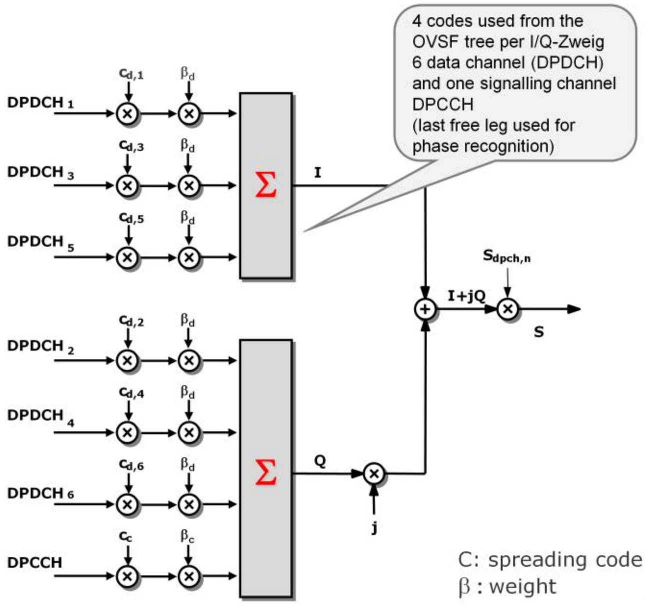

C: spreading code
β : weight

Up to 6 DPDCH in parallel

Different channelization (spreading) codes but same spreading factor for all branches

One DPCCH per connection

Weighting of branches for power adjustment

One DPDCH branch is either mapped to the I- or the Q-branch of the modulation and thus transmitted via BPSK

(the sum is transmitted via QPSK)

Possible Data Rates

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DPDCH Spreading factor	Channel bitrate kbit/s	Max. user rate based on code rate ½ (ca.)
256	15	7,5 kbit/s
128	30	15 kbit/s
64	60	30 kbit/s
32	120	60 kbit/s
16	240	120 kbit/s
8	480	240 kbit/s
4	960	480 kbit/s
4 with 6 parallel codes	5740	2.3 Mbit/s

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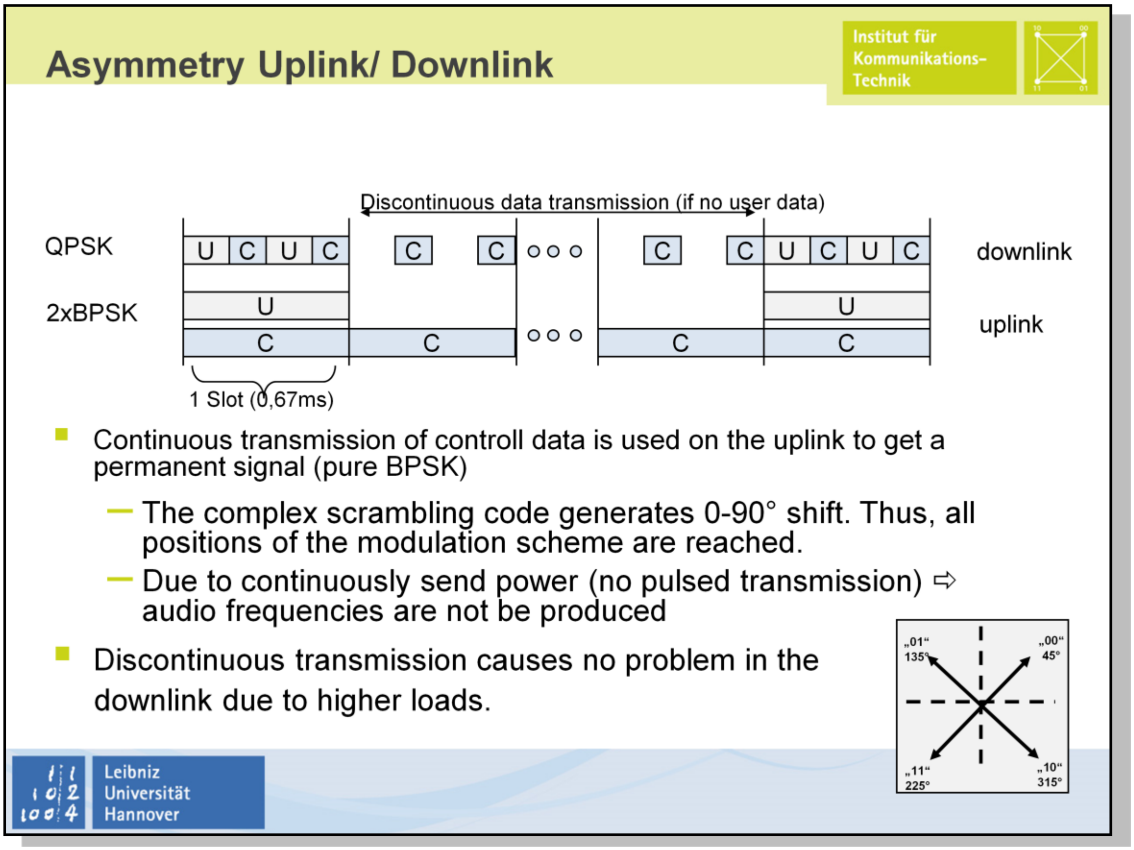


Im Uplink werden Kontroll- und Nutzdaten auf getrennten physikalischen Kanälen übertragen:

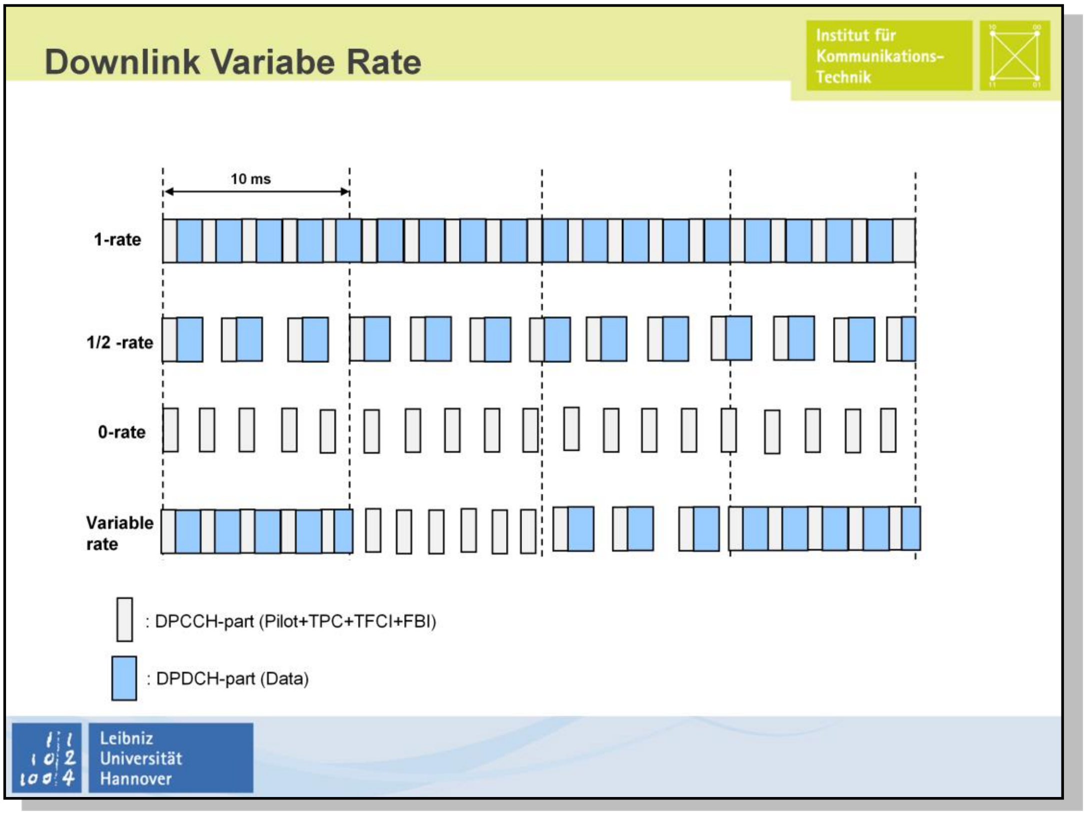
•Nutzdaten im DPDCH (dedicated physical data channel)

•Kontrolldaten im DPCCH (dedicated physical control channel)

Eine getrennte Modulierung der physikalischen Kanäle mit einer BPSK sorgt für eine kontinuierliche Übertragung von Daten über die Zeit, so dass die Sendeleistung nicht mehr getaktet wird -> keine hörbaren Audiofrequenzen

Ein komplexer Scrambling-Code sorgt anschließend dafür, dass Kontroll- uind Nutzdaten um 90° gegeneinander gedreht werden, was im Prinzip wieder eine QPSK ergibt

Im downlink werden Kontroll- und Nutzdaten im Zeitmultiplex übertragen und über eine QPSK moduliert. Da eine Basisstation I.A. an mehrere Mobilstationen gleichzeitig sendet, ergibt sich aufgrund der höheren Auslastung der Rahmen kaum eine diskontinuierliche Übertragung.



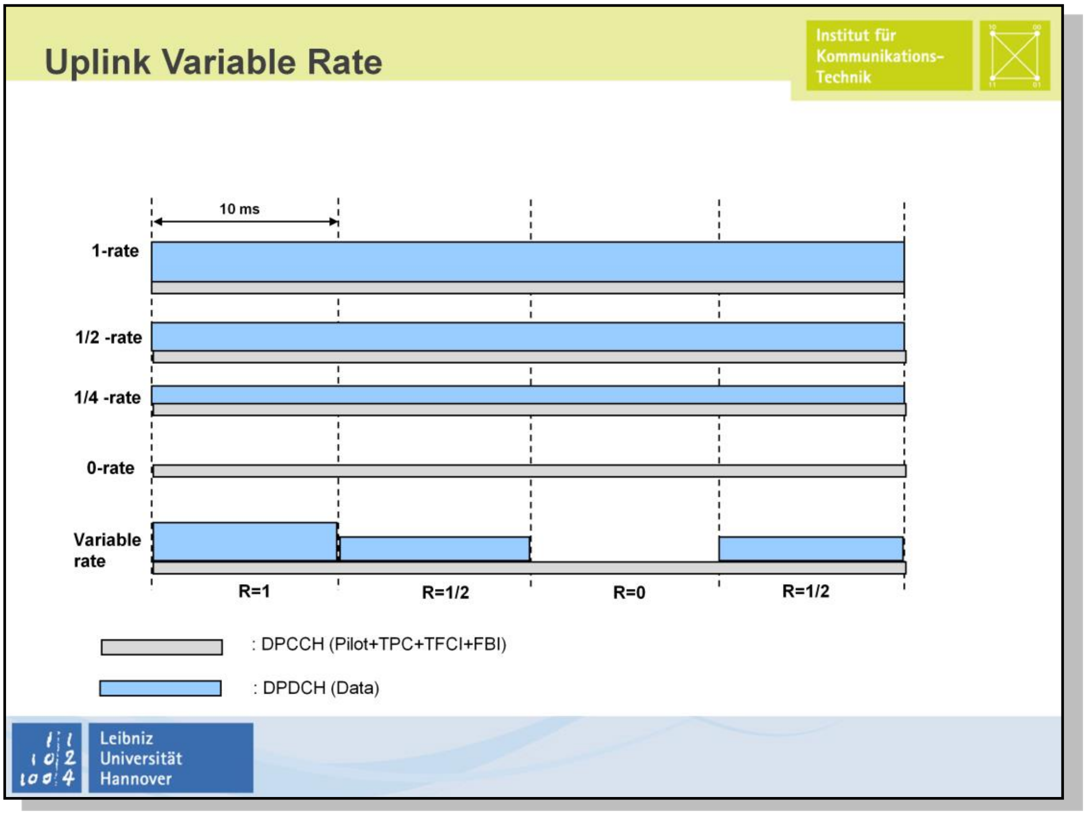
Downlink variable rate

For the downlink DPCH, DTX is used if the transport channels cannot completely fill the physical channel.

Thus DTX transmission is used, but the physical channel is transmitted with fixed power (except for the power control).

Thus, power control measurements can be done on the received downlink DPCH.

Note that the figure describes the principle, the number of slots per frame and the structure of the DPCCH information is different in reality.

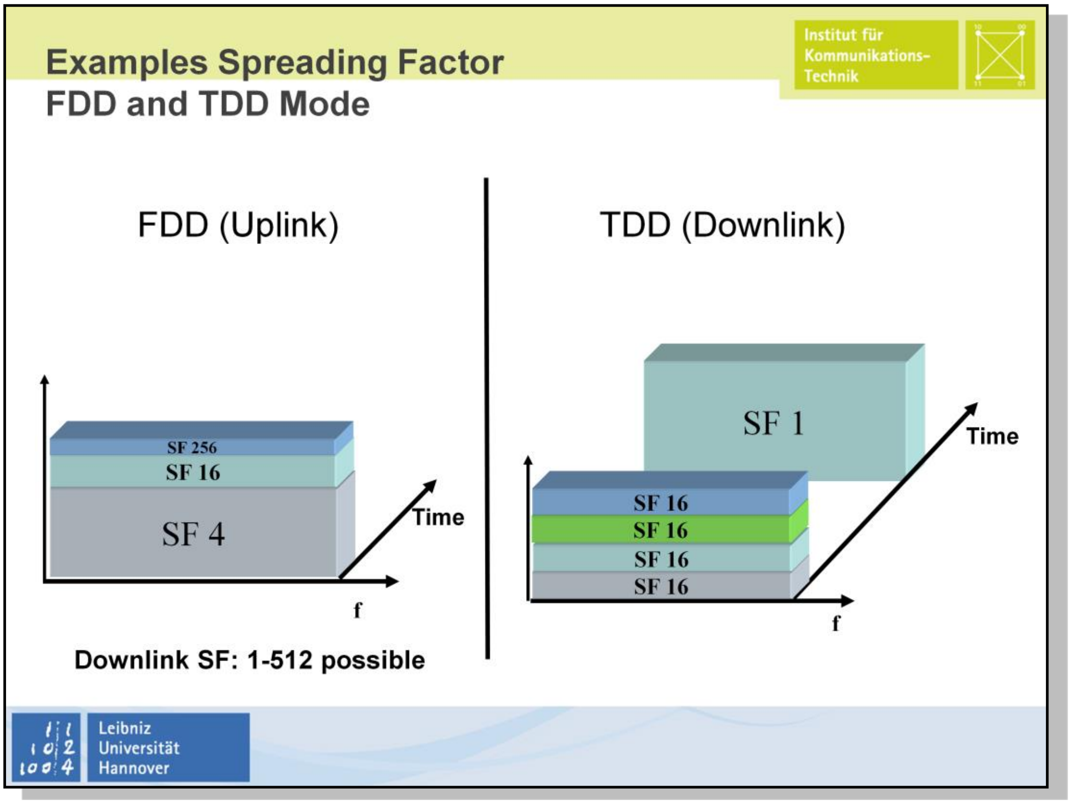


<u>Uplink variable rate</u>

For the uplink DPCH, DTX is not used if the transport channels can not completely fill the physical channel. Instead, the uplink DPCH transmit power depends on the instantaneous rate.

Thus, power control measurements can not be done on the received uplink DPDCH but are instead done on the fixed rate uplink DPCCH.

This is the reason for the different structure of downlink and uplink physical channels.

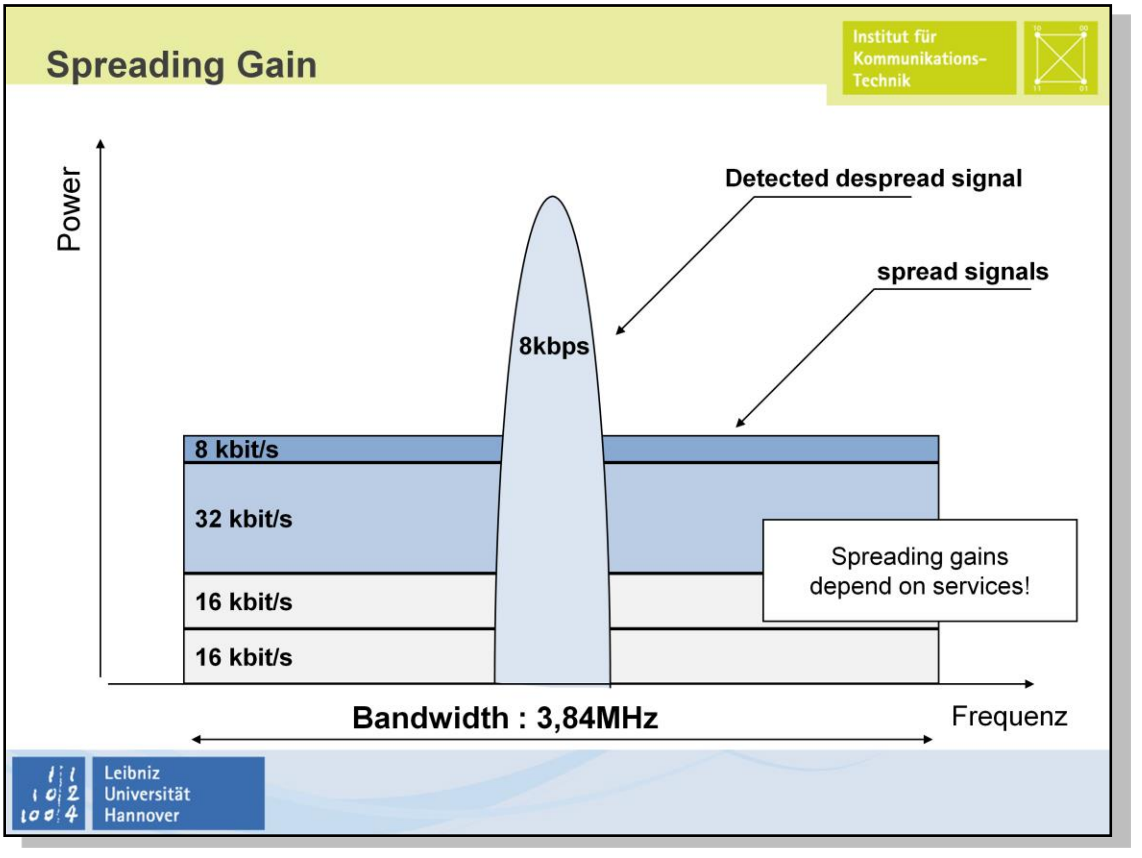


FDD:

Spreizfaktor UL: 4-256   Downlink 4-512 (es sind alle binären Spreizfaktoren möglich)

TDD:

Spreizfaktor UL: 1-16   Downlink: 1 oder 16 (in jedem Zeitschlitz möglicherweise unterschiedlich)



Beim Empfänger kommen typischerweise mehrere Teilnehmersignale überlagert an. Im Empfänger wird die Summe aus Teilnehmer – und Störsignal mit dem Spreizcode des Teilnehmers multipliziert und lässt sich sein Signal extrahieren. Dadurch wird die ursprüngliche Bitfolge des Teilnehmers wieder rekonstruiert, das entstehende Signal hat eine um den Spreizfaktor geringere Bandbreite als das gespreizte Signal. Die Leistungsdichte des Störsignals verringert sich um den Spreizfaktor, während sich die Leistungsdichte des Teilnehmersignals um den Spreizfaktor erhöht. Die Signale übriger Teilnehmer und auch das Rauschen bleiben hingegen nach dieser Operation weiterhin im Spektrum verschmiert und aber gegenüber dem Nutzsignal schwächer.

Outline Part IV

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1. Overview Radio Interface: Timing and Codes
2. Codes/ OSVF
3. Data rates – Spreading Factor
4. Coding/ Interleaving
5. Power Control
6. Handover
7. CAC
8. Timing Advance

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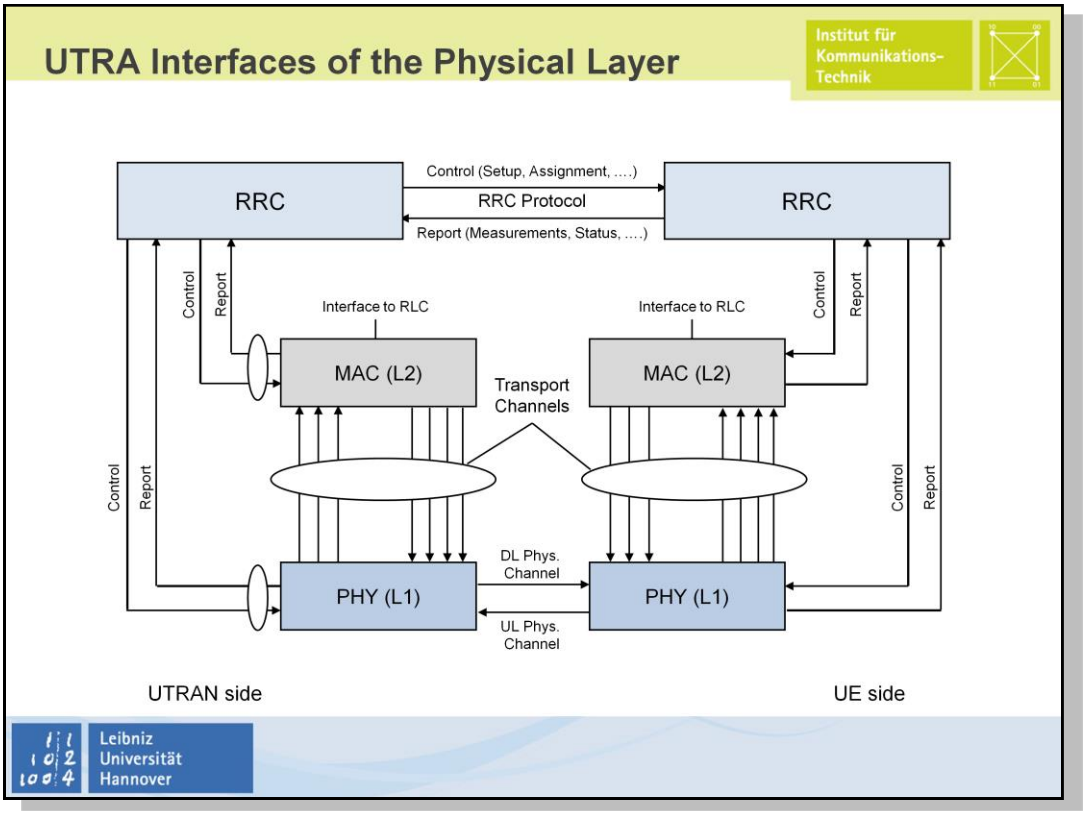

RRC Radio Resource Control

MAC Media Access Control

Physical Layer FDD Downlink

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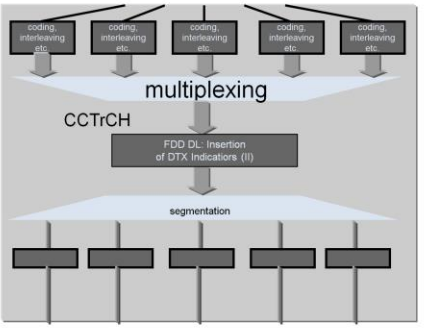
⇨High number of simultaneously active physical channels

⇨Alteration of the spreading factor has to be signalled (>10ms)

⇨Variable data rates realised by multicode-transmission or DTX

Insertion of DTX indicators for turning the transmitter to mute



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FDD Downlink

CRC Attachment	attach a checksum sequence
Transport block concatenation/ segmentation	create data block suitable for coding
Channel Coding	blockwise coding, convolutional or turbo coding, rate 1/2 or 1/3
Rate Matching	framewise matching of the data rate to realize variable transmisstion rates
Insertion of DTX Indication (I)	switch off the transmitter if DTX active (fixed positions)
First Interleaving	inter-frame interleaving >10ms
Radio Frame Segmentation	split the data to fit into multiple radio frames

Example:
12.2 kbps transport channel (speech)

Parameter	DCH	DCH
Transport Channel Number	1	2
Transport Block Size	244 bit	100 bit
Transport Block Set Size	244 bit	100 bit
Transmission Time Interval	20 ms	40 ms
Type of Error Protection	Convolution Coding	Convolution Coding
Coding Rate	1/3	1/3
Rate Matching attribute	256	256
Size of CRC	16 bit	12 bit
Position of TrCH in radio frame	fixed	fixed

Physical layer

Parameter	TDD	FDD
Information data rate [kbit/s]	12.2	12.2
Burst	type 1	Format 2
Interleaving	20 ms	20 ms
TFCI	16 bit/user	on
DPCCH [kbit/s]	2	14
DPDCH [kbit/s]	48,8	60
Spreading factor	8	64
Puncturing DCH/DCCH	5% / 0%	0%
Repetition	0%	23%

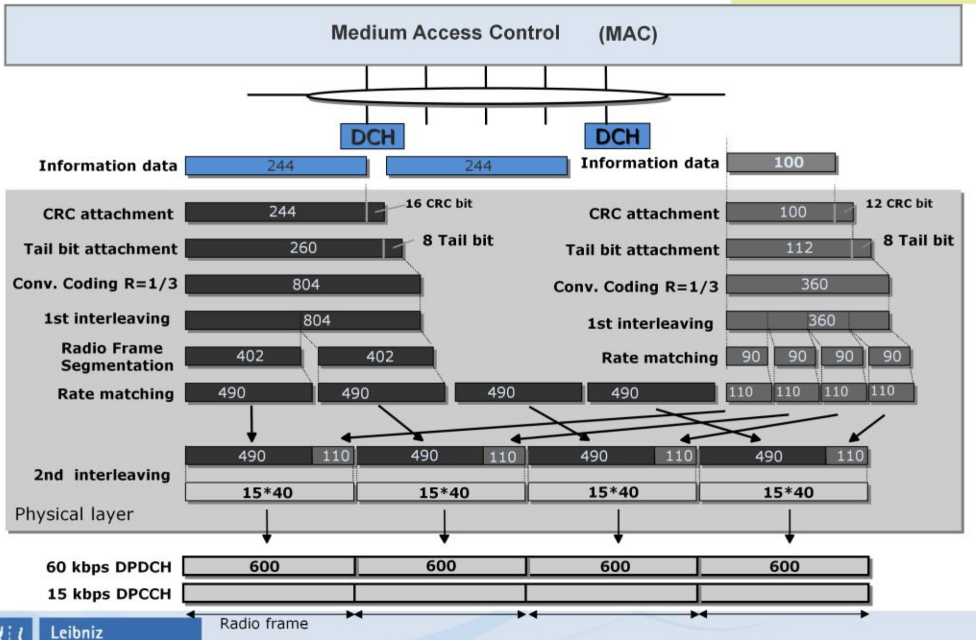
Example of a data transmission using two different transport channel (Dedicated Channel DCH). The transport format defines witch parameter set has to be used.

The first transport block (244bit) will be transmitted every 20 ms. Thus, a net data transmission rate of 12 kbit/s is achieved and the code rate is 1/3. A second block (100 bit) is being transmitted every 40ms. Both blocks are multiplexed and segmented to be transmitted over the same channel. This is done by sending 50 % of the first block and one quarter of the second every 10 ms.

Depending on the radio conditions the transmission could be done by a channel (FDD-Modus) with a spreading factor of 64 and 64 kbit/s gross bit rate. As the to be transmitted date is less than the capacity some date is added to match the transmission rate.

If the TDD mode is used with a spreading factor of 8 and one time slot, the channel would have a capacity of 48 kbit/s and 5% of the bit would have to be removed to match the data rate.

Example: FDD Mode



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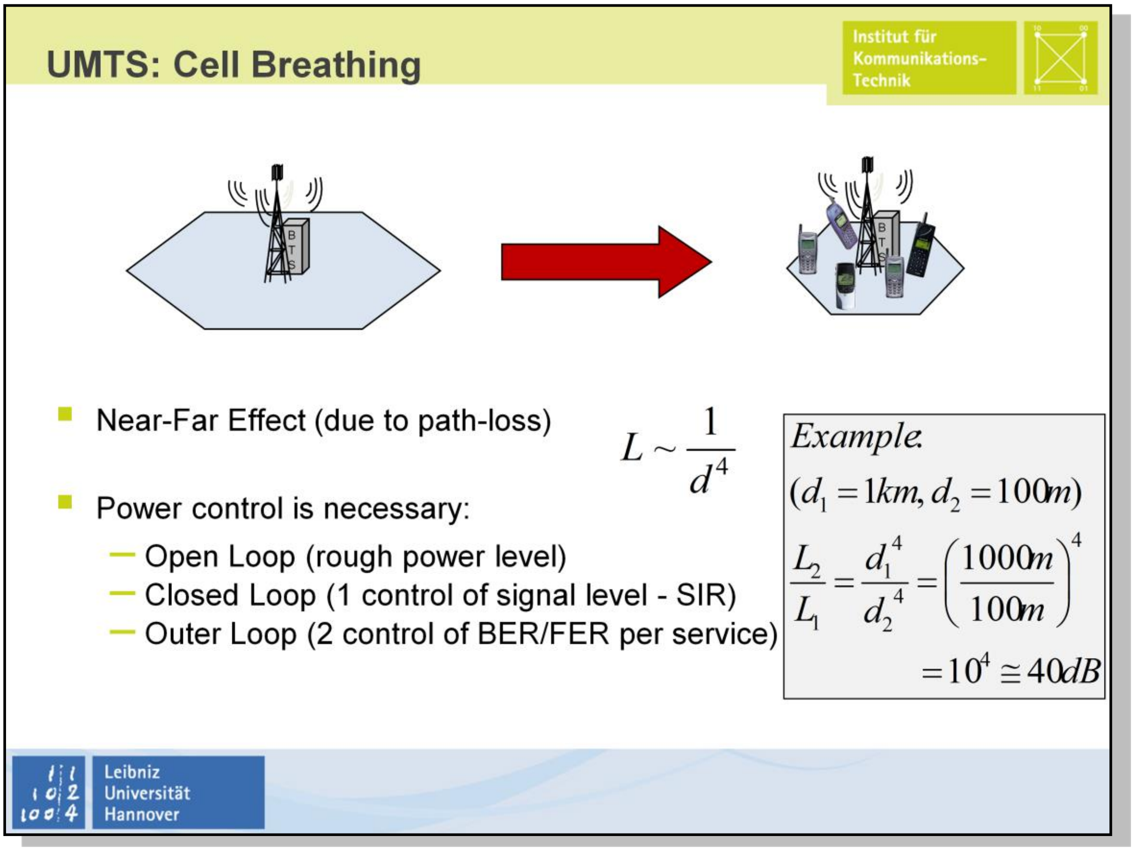
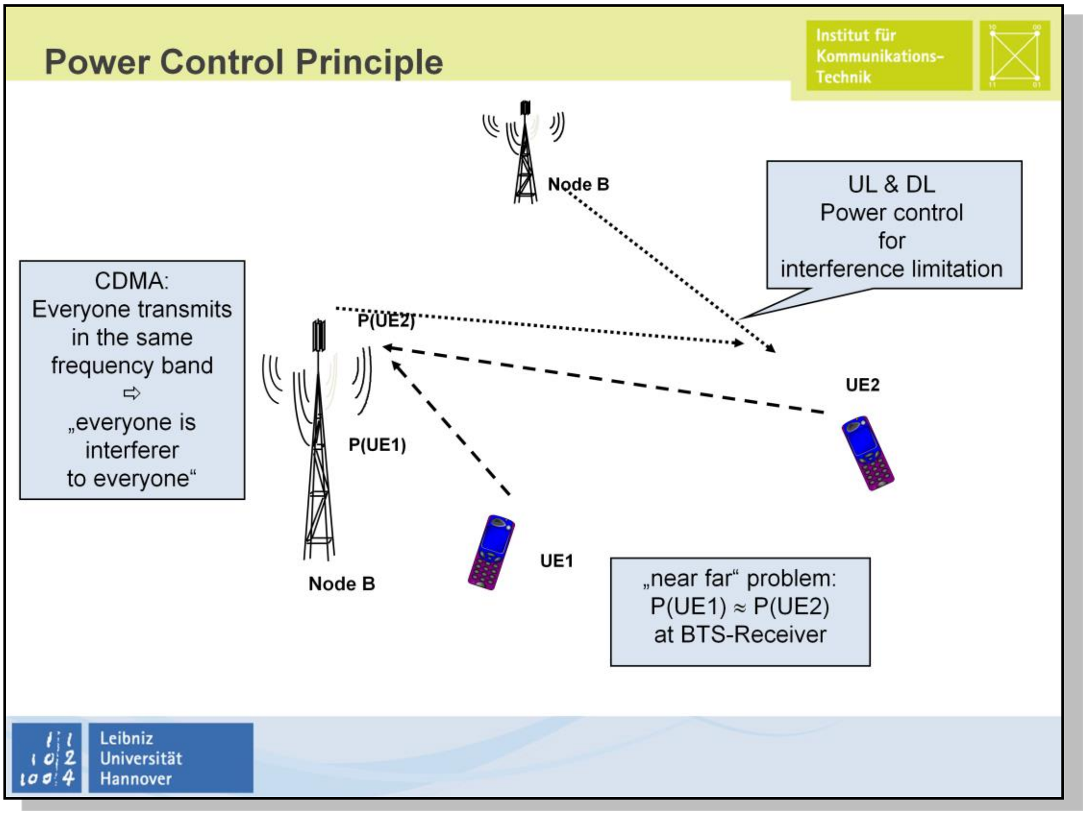


Die Leistungssteuerung in UMTS ist ein wichtiger Mechanismus zur Vermeidung des Nah-Fern-Effektes. Dieser Effekt tritt auf, wenn die Mobilstationen, die nahe der Basisstation sind, mit höherer Leistung senden als eigentlich erforderlich. Dadurch wird das Sendesignal der MS an der Basisstation stärker empfangen als das der weiter entfernten MS in der Zelle. Ohne Gegenmaßnahmen würde sich sowohl die Dienstgüte als auch die Kapazität deutlich reduzieren. In FDMA/TDMA Systemen, wie GSM, besteht nur eine geringe gegenseitige Beeinflussung unterschiedlicher Kanäle. In CDMA Systemen ist das anders, da alle Teilnehmer das gleicher Frequenzband verwenden. Daher eine schnelle und präzise Leistungsregelung notwendig. Das Verhältnis von Signalleistung zu Interferenzleistung (C/I) wird unter Berücksichtigung Parametern (z.B. Verkehrslast in der Zelle) ständig nachgeregelt. Dazu wird in der Regel ein eigener Kanal verwendet.

Nehmen wir an, eine beliebige Zelle in einem UMTS-Netz muss genau einen Teilnehmer versorgen welcher sich aber am äußersten Rand ihres Versorgungsbereichs aufhält. Damit das Signal unseres Testteilnehmers an der Antenne der Zelle mit der zur Decodierung mindestens erforderlichen Stärke eintrifft, muss das Handy bereits mit voller Sendeleistung arbeiten. Solange sich die Testperson alleine in der Zelle aufhält funktioniert das auch; Probleme ergeben sich aber, wenn zusätzliche Mobilteile von der Zelle mitversorgt werden müssen. Diese wirken auf den ursprünglich alleinversorgten Teilnehmer wie Störer (die Empfangsleistung der näheren Stationen an der Basisstation ist höher als die der entfernteren), will er weiter die Verbindung aufrechterhalten, muss er entweder mit höherer Leistung senden -- was aber nicht mehr geht -- oder dichter an die Antenne der Zelle heranrücken. Der mögliche Zellradius hat sich also verringert.

Verlassen die "Störer" die Zelle wieder, kann unserer Testperson den Abstand zur Mitte wieder vergrößern, die Zelle verändert also in Abhängigkeit von der Teilnehmerzahl ihren Versorgungsradius, sie "atmet". Äquivalent zu einer steigenden Teilnehmerzahl wirkt auch die Erhöhung der Datenrate (und somit der Sendeleistung) eines einzelnen "störenden" Mobilteils.

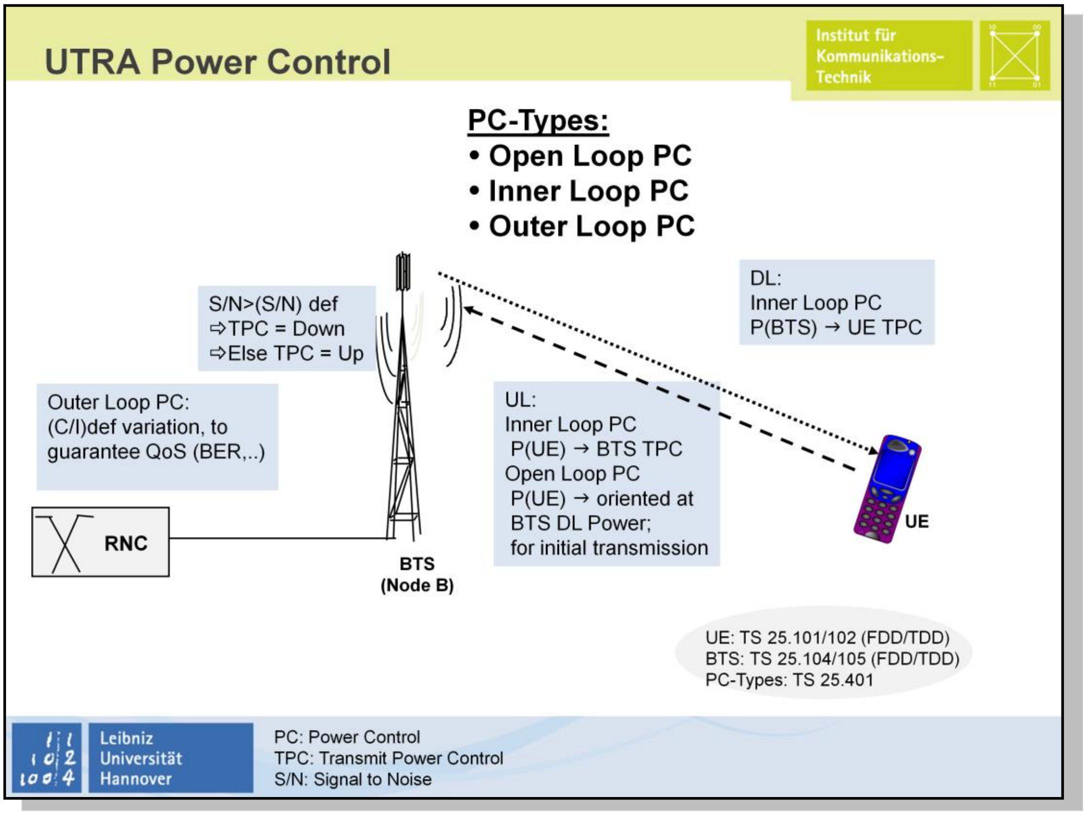


Power Control Principle

Fast power control is essential in CDMA systems. Since many subscribers transmit in the same frequency band and as the same frequency can be used in principle in each cell (re-use =1), each user will cause interference to the others. The power control is used to limit interferences. The capacity of the CDMA system is mainly limited by the level of the (inter-and intra-cell) interferences. As a result, an optimized power control greatly optimizes the system capacity. Uplink power control reduces the interference between different UE, Downlink power control the interference between neighbouring base stations, BTS.

The power control is also used to solve the so-called "near-far“ problem. For different UE with identical transmission power, the power received at the BTS of UE located near the BTS is more powerful than the power of the more remote UE. This may mean that only the information of the UE near to the BTS can be interpreted. This must be prevented as much as possible. In ideal cases, the power received at the

BTS is identical for all UE served by the BTS (assuming the transfer rates are identical). This ideal situation also represents the maximum capacity of the cell. Genuine fast power control is necessary because of the mobility of the UE. This mobility causes rapid variation in the attenuation of the power of the UE. Let us consider an example: the power of UE received at the BTS can increase by several factors in milliseconds because the UE, for example, has moved away from the "radio shadow“ of a building and has a direct line of sight to the BTS. The interference of the UE can then disrupt the communication between the BTS and all other UE – the situation must be governed by a fast power control.



Power Control Types

Three different power control types are used in UTRA for efficient power control: Open Loop Power Control, Inner Loop Power Control and Outer Loop Power Control.

Open Loop Power Control

Open Loop Power Control is used for UL transmissions to control the initial transmission power (e.g., for random access) of UE. The attenuation of the transmission power of the BTS is analyzed by the UE as part of the control. The original power of the BTS is radiated together with other system parameters as broadcast information. The UE power is initially controlled on the basis of the analyzed attenuation.

This initial control can only be coarse because the UL and DL attenuations (for FDD) can differ.

Inner Loop Power Control

For Inner Loop Power Control the BTS or UE compare the quality of the received signals with a specified value. This value describes the ratio of the (wanted) received signal power (the signal) and the (unwanted) interference from other sources (the noise) called the signal-to-noise ratio (S/N) or (S/N)def.

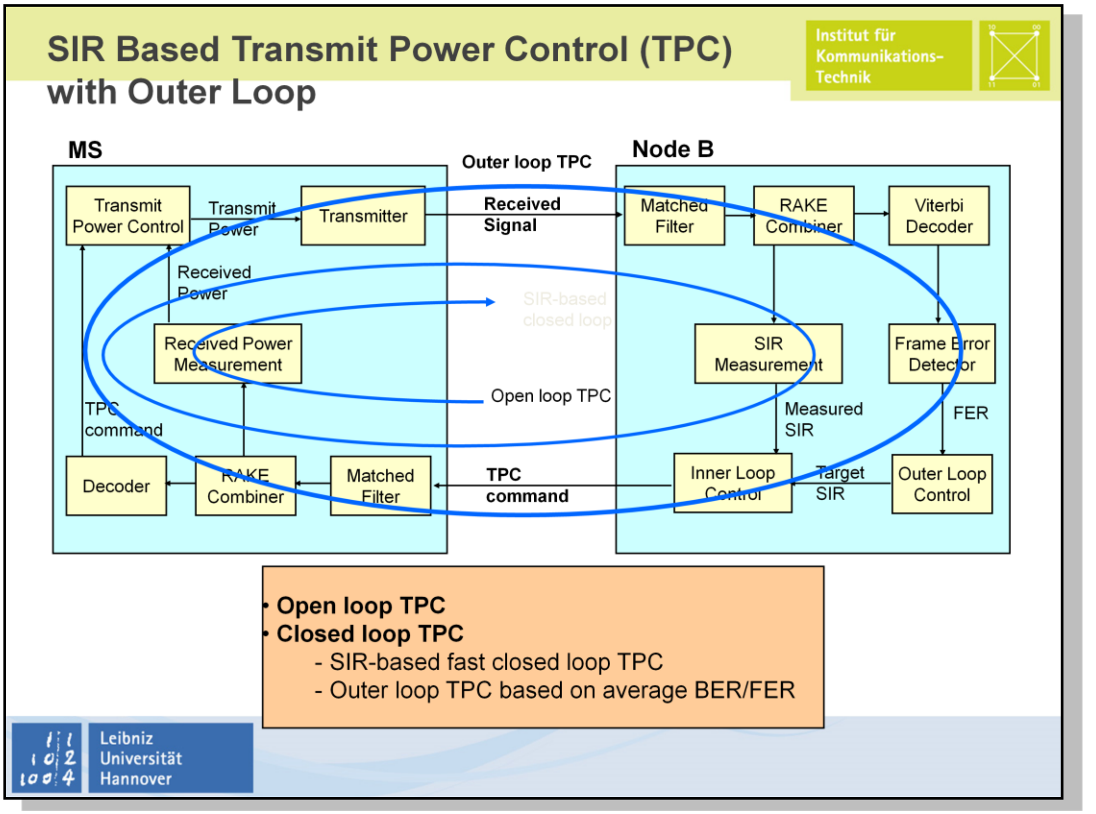
In the FDD mode, the Inner Loop Power Control is also referred to as a Closed Loop Power Control because of the different frequencies used for UL and DL.

If the analyzed S/N value is better than the defined value, (S/N)def, the BTS or UE transmit a command to the corresponding opposite side to reduce transmission power. If the S/N is poorer, an increase in transmission power is ordered. The commands are covered by the term Transmit Power Control (TPC). Values for TPC are "Up“ and "Down".

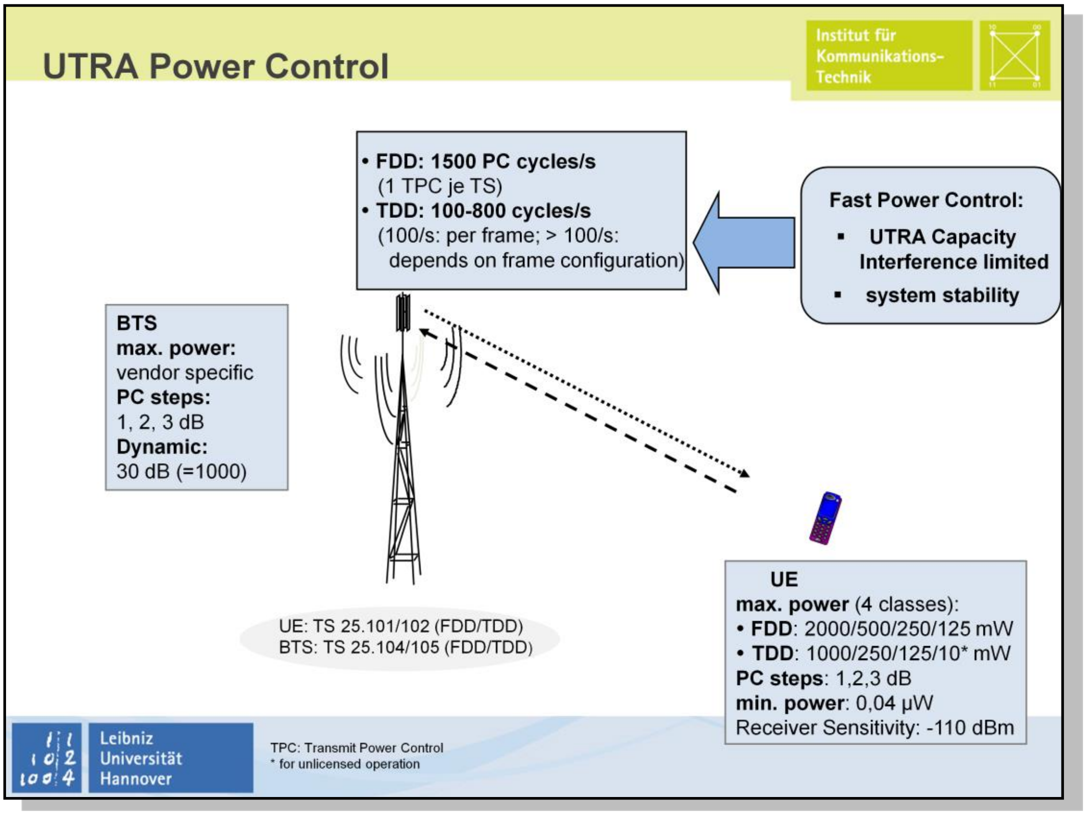
In the TDD mode, the BTS and UE independently control the power for themselves according to the completed S/N measurements and specified values (S/N)def because of the different frequencies used for UL and DL.

Outer Loop Power Control

The specification of the (S/N)def values used in the Inner Power Control is made by the Serving RNC (SRNC). The SRNC has access to estimates of the actual transmission quality using measurement reports for Node B's and UE. The quality can vary due to modified transmission conditions (e.g., UE speed). To assure transmission quality ,the SRNC must be able to vary the (S/N)def values.



Power control uses in principle two different algorithms: an inner and a outer circle.



UTRA Power Control – Parameters

The UTRA FDD and TDD modes have different power control cycles and maximum power stages of the UE.

Power Control Cycles

The UTRA FDD mode uses 1500 PC cycles/s for the Inner Loop Power Control. Each timeslot (TS)has a Transmit Power Control (TPC)command. The UTRA TDD mode flexibly uses 100 to 800 PC cycles/s for the Inner Loop Power. The minimum number of 100 PC cycles/s is correlated with the duration of a frame (10 ms).Depending on the frame configuration,up to 800 PC cycles may be required for a subscriber.

Power Classes and Dynamic Performance

The maximum power of the Node B (FDD &TDD)is vendor-specific. Dynamic performance of 30 dB must be ensured.The power can be provided in PC stages of 1,2 or 3 dB.

The UE has 4 power classes that differ in the FDD and TDD modes. In the FDD mode,the maximum power of the UE classes is 2000 mW,500 mW, 250 mW and 125 mW.

In the TDD mode,the maximum power of the UE classes is 1000 mW,250 mW, 125 mW and 10 mW.The 10 mW class is used for unlicensed operation. The minimum UE power should be about 0.04 µW.The power can be provided in PC stages of 1,2 or 3 dB.

3G TS 25.410 provides an overview of the different PC types. Power classes and dynamic performance are described in TS 25.101 or 25.102 for UE (FDD or TDD),in TS 25.104 or 25.105 for Node B (FDD or TDD).

Transmit Power Control Characteristics

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3G TS 25.224

- Power control (PC) applied to limit interference level within the systems, thus reducing intercell interference and power consumption in UE
- Slow PC scheme (similar to GSM) mandatory for UL/DL
- All codes within one timeslot allocated to same CCTrCH use same transmission power, in case they have same spreading factor

25.224 Table 1

	Uplink	Downlink
Power control rate	Variable 1 -7 slots delay (2 slot SCH) 1 – 14 slots delay (1 slot SCH)	Variable, with rate depending on the slot allocation
Step size	1, 2, 3 dB	
Remarks	All figures are without processing and measurement times	Within one timeslot the powers of all active codes may be balanced to within a range of 20 dB

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Power Control Loops - Uplink Open Loop

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3G TS 25.224

Transmit Power Control characterictics

- After synchronisation between UTRAN and UE established, UE transits into open-loop transmitter power control (TPC)
- Transmitter power of UE calculated by
  - $P_{UE} = \alpha L_{PCCPCH} + (1-\alpha)L_0 + I_{BTS} + SIR_{TARGET} +$ Constant value
    - P_{UE} : Transmitter power level in dBm
    - L_{PCCPCH} : Measure representing path loss in dB
    - L_O : Long term average of path loss in dB
    - I_{BTS} : Interference signal power level at cell`s receiver in dBm
    - α : Weighting parameter which represents quality of path loss measurements (calculated at UE and may be function of time delay between uplink time slot and most recent downlink PCCPCH time slot)
    - SIR_{TARGET} : Target SNR in dB (higher layer outer loop adjusts target SIR)
    - Constant value: Set higher layer (operator matter)

FDD mode: closed-loop

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Power Control Loops - Uplink Open Loop

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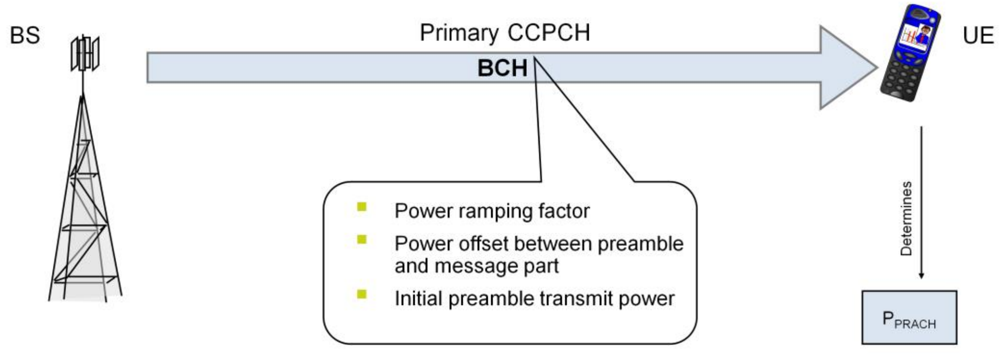
3G TS 25.214

25.214 5.1.1.1



- Adjustment of transmit power of physical random access channel
- Message part control and data part: different power
- UE employs gain factors βc for the control part (similar to (DPCCH) and βd for the data part (similar to DPDCH)

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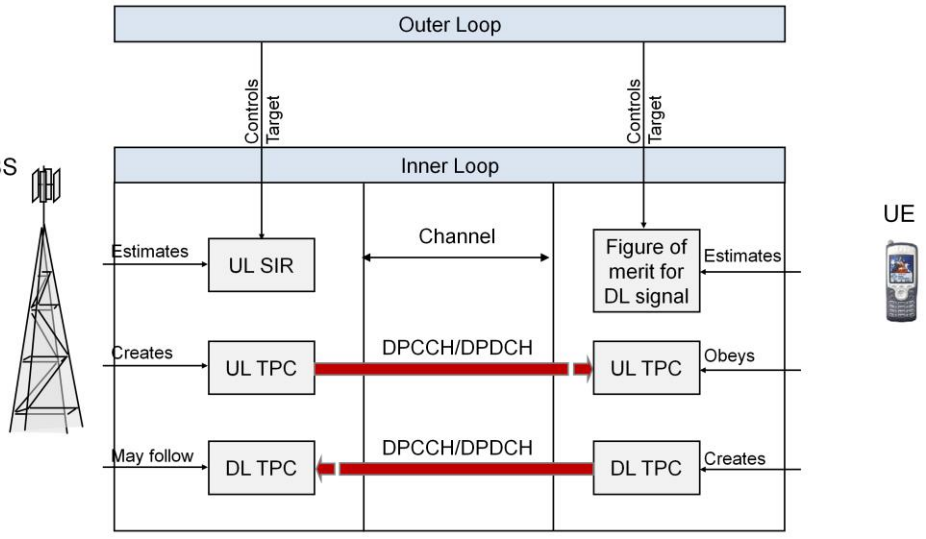
Power Control Loops - Inner/ Outer LOOP

3G TS 25.214



TPC: Transmit Power Control (Command)

Closed Loop Power Control

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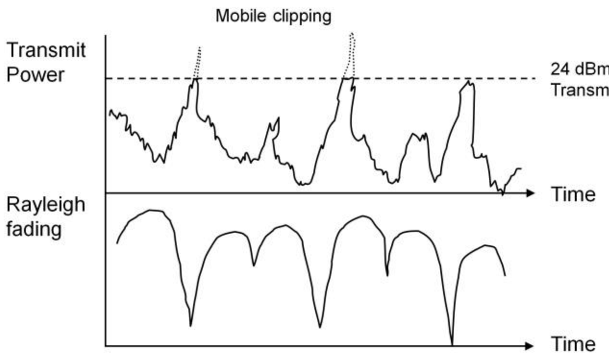

- Power control error:
  - Step size
  - Fade tracking
- Fade depths
  - f (MS speed, diversity, interleaving
- Increased transmit power
- Mobile/ BTS PA clipping rises to worse link QoS

- RNC decides right SIR target
- Uplink/ downlink power control loop ensures minimum required power for QoS (1500 Hz)
- Downlink interference environment depends on MS geography

Setting the SIR target is the key!!

Power Management
Variable Rate Transmission

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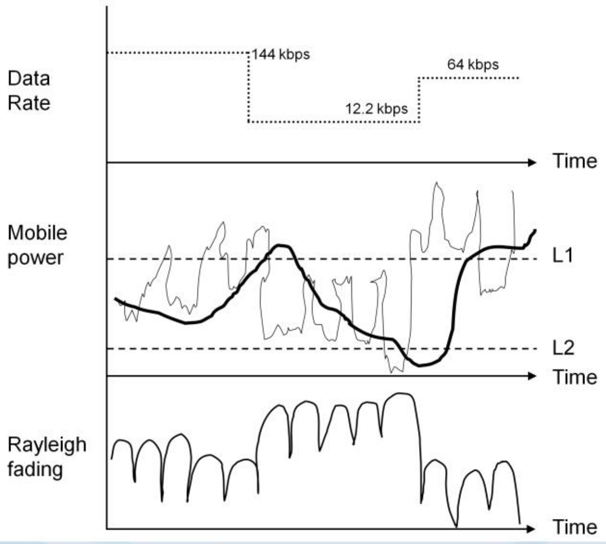

- RRC assigns TFCS to MAC
- Indicates allowable TX power min, max L1, L2
- L1 f (Traffic conditions, load conditions)
- L1, L2 are dynamic
- Averages tx. Power over N Frames
- If L1 is exceeded TFCS indicates data-rate drop
- If below L2 TFCS indicates data rate hike

IMPORTANT:

- Works in conjunction with data buffering
- Transport format indicator must take into account logical channel priorities
- If logical channel are carrying data for a codec supporting variable rates the codec rate has to be adapted accordingly.

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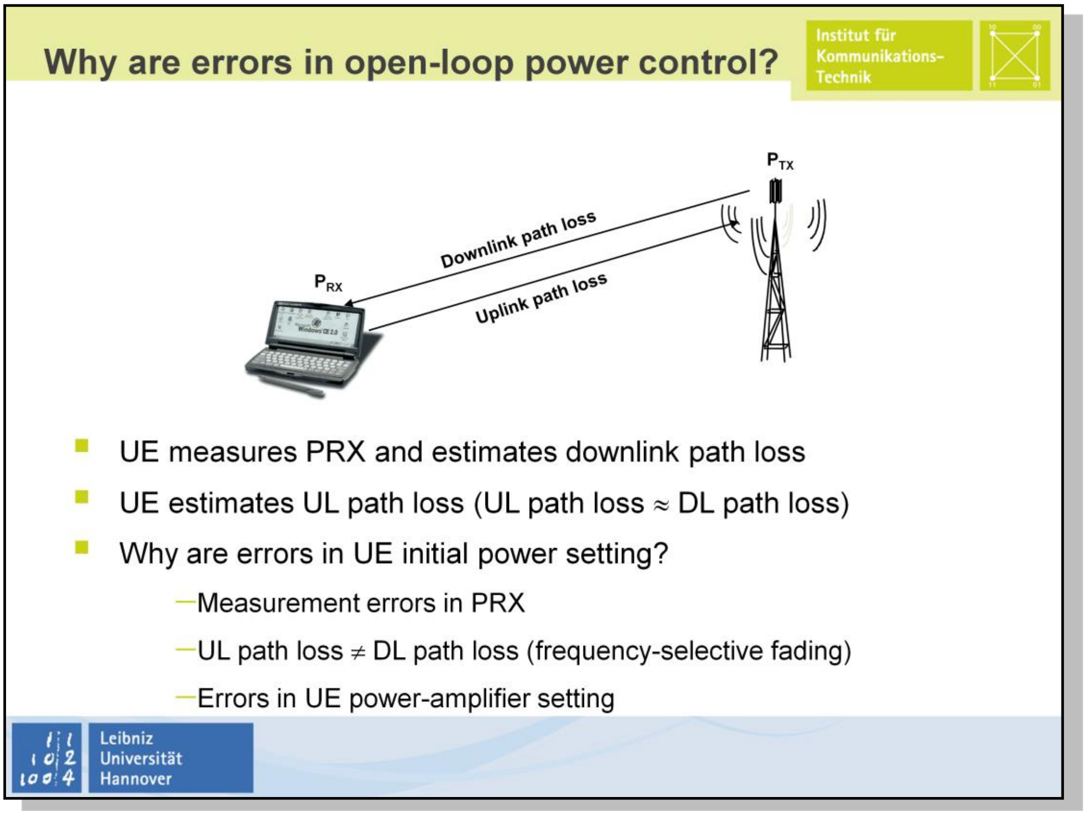
TX Transmit

RX Receive

TFCS Transport Format Combination Set



Why are errors in open-loop power control?

In case of open-loop power control, the UE estimates the transmit power from an estimate of the uplink path loss. Furthermore, the uplink path-loss estimate is derived from an estimate of the downlink path loss. For several reasons, the open-loop estimate will deviate from the correct transmit power:

- Errors in the downlink path-loss estimate, e.g. due to power-measurement errors
- Non-reciprocity between uplink and downlink path loss due to frequency-selectiove fading
- Errors in the power-amplifier settion. The absolute output power is difficult to set accurately. However, relative power changes can be done with high accuracy.

Outline Part IV

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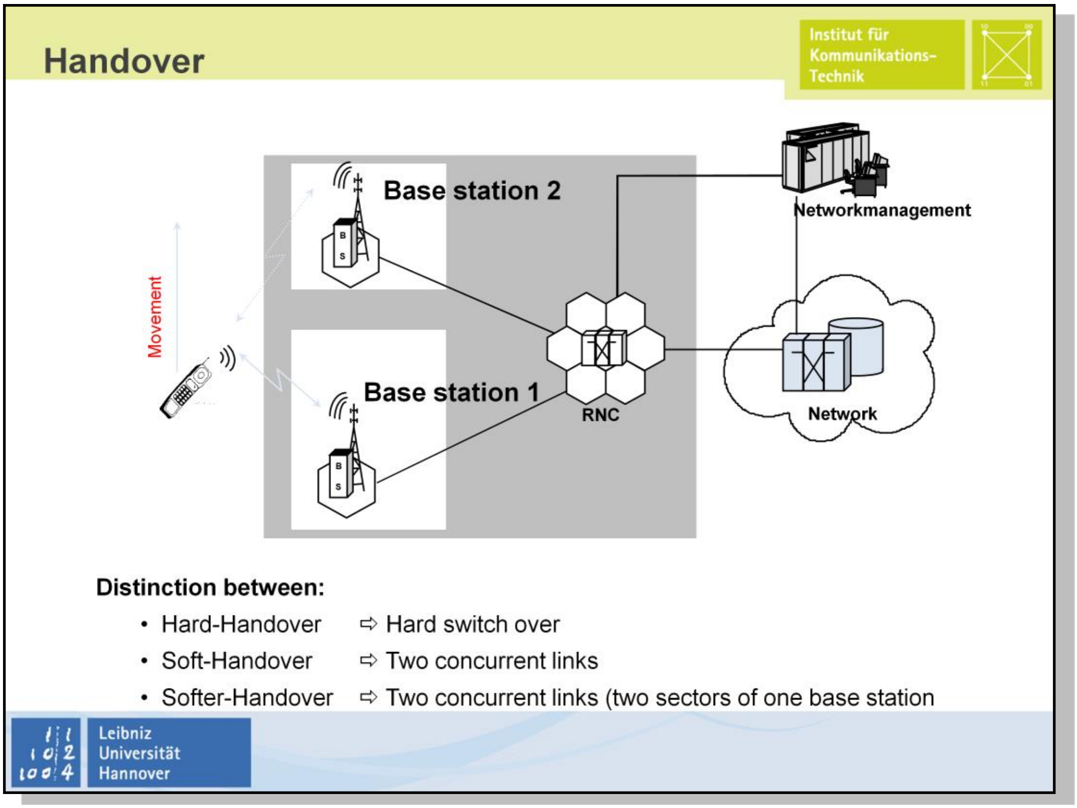


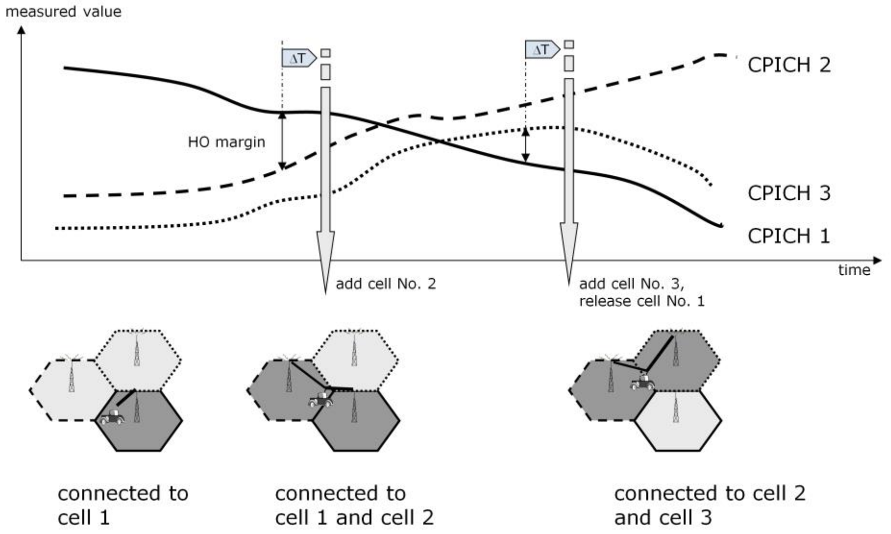
Gründe für Handover :

- ⇨ **die Bewegungen des Teilnehmers;**
- ⇨ **die Ergebnisse der Messung des Funkfeldes durch die MS;**
- ⇨ **hohe Verkehrslasten oder Wartungsmaßnahmen.**

Prinzipiell können drei Handover Mechanismen notwendig werden:

- ⇨ **„Rescue"-Handover, wenn das Gespräch verloren zu gehen droht, mit der extremen Form, in der die MS mit einem Call Reestablishment versucht, das verlorene Gespräch wieder herzustellen**
- ⇨ **Handover aus globalen Qualitätsgründen: Dieses kann erfolgen, wenn zwar die Gesprächsqualität der einen Verbindung ausreichend ist, aber eine Übergabe an eine andere Zelle eine wesentliche Verbesserung des globalen Interferenzlevels nach sich zieht (Confinement Handover).**
- ⇨ **Traffic Handover: Bei überlasteten Zellen können Handover ausgeführt werden, müssen aber mit Vorsicht behandelt werden, da dadurch die Qualitätskriterien in den Zellen verschlechtert werden können**
- ⇨ Beim Handover können folgende Kriterien zum Tragen kommen:
- ⇨ **Qualitätskriterien : Fehlerrate, Dämpfung, (Ausbreitungsverzögerungen)**
- ⇨ **Bei Traffic-Handover:**
  - Informationen über die Belastung der BTS notwendig
  - (Diese Handover-Art ist anders, da zwar bekannt ist, wie viele MS vorhanden sind, nicht aber, welche am geeignetesten für einen Handover sind. Welche MS ausgewählt wird, erfolgt nach dem Kriterium : „Bei dieser MS wäre als erstes ein Handover notwendig."
  - Die Handover-Kriterien sind nicht standardisiert. Im GSM-Standard 05.08 ist im Anhang ein Beispiel gegeben

Soft-Handover



Uses and Purpose of Soft Handover

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insensitive against shadowing effects

insensitive against fast fading effects

lower required C/I threshold for power control

↓

higher capacity

↑

less interference

↑

lower transmit power for mobiles at the cell edge

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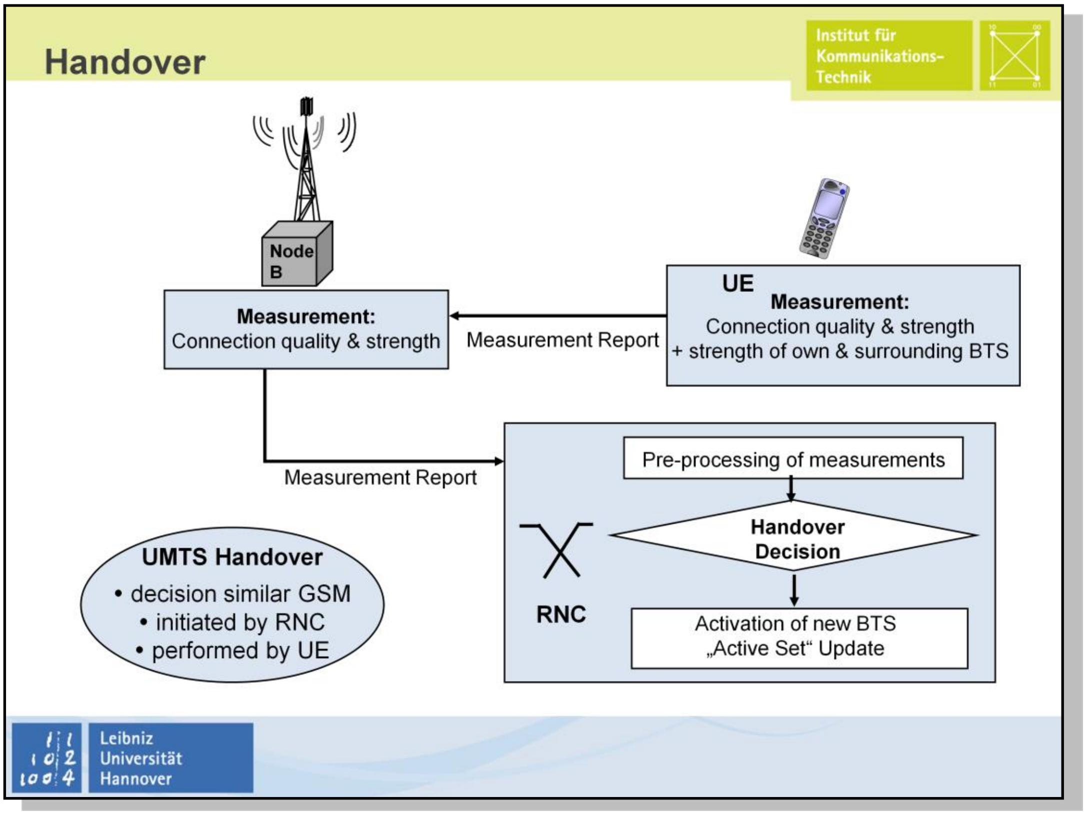


UTRA Handover

The criteria and procedures for performing handover in UMTS are similar to those in GSM. The UE and BTS determine the quality and strength of a radio transmission.

The UE also determines the signal strength and quality of its own and the local BTS's. The measurement values are compiled in a measurement report for use by the RNC as a basis for deciding for or against handover. If handover is decided upon, the new BTS is activated and included in the so-called active set. The RNC is responsible for decisions regarding the acceptance or rejection of handovers, while the execution (initiation of contact with the new BTS) Is the responsibility of the UE.

Hard Handover

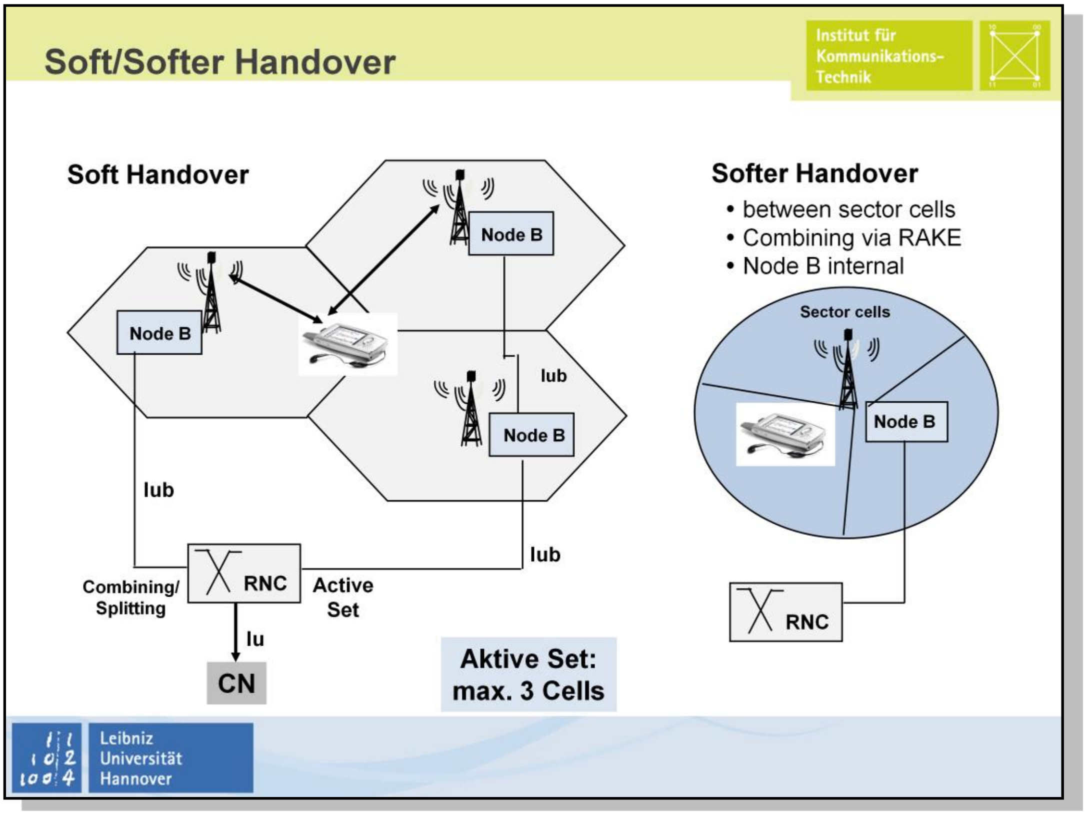
Hard handovers refer to handovers in which a mobile station (MS) transmits its user information only via one base station at any one time. Up until the time of the handover command, the MS communicates with the old base station over a specific physical channel. After the handover command, the MS changes the physical channel and then communicates with the new base station.

Hard handovers are used in GSM and in the following cases in UMTS:

- During TDD /TDD handovers,
- During FDD handovers if the frequency (interfrequency handover) or the Core Network is changed,
- During inter-system handovers –for example, when changing from FDD to TDD or
- from UMTS to GSM.

Soft Handover

Soft handovers refer to handovers in which a mobile station (MS) transmits its user information via more than one base station at the same time. Soft handovers can be used in CDMA systems in order to prevent an increase in power of the MS in boundary areas between different cells. This reduces the interference level and therefore increases the capacity of the system. Moreover, the contact with more than one base station ensures the connection to a moving MS in difficult terrain. Soft handovers are used in IS-95 and MC-CDMA and in the following cases in UMTS: During FDD /FDD handovers (without frequency changes).



Soft Handover

UE can communicate with two or three BTS's during soft handovers in the UTRA FDD mode due to the fact that all cells use the same frequency. If the mobile station enters the boundary area between two or three cells, the RNC can decide that a connection with two or three BTS's is advantageous. The RNC reserves corresponding codes in the different cells for the UE and commands the UE to implement handover to the new BTS (or BTS's). As of this time, the information is handled by the relevant BTS's.T he identity of the cells involved in the connection is stored in the RNC as an active set.

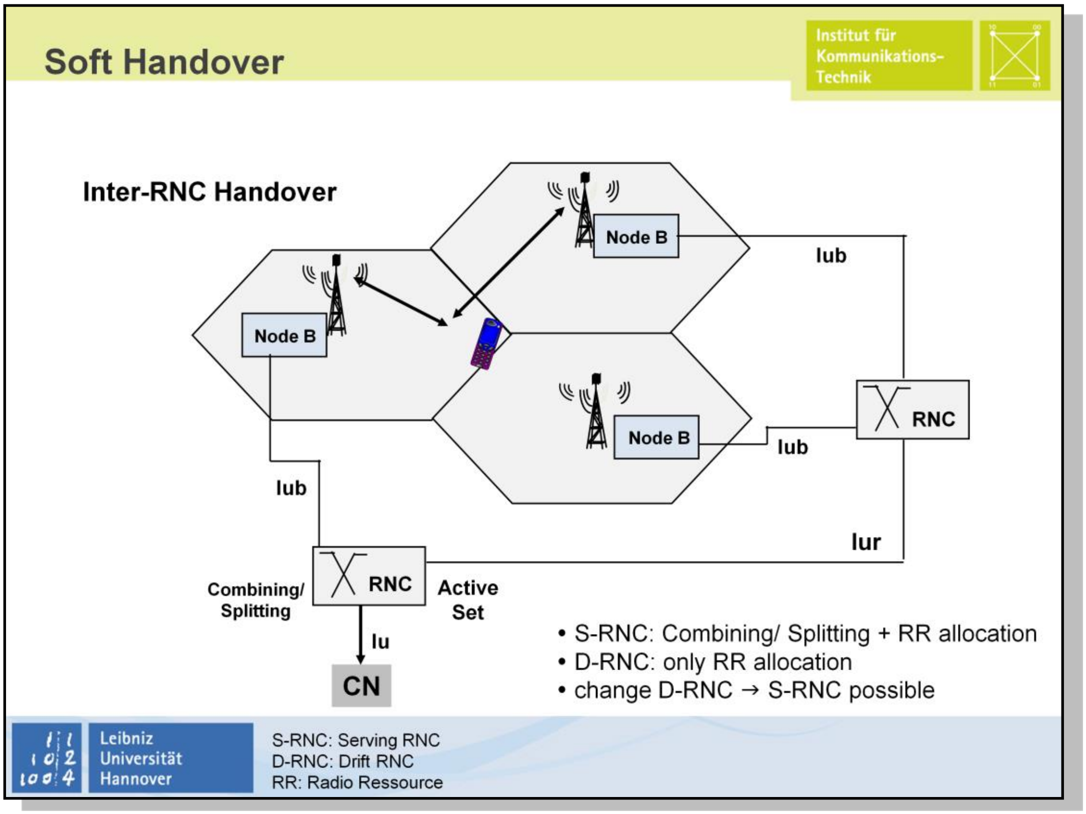
The Node B's receive the transmission from the UE, despread it and forward the information over the Iub interface to the RNC. The RNC combines this information and forwards it via the Iu interface to the Core Network (CN). This procedure is implemented frame for frame. The quality of the supplied frames is the basis for assessment. Only information in frames with top quality is used.

The gain due to reception of additional signals in soft handovers is also known as macro diversity.

In the opposite direction, the RNC splits the information from the Core Network and forwards it to the different Node B's. During soft handover the UE receives the transmission of the (apart from the TPC command) identical information from the various Node B's /BTS's. The transmission information from the BTS's is despread by different RAKE fingers and combined (Maximum Ratio Combining – MRC)).

Softer Handover

Softer handovers are handovers between sector cells in the same Node B. The transmission information received via the antennae of the different sector cells is handled by different RAKE receivers and combined in the Node B itself (Maximum Ratio Combining – MRC)). Softer handovers are internal Node B affairs. Additional (Iub) transmission capacity to the RNC is not required. The gain due to reception of additional signals in softer handovers is also known as macro diversity.



- ⇨ Inter-RNC Handover
- ⇨ An interesting special case of soft handover is the inter-RNC handover. In this case, the Node B's involved in the soft handover belong to different RNC's. The RNC responsible for control of the soft handover is referred to as the serving RNC (SRNC). It combines information received from the different Node B's in the direction of the Core Network (CN) or splits the information transmitted in the opposite direction. It also stores information regarding the cells involved in the soft handover (in an active set). The other RNC responsible only for allocating radio resources is known as the drift RNC (D-RNC). Since the handover is to be controlled autonomously in UMTS by the UTRAN as part of the Radio Resource Management (RRM), an interface is required between both of the RNC's participating in the soft handover. D-RNC and S-RNC exchange signalling information and user information via the Iur interface.
- ⇨ The S-RNC has no anchor functionality (comparable to an anchor MSC). The D-RNC can adopt the function of the S-RNC with an S-RNC relocation procedure if necessary. The previous S-RNC is then released. The link between both RNC's over the Iur interface is no longer required. The link is directly handled by the participating Node B (or Node B's) via the Iub interface using the new S-RNC and sent from there to the CN via the Iu interface.

Hard Handover-Inter-Frequency Handover

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3G TS 25.922

General receiver concepts supporting inter-frequency handover

Support of inter-frequency handover by two different approaches:

- Dual receiver:
  - two parallel UE receiver branches
  - simultaneous diversity reception and reception of different carrier frequencies
- Transmission with intermittent idle times:
  - Gaps in transmission need to be introduced without interrupting current data transfer
  - FDD: Compresses mode (also known as slotted mode)
  - Single-receiver UE can carry out measurements on other frequencies without affecting the ordinary data flow

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Compressed Mode

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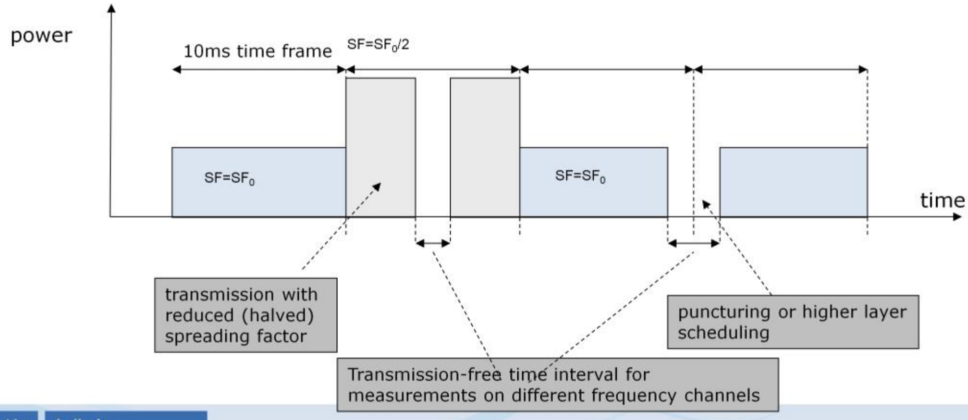
3G TS 25.922

- UE frequently needs “idle time“ to perform measurements
- Gaps can occur periodically or requested on demand
- Rate and type of gaps variable and depends on the environment and measurement requirements



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FDD compressed mode creates gaps in transmission

⇨ Data to be transmitted is “compressed “ ….
…. by changing the FEC rate or
…. by reducing the spreading factor by a factor of 2

⇨ No loss of data in compressed mode (← number of information bits in the frame is kept constant)

⇨ Loss of processing gain is compensated by increasing transmitt power

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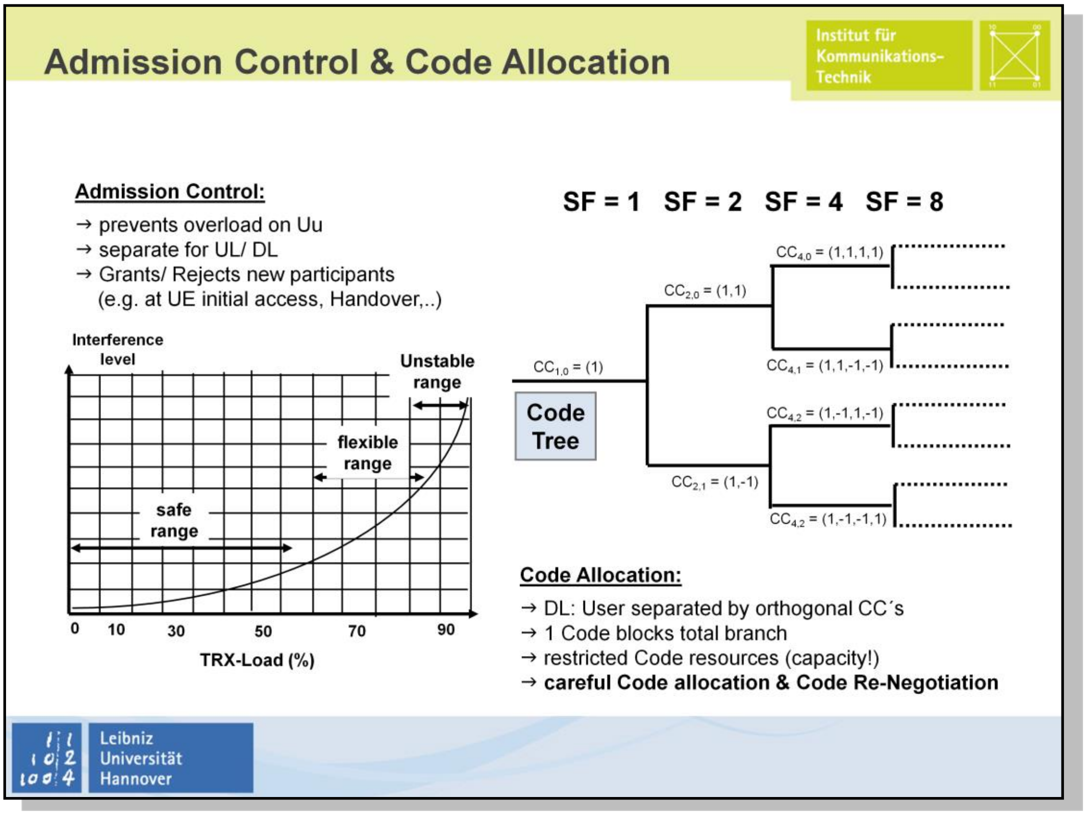

Admission Control

Admission Control refers to the analysis of resources required for a requested service, the control of the availability of the resources and, if necessary, the reservation of the resources or rejection of a new user. Its purpose is to prevent congestion situations from occurring. Admission Control uses measurements of the interference level for its analyses. Existing links must not be allowed to be impaired by new links (initial access or handover) that could raise the interference level above a critical limit. The calculation of packet-switched transmissions in particular presents difficulties because the precise time of UL transmission cannot be determined. The load on a carrier must therefore be limited. Loads of up to 50% of the maximum TRX load are regarded as "safe". Simultaneous UL PS transmissions at higher data rates are possible in higher TRX load ranges ("flexible range" / "soft" capacity limit in CDMA systems) for short periods. The interference level in the "flexible" range for TRX loads of up to 80% rises exponentially but does not yet cause deterioration in the link quality. Increases in interference beyond this range must be prevented because otherwise a link to other remote UE may break (unstable range). What is more, the increase in interference level may also increase the interference levels in neighboring cells resulting in the worst case in a domino effect.

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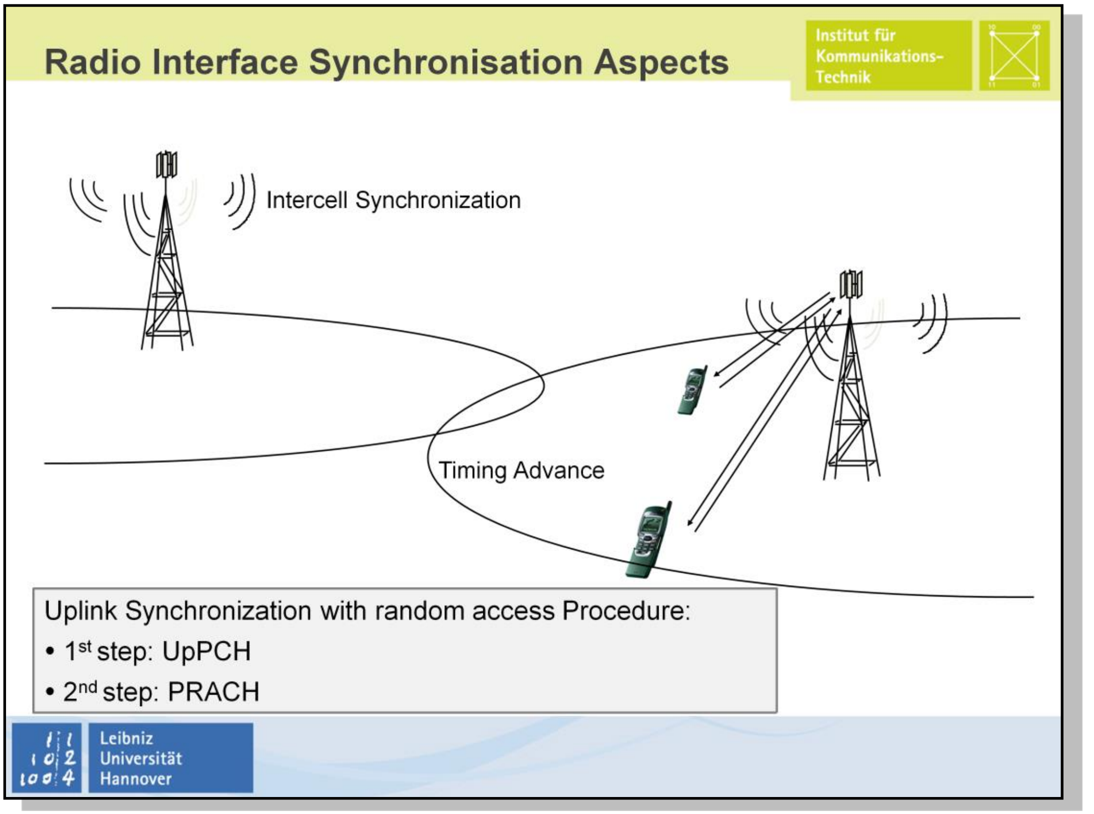


Radio Interface Synchronization

Radio frame transmission requires timing. In the TDD mode, there are two aspects:

- Intercell Synchronization
  Hereby, an inter-Node B synchronization is made. It ensures, that the frame boundaries are set at the same time instant in neighboring cells. This is done to minimize the interference between UEs in neighboring cells. As a side effect, it simplifies and fastens procedures such as handover and cell (re-) selection.
- Timing Advance
  Timing Advance describes the problem, that UEs have different distances from the Node B. They send bursts, which have to arrive within a dedicated timeslot. The timing advance gives the UE the time when it has to send its bursts.
  In the low chip rate TDD option, timing advance is made available by uplink synchronization.

Uplink Synchronization

The UE was switched on, and has successfully performed the downlink synchronization. With that, chip, timeslot, frame synchronization was performed, and the UE knows the spreading code in use in the cell. It can read the system information, which is broadcasted in each cell.

In order to send user information to the Node B, an uplink synchroniaztion must take place. In contrast to the high chip rate TDD option, this is a two step approach, called uplink synchroniaztion.

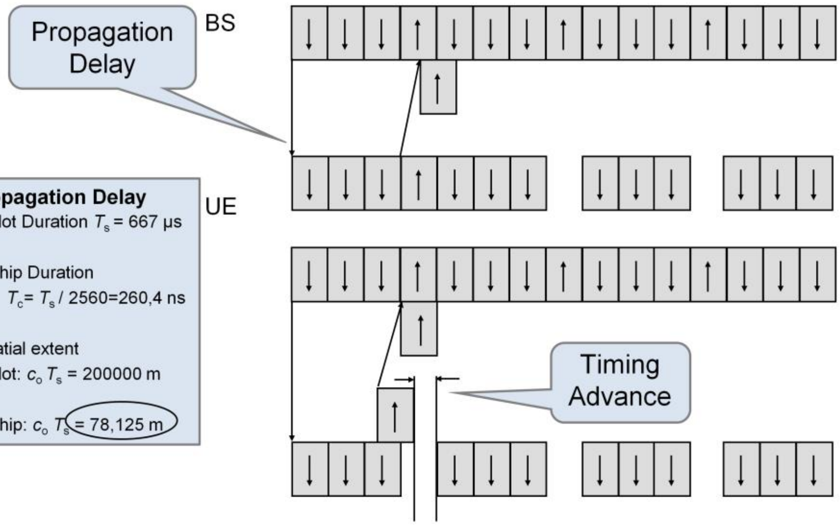
The uplink synchronization takes place during the random access procedure. Two physical channels are involved: the Uplink Pilot Channel (UpPCH) and the Physical Random Access Channel (PRACH). In order to avoid interference with the timeslots, which are used to transmit user traffic, the first uplink transmission is done in the UpPTS time slot. The timing for the transmission of the UpPTS burst is calculated form the received power level of the DwPTS and/or P-CCPCH, etc.

After detecting the pilot sequence in the UpPTS timeslot (search window), the Node-B informs the UE how to set the uplink timing. Thereafter, the UE sends the PRACH, with which the uplink synchronization was done.

For maintaining the uplink synchronization, the midample field of each burst can be used. The Node B signals the synchronization information with the Synchronization Shift (SS) Symbol to the UE.

UTRA Physical Layer - TDD Mode
Timing Advance

3G TS 25.224



Propagation Delay
- Slot Duration T_s = 667 µs
- Chip Duration
  $T_c = T_s$ / 2560=260,4 ns

-Spatial extent
- Slot: $c_o\,T_s$ = 200000 m
- Chip: $c_o\,T_s$ = 78,125 m