Evolution der öffentlichen Mobilfunknetze (3G/4G)

Chapter IV-II: Channel Multiplexing and Coding

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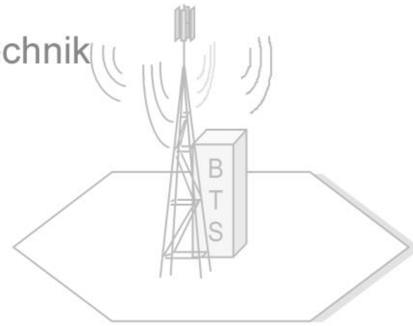

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Evolution of public radio networks

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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-II

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1. Overview
2. Transport Blocks
3. Physical Channel
4. Transport Channel
5. Logical Channel
6. Cell Search
7. Random Access
8. Packet Transmission

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Radio Interface Protocol Architecture

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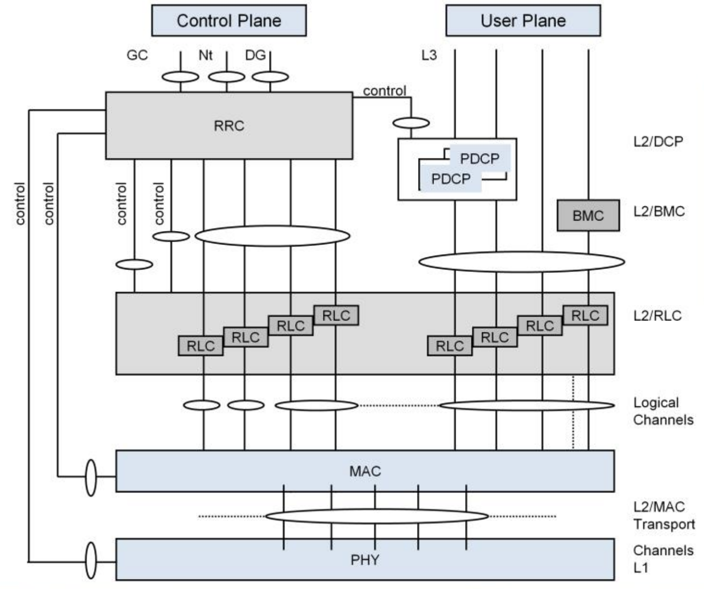


MAC Medium Access Control

PHY Physical Layer

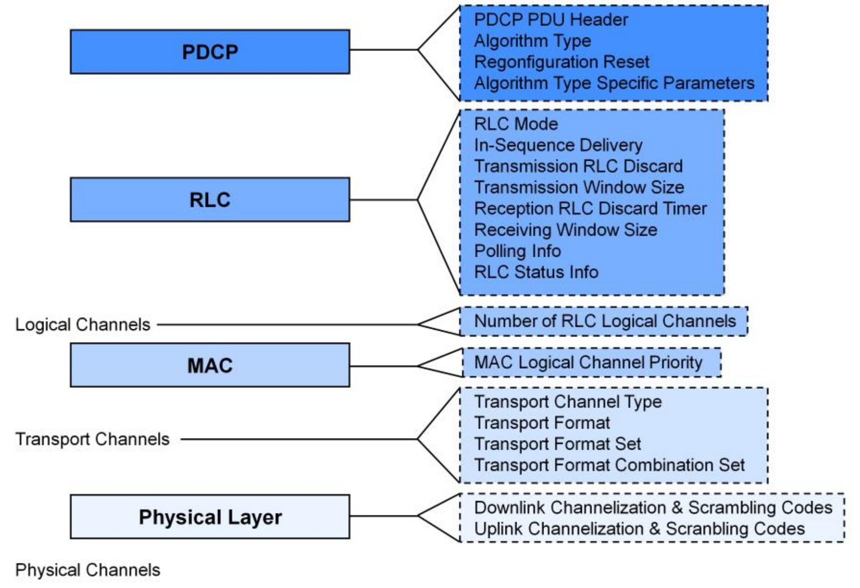
RLC Radio Link Control

RRC Radio Resource Control

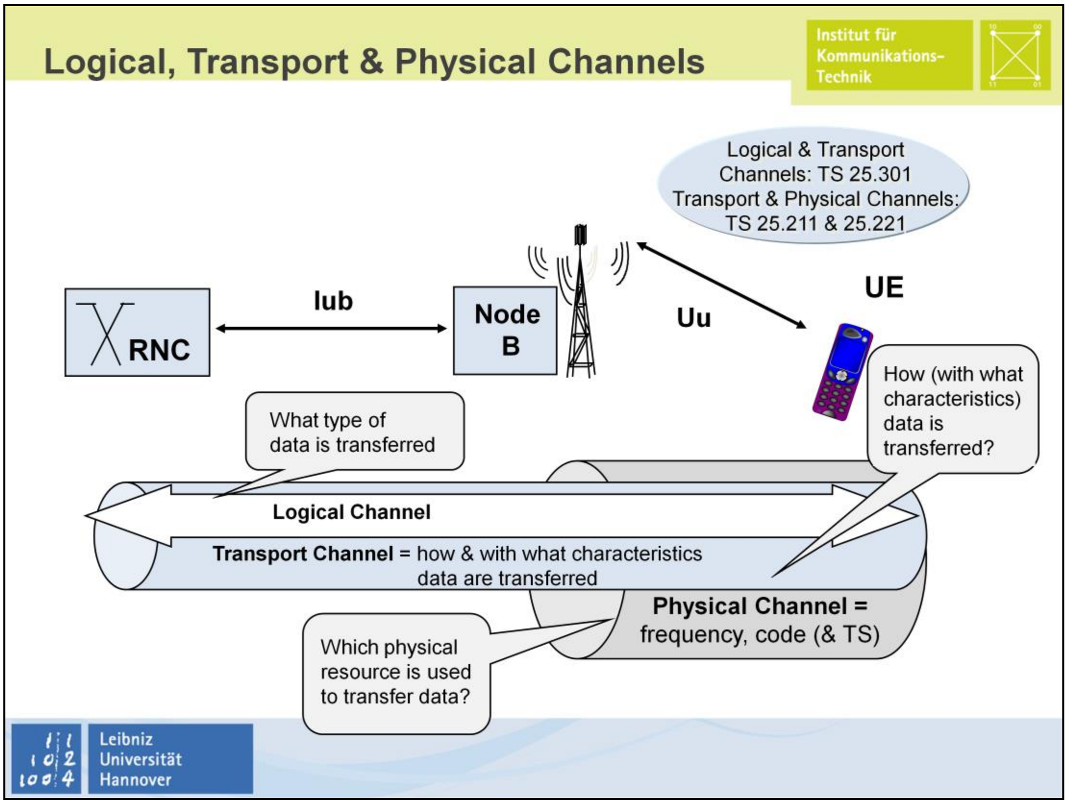
BMC Broadcast/Multicast

PDCP Packet Data Convergence Protocol

Summary
RRM mapping for different layers



PDCP	Packet Data Convergence Protocol	MAC	Medium Access Control
RLC	Radio Link Control	PDU	Protocol Data Unit



Logical Channel

Comparable to GSM, a set of logical channel types is defined in UMTS for different kinds of data transfer services. Each logical channel type is defined by “what type of information” is transferred. The UMTS Logical Channels are described in 3G TS 25.301.

Transport Channel

Compared to GSM, in UMTS a new concept, the concept of Transport Channels, has been defined. Transport Channels are described by “how and with what characteristics data are transferred over the radio interface”. Different Logical Channels can be mapped together onto one Transport Channel. The Transport Channels can be sub-divided into two general classes:

• common transport channels, where there is a need for in-band identification of the User Equipments UEs when particular UEs are addressed

• dedicated transport channels, where the UEs are identified by the physical channel. i.e. code & frequency of the FDD mode and code, time slot & frequency for the TDD mode.

The UMTS Transport Channels are described in 3G TS 25.301. The mapping of Logical Channels onto Transport Channels is described in 3G TS 25.301, too.

Physical Channel

Physical channel describe the physical transmission of the information over the radio interface. In UMTS physical channels of the UTRA FDD mode are characterized by the code and frequency (UL & DL) and the physical channels of the TDD mode are characterized by code, frequency and time slot TS.

The UMTS Physical Channels and the mapping of Transport Channels onto Physical Channels are described in 3G TS 25.211 for the FDD mode and in 3G TS 25.221 for the TDD mode.

A general overview of the UMTS physical layer is given in 3G TS 25.201. Details of the FDD mode physical layer are given in 3G TS 25.211 – 25.215, of the TDD mode in 3G TS 25.221 – 25.225.

Due to clarity, not all the UMTS Logical, Transport and Physical Channels are described in the following. The full set of Logical, Transport and Physical Channels can be found in 3G TS 25.301, 25.211 and 25.221.

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MAC-Layer

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- Segmentation of PDUs received from RLC over logical channels to transport blocks that may belong to different transport channels (downstreams)
- Reassembly and mapping of received transport blocks to logical channels (upstream)
- Scheduling, priority handling
- Reporting of throughput, used TFCS etc. to the RRC Layer

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Transport Blocks – Transport Format

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3G TS 25.302

Transport Format **25.302 7.1.6**

- Describes the format of transport block set during a transmission time interval on a transport channel. Used by L1 and MAC.
- Transport Format
  - Semi-Static part (equal for all transport formats in a transport format set):
    - Transmission time interval (TTI)
    - Error protection scheme to apply
    - Size of CRC
  - Dynamic part:
    - Transport block size
    - Transport block set size
    - Transmission time interval (optional dynamic attribute for TDD only)
- Transport Format Set: set of transport formats associated with a TrCH (Traffic Channel

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Transport Blocks
TFCI Transport Format Combination

3G TS 25.302

Transport Format **25.302 7.1.6**

- TFI Transport Format Indicator:
  - A label for a specific transport format
  - Used in communication between MAC and L1 each time a transport block set is exchanged between the two layers on a transport channel
- Transport Format Combination
  - An allowed combination of elements of transport format sets of several TrCH

Transport Blocks
TFCI Transport Format Combination

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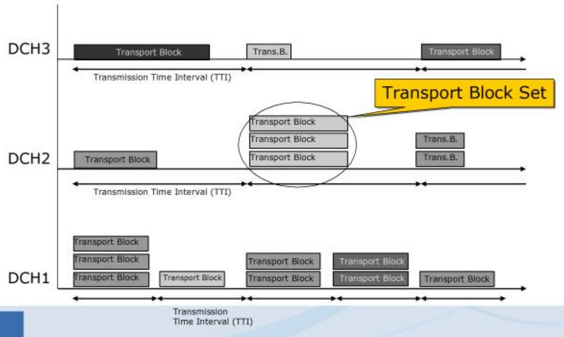
3G TS 25.302

Transport Format 25.302 7.1.6

- Transport Format Combination Set
  - A set of transport format combinations
- TFCI Transport Format Combination Indicator
  - Represents the current transport format combination



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Transport Format Concept

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- Transport Format (TF) defines coding and bit rate mapping in every transmission time interval and consists of:
  - Transport Block (TB)
    - basic unit exchanged between L1 and MAC
    - Layer 1 adds a CRC for each Transport Block
  - Transport Block Set
    - a set of Transport Blocks, which are exchanged between L1 and MAC at the same time instance using the same transport channel
  - Transport Block Size
    - number of bits in a Transport Block
  - Transport Block Set Size
    - number of bits in a Transport Block Set
- Transport Format Combination (TFC)
  - Combination of currently valid TFs on all transport channels of an UE
- Transport Format Combination Set
  - A set of TFCs to be used by an UE

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Transport channels and Transport format

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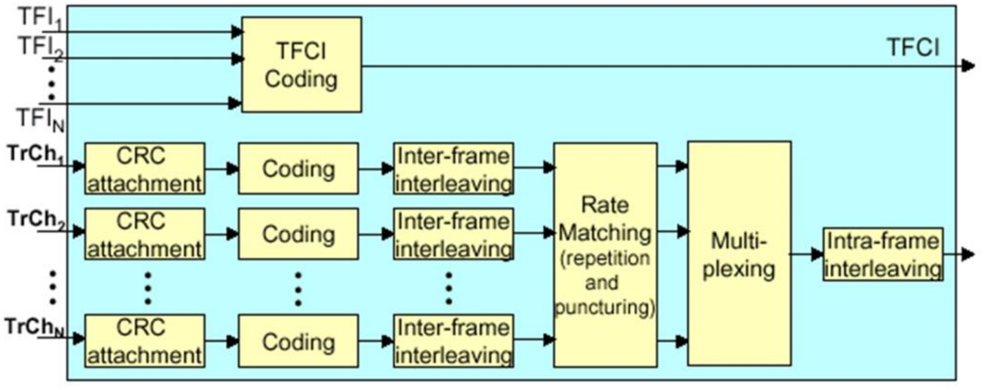

TF: Transport Format
TrCh: Transport Channel
TFCI: Transport Format Combination Indicator

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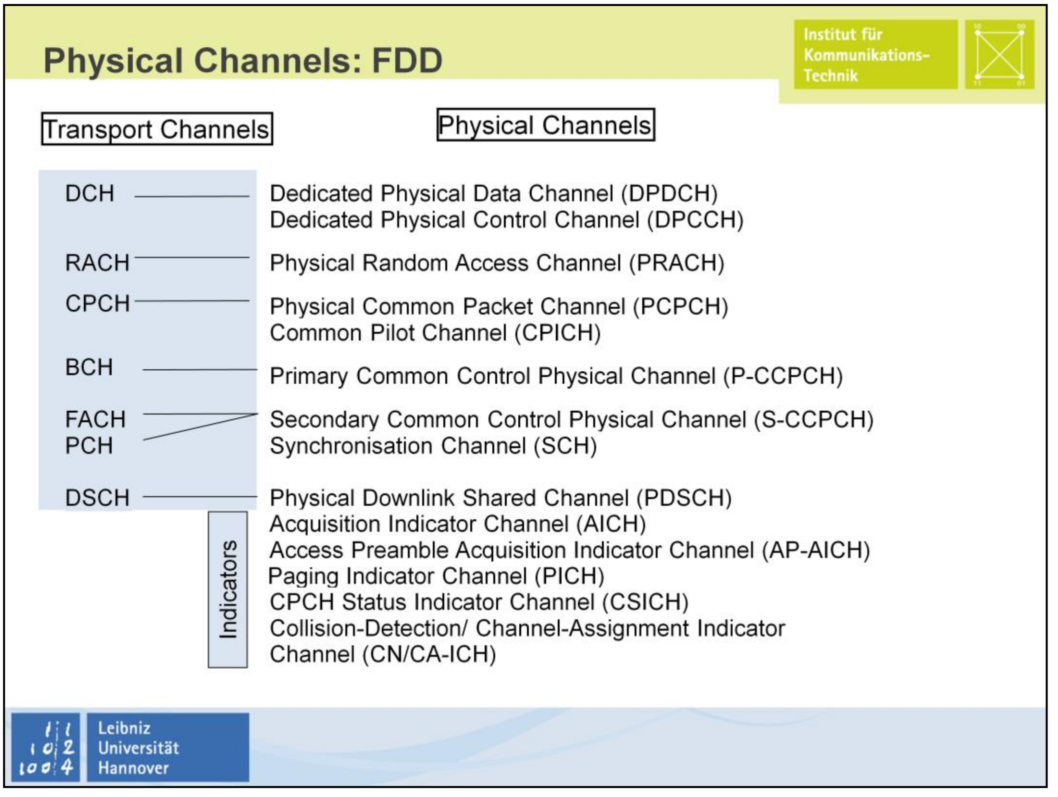

Physical Channels: FDD
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Transport Channels
Physical Channels
DCH
Dedicated Physical Data Channel (DPDCH)
Dedicated Physical Control Channel (DPCCH)
RACH
Physical Random Access Channel (PRACH)
CPCH
Physical Common Packet Channel (PCPCH)
Common Pilot Channel (CPICH)
BCH
Primary Common Control Physical Channel (P-CCPCH)
FACH
PCH
Secondary Common Control Physical Channel (S-CCPCH)
Synchronisation Channel (SCH)
DSCH
Physical Downlink Shared Channel (PDSCH)
Indicators
Acquisition Indicator Channel (AICH)
Access Preamble Acquisition Indicator Channel (AP-AICH)
Paging Indicator Channel (PICH)
CPCH Status Indicator Channel (CSICH)
Collision-Detection/ Channel-Assignment Indicator Channel (CN/CA-ICH)
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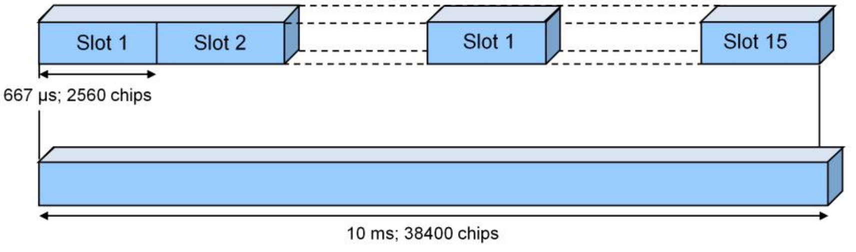
Frames and Slots

3G TS 25.211

Features **25.211.5 25.221 5.1**

- Radio frame: “ A processing unit with consists of 15 time slots. The length of a radio frame corresponds to 38400 chips.“
- Time slot: “A slot is a unit which consists of fields containing bits. The length of a slot corresponds to 2560 chips. The number of bits per slot maybe different for different physical channels and may, in some cases, vary in time.“



Physical Channels – DPCH
Dedicated Physical Channel

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3G TS 25.211

DPDCH / DPCCH **25.2111 5.2.1** **25.2111 5.3.2**

Dedicated physical channels are composed of two parts:

- DPDCH Dedicated Physical Data Channel
  - Carries data generated at layer 2
- DPCCH Dedicated Physical Control Channel
  - Carries data generated at layer 1:
    - Pilot bits
    - TPC – Transmit Power Control
    - FBI – FeedBack Information
    - TFCI – Transport Format Combination Indicator

DPDCH/DPCCH
UL: Code Multiplexed²
DL: Time Multiplexed

- Different modulation schemes !
  - Uplink: 2 x BPSK
  - Downlink: QPSK

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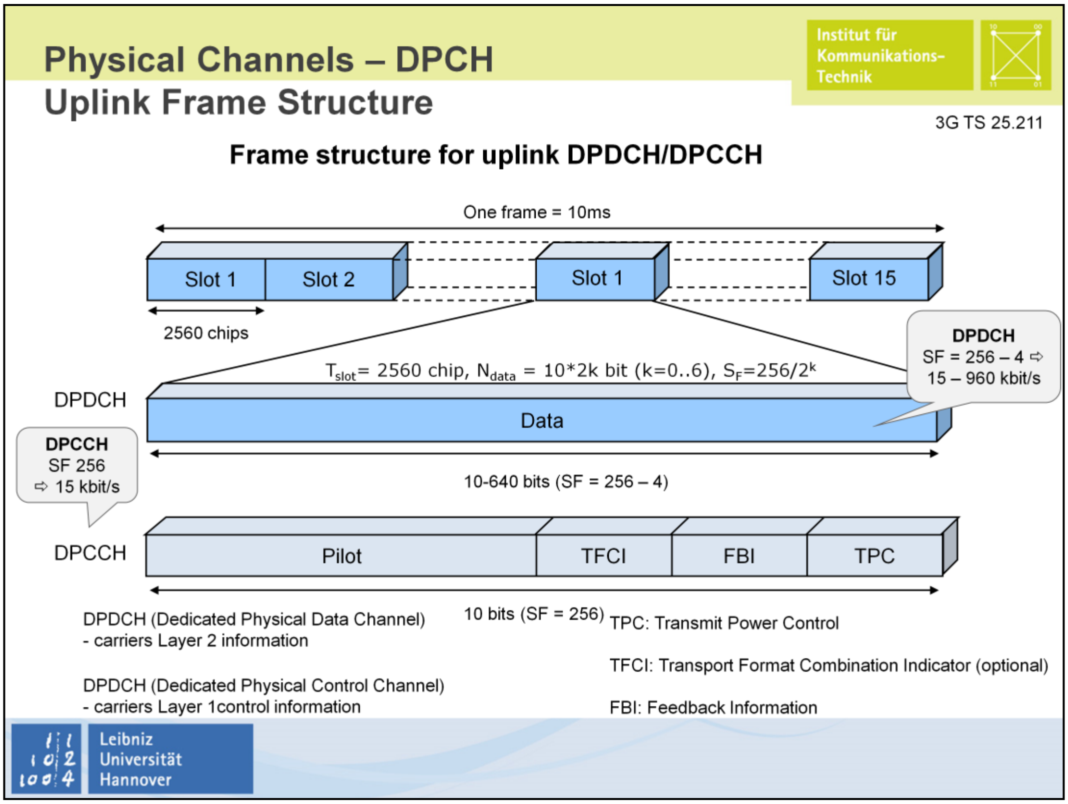
² preventing **EMC** (ElectroMagnetic Compatibility) problems at **DTX**

FBI used for softhandover



A Physical Channel of the UTRA FDD mode is characterized by UL/DL frequency and a unique code (i.e. Scrambling & Channelisation Code). Based on pure WCDMA, the transmission is continuously, at least over the duration of one frame.

Dedicated Physical Channels

In the UL, the Transport Channel DCH is mapped onto one Physical Channel for physical layer control information, the Dedicated Physical Control Channel DPCCH, and one or several (up to 6) Dedicated Physical Data Channel DPDCH for the user data. These so-called I-/Q-code-multiplexing of dedicated user and control data on different Physical Channels prevents EMC (Electro-Magnetic Compatibility) problems at DTX (Discontinuous Transmission). During silent periods no DPDCH information are transmitted, but DPCCH information are necessary. Time multiplexing of DPCCH and DPDCH information onto the same physical channel would result in cyclically very short bursts, causing severe EMC problems to external equipment as well as to terminal interiors.

Dedicated Physical Control Channel DPCCH: The DPCCH contains the physical layer control information necessary to maintain the connection. It uses a fixed Spreading Factor SF of 256, i.e. carrying 15 kbit/s (due to I-Q-code multiplexing). The

DPCCH consists of the Pilot, the Transmit Power Control TPC command, the Transport Format Combination Indicator TFCI (optional) and the Feedback Information (optional). These DPCCH information are repeated every time slot TS.

The Pilot is a pre-defined bit sequence used for channel estimation in the receiver. The TPC is used for Closed Loop Power Control. The TFCI is used to indicate the currently used data rate of the frame and the multiplexing of several different

services. It is not necessary in the case of one single fixed rate service. The optional FBI bits are used at DL closed loop transmission diversity. Dedicated Physical Data Channel DPDCH: The DPDCH contains the user data, including higher layer control information. The Spreading Factor of the DPDCH may vary on a frame-by-frame basis from 256 to 4. The resulting data rate is 15 kbit/s to 960 kbit/s (due to I-Q-code multiplexing). The current Spreading Factor of the DPDCH is given by the DPCCH TFCI.

In the DL, one DPCH contains user data and control information. DPCCH and DPDCH are time-multiplexed on the basis of one time slot TS. Dedicated Physical Channel DPCH: The DPCH contains 2 data blocks of variable

length, depending on the selected SF and slot format (49 options). The data blocks are separated by the TPC command and the TFCI (optional). The Pilot is transmitted after data block 2 at the end of every TS. The SF of the DPCH may vary from 512 to 4, resulting in a data rate of 15 kbit/s to 1920 kbit/s. Detailed information about the bit mapping per TS on DPCCH and DPCH are given in 3G TS 25.211.

Physical Channels – DPCH
Downlink Frame Structure

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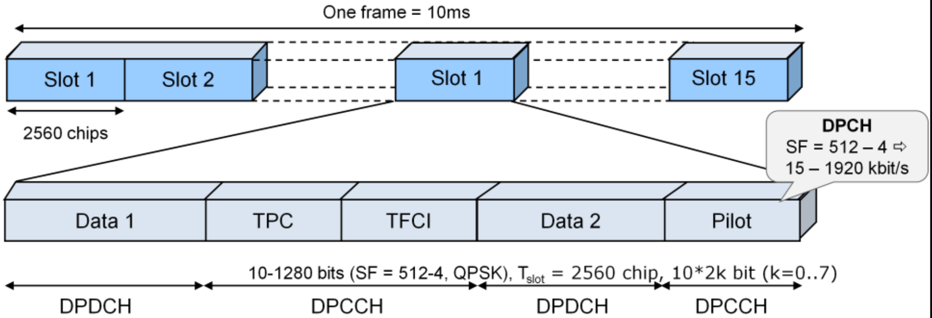
3G TS 25.211

Frame structure for downlink DPDCH/DPCCH 25.211 5.3.2



DPDCH (Dedicated Physical Data Channel)
- carriers Layer 2 information

DPDCH (Dedicated Physical Control Channel)
- carriers Layer 1control information

TPC: Transmit Power Control

TFCI: Transport Format Combination Indicator (optional)

DPCH: time-multiplexing of DPDCH and DPCCH
DPCCH: Npilot = 5..8, NTFCI = 0 o. 2, NFBI = 0..2, NTPC = 1 o. 2, SF = 256

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DPDCH/DPCCH Configurations and Gross Data Rates

S_F	bit/Slot	bitrate [kbit/s]
4	640	**960** (gross)
8	320	480
16	160	240
32	80	120
64	40	**60**
128	20	30
256	10	**15**

maximum

typical
(12.2 kbps speech)

minimum

DPCH Configurations and Gross Data Rates (Downlink)

S_F	bit/Slot	bitrate [kbit/s]	max. bitrate DPDCH [kbit/s]
4	1280	1920	1872
8	640	960	912
16	320	480	432
32	160	240	210
64	80	120	90
128	40	60	51
256	20	30	24
512	10	15	6

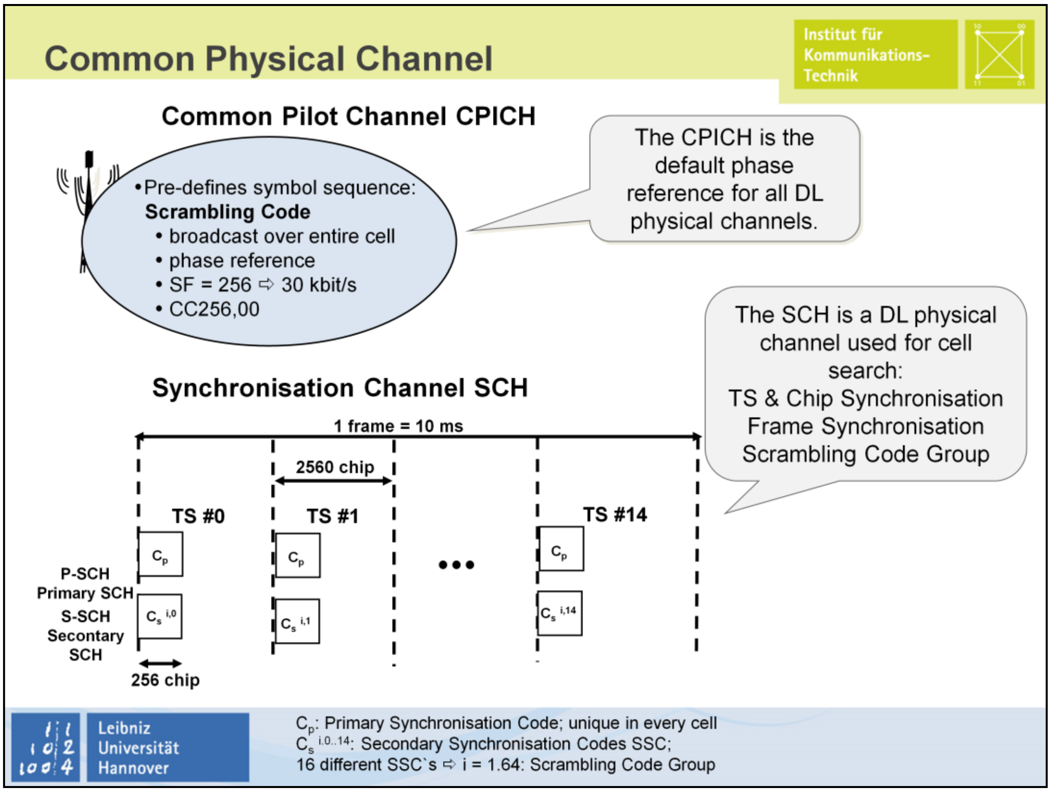
maximum gross data rate per DPCH

typical (12.2 kbit/s speech)

minimum data rate

Combination of Dedicated Physical Channel

FDD-Mode
Physical Channel



Common Pilot Channel CPICH

The CPICH is a fixed rate DL physical channel carrying a pre-defined bit sequence. The SF is 256, the data rate 30 kbit/s. It has been introduced into the UTRA FDD mode due to the harmonization with cdma2000 (now: MC-CDMA). The CPICH uses always the same Channelisation Code C256,0. It is scrambled by the cell specific Scrambling Code. It is broadcast over the entire cell. The CPICH is the default phase reference for all DL physical channels.

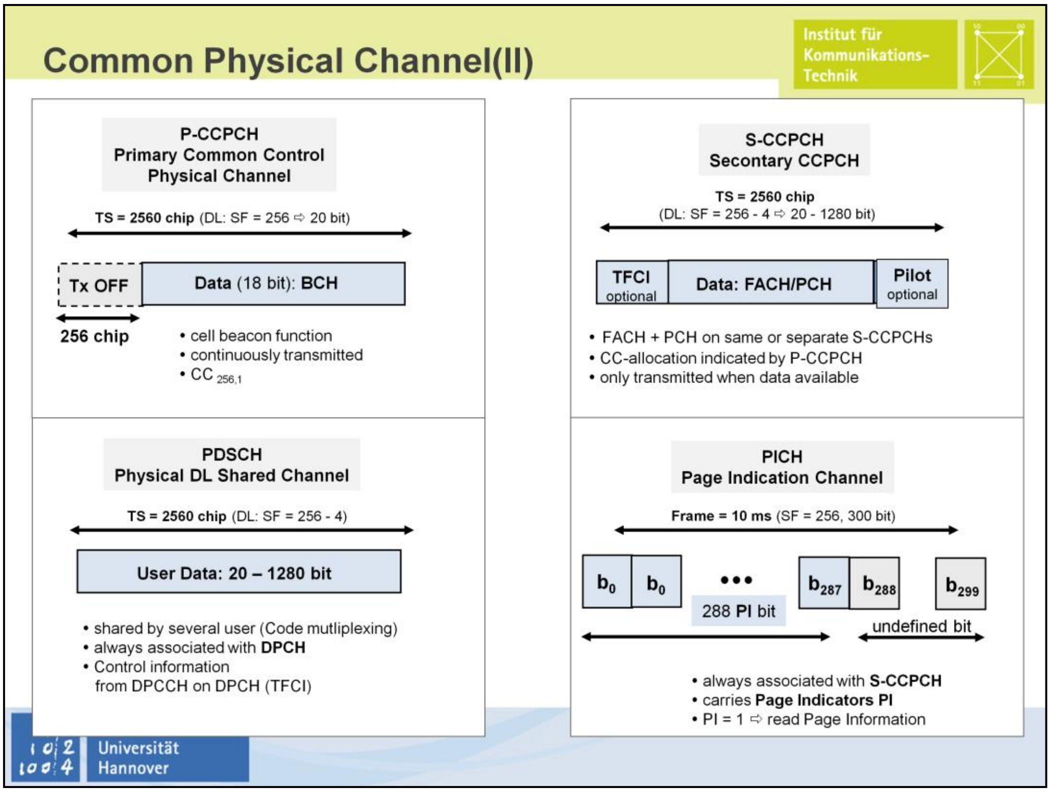
Synchronization Channel SCH

The SCH is a DL physical channel used for cell search. It is needed by the UE for time synchronization on basis of a chip, time slot TS and frame. Furthermore, it provides the Scrambling Code Group of the cell. The SCH consists of two sub-channels:

the Primary SCH and the Secondary SCH. Primary and Secondary SCH are transmitted in parallel.

Primary Synchronization Channel P-SCH: The P-SCH consists of a modulated code of length 256 chip, the Primary Synchronization Code PSC. This PSC is the same in every UMTS cell. The PSC position is at the start of every TS. The P-SCH is needed by the UE at cell search to get synchronization on basis of the TS and the chip, i.e. the precise clock of the network.

Secondary Synchronization Channel S-SCH: The S-SCH is built up by a set of 16 different codes, each of length 256 chip. 64 different options to arrange this different codes at the start of the 15 TS of one frame are defined – the so-called Secondary Synchronization Codes SSC. The SSC enables a the UE to recognize the start of a frame. Furthermore, the SSC indicates the Scrambling Code Group of the cell. This enables a faster recognition of the Scrambling Code of the cell, which is necessary for the following network access of the UE.



Primary Common Control Physical Channel P-CCPCH

The P-CCPCH is a DL physical channel used to carry the BCH transport channel. The BCCH information is necessary for every UE to perform network access. It offers network information and cell parameters, i.e. the Channelisation Codes of all other Common Channels and the capabilities of the cell. The P-CCPCH is transmitted at a fixed SF = 256 (i.e. 30 kbit/s). It always uses the same Channelisation Code C256,1. This enables the UE to detect the Scrambling Code, which is a necessary to read the BCCH information. The P-CCPCH is used as beacon of the cell, so it has to be broadcast over the entire cell. It is not transmitted in the first 256 chip of every TS, i.e. in the transmission time of the P-SCH and S-SCH.

Secondary Common Control Physical Channel S-CCPCH

The S-CCPCH is a DL physical channel used to carry the transport channels FACH and PCH. The FACH and PCH can be mapped to the same or to separate S-CCPCHs. If they are mapped to the same S-CCPCH, they can be mapped to the same frame. An S-CCPCH carrying both, FACH and PCH information has a fixed SF

= 256 (i.e. 30 kbit/s). If FACH and PCH are on separate S-CCPCHs, one S-CCPCH carrying the PCH information has a fixed SF = 256 and one S-CCPCH carrying FACH has a fixed SF = 256, too. Additional S-CCPCHs, carrying FACH information, can have SF in the range from 256 down to 4 (i.e. 30 kbit/s – 1920 kbit/s). The S-CCPCH consists of a TFCI field (optional), a data field and a Pilot field (optional). The

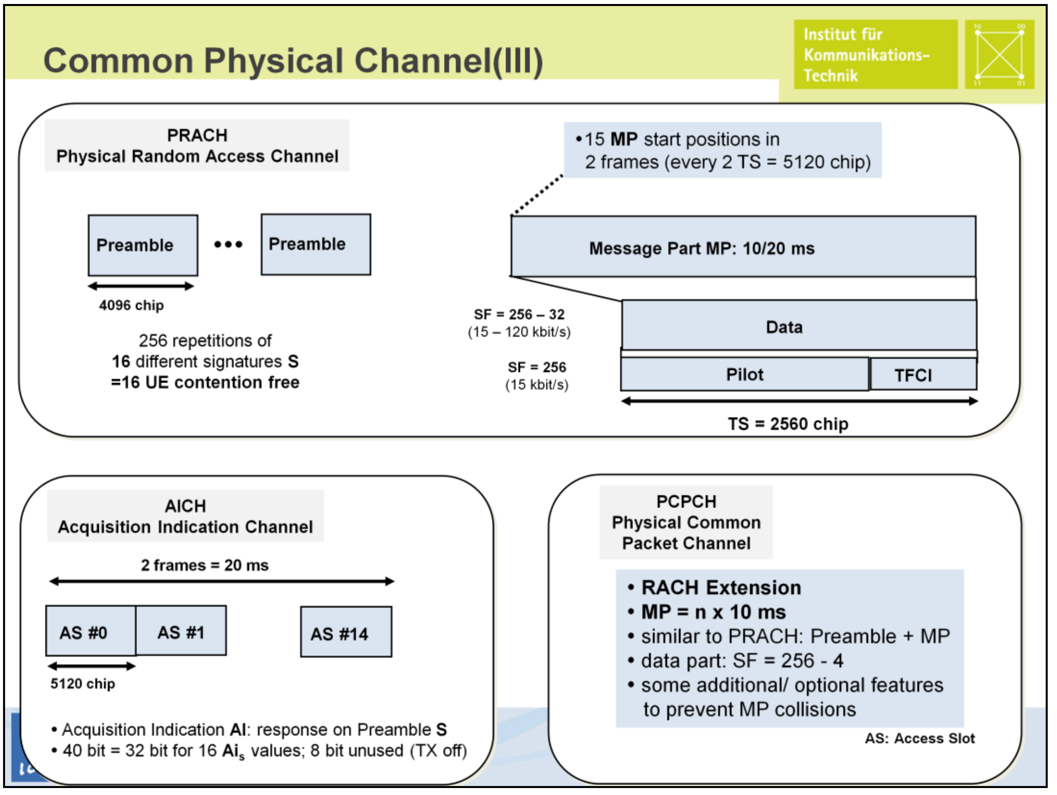
Channelisation Codes used for S-CCPCHs in a cell are given in by the P-CCPCH.

Page Indication Channel PICH

The PICH is a DL physical channel at fixed SF = 256 (i.e. 256 kbit/s). It is used together with the PCH to provide UEs with efficient sleep-mode operation, enhancing the UE stand-by times. The PICH carries the Page Indicators PI. Every frame incorporates 288 bit for page indication; 12 bits are undefined. Depending on PI repetition ratio, 18, 36, 72 or 144 PI's can be transmitted in every PICH frame. If a UE's PI in a frame is set to "1", the UE should read the paging information on the corresponding frame of the associated S-CCPCH. If the PI = "0", the UE should stay in sleeping-mode. The exact time to listen the PI is parameterized depending on the system frame number (SFN).

Physical DL Shared Channel PDSCH

The PDSCH is always associated with a DL DPCH. It is shared by several users based on code-multiplexing. The PDSCH can be used in the case of high peak data rate and low activity cycles to prevent a lack of Channelisation Codes. The PDSCH has a flexible SF = 256 – 4 (i.e. 30 – 1920 kbit/s). It uses the DPCCH information of the associated DPCH. The TFCI of the DPCH informs the UE to use the PDSCH and gives the instantaneous PDSCH parameters (higher layer signalling is possible, too).



Physical Random Access Channel PRACH

The PRACH is a contention based UL physical channel carrying RACH data. It is used for initial access to the network and to carry small (NRT) data packets on common resources in the UL. The Scrambling Codes to be used for PRACH are given by the P-CCPCH. The PRACH consists of Preambles of 4096 chip length and a Message Part of 10 or 20 ms length. The Preambles consists of 256 repetitions of 16 different signatures S, each of 16 chip length. The Message Part consists of a data and a control part, being code-multiplexed. The control part uses SF = 256, consisting of 8 Pilot bits and 2 TFCI bits. The data parts SF is in the range of 256 – 32 (i.e. 15 – 120 kbit/s). 15 start positions for the transmission of the PRACH message part exists within two frames, i.e. every 2 TS.

Physical Common Packet Channel PCPCH

The PCPCH is a contention based UL physical channel to carry infrequent data packets on common resources without extensive link management. It can be regarded as PRACH extension. The PCPCH consists of Preambles and a Message Part, similar to the PRACH. Different to the PRACH, the Message Part can be N times 10 ms (operator dependent) and the data part SF can be 256 - 4. Furthermore, the control part is similar to the DPCCH control part and additional features to prevent collisions of the Message Parts have been defined.

Acquisition Indication Channel AICH

The AICH is a DL physical channel of fixed SF = 256, which is used to indicate the reception of the PRACH / PCPCH Preamble. It consists of Acquisition Indicators AIs of 5120 chip (40 bit) length. 32 or the 40 bit of the AI are used to carry one of the 16 possible AIs values, which are the response to one PRACH Preamble of signature S. 8 bits are unused, i.e. the transmission is off during a period of 1024 chip at the end of the 5120 AI chip period. 2 frames consist of 15 consecutive Access Slots AS for AIs.

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TDD-Mode
Physical Channel

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Physical Channels: TDD

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Transport Channels	Physical Channels
DCH	Dedicated Physical Channel (DPCH)
BCH	Primary Common Control Physical Channel (P-CCPCH)
FACH PCH	Secondary Common Control Physical Channel (S-CCPCH)
RACH ORACH	Physical Random Access Channel (PRACH)
USCH	Physical Uplink Shared Channel (PUSCH)
DSCH	Physical Downlink Shared Channel (PDSCH)
	Page Indicator Channel (PICH)
TDD high chip rate only	Synchronisation Channel (SCH) Physical Node B Synchronisation Channel (PNBSCH)
TDD low chip rate only	Uplink/ Downlink Synchronisation Channel (UpPCH, DwPCH) Fast Physical Access Channel (FPACH)

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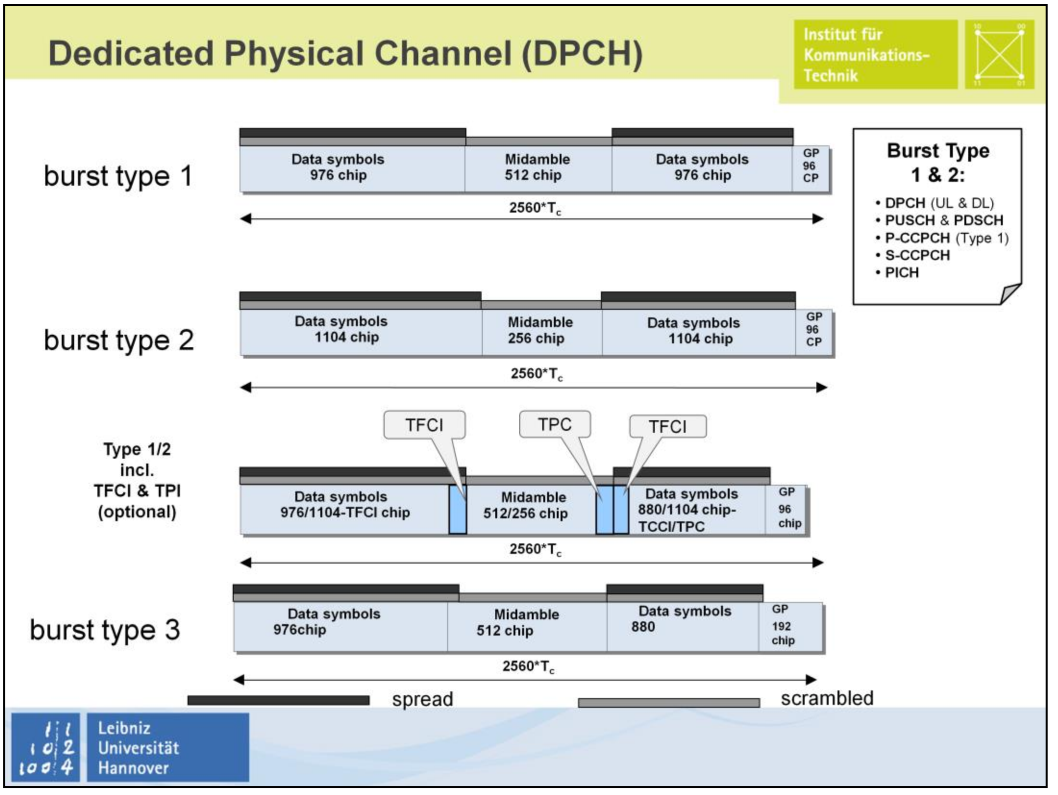


Physical channel: for the DPCH (UL & DL), PUSCH and PDSCH, P-CCPCH (Type 1 only) and S-CCPCH and PICH. Only the PRACH and SCH are not using Burst Type 1 or 2.

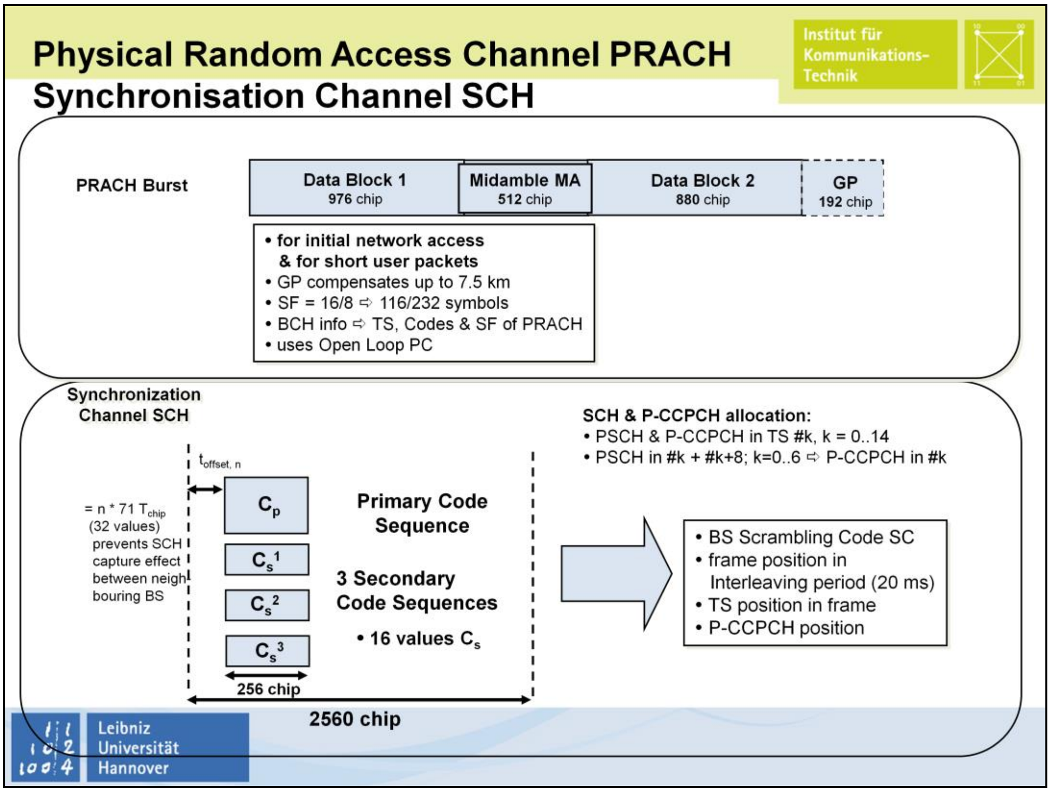
The duration of a Burst is one TS, i.e. 2/3 ms. Different to GSM, several Bursts can be transmitted at the same TS from one HF source, using different Channelisation Codes.

Generally, a burst consists of two Data Blocks (for the dedicated or common data transmission), a Midamble (for channel estimation) and a Guard Period (preventing Inter-Channel Interference).

Transmit Power Control TPC commands for Closed Loop Power Control and Transport Format Combination Indication TFCI for the indication of multi-service transmission and usage of common channel resources can be included. The usage of the TFCI and TPC is negotiated at call setup. It can be re-negotiated during the call. The TFCI and the TPC are spread with the same SF and Spreading Code as the Data Blocks of the respective physical channel.

Burst Type 1 consists of two Data Blocks, one Midamble, one Guard Period GP, two TFCI parts (optional) and one TPC command (optional). Both Data Blocks are of 976 chip length. The Midamble is of 512 chip length and the Guard Period of 96 chip length. The usage and length of TFCI and TPC are depending on the selected slot format (many different options; see 3G TS 25.221) If TFCI and TPC are used, their length is subtracted from the length of the Data Blocks. If used, the 1st TFCI part is located directly in front of the Midamble, the TPC and then the 2nd TFCI part are placed after the Midamble.

Burst Type 2 is defined similar to Type 1. The Midamble is of 256 chip length only, the data blocks are extended to 1104 chip length. Burst Type 1 can be used in general in the UL & DL. Burst Type 2 can be used in general for DL transmission. In UL transmission Burst Type 2 can only be used, if the bursts within a TS are allocated to less than 4 users.



GP Guard Period

Physical Random Access Channel PRACH

The UL transport channel RACH is mapped onto one or more (operator dependent) PRACH. The position (TS and Code) and the SF of the PRACH (SF = 16 or 8) are indicated by the P-CCPCH. The PRACH is used for initial network access, carrying common control and dedicated traffic. The PRACH uses Open Loop Power Control. For the PRACH an own type of burst has been defined – the PRACH burst.

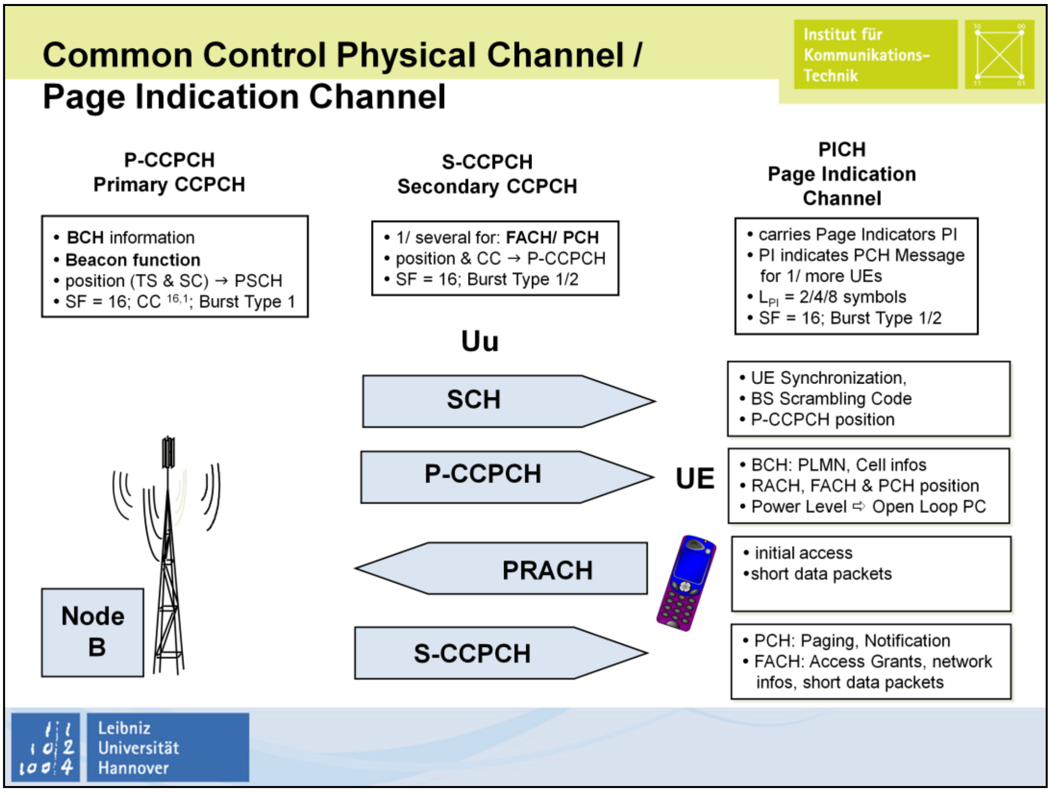
PRACH Burst

The PRACH burst is similar to Burst Type 1. It consists of two Data Blocks, a Midamble and a Guard Period.

Identically to Burst Type 1, Data Block 1 is of 976 chip length and the Midamble of 512 chip length. The Guard Period of the PRACH Burst is of 192 chip length, different to the 96 chip length of Burst Type 1. Due to this, the Data Block 2 of the PRACH Burst is 96 chip shorter than that of Burst Type 1, i.e. it is of 880 chip length. Total, the PRACH offers 1856 chip for control or dedicated data, i.e. 116 or 232 symbols at SF = 16 or 8. The larger Guard Period of the PRACH enables to compensate delay times in cells with a radius of up to 7.5 km.

Synchronization Channel SCH

The DL physical channel SCH is used by the UE to determine the cell Scrambling Code and achieve the synchronization on basis of the chip, TS and frame. Furthermore, is indicating the position of the cell beacon, i.e. the P-CCPCH. Two option of SCH and P-CCPCH location exists: The SCH can be allocated in only one TS, no matter which one (TS #k; k = 0..14). Then the P-CCPCH is allocated in the same TS #k. Or the SCH can be allocated in two TS (TS #k and TS #k+8; K = 0..6). In this case the P-CCPCH is allocated in TS #k. The SCH consists of a Primary Code Sequence and three Secondary Code Sequences (defined in 3G TS 25.223) with 256 chip length. Primary and Secondary Code Sequences are transmitted simultaneous. The TDD mode cells need to be synchronized. A capturing concerning the SCH can arise, i.e. a stronger SCH can mask weaker ones. To prevent this capturing effect, a time offset is defined between the start of a TS and the SCH Code Sequences. 32 values for this time offset have been defined, two consecutive offsets shifted for 71 chip. The SCH Code Sequences are indicating the following information to the UE: the position of the frame with a interleaving period of 20 ms, the position of the TS within the frame, the time offset (i.e. the start of the TS), the P-CCPCH position and the cell Scrambling Code.



Primary Common Control Physical Channel P-CCPCH

The P-CCPCH provides the beacon function for the cell. Therefore, it is transmitted with reference power, without beamforming, i.e. over the entire cell and with midambles, which are not used by any other physical channel in this TS. The P-CCPCH position is known from the PSCH. It broadcasts the BCH information over the entire cell. One Channelisation Code (CC16,1) has been reserved for the P-CCPCH (i.e. a bit rate of 32 kbit/s). Only Burst Type 1 is used.

Secondary Common Control Physical Channel S-CCPCH

The PCH (for Paging & Notification) and FACH (e.g. for Access Grants and short data packets) information are mapped onto one or more S-CCPCHs. The S-CCPCHs position (TS and Codes) are known from the P-CCPCH. The S-CCPCH Spreading Factor is fixed at SF = 16; Burst Type 1 or 2 can be used. To allow efficient Discontinuous Reception DRX, the PCH is divided into several sub-channels within the allocated superframe (i.e. 72 frames) structure. The UEs can be assigned to a PCH sub-channel for efficient DRX.

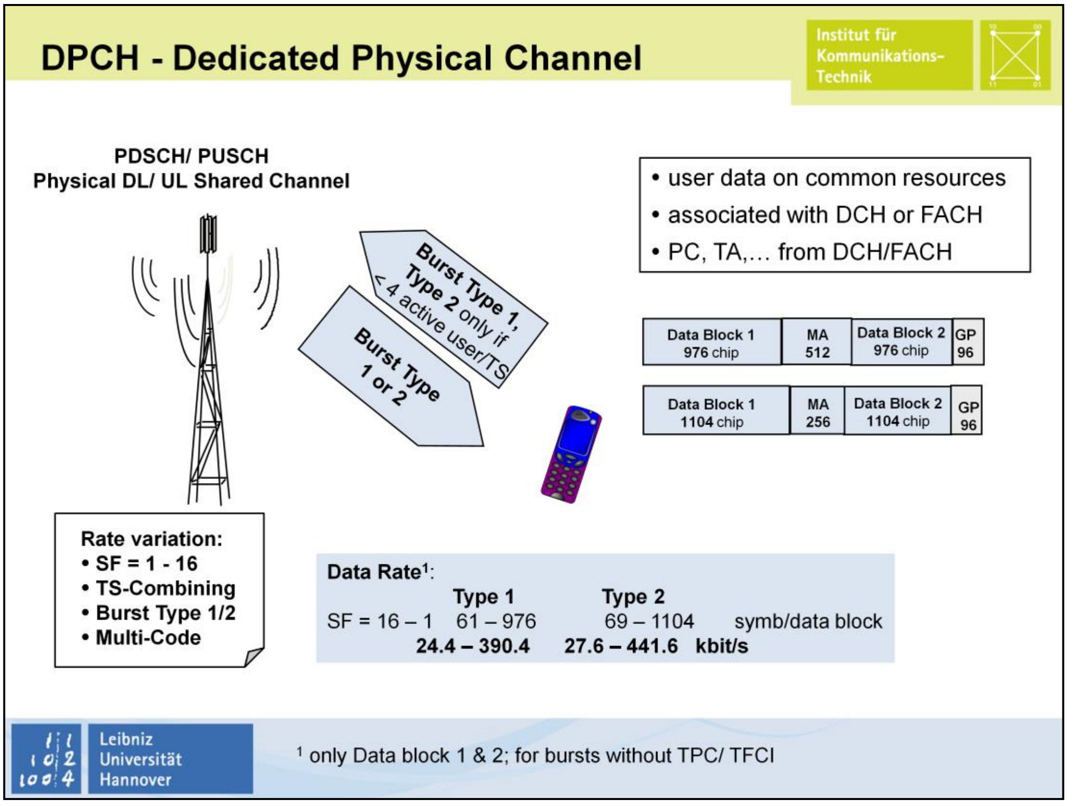
Page Indication Channel PICH

The PICH is used for efficient sleep-mode procedures. It carries pre-defined physical signals, the Page Indicators PI. The PICH substitutes one or more PCH sub-channels that are mapped on a S-CCPCH. A PI can be assigned to an UE or a group of UEs. This PI indicates to the UE(s) whether there are or not paging messages on the associated S-CCPCH. Burst Type 1 or 2 can be used for the PICH. Depending on the PI length (2, 4 or 8 symbols) 61, 20 or 15 PIs (Burst Type 1) or 69, 34 or 17 PIs (Burst Type 2) can be transmitted in one TS.

If a UE tries to access to a TDD cell, is has to:

Listen to the SCH, to achieve time synchronization (chip, TS & frame), the cells Scrambling Code and information on the P-CCPCH position. Listen to the P-CCPCH. The BCH data on the P-CCPCH informs the UE e.g. about the PLMN and cell parameters. Very important are the position (TS and Codes) of the S-CCPCH and PRACH.

Sent a PRACH to request for network access. Listen to the S-CCPCH. The network grants the network access by FACH information on the S-CCPCH. An FACH or DCH port will be opened.



Dedicated Physical Channel DPCH

- The DPCH carries dedicated control and user data on dedicated resources bi-directional between UTRAN and a UE. Burst Type 1 or Burst Type 2 can be used. In the UL, Burst Type 2 is only applicable, if the bursts within one TS are allocated to less than four users. The data rate can be varied by: Variation of the Spreading Factor (SF = 16 – 1), combining of TS to one user, using Burst Type 1 or 2 and using Multi-Code transmission. Within one TS, the data rate (including redundancy and higher layer control information) can be varied from 24.4 kbit/s – 390.4 kbit/s using Burst Type 1 or from 27.6 kbit/s – 441.6 kbit/s using Burst Type 2. Higher data rates can be achieved by TS combining.

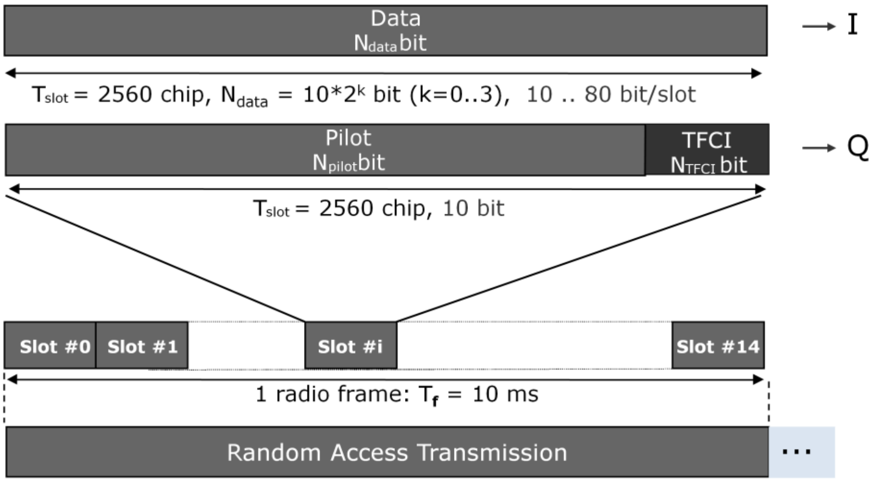
Physical DL Shared Channel PDSCH

- The PDSCH is used to transmit dedicated data with high peak rate and low activity cycle on common resources. It is always associated with a DCH or a FACH. User specific physical layer parameters like power control are derived from these associated channel. For the PDSCH the burst structure of the DPCH is used.

Physical UL Shared Channel PUSCH

- The PUSCH is the UL counterpart to the DL PDSCH. The PUSCH is always associated to a FACH or DCH, deriving user specific physical layer parameters from these associated channel. The PUSCH and PDSCH are used in the same way as the dedicated channels, they are only allocated on a temporary basis.

Random Access Burst (data part)



DPCH Configurations and Gross Data Rates

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	bit/slot		data rate (1 slot) [kbit/s]		data rate (1 slot/frame) [kbit/s]	
S_F	type 1	type 2	type 1	type 2	type 1	type 2
1	3904	4416	5856	6624	390,4	441,6
2	1952	2208	2928	3312	195,2	220,8
4	976	1104	1464	1656	97,6	110,4
8	488	552	732	828	48,8	55,2
16	244	276	366	414	24,4	27,6

maximum data rate (per slot, gross)

minimum data rate (per slot, gross)

Typical (12.2 kbit/s speech)

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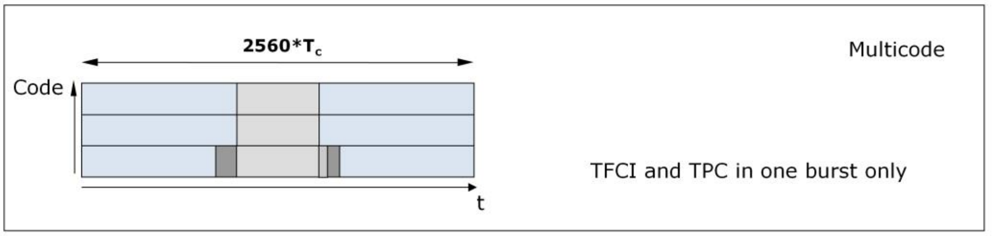
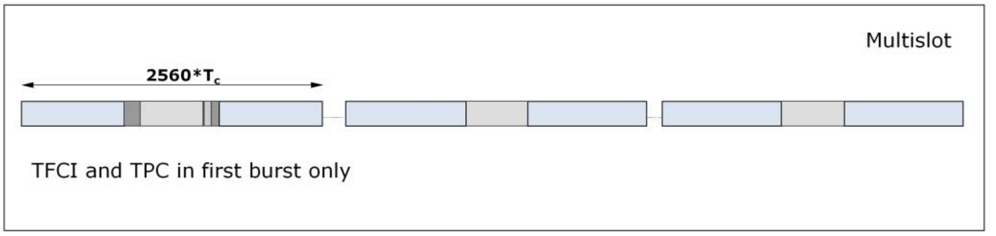
Downlink max. 12 slots/UE => 5299,2 kbit/s

Uplink max. 9 slots/UE => 3974,4 kbit/s

Multicode/ Multislot Transmission





TFCI: Transport Format Combination Identifier
TPC: Transmitter Power Control

TPC only in UL

Data — Midamble — TFCI — TPC (UL)

TDD-Mode
Low Chip Rate Physical Channel

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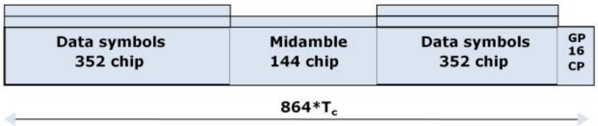
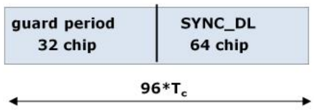
TDD mode low chip rate option bursts

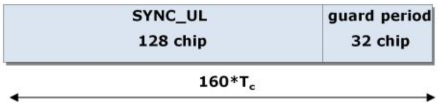
DPCH burst



DwPCH burst



UpPCH burst



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Tdd low chip rate gross data rates

	Bits /Slot		data rate 1 slot/sub-frame [kbit/s]		data rate 6 slots/sub-frame [kbit/s]	
S_F	QPSK	8PSK	QPSK	8PSK	QPSK	8PSK
1	1408	2112	209.6	422.4	1257.6	2534.4
2	701	-	140.2	-	841.2	-
4	352	-	70.4	-	422.4	-
8	176	-	35.2	-	211.2	-
16	88	132	17.6	24.6	105.6	158.4

Note: in DL only S_F 1 or 16

Outline Part IV-II

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1. Overview
2. Transport Blocks
3. Physical Channel
4. Transport Channel
5. Logical Channel
6. Cell Search
7. Random Access and Paging
8. Packet Transmission

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Transport Channels (selection)

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RACH: (UL)	Random Access Channel random access, small data packets
PCH: (DL)	Paging Channel paging procedure for call establishment
BCH: (DL)	Broadcast Channel broadcast of system information
DSCH: /USCH:	Downlink (Uplink) Shared Channel shared between a number of UEs for data transmission

common channels

DCH: (UL/DL)	Dedicated Channel dedicated data transmission

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Logical Channels (selection)

DTCH:	Dedicated Traffic Channel transmission of user data
DCCH:	Dedicated Control Channel transmission of connection-related control data
BCCH:	Broadcast Control Channel broadcast of system information
CCCH:	Common Control Channel transmission of control data

Transport Channels – Dedicated

DL/UL Transport Channel

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3G TS 25.211

DCH – Dedicated Channel 25.211 4.4.1

- Function: carries layer 2 information between the network and the UE
- Type: uplink or downlink transport channel
- Transmission: over entire cell or part of cell using beam-forming antennas
- Data rate change: possibly fast (every 10ms)
- Power Control: fast
- UE addressing: inherent
- Mapping: to Dedicated Physical Data Channel (DPDCH)

Transport Channels – Common Uplink – RACH, CPCH

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3G TS 25.211

RACH – Random Access Channel

25.211 4.2.4

- Function: carries control information from UE to BS
- Packets: may also carry short user packets
- Power Control: open loop
- Reception: always received from the entire cell
- UE identification: in-band
- Mapping: to Physical Random Access Channel (PRACH)
- Characterized by a collision risk

CPCH-Common Packet Channel

25.211 4.2.5

- Function: transmission of packet data
- Contention based random access channel
- Association: associated with a DL dedicated channel for power control
- Mapping: to Physical Common Packet Channel (PCPCH)

Transport Channels – Common Downlink – BCH, FACH

3G TS 25.211

BCH – Broadcast Channel
25.211 4.2.1

- Function: broadcast of system- and cell-specific information
- “Point-to-Multipoint“
- Data rate: low, fixed
- Transmission: always over entire cell
- Mapping: to Primary Common Control Physical Channel (P-CCPCH)

FACH – Forward Access Channel
25.211 4.2.2

- Function: carries control information to a mobile
- Transmission: entire cell or only a part of the cell (beam-forming)
- Power Control: slow
- Mapping: to Secondary Common Control Physical Channel (S-CCPCH)

Transport Channels – Common Downlink – PCH, DSCH

3G TS 25.211

PCH – Paging Channel 25.211 4.2.3

- Function: carries control information to a mobile
- Transmission: always transmitted over entire cell
- Association: associated with Paging Indicator
- Mapping: to Secondary Common Control Physikal Channel (CCPCH)

DSCH – Downlink Shared Channel 25.211 4.2.6

- Shared by serveral Ues carrying dedicated layer 2 data
- Association: associated with a DCH
- Mapping: to Physical Downlink Shared Channel (PDSCH)

Outline Part IV-II

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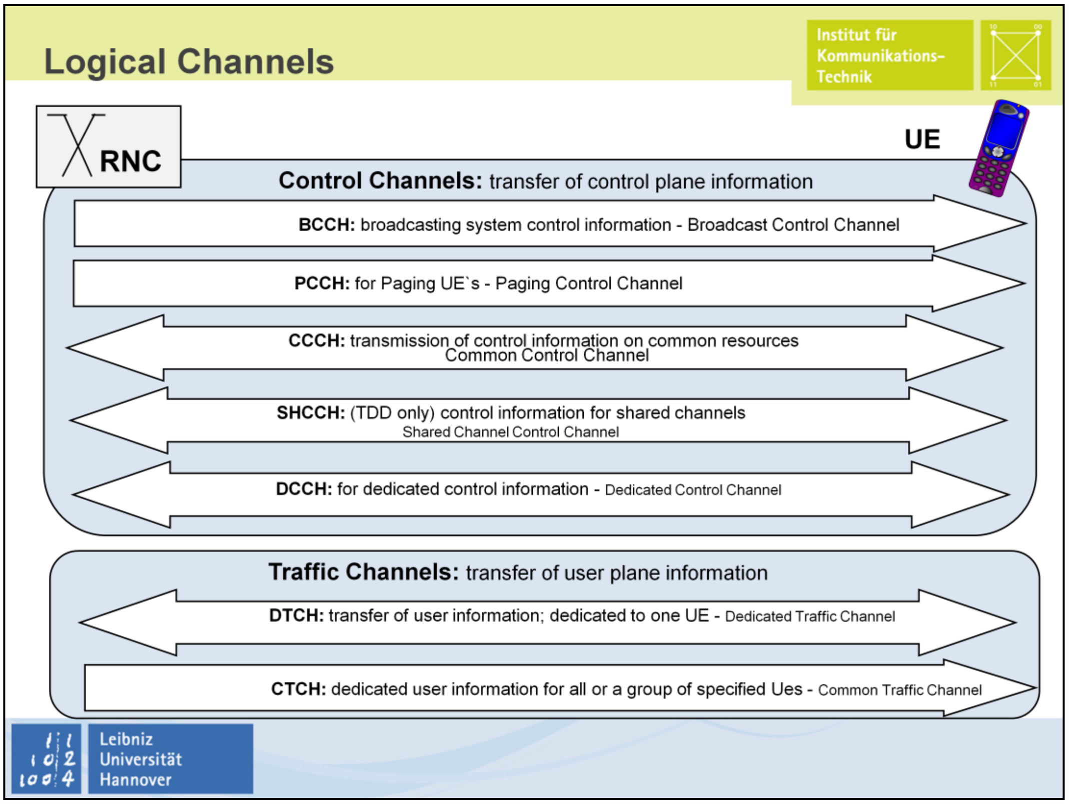


Logical Channel:

Similar to GSM, the UMTS Logical Channels are defined by "what type of information" is transferred.

The UMTS Logical Channel can be sub-divided into two groups: Control Channels

and Traffic Channels.

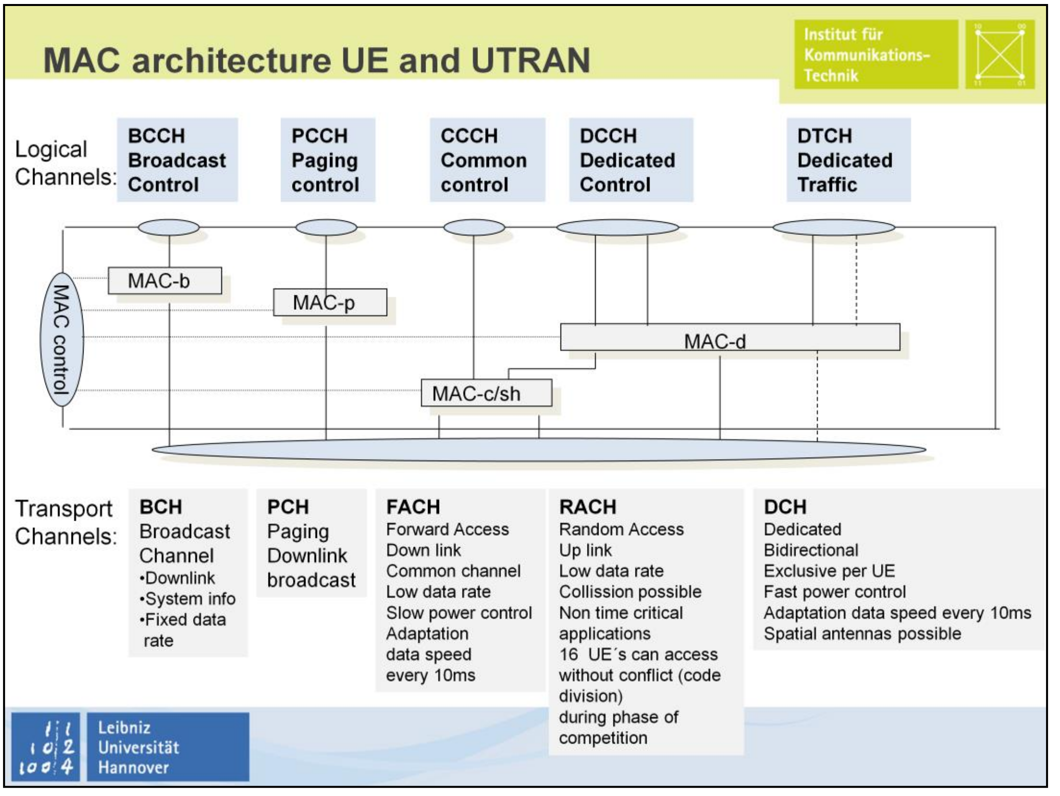
Control Channels are used for the transfer of control plane information. Traffic Channels are used for the transfer of user plane information.

Control Channels are:

- Broadcast Control Channel BCCH, which is a DL channel for broadcasting system control information.
- Paging Control Channel PCCH, which is used in DL to transfer paging information. The PCCH is utilized e.g. when the network does not know the UE's cell.
- Common Control Channel CCCH, which is a bi-directional channel for the exchange of control information between the network and the UEs. CCCH's are used e.g. by UEs without Radio Resource Control RRC connection during the RRC connection establishment procedure.
- Shared Channel Control Channel SHCCH, which is used in TDD only. The SHCCH is defined for the transmission of control information for UL and DL shared channels between the network and the UEs.
- Dedicated Control Channel DCCH, which is a channel to transmit dedicated physical layer control information between one UE and the network. Different to the other Control Channels, the DCCH is a PtP bi-directional channel.

Traffic Channels are:

- Dedicated Traffic Channel DTCH, which is used for the UL and DL transfer of user information. The DTCH is PtP channel, dedicated to only one UE.
- Common Traffic Channel CTCH, which is used for the transfer of user information for all or a group of specified UEs. I.e. the CTCH is a unidirectional PtMP channel.



MAC-b

•Handling of broadcast information

MAC-p

•Handling paging information

MAC-d

•Terminal specific tasks

•Controlling transmission on DCH

•One entity per RRC-connection

•Dynamic switching between common (MAC-c/sh) and dedicated transport channels

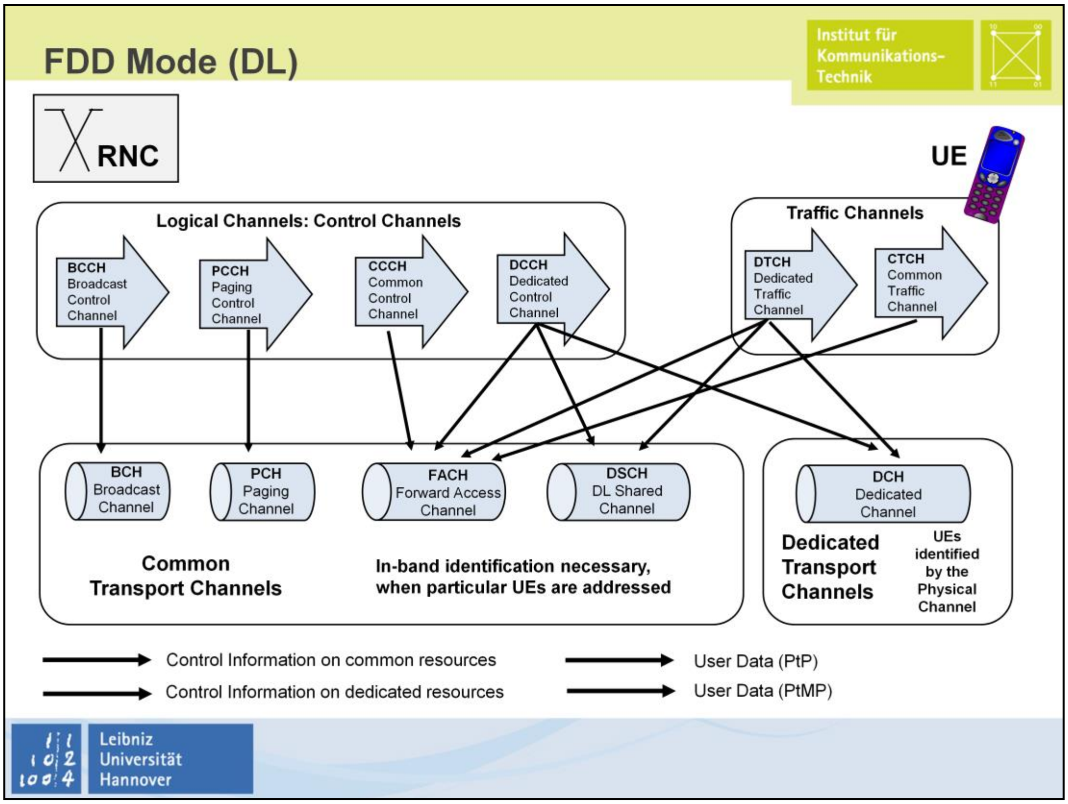
•Multiplexing of dedicated logical channels onto one transport channel

•Selection of Transport Format Class (TFC) for dedicated channels based on offered load

MAC-c

•Tasks related to RACH and FACH

•One MAC-c per UTRA access point (cell)



Mapping of Logical to Transport Channels:

FDD Mode (DL)

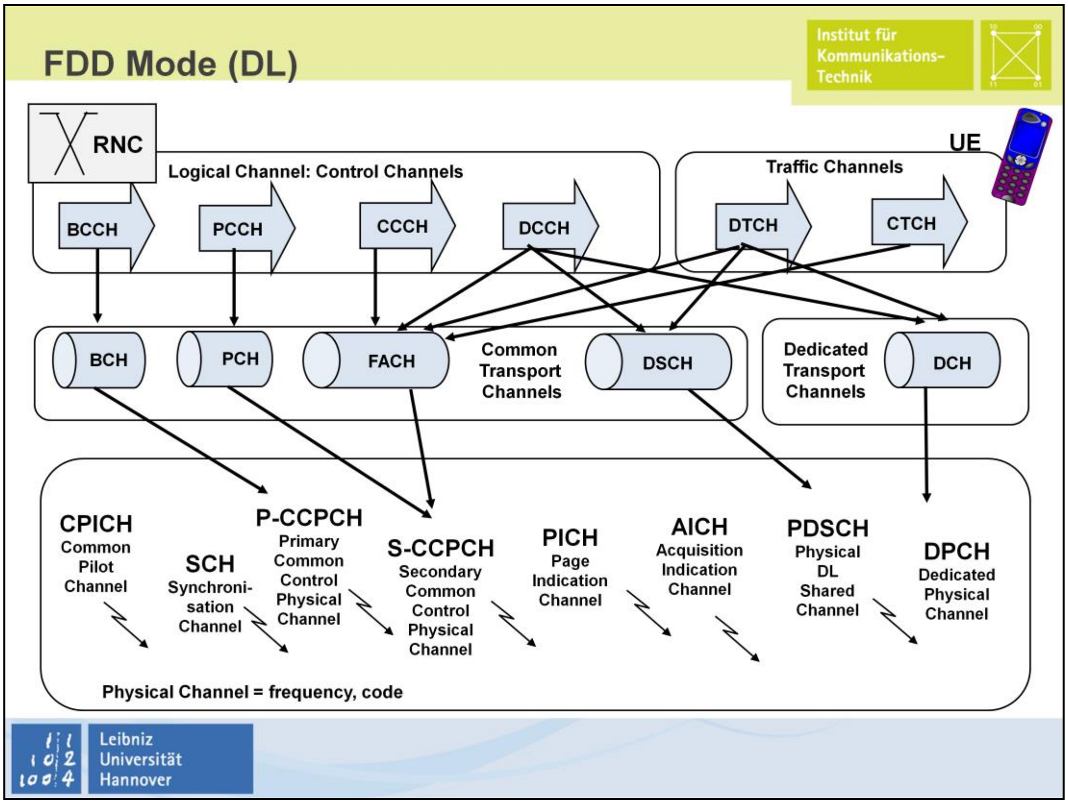
Transport Channels are described by “how and with what characteristics data are transferred over the radio interface”. Different Logical Channels can be mapped together onto one Transport Channel. The Transport Channels can be sub-divided into Common Transport and Dedicated Transport Channels.

Common Transport Channels are channels, where there is a need for in-band identification of the UEs when particular UEs are addressed. Important Common Transport Channels for FDD mode DL transmission are:

- Broadcast Channel BCH. The BCH is used to broadcast system information to the total cell area. The BCCH is mapped onto the BCH.
- Paging Channel PCH. The PCH broadcasts control information (paging and notification) to the total cell area. The PCCH is mapped onto the PCH.
- Forward Access Channel FACH. The FACH is used to transmit common control information (e.g. access grants, acknowledgements) and / or small data packets to one UE or a group of UEs. The Logical Channels CCCH, DCCH, DTCH and CTCH can be mapped onto the FACH.
- DL Shared Channel DSCH. The DSCH is used to carry dedicated control or traffic data on common resources. A DSCH is shared by several UEs. The DCCH and DTCH are mapped onto the DSCH.

Dedicated Transport Channels are channels, where the UEs are identified by the physical channel (i.e. code & frequency). A Dedicated Transport Channel for FDD mode DL transmission is the:

- Dedicated Channel DCH. The DCH is carrying dedicated control and traffic data on dedicated resources, i.e. dedicated to one UE. The DCCH and DTCH are mapped onto the DCH.



The Physical Channels of the FDD mode are defined by their frequency (DL and UL) and their code, for the TDD mode additionally TS information are needed.

Most Transport Channels are mapped directly onto equivalent Physical Channels, some are mapped together on one Physical Channel or separated to two different Physical Channel. Furthermore, some Physical Channels exist, carrying information relevant only to physical layer procedures. No Transport Channels are mapped onto them. The Physical Channel and the Mapping of Transport Channels to Physical

Channels are described in 3G TS 25.211 (FDD mode) and 25.221 (TDD mode). Due to simplicity, only the most important Physical Channels are described in the following.

Mapping of Transport Channels to Physical

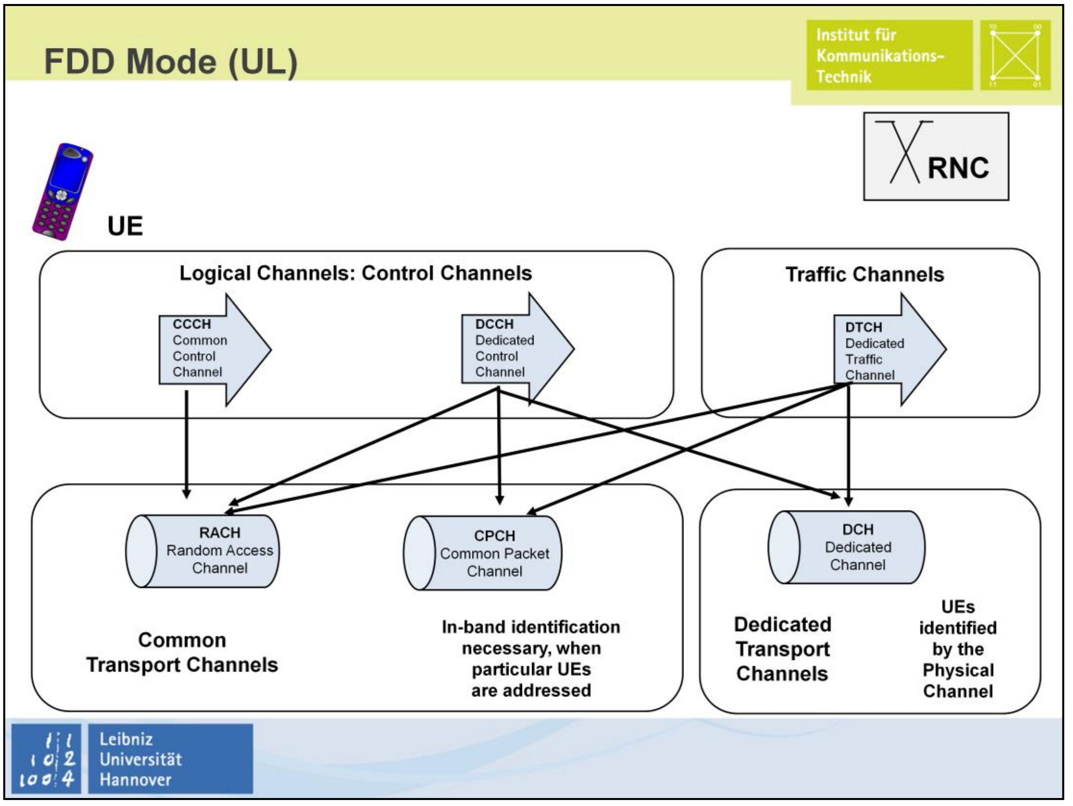
Channels: The FDD Mode (DL)

Common Physical Channel:

- Common Pilot Channel CPICH. The CPICH is an unmodulated code channel, carrying the Scrambling Code of the cell.
- Synchronization Channel SCH. The SCH is needed for time synchronization of the UEs at cell search.
- Primary Common Control Physical Channel P-CCPCH. The P-CCHCH is carrying the Broadcast Channel BCH.
- Secondary Common Control Physical Channel S-CCPCH. The S-CCPCH carries two different Common Transport Channel: the PCH and the FACH. They can be multiplexed together on one single S-CCPCH or use two / several S-CCPCH, depending on network operators decision.
- Page Indication Channel PICH. The PICH can be used in connection with the PCH for efficient sleep mode operation of the UE.
- Acquisition Indication Channel AICH. The AICH is used in connection with the RACH for random access.
- Physical DL Shared Channel PDSCH. The PDSCH is used to carry the transport channel DSCH. The PDSCH is used to transmit dedicated data with high peak rateand low activity cycle on common resources. It is shared by several users based on code multiplexing. The PDSCH is always associated with a DPCH.

Dedicated Physical Channel:

- Dedicated Physical Channel DPCH. The DPCH is used to carry dedicated user data (DTCH) and control information (DCCH) on dedicated resources. DTCH and DCCH information are time-multiplexed in the DPCH.



Mapping of Logical to Transport Channels:

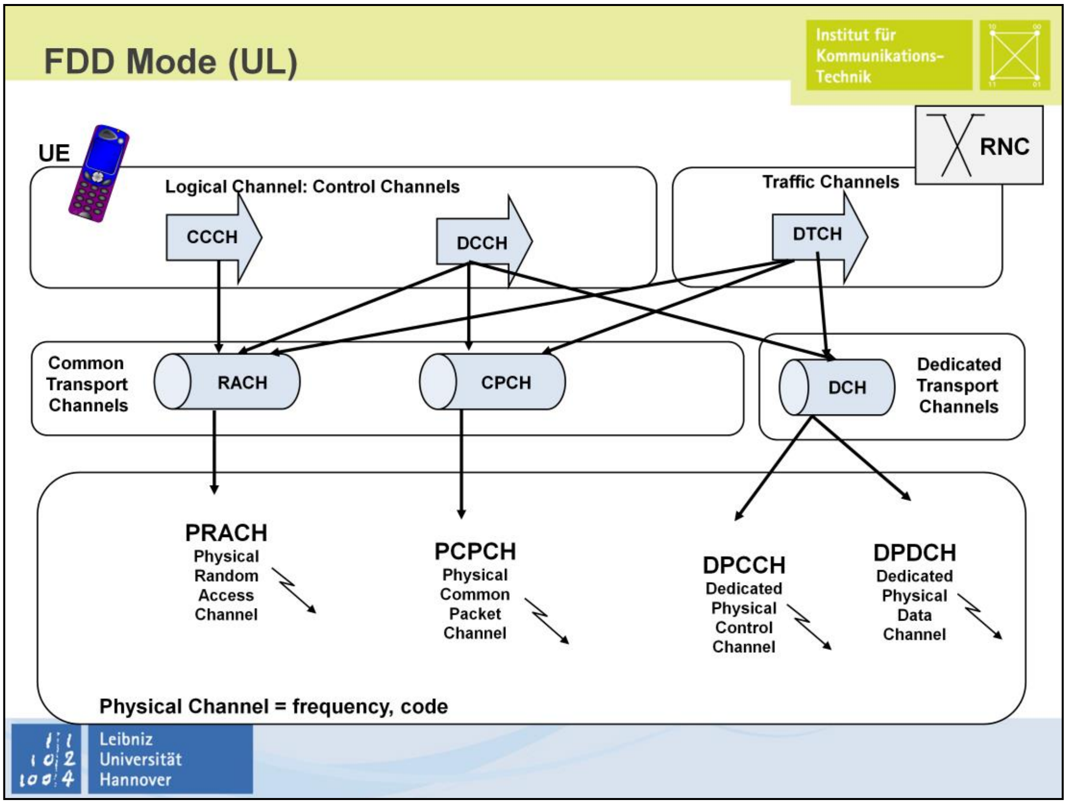
FDD Mode (UL)

Important Common Transport Channels for FDD mode UL transmission are:

- Random Access Channel RACH. The RACH is an UL channel for initial access or Non-Real Time dedicated control or traffic data. It is contention based. The Logical Channels CCCH, DCCH and DTCH can be mapped onto the RACH. The RACH can be regarded as counterpart to the DL FACH.
- Common Packet Channel CPCH. Similar to the RACH, the CPCH is a contention based channel. The CPCH is existing only in the FDD mode. It is used for the transmission of short data packets (bursty traffic) on common resources. The Logical Channels DCCH and DTCH are mapped onto the CPCH.

A Dedicated Transport Channel for FDD mode DL transmission is the:

- Dedicated Channel DCH. The DCH is carrying dedicated control and traffic data on dedicated resources in both directions, i.e. DL and UL. The DCCH and DTCH are mapped onto the DCH.



Mapping of Transport Channels to Physical

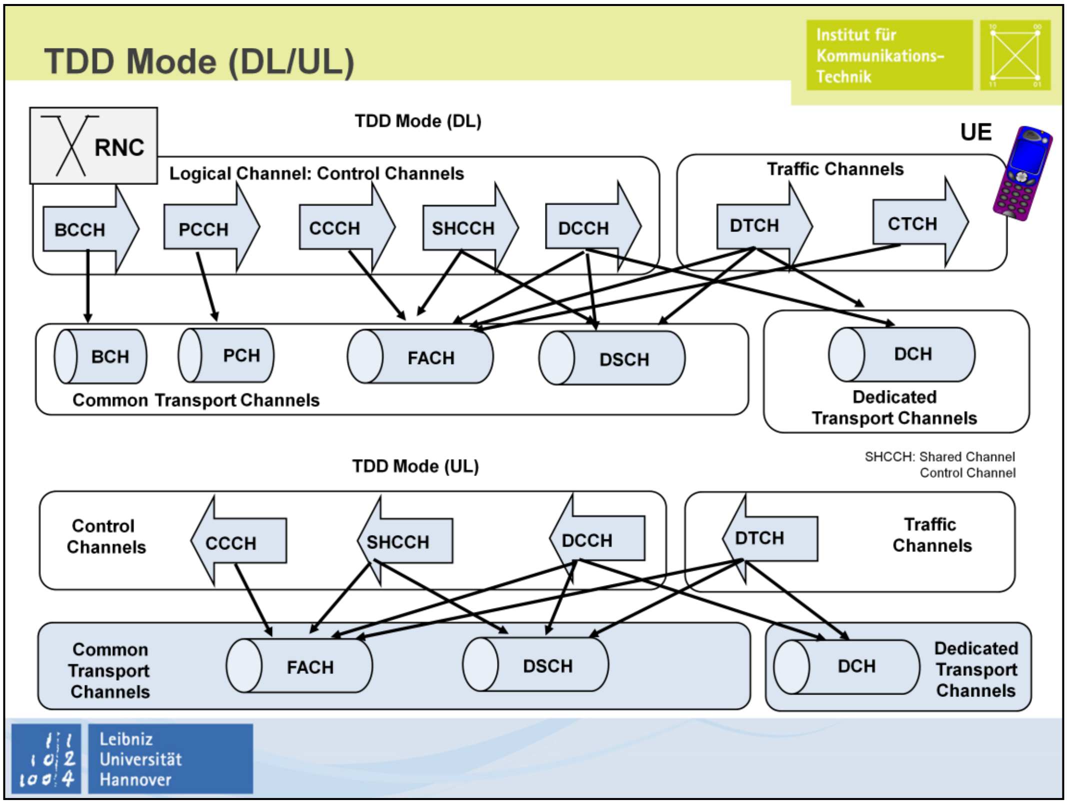
Channels: The FDD Mode (UL)

Common Physical Channel:

- Physical Random Access Channel PRACH. The PRACH is used to carry the RACH data, i.e. for initial network access and transmission of small user data packets on common resources.
- Physical Common Packet Channel PCPCH. The PCPCH is used to carry the CPCH data, i.e. it is used to transmit small and medium size data packets on common resources.

Dedicated Physical Channel:

- Different to the FDD mode DL transmission, the Dedicated Traffic (DTCH) and Dedicated Control (DCCH) information of the DCH are not time-multiplexed at UL transmission. They are code-multiplexed onto different physical cannel:
- Dedicated Physical Control Channel DPCCH. The DPCCH carries the UL DCCH physical layer control information to maintain the connection (DPDCH).
- Dedicated Physical Data Channel DPDCH. The DPDCH carries the UL user traffic (DTCH), i.e. user data and higher layer signaling. In a dedicated connection, the UE may use one DPCCH and one or more DPDCH (up to 6; TS 25.213) for UL transmission.



Mapping of Logical to Transport Channels:

TDD Mode (DL)

Most of TDD mode Transport Channels are still the same as in the FDD mode. Important Common Transport Channels for TDD mode DL transmission are:

- Broadcast Channel BCH, which is identically in FDD and TDD mode
- Paging Channel PCH, which is identically in FDD and TDD mode
- Forward Access Channel FACH, which is nearly identical in FDD and TDD mode.
- Different to the FDD mode, not only CCCH, DCCH, DTCH and CTCH, but also the SHCCH (TDD only) can be mapped onto the FACH.
- DL Shared Channel DSCH, which is similar in FDD and TDD mode. Additional to DCCH and DTCH, the SHCCH is mapped onto the DSCH.

A Dedicated Transport Channel for FDD mode DL transmission is the:

- Dedicated Channel DCH, which is identically in FDD and TDD mode, carrying
- dedicated control (DCCH) and traffic (DTCH) data on dedicated resources.

Mapping of Logical to Transport Channels:

TDD Mode (UL)

Important Common Transport Channels for TDD mode UL transmission are:

- Random Access Channel RACH, which is nearly identically in FDD and TDD mode. Additional to CCCH, DCCH and DTCH, the SHCCH can be mapped onto the RACH in the TDD mode. The RACH can be regarded as FACH counterpart.
- UL Shared Channel USCH, which is the DSCH counterpart. Similar to the CPCH of the FDD mode, it is used for the transmission of short data packets on common resources. The Logical Channels SHCCH, DCCH and DTCH are mapped onto the USCH.

A Dedicated Transport Channel for FDD mode DL transmission is the:

- Dedicated Channel DCH. The DCH is identically in FDD and TDD mode, UL and DL, carrying DCCH and DTCH data.

Outline Part IV-II

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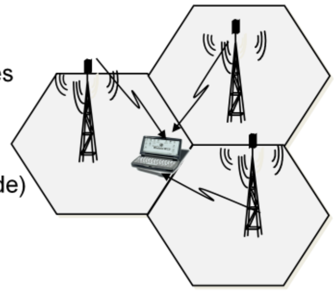
Cell search

Basic steps 25.214 cell search procedure

- Find new cells:
  - at power on (initial cell search)
  - in idle mode, find better cells to camp on
  - in active mode, find cells that are soft-handover candidates
- Two main tasks:
  - Find slot and frame timing of the cells
  - Slot synchronisation (SCH Primary synchronisation code)
  - Frame synchronisation and code group identification (SCH Secondary synchronisation code)
  - Identify primary scrambling code of the cell
  - Scrambling code identification (Uses CPICH)
  - WCDMA uses 3-step cell-search scheme to support asynchronous base-station operation



Cell search

There are different types of cell search:

- Initial cell search, i.e. the process by which a mobile terminal finds the „best“ cell at power-on.
- Idle-mode cell search, i.e. the process by which a mobile terminal in idle mode searches for neighbor cells. If a neighbor cell is found that is sufficiently „better“ than the current cell, the mobile terminal should use this cell to listen for page messages etc.
- Active-mode cell search, i.e. the process by which a mobile terminal in active mode searches for neighbor cells. If a neighbor cell is found that is sufficiently „good“, compared to the current cells in the active set, the mobile terminal should add this cell to the active set.

This third case, i.e. active-mode cell search, is by far the most critical. If a neighbor cell is not properly added to the active set, there may be extensive excess interference with a significant loss of capacity as a consequence. There are thus tight time constraints for active-mode cell search. However, the process is simplified by the fact that some kind of a priori information is normally available to the mobile terminal. This information is typically in form of a neighbor list that contains the information on the primary scrambling code of potential neighbor cells and possibly also a priori timing information.

CCPCH - Common Control Physical Channel

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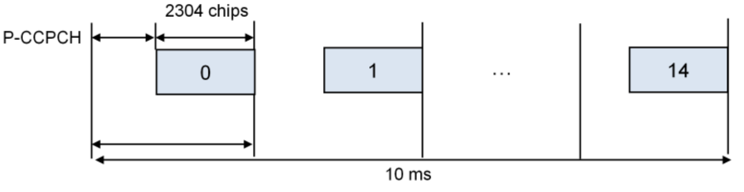
- Primary CCPCH is the physical channel carrying the BroadCast Channel (BCH).

  - Delivers system parameters needed by all the terminals in the cell (e.g. codes to be used with RACH). Hence, it needs to be decoded by all the terminals served by the cell.

  - P-CCPCH channel alternates with the SCH channel

  - Available bit rate for control information is only 27 kbit/s



- Secondary CCPCH Carries FACH and PCH which can either share the same physical channel or to both have their own channels.

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SCH - Synchronisation Channel

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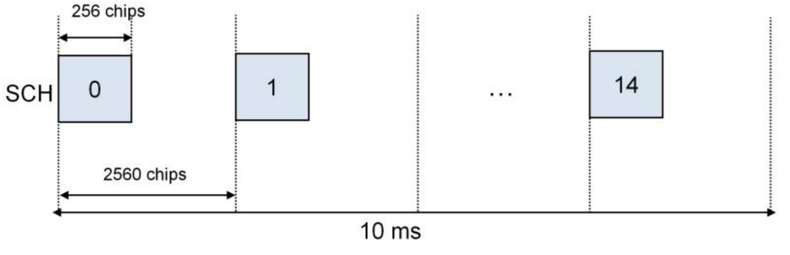
- Primary synchronisation channel:

  - is utilized to find the slot timing used in one particular cell so that the control information broadcasted in that cell could be heard.

  - it uses 256-chip spreading sequence identical in every cell

- Secondary synchronisation:

  - is utilized to find the frame synchronisation and the code group utilized by the cell (Codes are grouped into 64 different code groups)



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CPICH - Common Pilot Channel

- Unmodulated code channel with spreading factor 256 which is scrambled with the cell-specific primary scrambling code.
- Provides a known reference signal to aid channel estimation (Amplitude and phase information for the Rake receiver and SIR estimator)
- There are two kinds of pilot signals:
  - Primary: Cell/ sector specific primary scrambling code to be used for the whole cell/ sector
  - Secondary: A secondary scrambling code with or without a channelisation code of length 256 to be used in a narrow beam (Adaptive antennas/ Beam steering) e.g. hotspot areas.
- Primary CPICH channel power defines the handover regions. I.e. cell boundaries. By adjusting the CPICH channel powers of two neighbouring base stations, the traffic load can be balanced between them.

Cell Search

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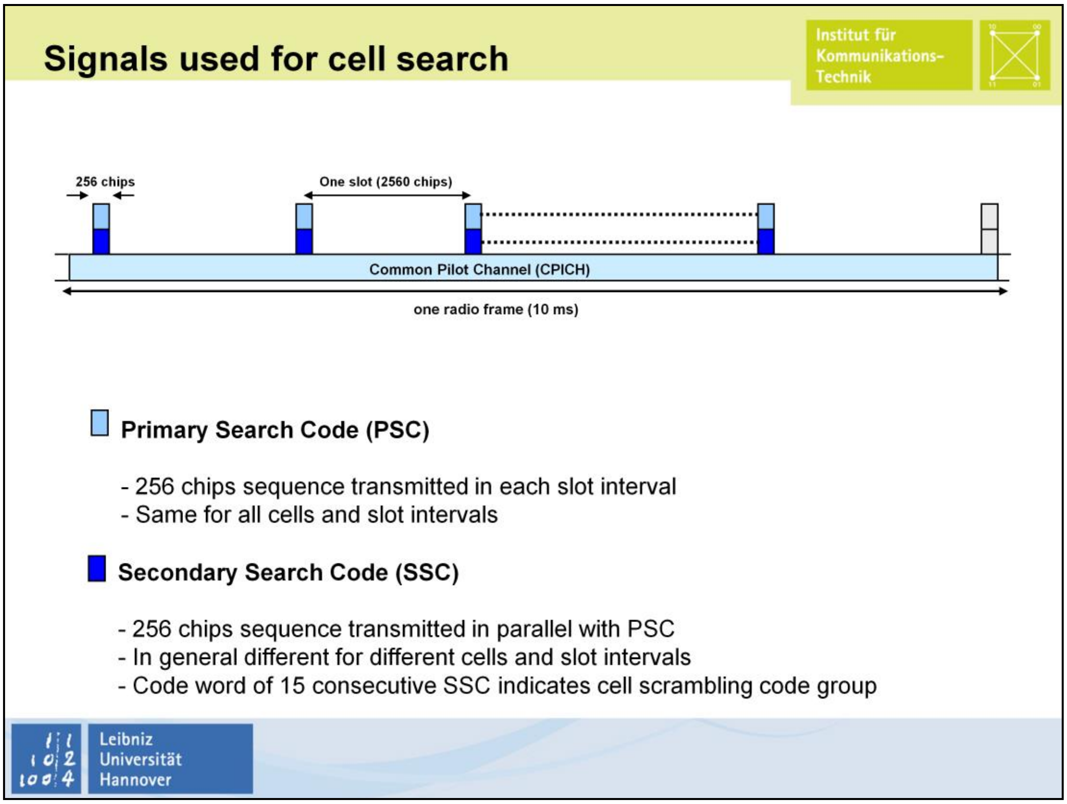
- ***Step 1:*** Correlate against the common 256-chip primary synchronisation code. Maximum correlation peak gives the slot boundary. [P-SCH]
- ***Step 2:*** Detect scrambling code group by cross-correlation of the received signal with all 64 permitted secondary synchronisation code sequences at the timing instants found in step 1; this also establishes frame synchronisation (as each sequence has unique cyclic shifts).
[S-SCH]
- ***Step 3:*** identify the primary scrambling code by cross-correlation with the received signal with all scrambling codes belonging to the group (8 possibilities) found in step 2 [CPICH]
- Detect primary common control physical channel (carrying the broadcast channel) and real system information



Signals used for cell search

WCDMA cell search is based on the following three signals broadcast by every cell:

- The *Primary Search Code* (PSC) is a specific chip sequence of length 256 chips, transmitted at a pre-defined position in every slot interva (2560 chips). The PSC is the same for every cell and every slot interval and has been chosen to have very good aperiodic auto-correlation properties.
- The *Secondary Search Code* (SSC) is also a chip sequence of length 256 chips and is transmitted in parallel with the PSC. In contrast to the PSC, the SSC is, in general, different between different cells and also different between slot intervals. The 15 consecutive SSC in a frame define a code word of length 15. A total of 64 such SSC code words have been defined and they specify to which scrambling-code group the primary scrambling code of the cell belongs.
- The common pilot channel, i.e. the pre-defined bit sequence spread by the primary downlink scrambling code.

Outline Part IV-II

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2. Transport Blocks
3. Physical Channel
4. Transport Channel
5. Logical Channel
6. Cell Search
7. Random Access and Paging
8. Packet Transmission

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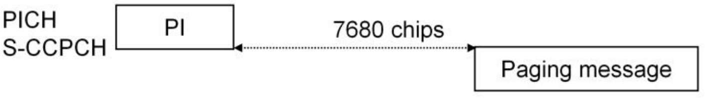
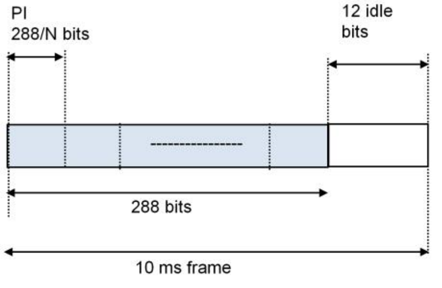
Paging

- User equipments are divided into groups
- Paging Indication (PI) message per paging group are periodically transmitted in the PICH channel when some UE in the group is paged.
- UE has to listen for the PI messages in those intervals defined its paging group.
- If PI reception indicates that someone in the group is paged, then all the members of the group have to decode the next PCH frame from the Secondary Common Control Physical Channel (S-CCPCH).
- The less frequently PI is sent, the less often must UE awake from the sleep mode to listen to the channel, but also the longer is the delay in connection establishment.



Paging

- PICH frame structure:



N is the paging indicator repetition ratio (17,36,72 or 144)

- How often a terminal needs to listen to PICH channel is parameterised and the exact moment is determined by System Frame Number (SFN).

Random Access

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- **The process by which a UE access the network when there is no dedicated channel**
- **Random-access-specific problems:**
  - Timing of UE random-access transmission unknown to base station
    - ⇨ Random-access transmission should start with a known sequence (a preamble) to which the network can easily synchronize
  - Transmit power to use for random-access transmission?
    - ⇨ Initial random-access transmit power should be low and gradually increase until correct power is reached (power ramping)

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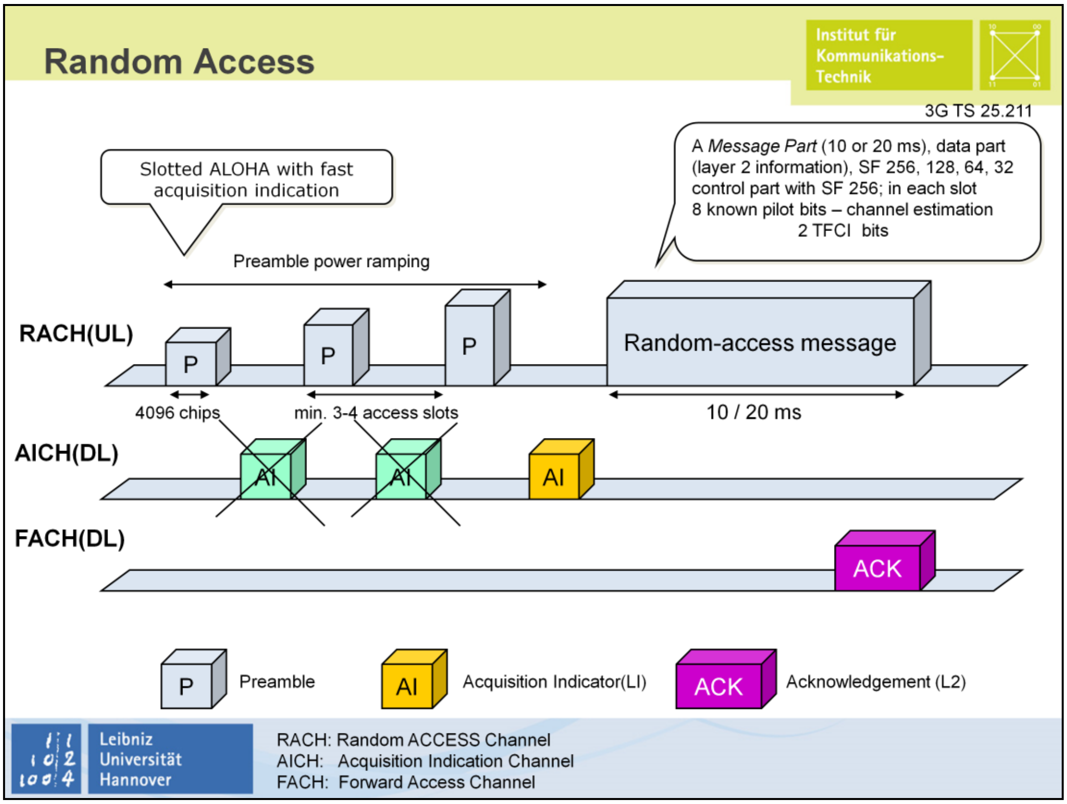
<u>Random Access</u>

Random-access is the process by which a UE accesses the network when it has not been allocated any dedicated channel. Compared to uplink dedicated-channel transmission, random-access transmission is subject to the following constraints

- The network does not know the exact timing of the random-access transmission. The random-access transmission must therefore be preceded by the transmission of a pre-defined chip sequence (a preamble) to which the network can synchronize
- In case of dedicated-channel transmission, the closed-loop power control ensures that the uplink signal is received with approximately the correct power. For random-access transmission, the UE can only determine the required transmit power from an estimate of the uplink path loss (open-loop power control). Furthermore, the uplink path-loss estimate can only be determined from an estimate of the downlink path loss. For several reasons, the open-loop estimate will deviate from the correct transmit power, e.g. due to errors in the downlink path-loss estimate and non-reciprocity between uplink and downlink path loss. In order to avoid that the random-access transmission is received with too high power, the UE should therefore start the random-access transmission with a sufficiently low power and apply some kind of power ramping until the correct power is reached.



The Random Access Procedure

The UE first has to be synchronized on the base on chip, TS and frame by listening to the P-SCH and S-SCH. Furthermore, the Scrambling Code Group is recognized by the S-SCH.

Then the UE is searching the Scrambling Code of the cell to read the BCH information of the P-CCPCH. The P-CCPCH gives information about the Scrambling Codes and Signatures to be used in this cell. The UE selects randomly one of the RACH sub-channels from the group its access class allows it to use (i.e. of the allowed SF). Furthermore it selects one of the 16 available signatures S.

The UE is performing Open Loop Power Control to adjust the transmission power of the first Preamble. The UE transmits the Preamble with the Signature S. The UE listens to the AICH information AIs to get information, whether the Node B detected its Preamble.

If no AICH with the correct AIs is detected the UE transmits again a Preamble, increasing the transmission power.

If an AICH with the correct AIs is detected, the UE transmits the Message Part at the same power level as the last Preamble.

The correct reception of the PRACH Message Part can be acknowledged by the network with a S-CCPCH carrying FACH information. The transmission of CPCH information is similar, incorporating an additional collision detection mechanism to enhance the security of the larger data packets transmission.

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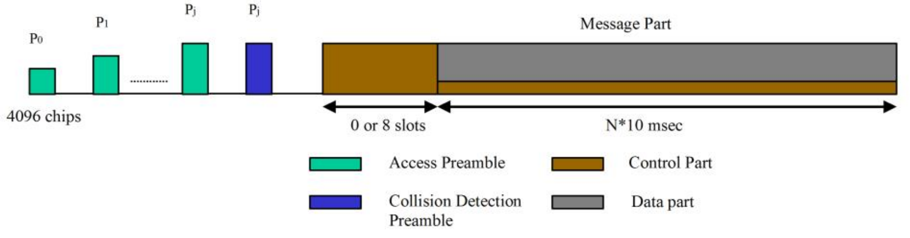
Packet transfer PCPCH



- Similar to RACH
- Additional Collision Detection Preamble