Cellular Mobile Networks - GSM
GSM Radio Interface

Contents - GSM - GSM Radio Interface

- Physical Layer
- Logical Channels
- Mapping of Logical Channels to the Physical Layer
- Radio Link Control
- Example: Voice Signal Processing

Physical Layer

Contents - GSM - GSM Radio Interface - Physical Layer

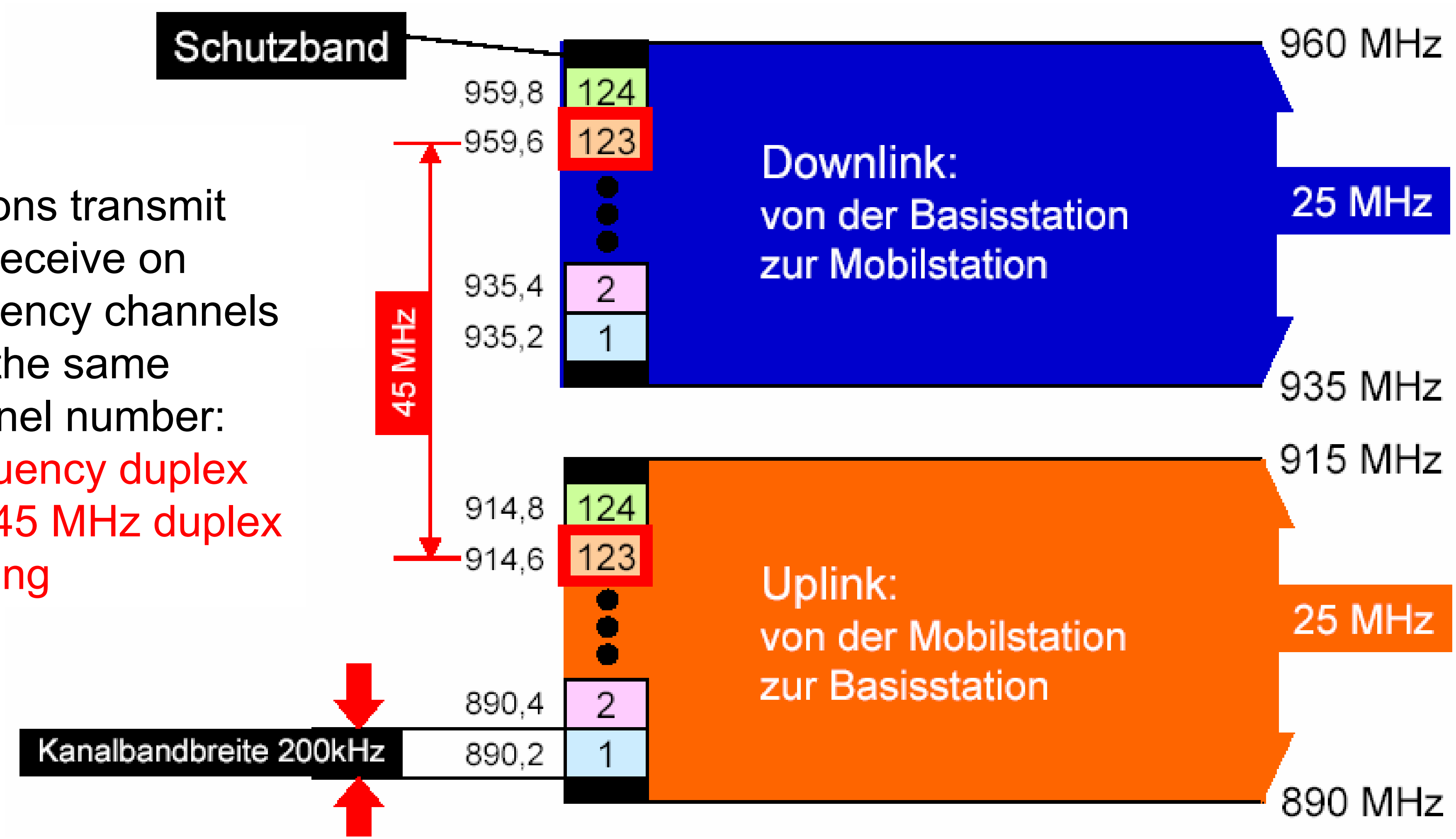
- Multiple Access and Duplex
- Bursts
- Hyperframes

Multiple Access and Duplex - GSM Channel Structure

- GSM 900:
  - Uplink: 890-915 MHz
  - Downlink: 935-960 MHz
  - 124 bidirectional channels (Radio Frequency Channels, RFChs) a 200 kHz
- DCS 1800:
  - Uplink: 1710-1785 MHz
  - Downlink: 1805-1880 MHz
  - 372 bidirectional channels (RFChs) a 200 kHz
- Channel assignment in Germany:
  - T-Mobile: channels 1-12, 51-80, 105-119 (overall 57 channels)
  - Vodafone: channels 14-49, 82-102 (overall 57 channels)
  - 10 channels as backup

Multiple Access and Duplex - GSM Channel Structure

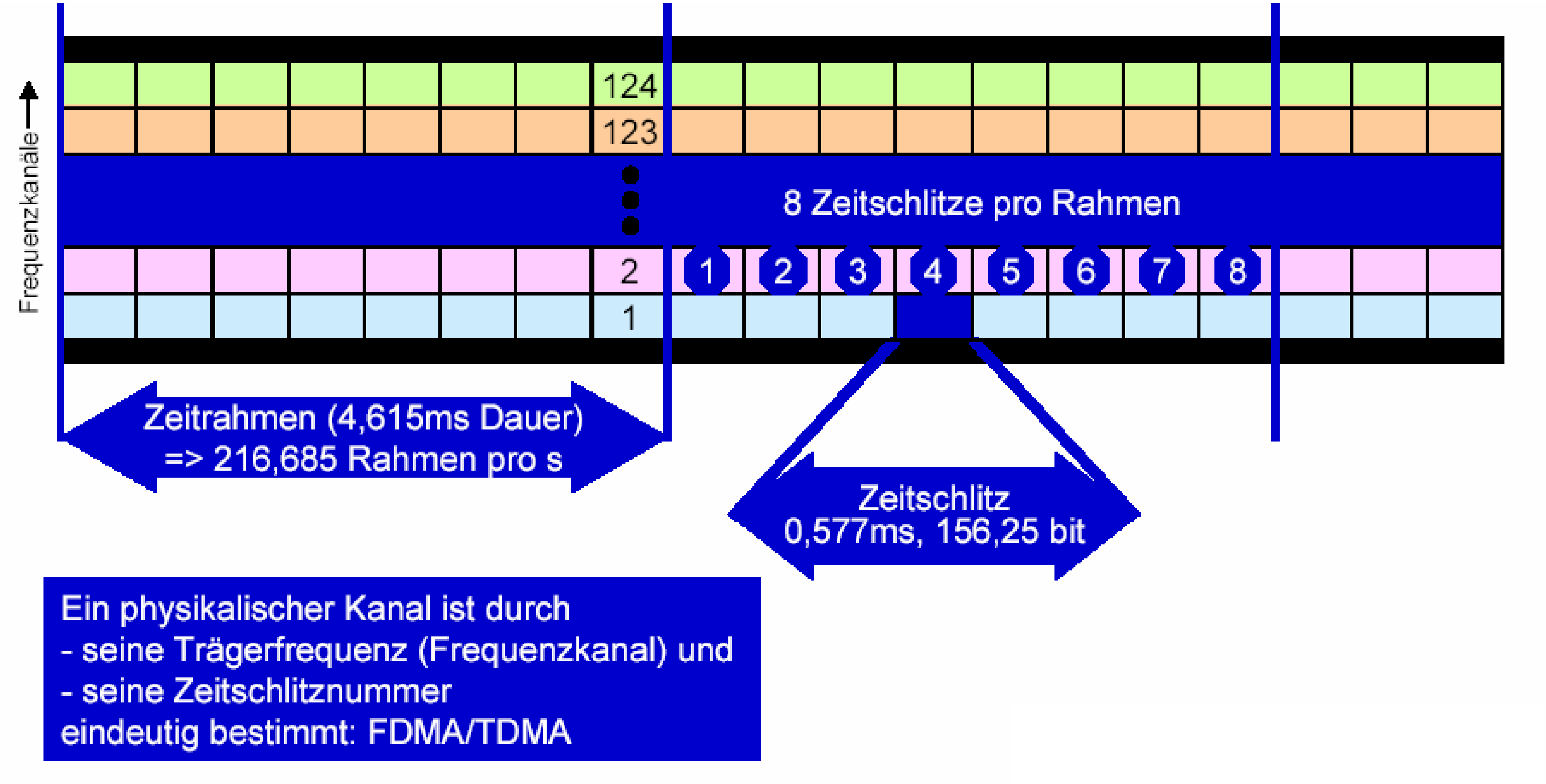
Stations transmit and receive on frequency channels with the same channel number:
Frequency duplex with 45 MHz duplex spacing



Multiple Access and Duplex - FDMA/TDMA Multiplex

- Access to a frequency channel is only allowed at defined periodic time instances (time slots)
- Each mobile station (MS) with an active circuit switched (CS) connection is assigned one time slot within a TDMA frame
- Extension for HSCSD and GPRS: grouping (bundling) of time slots
  - up to 8 time slots can be grouped (typically 4 time slots)
  - in HSCSD: the time slots are reserved for the whole time of the connection
  - in GPRS: the time slots are **not** reserved for the whole time - they could be requested dynamically → multiple data connections (PS connections) share the time slots (statistical multiplexing)

Multiple Access and Duplex - FDMA/TDMA Multiplex



FDMA: Frequency Division Multiple Access
TDMA: Time Division Multiple Access

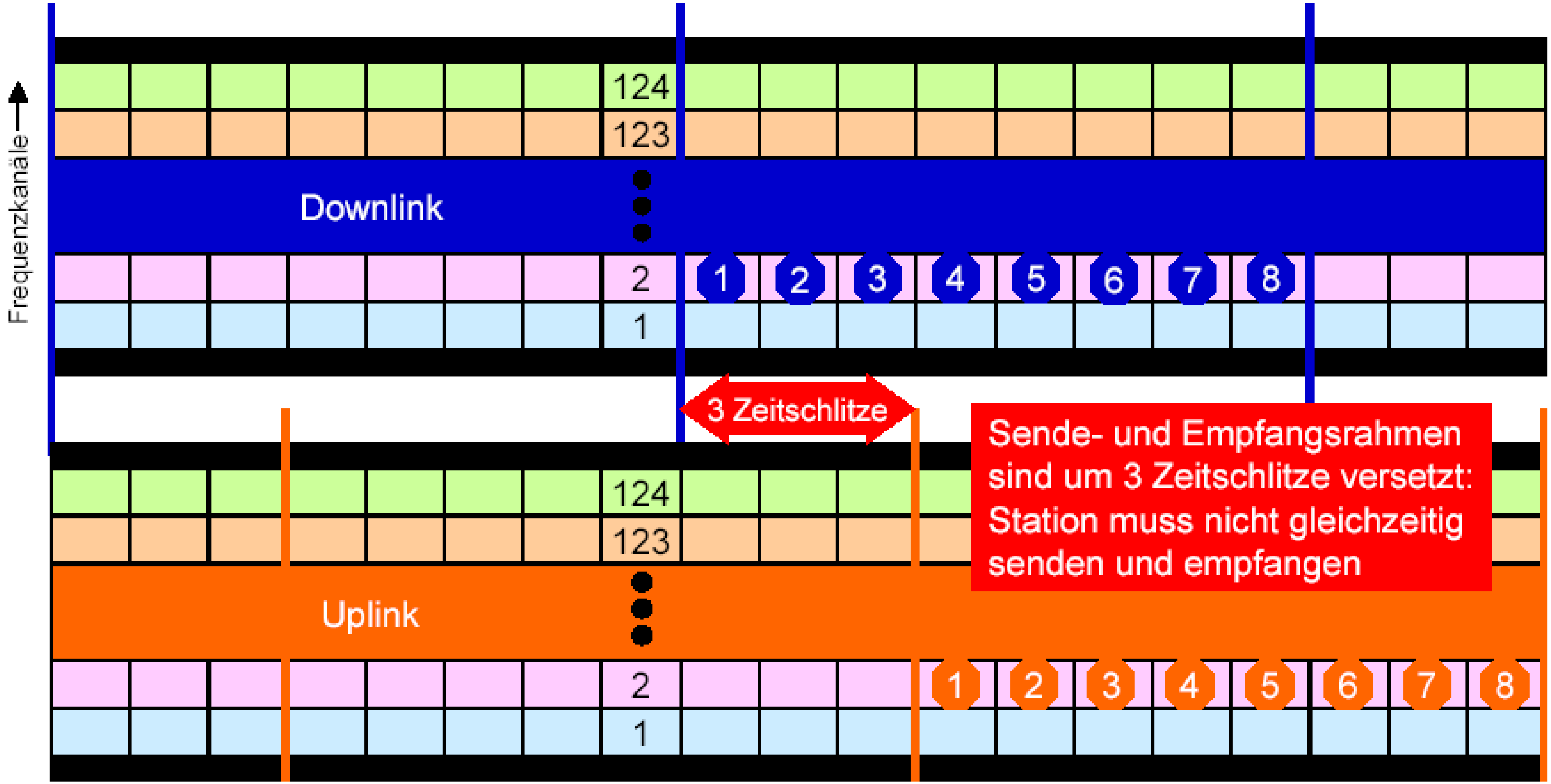
Multiple Access and Duplex - Receive/Transmit Time Offset

- The same TDMA time slots are assigned for uplink and downlink to the MS, but the TDMA frames are shifted by 3 time slots (time offset)
- Advantage of the time offset:
  - no simultaneous transmitting and receiving necessary

    → lower power

    → lower costs (due to less sophisticated implementation)

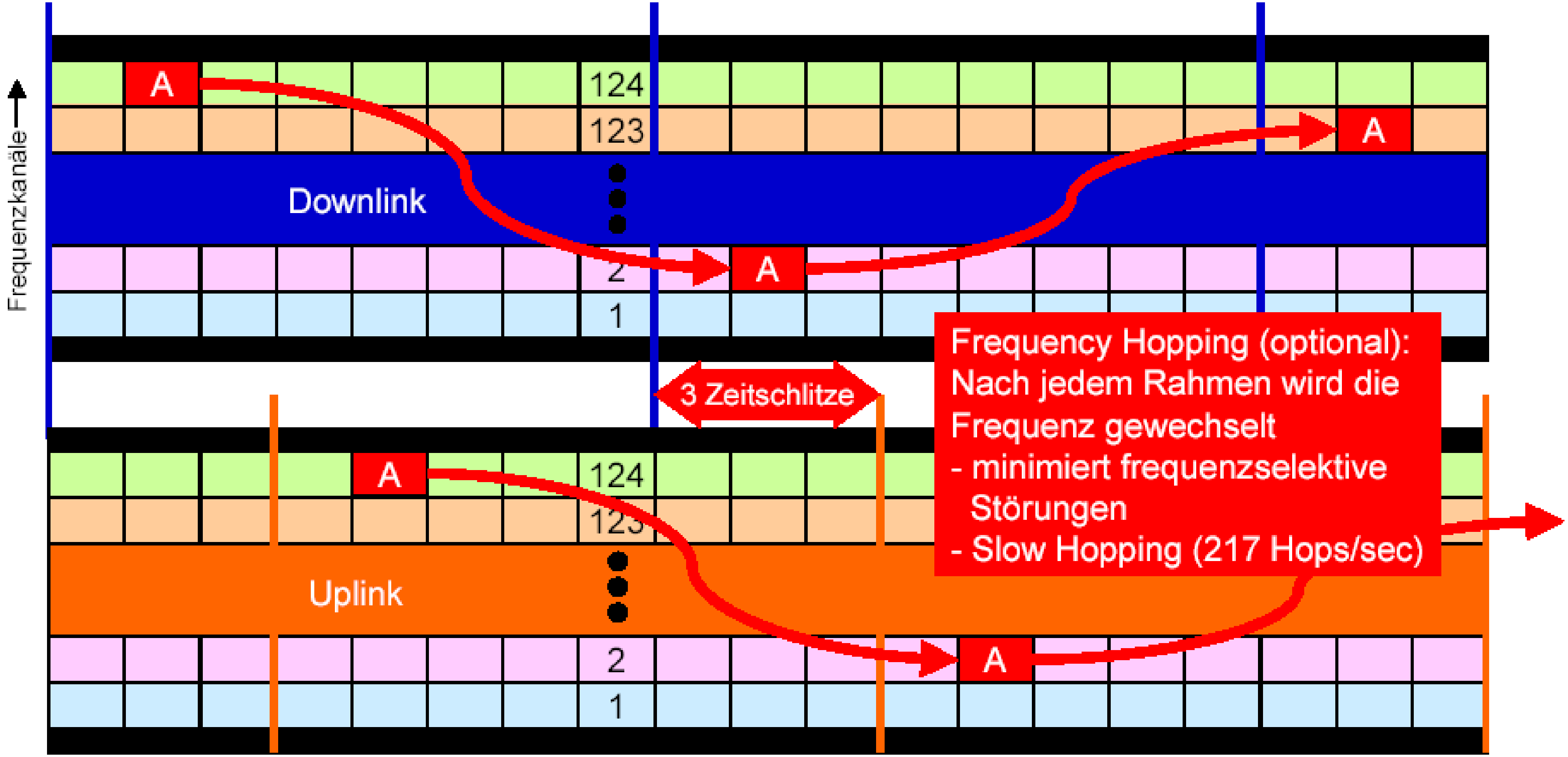
Multiple Access and Duplex - Receive/Transmit Time Offset



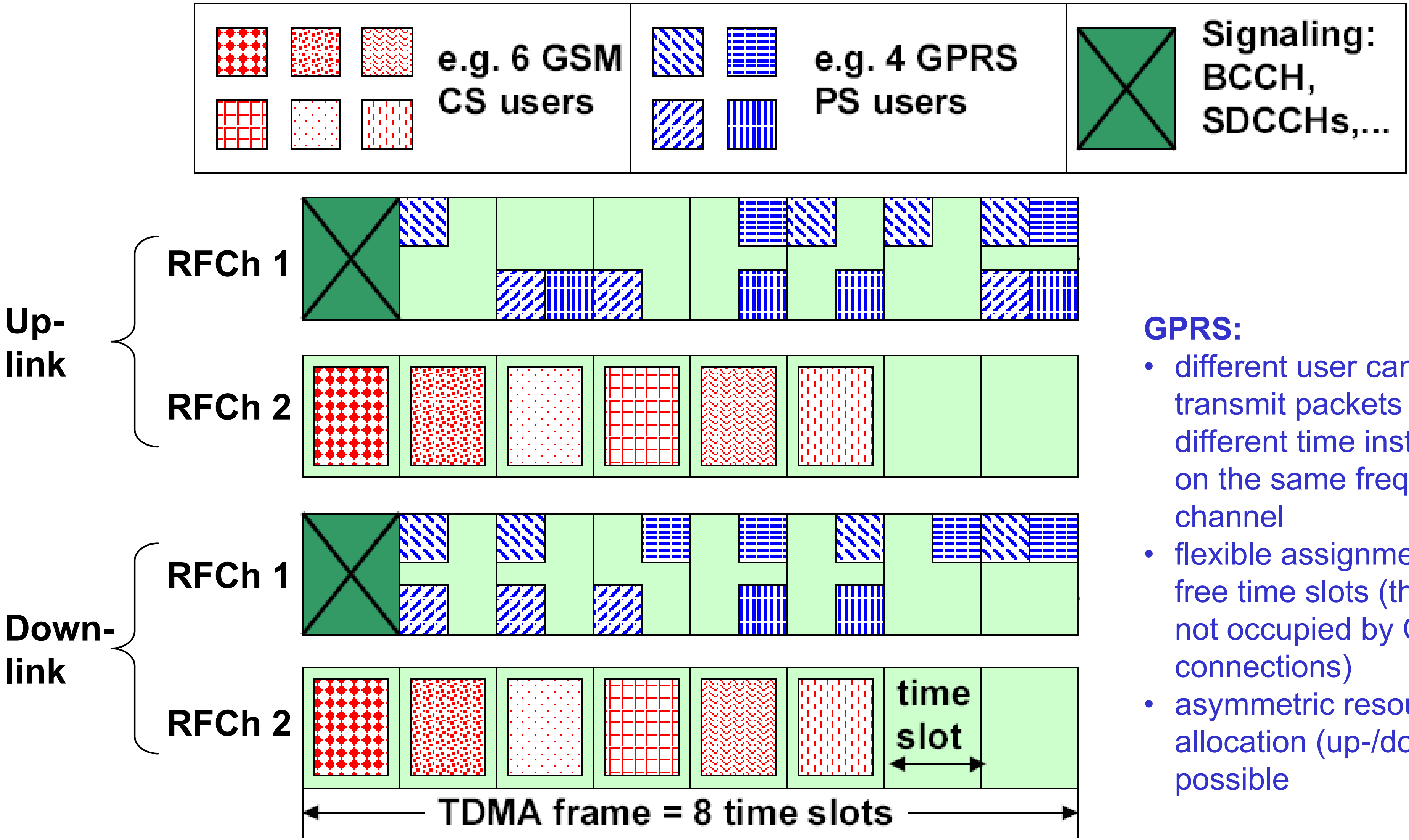
Multiple Access and Duplex - Frequency Hopping

- Frequency hopping = change of the frequency channel during the active connection
- Frequency hopping is an optional feature (completely specified by the mobile network operator)
- Frequency hopping can improve the connection quality in bad propagation conditions (frequency selective fading)
- Frequency hopping can improve the connection quality in case of high co-channel interference → interfering BS and/or MS are decoupled
- Hopping frequency: a change of the frequency channel is possible after every TDMA frame (4,615 ms) (→ 1/4,615 ms ≈ 217 hops/s)
- FDMA multiple access with frequency hoping is also named FHMA (Frequency Hopping Multiple Access)

Multiple Access and Duplex - Frequency Hopping



Multiple Access and Duplex - GSM/GPRS Resource Sharing



GPRS:

- different user can transmit packets at different time instances on the same frequency channel
- flexible assignment to free time slots (that are not occupied by CS connections)
- asymmetric resource allocation (up-/downlink) possible

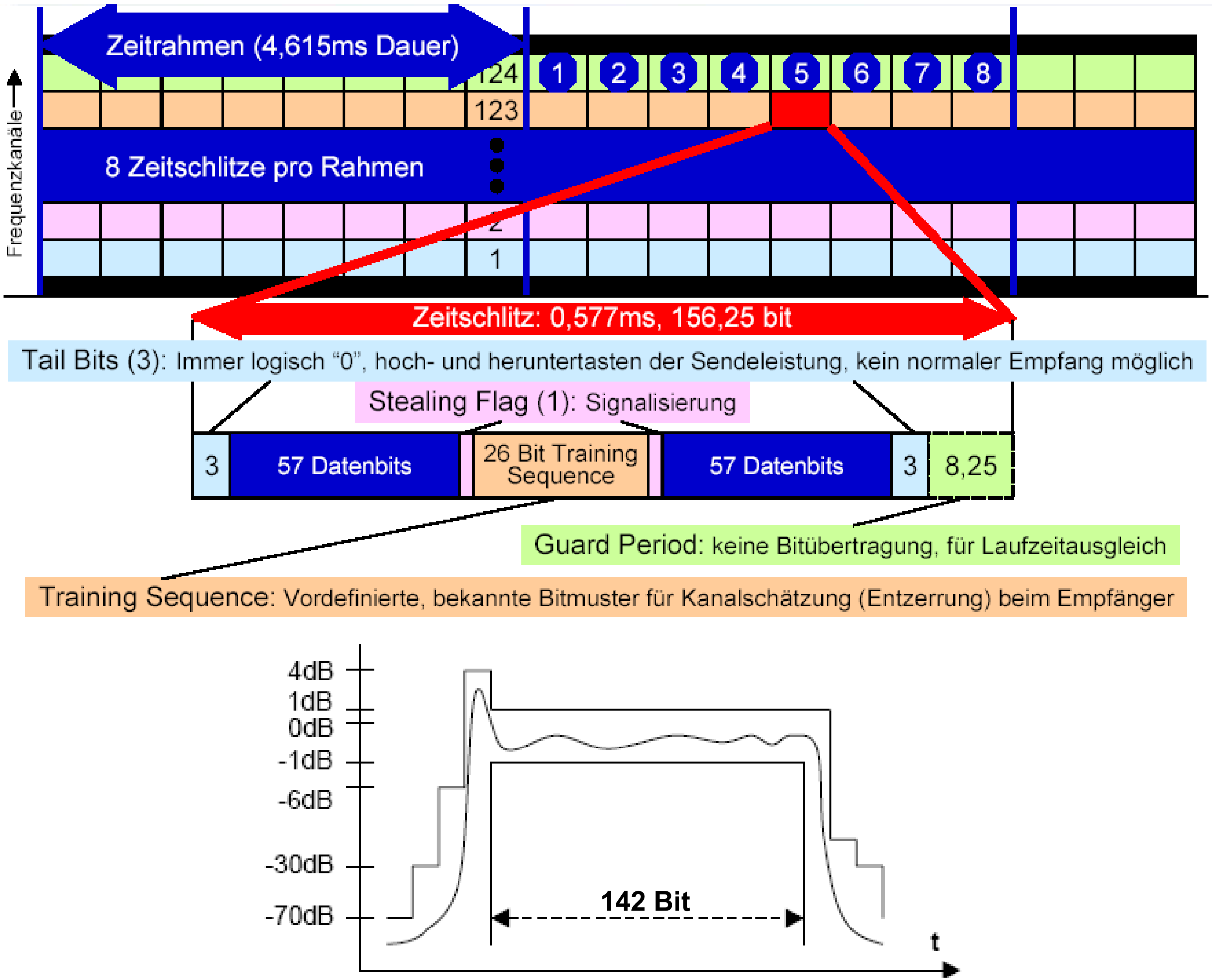
Multiple Access and Duplex - Summary

- Multiple Access (for user separation):
  - FDMA: partitioning of the (2x25MHz) spectrum into 124 frequency channels á 200kHz (in GSM900)
    - one frequency channel pair is characterized by an unique ARFCN (Absolute Radio Frequency Channel Number) (in GSM900: 1…124, in GSM1800: 512…885)
  - TDMA: partitioning into 8 time slots per frame
- Duplex (for uplink/downlink separation):
  - FDD: 45MHz duplex spacing
    - the lower frequency band is used for the uplink (because of lower propagation loss)
  - TDD: shift of 3 time slot of uplink and downlink TDMA frames
    - allows less complex handset implementation - no simultaneous transmission and reception necessary

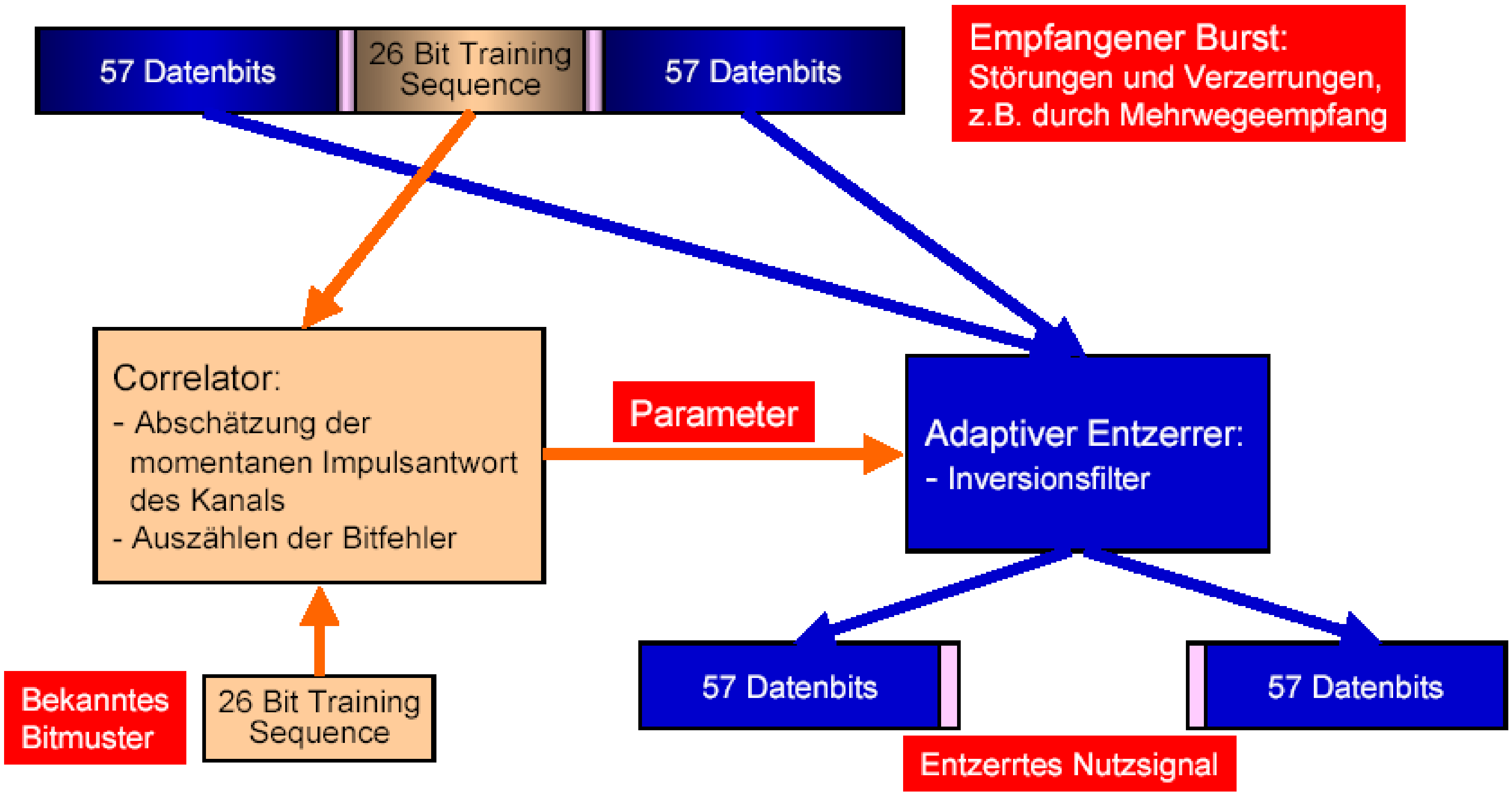
Bursts - Definition

- In TDMA at least one time slot is assigned to every active user
  - the time slot can carry user data (voice, data) or signaling data
- Time slots are structured according to their purpose
  - the structure defines, when and which informations are carried within the time slot
- The different time slot structures are called **bursts**
  - in GSM: five standardized burst formats for user and signalling data
- Burst duration: 156,25 bit (burst duration = time slot duration)
  - → 0,577ms per burst or 1733 bursts per second
- Bursts include an unused guard period
  - to avoid burst overlaps (due to different time delays)
- Bursts also include bit sequences to allow synchronization and channel estimation
- Logical channels are mapped into an burst

Bursts - Definition (Example: Normal Burst)

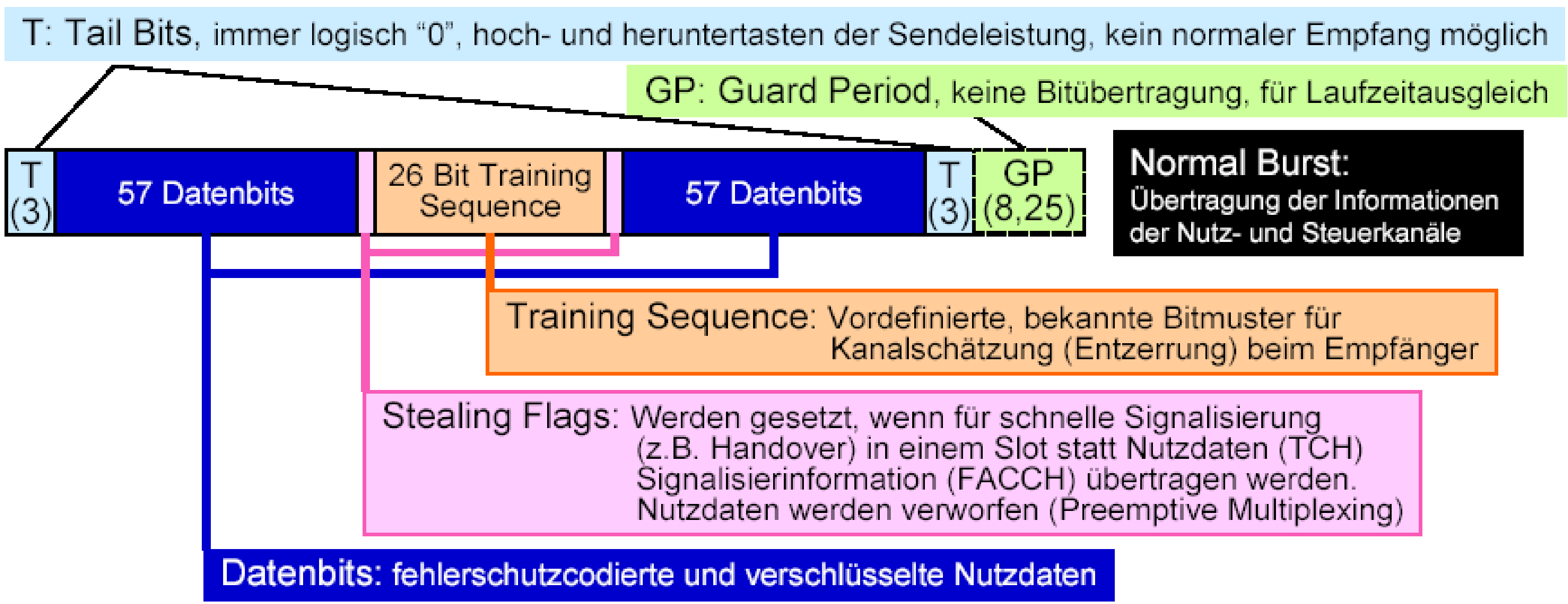


Bursts - Adaptive Equalization through Training Sequences



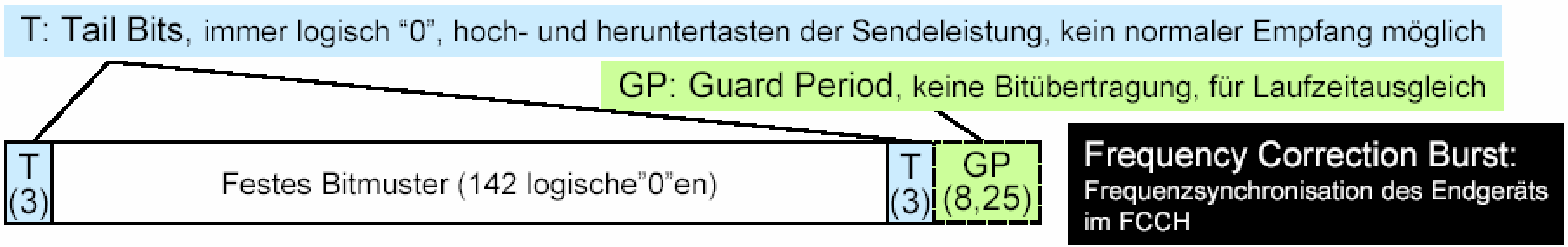
Bursts - Normal Burst

- Normal Burst
  - used for traffic channels and dedicated control channels
  - mostly used burst structure in an active connection



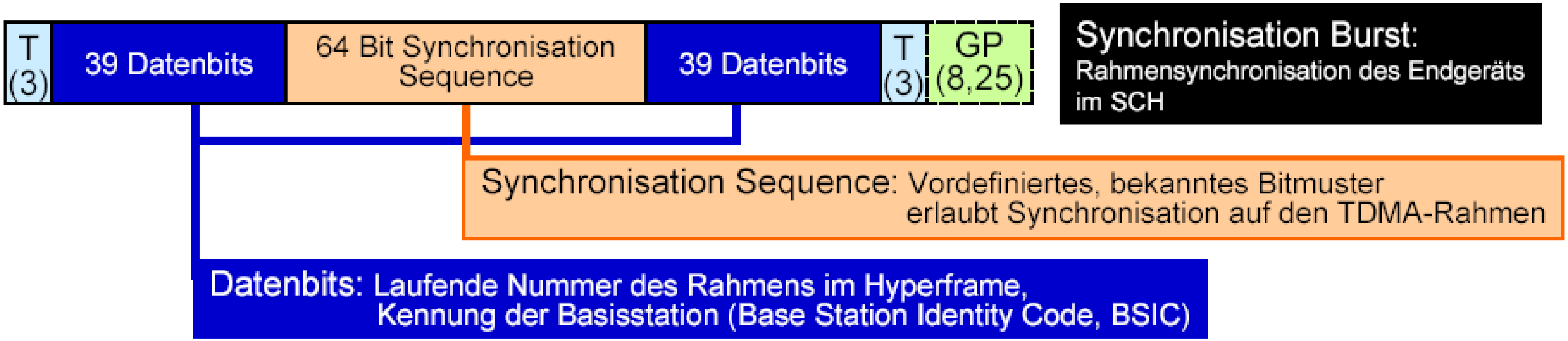
Bursts - Frequency Correction Burst

- Frequency Correction CHannel (FCCH) Burst
  - used for frequency synchronization of the mobile stations
  - all bit values are logical "0" → pure sinus signal on the physical layer
    - due to the modulation scheme used in GSM (GMSK) the sequence of logical "0"s generates a pure sinus signal, that lies 1625/24 kHz = 67,7 kHz (=1625/24 kHz) above the carrier frequency



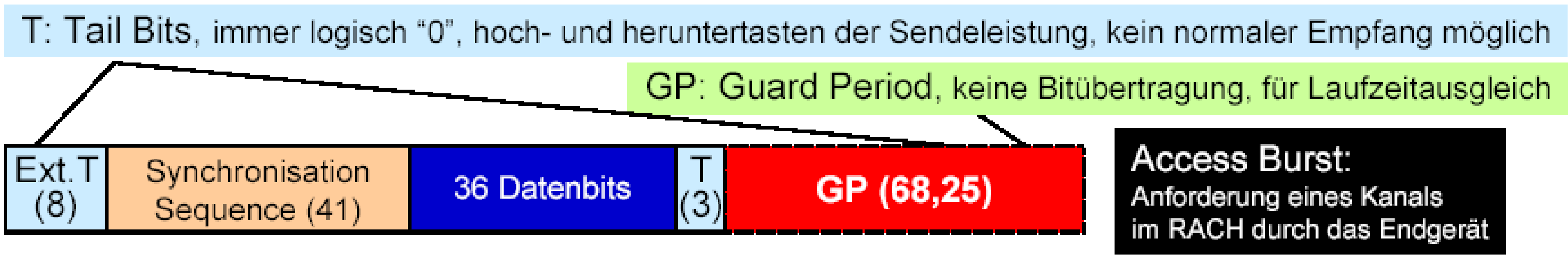
Bursts - Synchronization Burst

- Synchronization CHannel (SCH) Burst
  - used for TDMA frame synchronization of the mobile stations
  - the extended (64 Bit) synchronization sequence simplifies the time synchronization of the frames
  - the user data bits contain the following informations:
    - ID of the transmitting base station = Base Station Identity Code (BSIC)
    - TDMA frame number (FN)



Bursts - Access Burst

- Random Access CHannel (RACH) Burst
  - used to request a channel during connection setup
  - the RACH burst is only available in the uplink (and can be used by all mobile stations within a cell)
  - it contains specific start bits and a specific synchronization sequence
  - the user data bits contain informations about the transmitting mobile station
  - the extended guard period is necessary, as mobile stations are not fully synchronized in the phase before the connection setup is completed



Bursts - Dummy Burst

- Dummy Burst
  - used for filling unused time slots in the downlink
  - enables a mobile station to perform measurements, even if it is not connected to the base station
    - the dummy burst is transmitted on the frequency channel of the broadcast channel (BCH) if currently no other bursts have to be transmitted → this channel is always active and enables the mobile station to measure the received power of the broadcast control channel (BCCH) (BCCH quality monitoring)

Bursts - Using Bursts for Synchronization

- A base station uses one frequency channel (200 kHz) as base channel (Broadcast CHannel, BCH)
- Mobile stations search for specific signal patterns within the base channel that are caused by Frequency Correction CHannel (FCCH) bursts and Synchronization CHannel (SCH) bursts
- With the help of FCCH bursts a mobile station is able to perfom frequency synchronization and by using SCH bursts it can perform time synchronization (TDMA frame synchronization)
- Additionaly the mobile station can read relevant informations that are continuously transmitted by the base station on the base channel:
  - ID of the base station (BSIC)
  - network operator information (T-Mobile, Vodafone, …)
  - location the cell (new VLR) (→ location update procedure)

Bursts - Timing Advance and adaptive Frame Synchr. (1)

- A mobile station has to transmit a burst, so that it is received in the right time slot at the base station
- Because of the finite transmission speed of electromagnetic waves (ca. 300 000 km/s), the mobile station has to send its burst the earlier, the larger its distance is to the base station
- For that in GSM the method "**Timing Advance**" is defined: the sending time offset is controlled for each mobile station by the base station
  - the base station tells each mobile station an 6-bit value that corresponds to the distance between the base station and the mobile station; each increment of this value denotes a distance step of 555 m; therefore the maximum cell size is ca. 35 km (= 63·555 m)
  - the mobile station transmits its burst one bit duration (= 3,7µs) earlier per step (3,7 µs = (2·555 m)/(3·10^8 m/s))

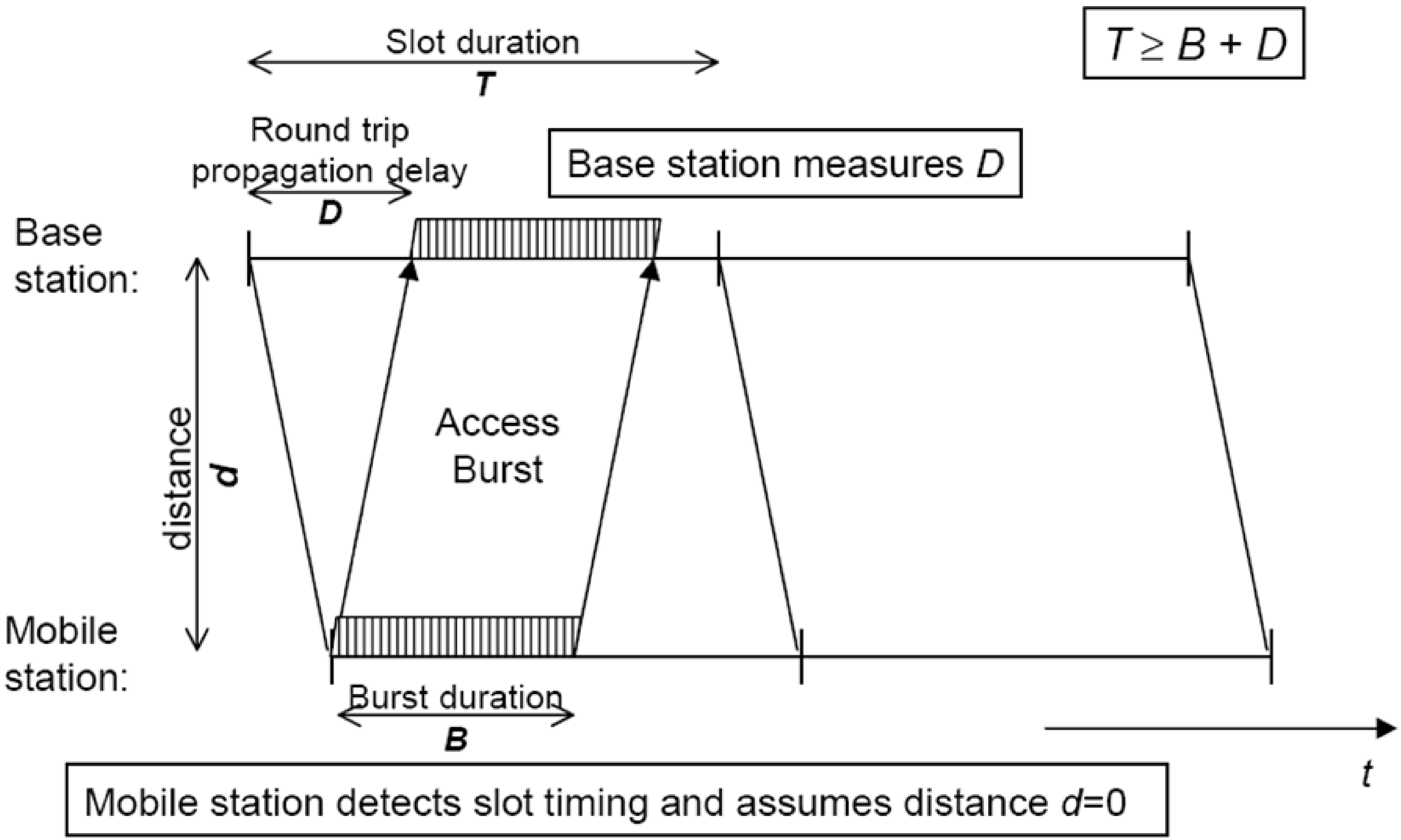
Bursts - Timing Advance and adaptive Frame Synchr. (2)

- **Initial Access:** if no channel is established between BS and MS
  - the transmission of the first uplink time slot takes place without the knowledge of the necessary timing advance (x=0)
  - only a short burst is allowed, which causes no collision even in the case of maximum delay: Access Burst with 68,25 bit guard period

- **Timing Advance:** if a channel is established between BS and MS
  - the base station measures the time delay continuously in the uplink and signals the 6-bit timing advance parameter (0 < x < 63) to the MS
  - the MS starts its transmission x bit durations before the beginning of its actual time slot

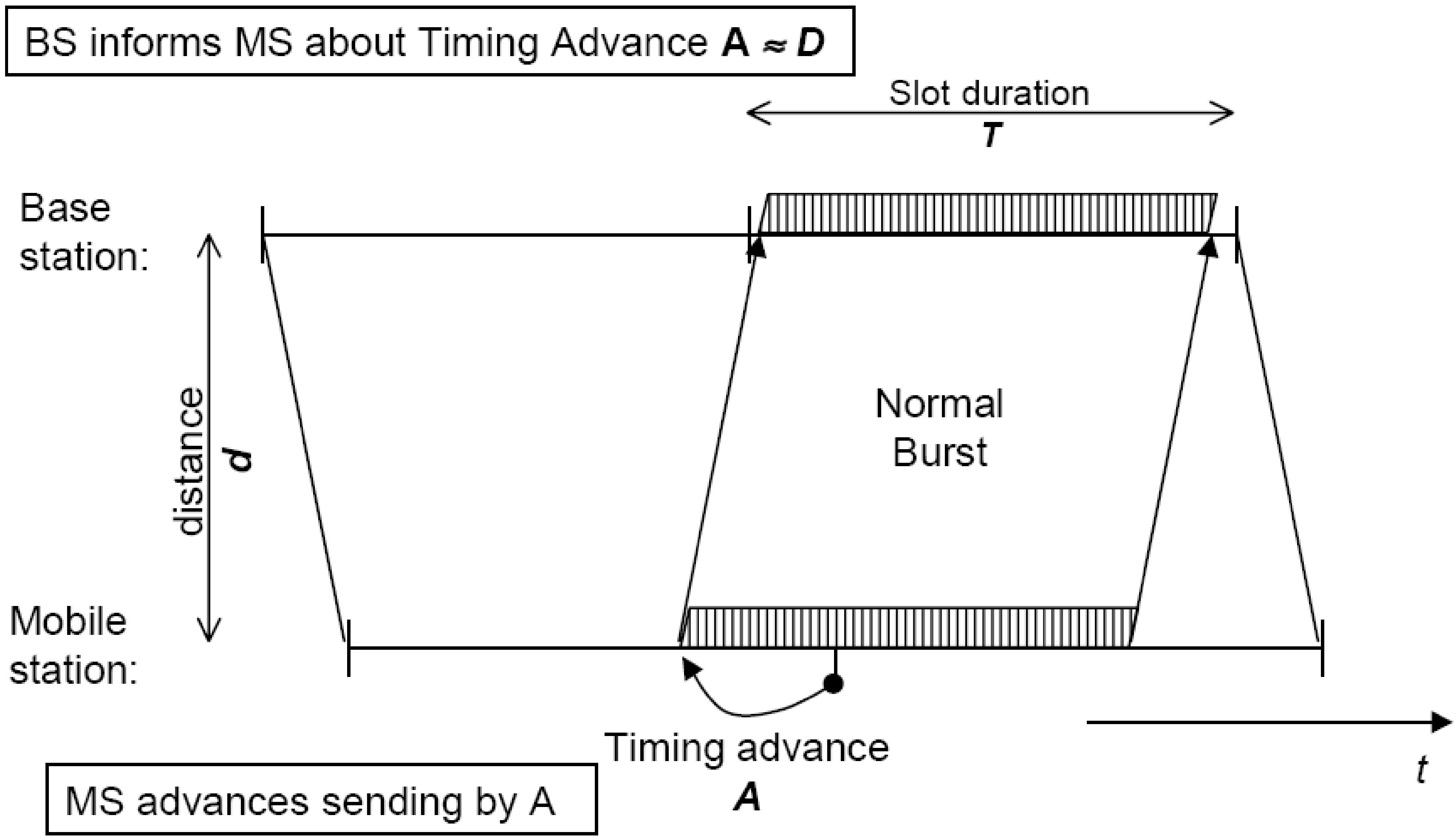
Bursts - Timing Advance and adaptive Frame Synchr. (3)

- **Initial Access (basic principle)**



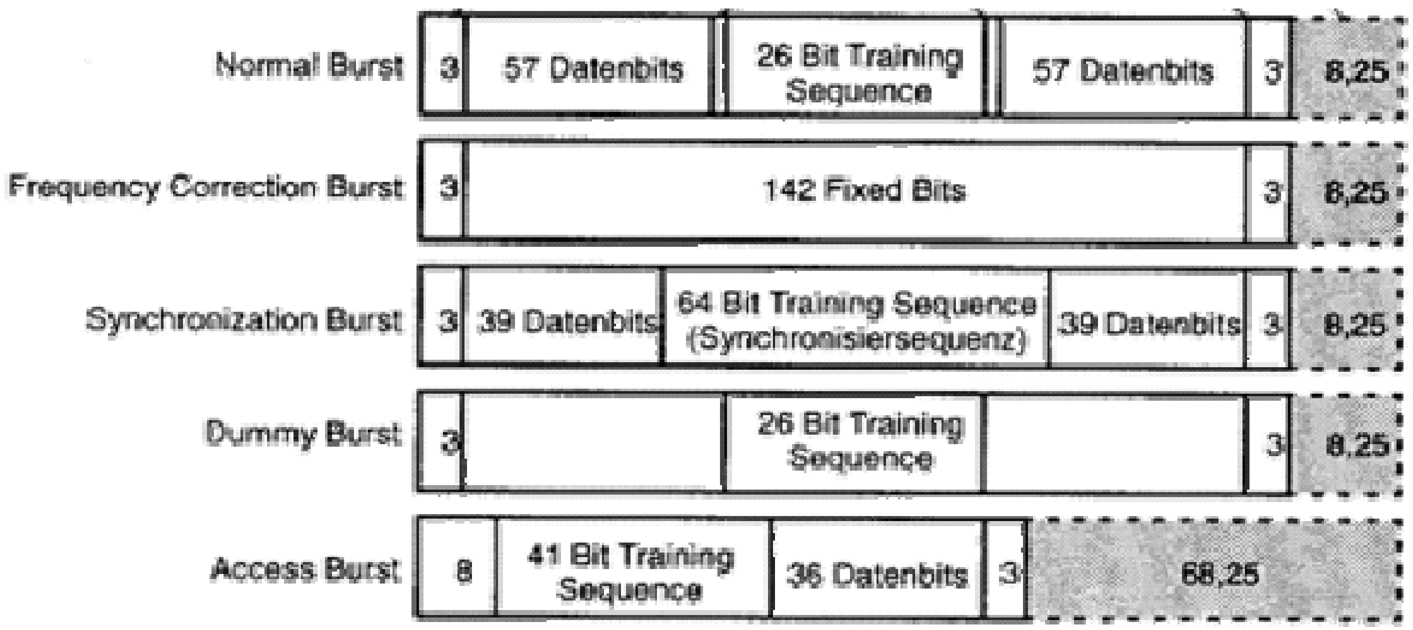
Bursts - Timing Advance and adaptive Frame Synchr. (4)

- **Timing Advance (basic principle)**



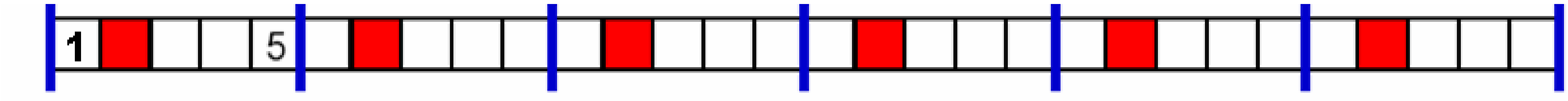
Bursts - Summary

- **Normal Burst:** for user data transmission (e.g. voice)
- **Frequency Correction Burst:** for frequency synchronization
- **Synchronization Burst:** for time (frame) synchronization
- **Access Burst:** for initial request of a channel
- **Dummy burst:** sent, if no other burst are present for transmission

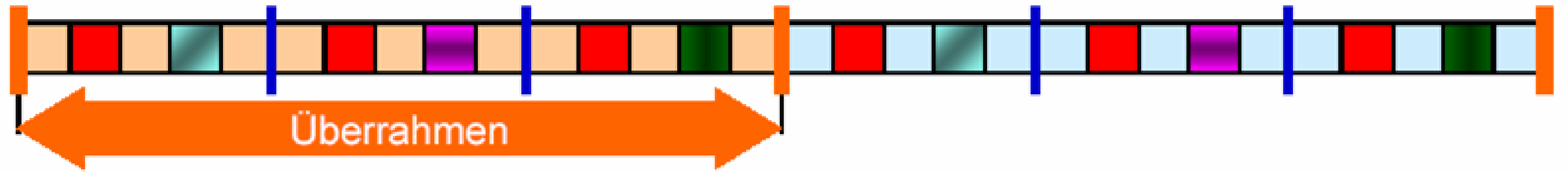


Hyperframes - Definition

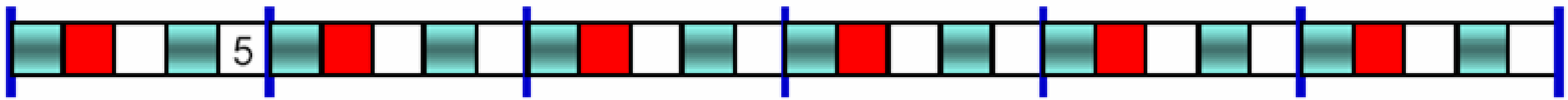
- Example of a simple frame structure: 5 physical channels (time slots) per frame, each with b kbit/s → 5 parallel connections with b kbit/s each can be realized



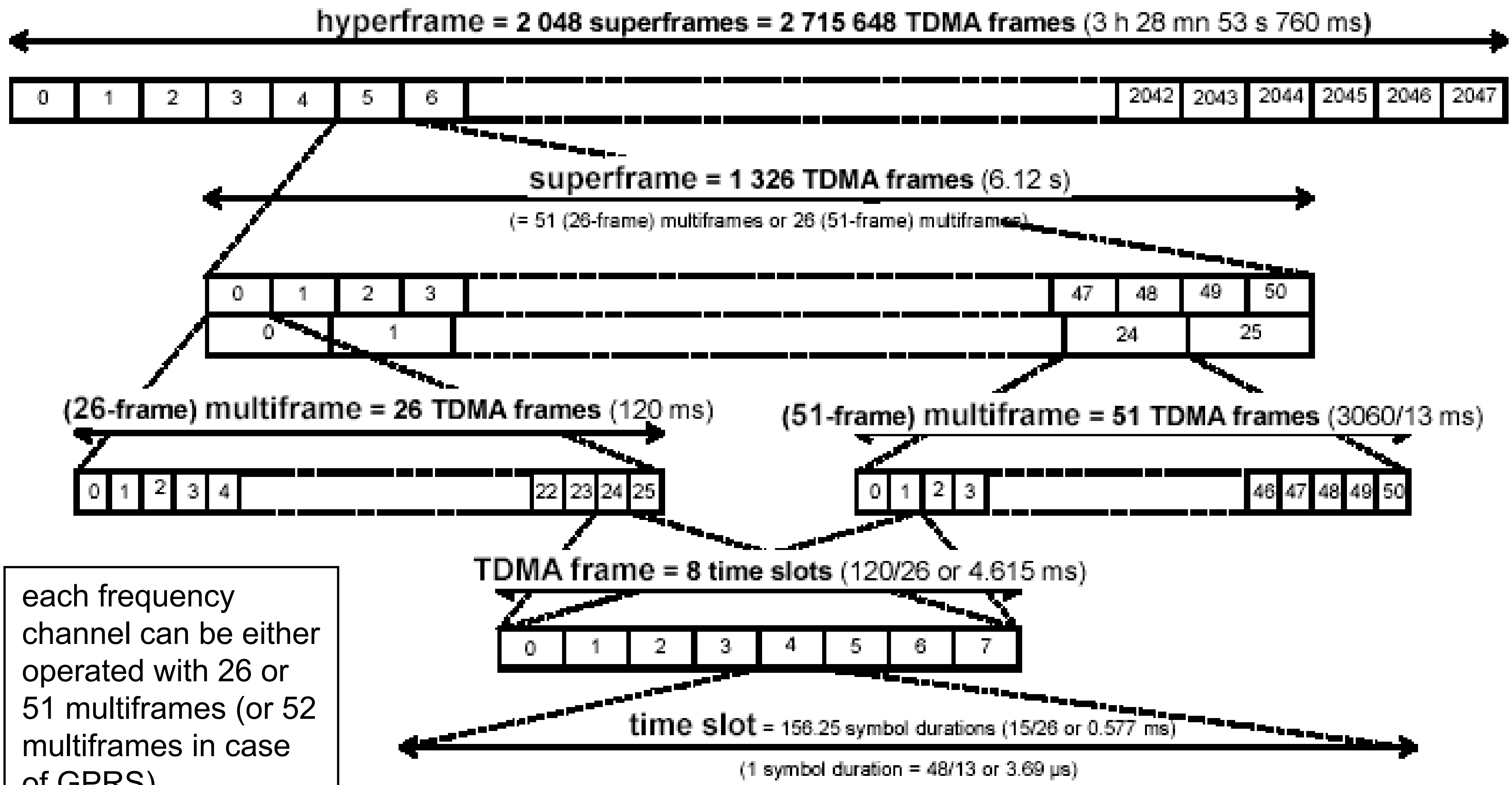
- Definition of a hyperframe with n frames to realize bitrates less than b kbit/s: 5·n logical channels with b/n kbit/s each per hyper frame → 5·n parallel connections with a bitrate of b/n kbit/s each can be realized (in this example: n=3)



- Problem: there is no indicator for the start of a hyperframe within a physical frame → frames have to be counted synchronously at the receiver and the transmitter
- It is possible to mix logical channels with different capacities (bitrates)
- It is also possible to group k physical channels to one logical channel (multi channel connections) → connections with k·b kbit/s can be realized

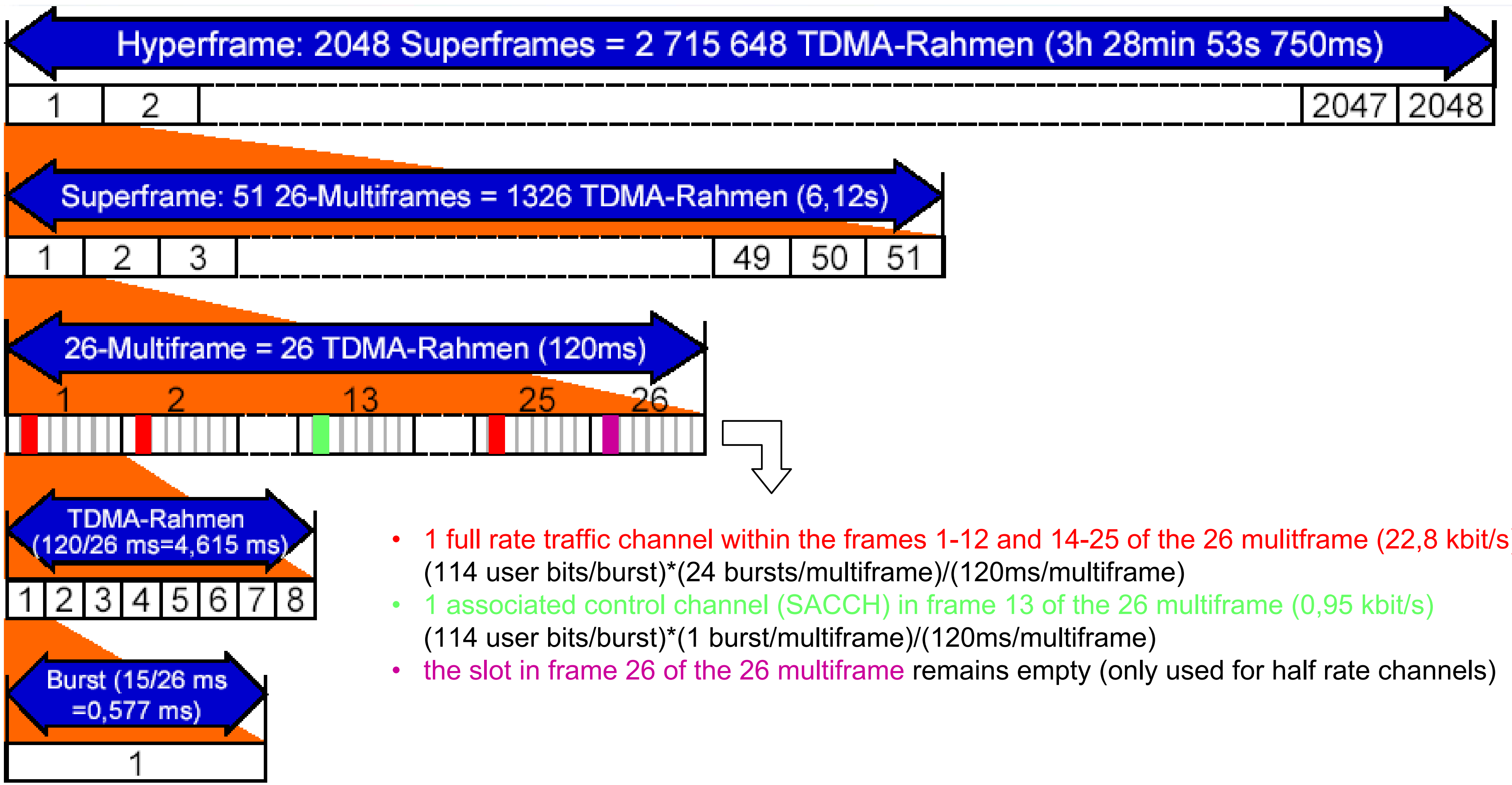


Hyperframes - Frame Hierarchy for logical Channels



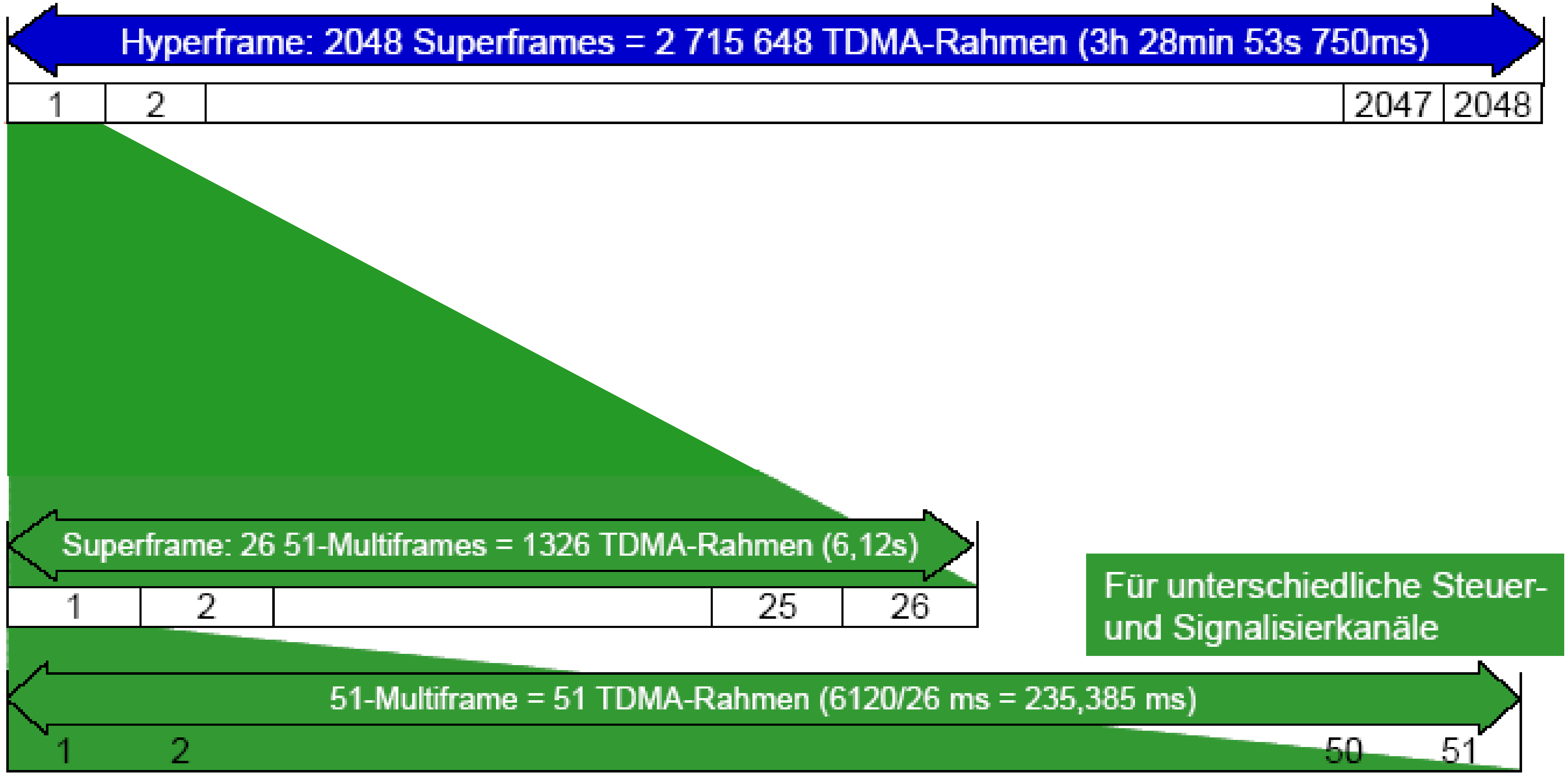
each frequency channel can be either operated with 26 or 51 multiframes (or 52 multiframes in case of GPRS)

Hyperframes - Multiframes with 26 TDMA Frames



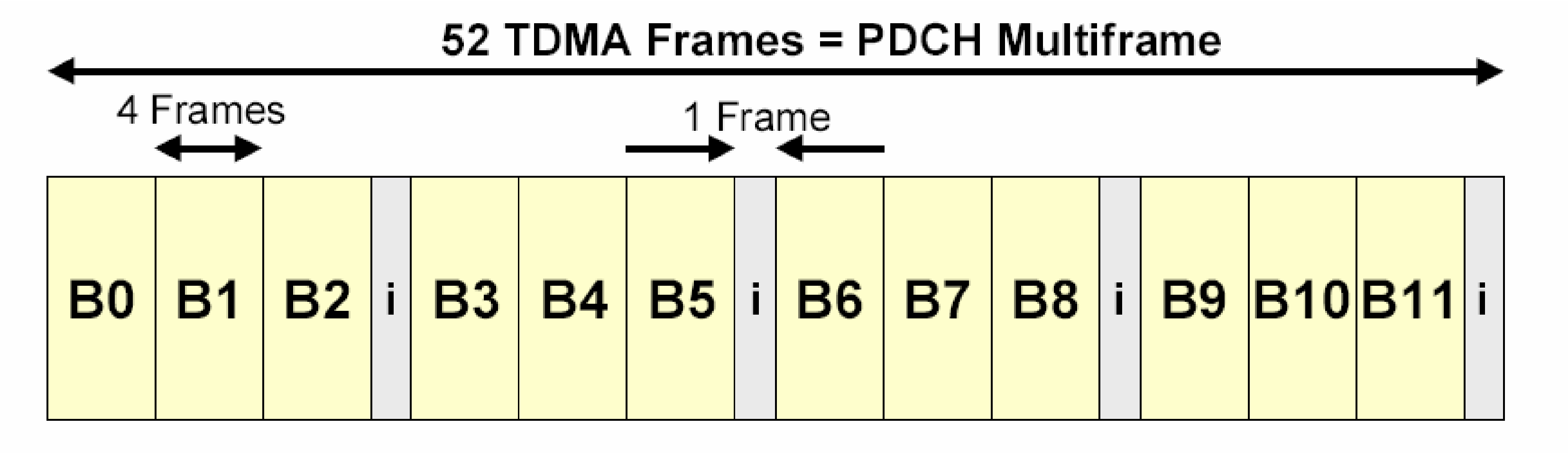
- 1 full rate traffic channel within the frames 1-12 and 14-25 of the 26 mulitframe (22,8 kbit/s)
  (114 user bits/burst)*(24 bursts/multiframe)/(120ms/multiframe)
- 1 associated control channel (SACCH) in frame 13 of the 26 multiframe (0,95 kbit/s)
  (114 user bits/burst)*(1 burst/multiframe)/(120ms/multiframe)
- the slot in frame 26 of the 26 multiframe remains empty (only used for half rate channels)

Hyperframes - Multiframes with 51 TDMA Frames



Hyperframes - Multiframes with 52 TDMA Frames (GPRS)

- 52 Multiframe: 12 radio blocks á 4 TDMA frames



B0 - B11: **radio blocks** (for user data and signaling data)

i: **idle frames**

- for identification of BSICs
- to realize the timing advance update procedure
- for interference measurements (for power control)

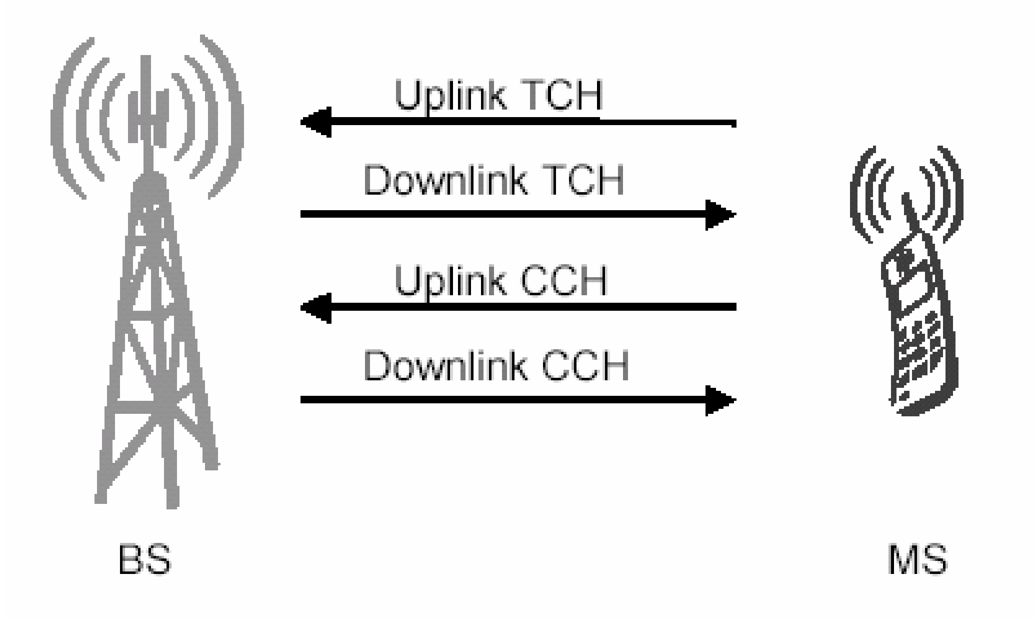
Logical Channels

Contents - GSM - GSM Radio Interface - Log. Channels

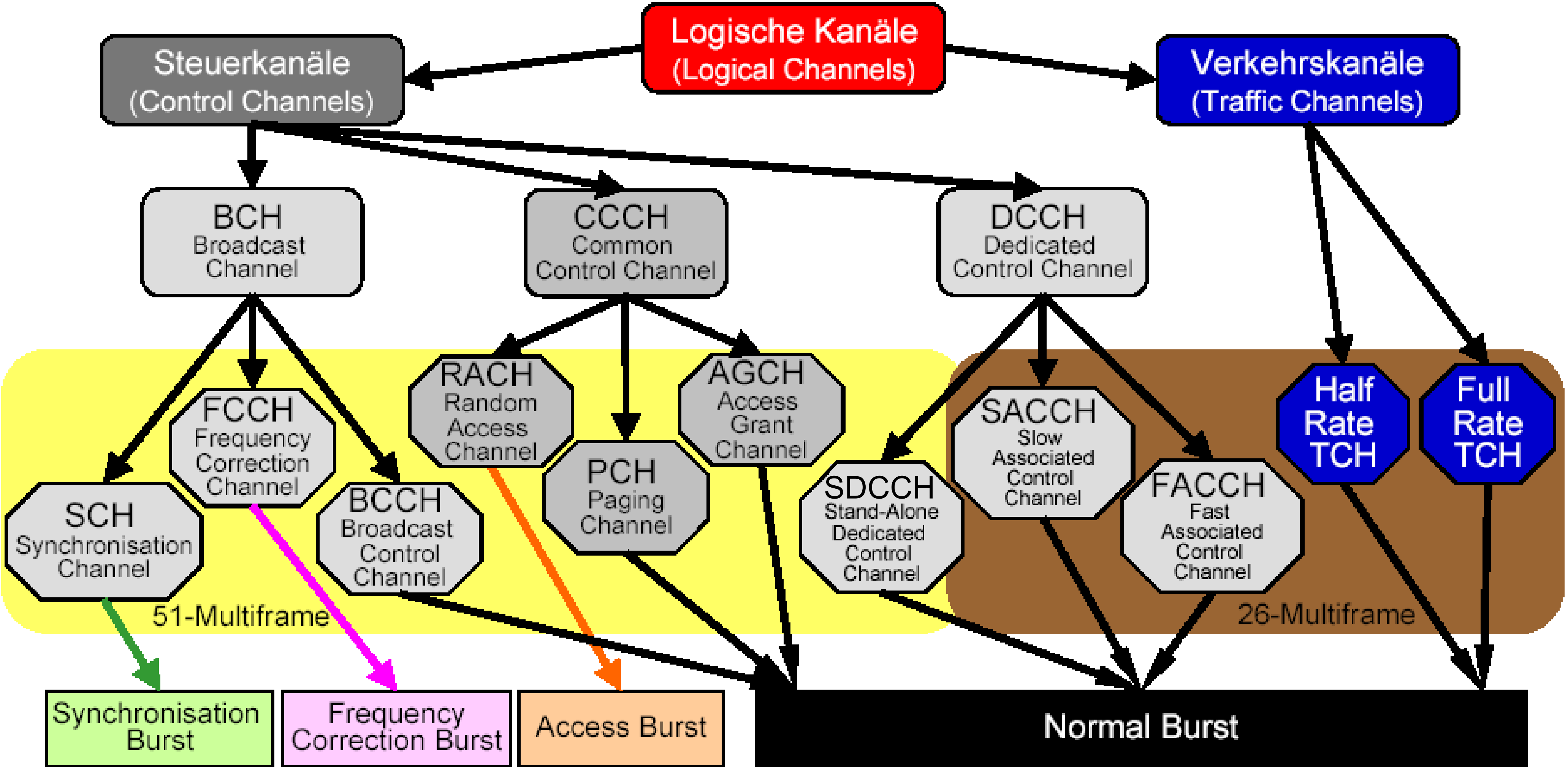
- Overview
- Traffic Channels (TCH)
  - Full- and Half-Rate TCH
- Control Channels (CCH)
  - Broadcast Channels (BCH)
  - Common Control Channels (CCCH)
  - Dedicated Control Channels (DCCH)
- Possible Combinations of Logical Channels
- Use of Logical Channels at Connection Setup
- Extensions for GPRS

Overview - Traffic and Control Channels

- Classification of logical channels according to the carried informations:
  - Traffic CHannel (TCH): for user data
  - Control CHannel (CCH): for signaling



Overview - Types of Logical Channels



Traffic Channels (TCH)

- TCHs are bidirectional, point-to-point channels, used for transport of user data (e.g. voice)
- Full rate channel (Full Rate TCH, TCH/F, mobile B channel B_m)
  - 22,8 kbit/s gross data rate
  - 13 kbit/s net data rate for voice or 9.6, 4.8, 2.4 kbit/s for data
- Half rate channel (Half Rate TCH, TCH/H, Lower-rate mobile channel L_m)
  - 11,4 kbit/s gross data rate
  - 6,5 kbit/s net data rate for voice or 4.8, 2.4 kbit/s for data
  - two half rate channels share one full rate channel

Channel	Type	Usage	net data rate [kbit/S]	data rate (after channel coding) [kbit/s]
TCH/FS	full rate	digital voice	13	22.8
TCH/F9.6	full rate	data	9.6	22.8
TCH/F4.8	full rate	data	4.8	22.8
TCH/F2.4	full rate	data	2.4	22.8
TCH/HS	half rate	digital voice	6.5	11.4
TCH/H4.8	half rate	data	4.8	11.4
TCH/2.4	half rate	data	2.4	11.4

Control Channels (CCH)

- CCHs are used for signaling and synchronization between BS and MS
  - continuous transmission of system informations
- Further separation of CCH in:
  - Broadcast Channel (BCH)
  - Common Control Channel (CCCH)
  - Dedicated Control Channel (DCCH)
- BCH and CCCH are transmitted on a specific frequency channel and in specific time slots (0, 2, 4, 6)
  - realization of different channel combinations within a 51-multiframe:
    - BCCH+FCCH+SCH+CCCH: only in time slot 0
    - BCCH+FCCH+SCH+CCCH+4·(SDCCH+SACCH): in time slot 2, 4, 6
    - BCCH+CCCH: only in time slot 0
- DCCH can be transmitted in every frequency channel and every time slot
  - realization of the channel combination 8·(SDCCH+SACCH) within a 51-multiframe

Control Channels - Broadcast Channel (BCH)

- BCHs are used to transmit physical information (for synchronization) and cell specific infos from the base station to the mobile station
- Broadcast Control Channel (BCCH)
  - unidirectional, only in downlink (BS → MS), pt-to-mpt (broadcast)
  - transmission of radio interface specific informations e.g.:
    - radio channel configuration of the own and the neighboring cells
    - cell and base station IDs
    - informations about the organization of the CCCH
    - availability of options (frequency hopping, …)
- Frequency Correction Channel (FCCH)
  - unidirectional, only downlink (BS → MS), pt-to-mpt (broadcast)
  - transmission of a signal for frequency synchronization of the MS
- Synchronization Channel (SCH)
  - unidirectional, only downlink (BS → MS), pt-to-mpt (broadcast)
  - transmission of the base station ID and of informations for frame synchronization (synchronization sequence, frame number)

Control Channels - Common Control Channels (CCCH)

- CCCHs are used to establish a physical channel between MS and BS
  - they can be requested either by the mobile station or the base station
- Random Access Channel (RACH)
  - unidirectional, only in uplink (MS $\rightarrow$ BS), pt-to-pt
  - used to request a dedicated control channel by the MS at the beginning of the signaling transaction
  - all MS access the RACH in a asynchronous manner (slotted aloha principle)
- Access Grant Channel (AGCH)
  - unidirectional, only in downlink (BS $\rightarrow$ MS), pt-to-pt
  - used to grant the assignment of the requested dedicated control channel
- Paging Channel (PCH)
  - unidirectional, only in downlink (BS $\rightarrow$ MS), pt-to-pt
  - used to transmit a paging signal to localize a subscriber

Control Channels - Dedicated Control Channels (DCCH)

- DCCHs are used for signalling between MS and BS
  - only in combination with a connection between MS and BS
- Slow Associated Control Channel (SACCH)
  - bidirectional, pt-to-pt, data rate 950 bit/s
  - only used in combination with a TCH or SDCCH
  - only established for continuous transmissions (active connections)
  - downlink: used for power control and adaptive frame synchronisation
  - uplink: reports the quality and received field strenght of the radio channel
- Fast Associated Control Channel (FACCH)
  - bidirectional, pt-to-pt, data rate 4.6 or 9.2 kbit/s
  - only used in combination with a TCH
  - only established temporary; required, in case a fast transmission of plenty of control data is necessary (e.g. during handover)
  - realized by dynamic preemptive multiplexing
    - if necessary, a TCH burst is used to transmit control information instead of user information (bit stealing) → some user data is lost
    - indication via setting of stealing flags within the normal burst

Control Channels - Dedicated Control Channels (DCCH)

- Stand-alone Dedicated Control Channel (SDCCH)
  - bidirectional, pt-to-pt, data rate 782 bit/s
  - dedicated signaling channel
    - for signaling transactions that are not related to a setup of a TCH, e.g.:
      - for updating of location information
      - for transmission of a SMS (could be done alternatively via SACCH)
    - or: used during the connection setup phase before the TCH is established
  - released after the signaling transaction is over

Possible Combinations of Logical Channels

- Logical channels can only be used in certain combinations
- The allowed combinations are defined by the GSM standard
- The BS tells the MS the currently used channel configuration (via BCCH)
  - depending on its actual state the MS uses a subset of the channel configuration

Combinations of Logical Channels offered by the BS

	B1	B2	B3	B4	B5	B6	B7	B8	B9
TCH/F									
TCH/H									
TCH/H									
BCCH									
FCCH									
SCH									
CCCH									
SDCCH									
SACCH									
FACCH									

Combinations of Logical Channels used by the MS

	M1	M2	M3	M4	M5	M6	M7	M8
TCH/F								*n+m*
TCH/H								
TCH/H								
BCCH								
CCCH								
SDCCH								
SACCH								*n+m*
FACCH								

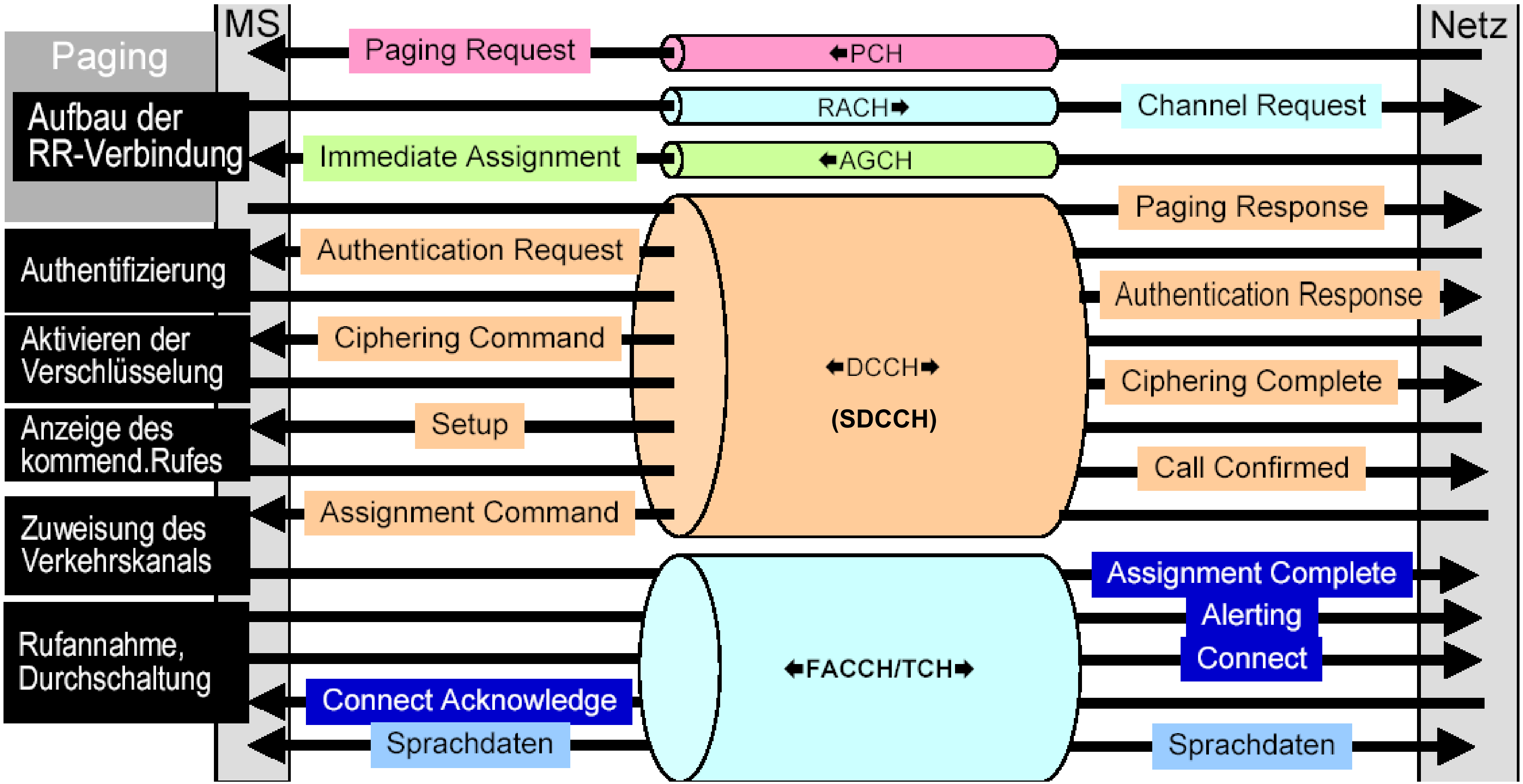
MS without physical connection to the BS:
- after switch-on
- after disruption of the connection

MS in standby mode

MS requires a dedicated control channel

MS with a active connection (TCH)

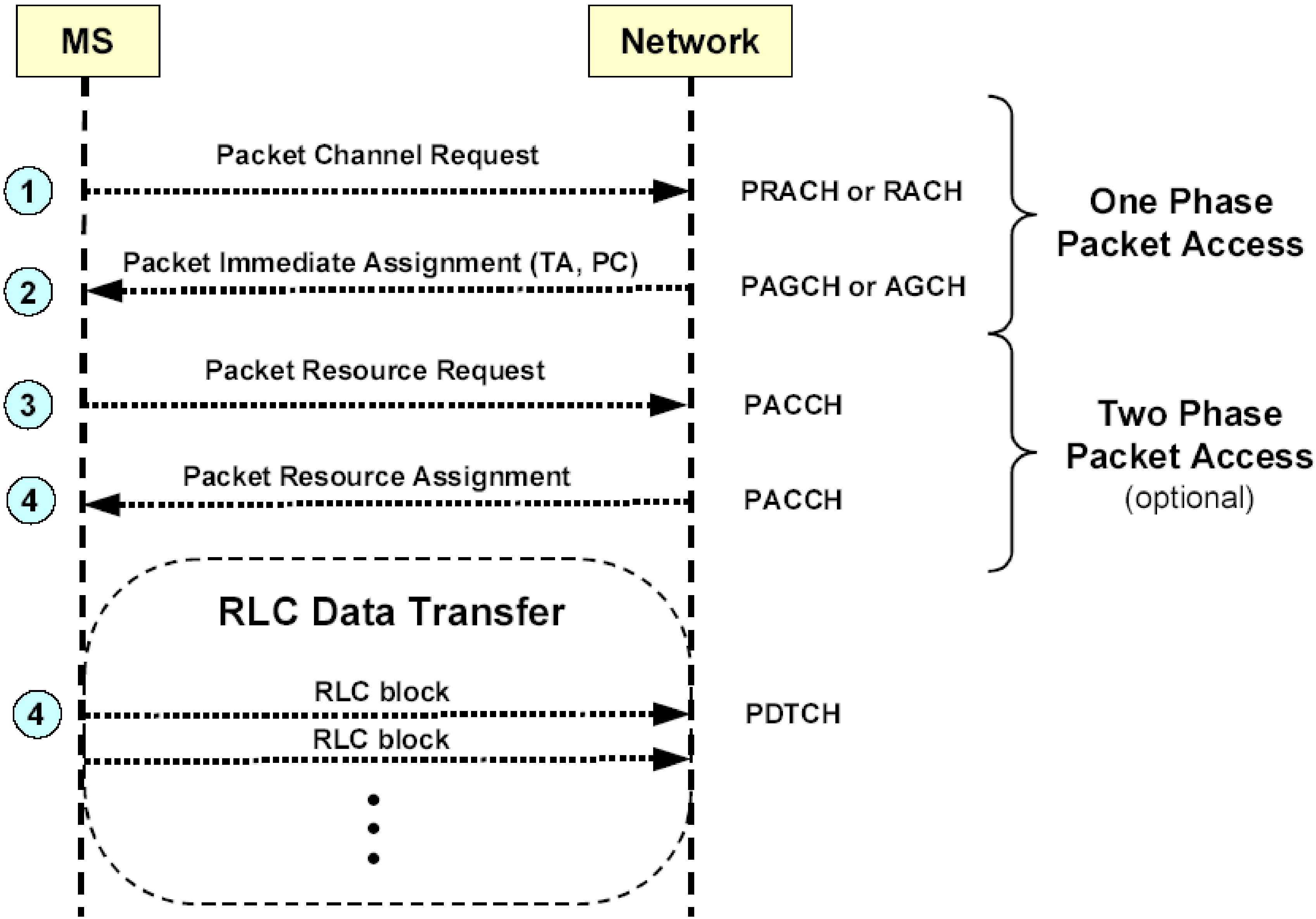
Use of Logical Channels at CS Connection Setup



Extensions for GPRS - New Logical Channels

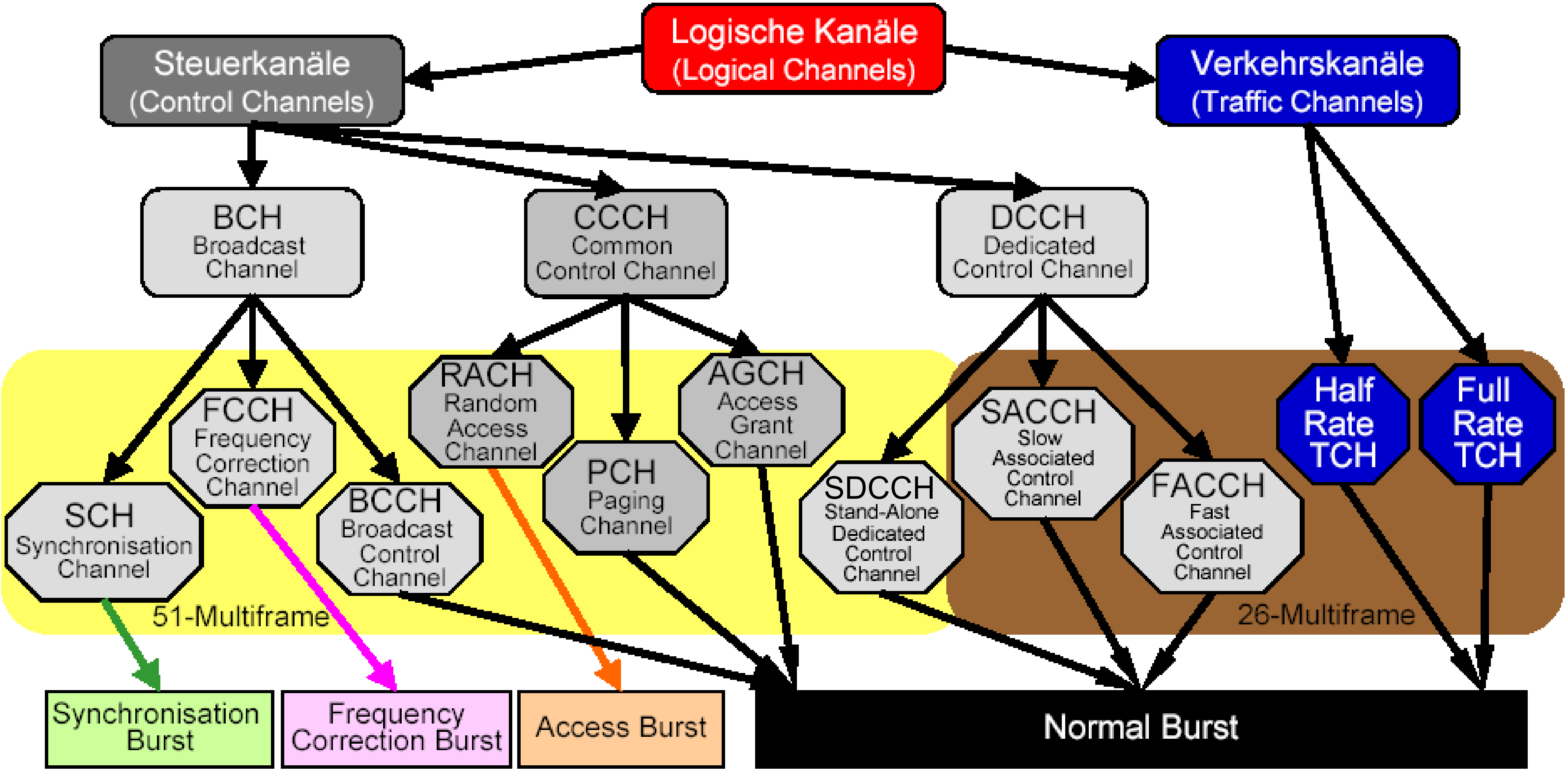
Packet Control Channels	Packet Broadcast Channels	**PBCCH** Packet Broadcast Control Channel	Transmit of system information for GPRS-MS
	Packet Common Control Channels (PCCCH)	**PPCH** Packet Paging Channel	Paging of GPRS-MS
		PAGCH Packet Access Grant Channel	Resource assignment grant
		PNCH Packet Notification Channel	Transmission of ACKs for GPRS-MS Multicast-Mode (pt-t-mpt)
		PRACH Packet Random Access Channel	Request of a dedicated control channel for the uplink packet data transmission
	Packet Associated Control Channels	**PACCH** Packet Associated Control Channel	Control channel in case of active data connection, used e.g. for ACKs, power control, resource allocation
Packet Traffic Channels		**PDTCH** Packet Data Traffic Channel	Transmission of packet data; multislot mode possible (i.e. a MS may use multiple PDTCH in parallel)

Use of Logical Channels for GPRS Packet Data Transm.



Mapping of Logical Channels to the Physical Layer

Mapping of Logical Channels to Multiframes and Bursts



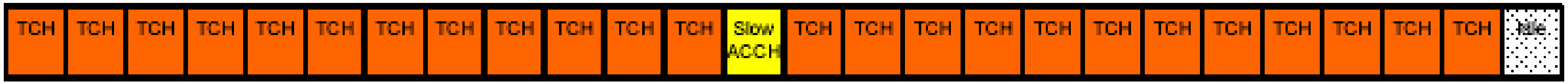
51-Multiframe:
for control channels without association to a TCH

26-Multiframe:
for traffic channels (TCH) and associated control channels (SACCH, FACCH)

Channel Organization in a 26-Multiframe

26-Multiframe: for traffic channels and associated control channels

- Type 1: 8 Full Rate Traffic CHannels (TCH/F) +
  8 Slow Associated Control CHannels (SACCH)
  - TDMA frame 0-11 and 13-24 are used for 8 TCH/F
  - TDMA frame 12 is used for 8 SACCH
  - TDMA frame 25 is used by the MS for channel measurements



- Type 2: 16 Half Rate Traffic CHannels (TCH/H) +
  16 Slow Associated Control CHannels (SACCH)
  - alternating use of the TDMA frames for TCH/H (2*8=16 TCH/H)
  - TDMA frame 12 and 25 are used for the corresponding SACCH

- Fast Associated Control Channels (FACCH) steal TDMA frames from TCHs

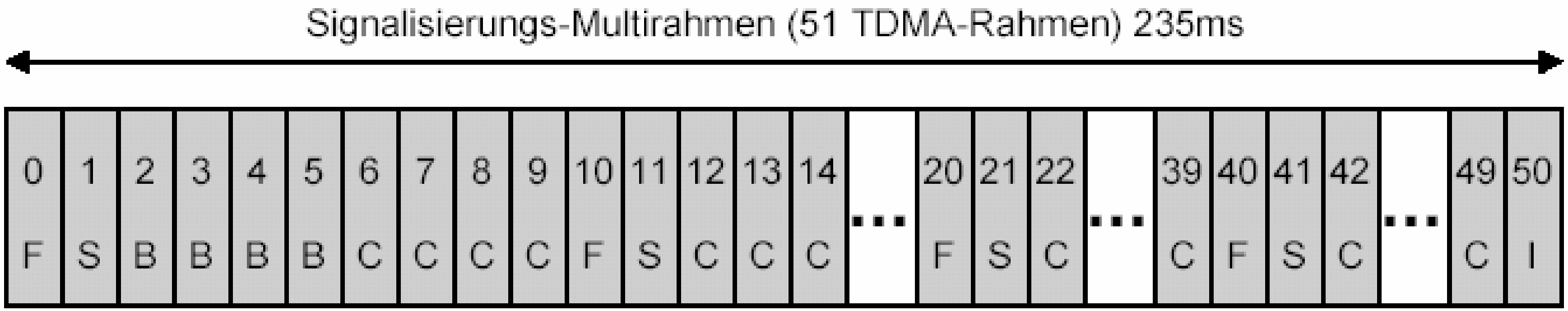
Channel Organization in a 51-Multiframe

51-Multiframe: for control channels (except SACCH and FACCH)

- the use of the 51-multiframe is determined by the channel combination defined in the channel configuration
- the current channel configuration can be extracted from the BCCH (the BCCH is transmitted in the downlink in a specific frequency channel)
- different channel combinations might be used for up- and downlink
- RACH requires a relative high bitrate in the uplink (because of access collisions due to the slotted ALOHA mechanism)
- SDCCHs also require sufficient bitrate to handle the signaling traffic (e.g. for mobility management, subscriber authentication, connection establishment, SMS, etc.); often network operators assign exclusive frequency channels for SDCCHs

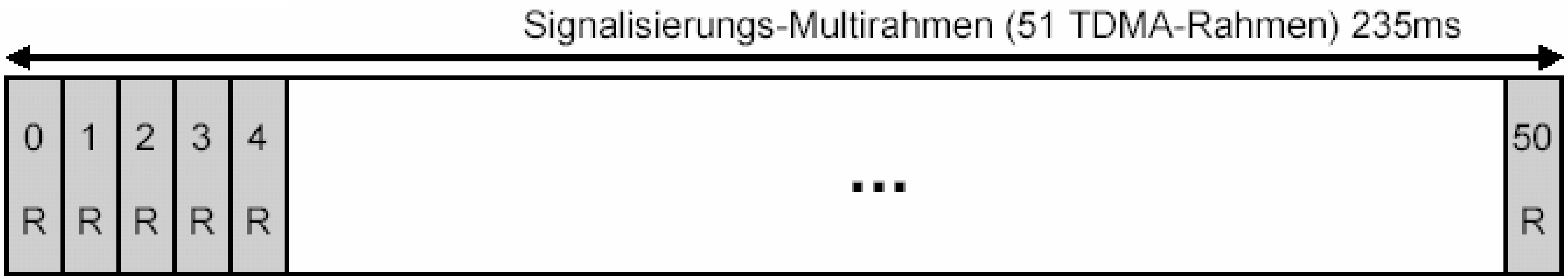
Channel Organization in a 51-Multiframe (Example)

- Channel combination (BCCH+FCCH+SCH+CCCH) - downlink (time slot 0):



F: FCCH burst (BCH); S: SCH burst (BCH); B: BCCH burst (BCH);
C: PCH/AGCH burst (CCCH); I: idle

- Channel combination (BCCH+FCCH+SCH+CCCH) - uplink (time slot 0):



R: uplink RACH burst (CCCH)

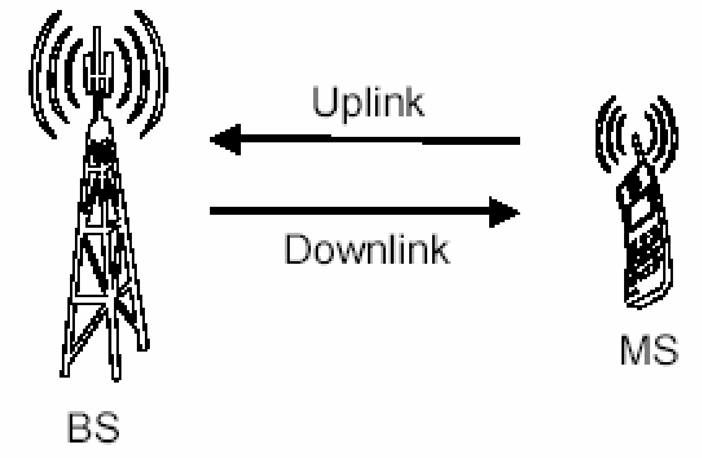
Radio Link Control

Main Tasks of Radio Link Control

- Quality measurements of the radio link
  - applied to power control
  - applied to cell selection/reselection and handover control

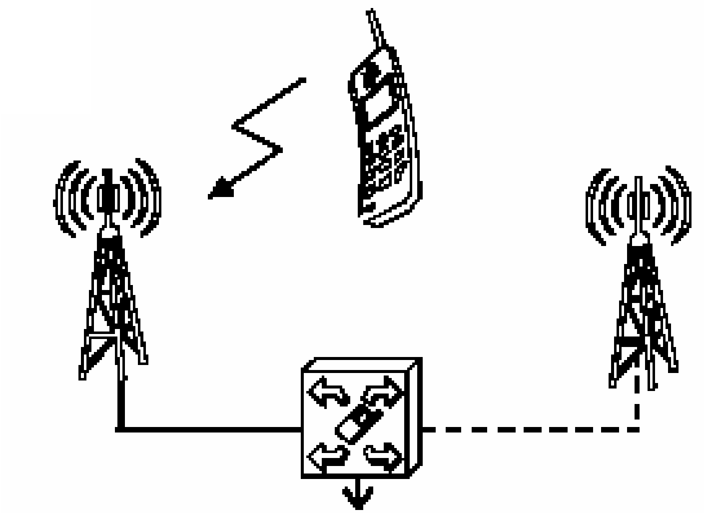
Radio Link Control for Power Control

- In uplink direction:
    - measurement of the received signal at the BS and feedback to the MS
- In downlink direction (optional):
    - measurement of the received signal at the MS and feedback to the BS
- Quality indicators: received power and bit error rate
- Goal of power control:
    - setting the minimal required transmission power required for sufficient quality
        - reduction of the average transmitted power → interference reduction
        - increase of the battery life time
- Power control parameter adjustment:
    - range: 30dB
    - step size: 2dB
    - maximal change rate: 2dB / 60ms



Radio Link Control for Mobile-assisted Handover Control

- The MS assists the network (MSC) in estimating whether a handover is required:
  - the MS measures the received signal strength of pilot signals from other BS (in the reach of the MS) and informs the network accordingly
  - the measurement is performed by the MS in time slots (bursts), where it neither transmits or receives
- By that the network gets a list of possible BS that are handover candidates for the MS; it can compare the current BS (the MS is attached to) with other BSs; if required the MSC initiates a handover to a better BS

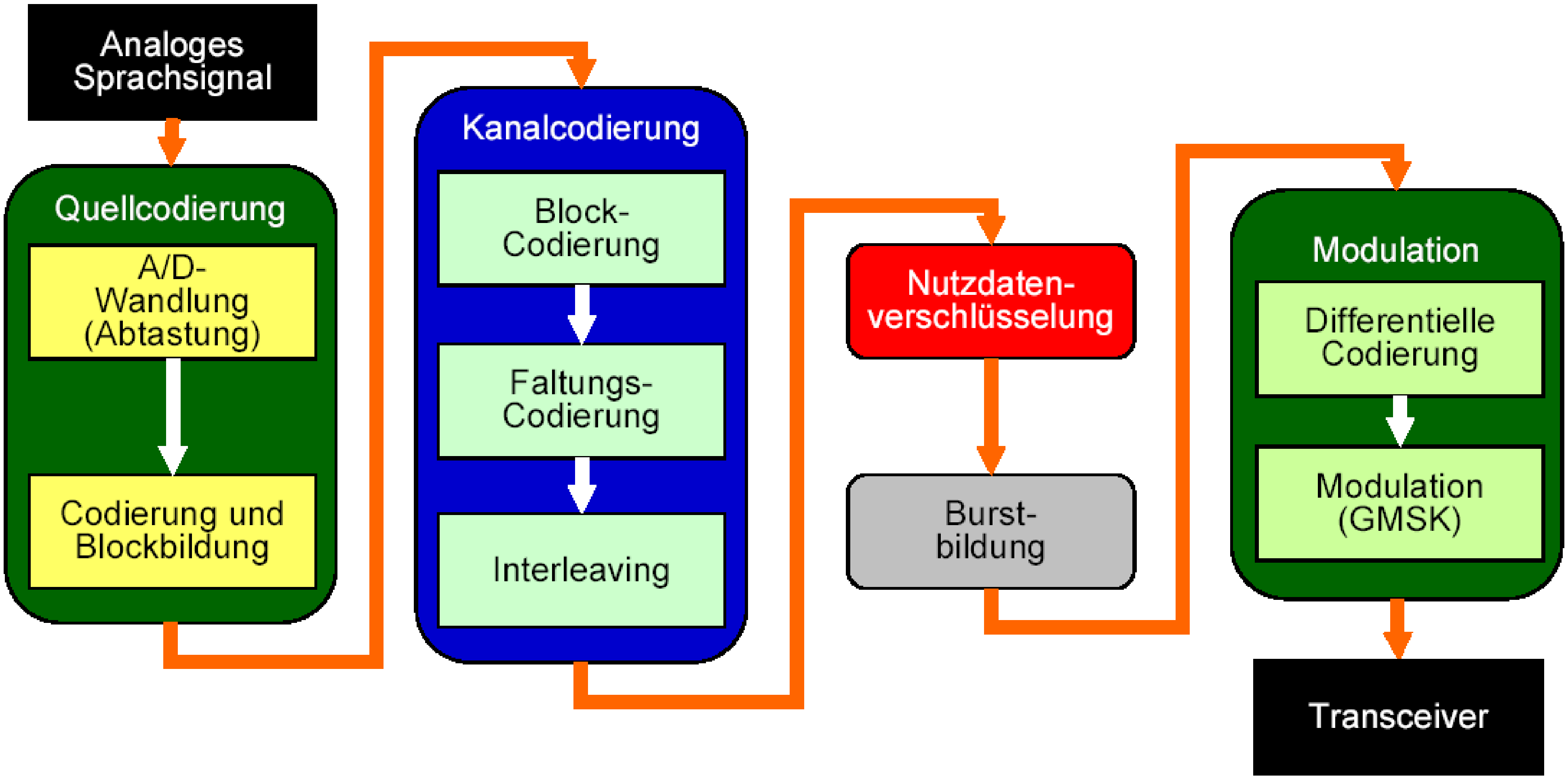


Example: Voice Signal Processing

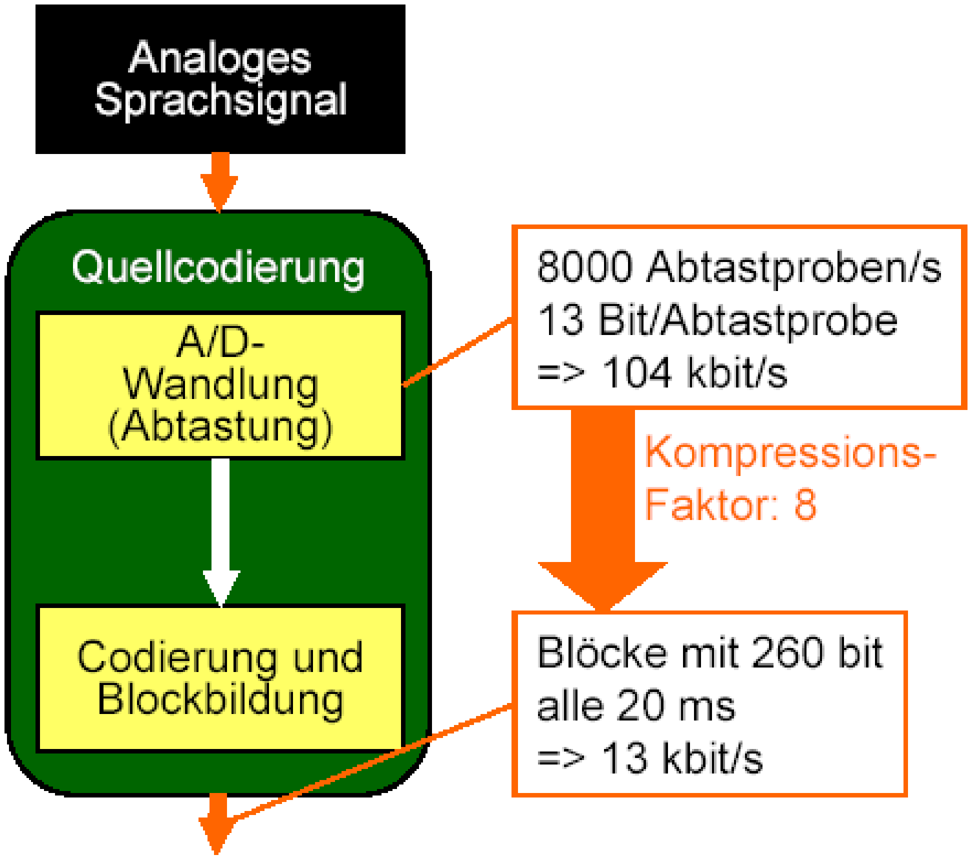
Contents - GSM - GSM Radio Interface - Voice Sign. Pr.

- Overview
- Source Coding
- Channel Coding
- Encryption
- Modulation

Overview


Analoges Sprachsignal
Quellcodierung
A/D-Wandlung (Abtastung)
Codierung und Blockbildung
Kanalcodierung
Block-Codierung
Faltungs-Codierung
Interleaving
Nutzdaten-verschlüsselung
Burst-bildung
Modulation
Differentielle Codierung
Modulation (GMSK)
Transceiver

Source Coding

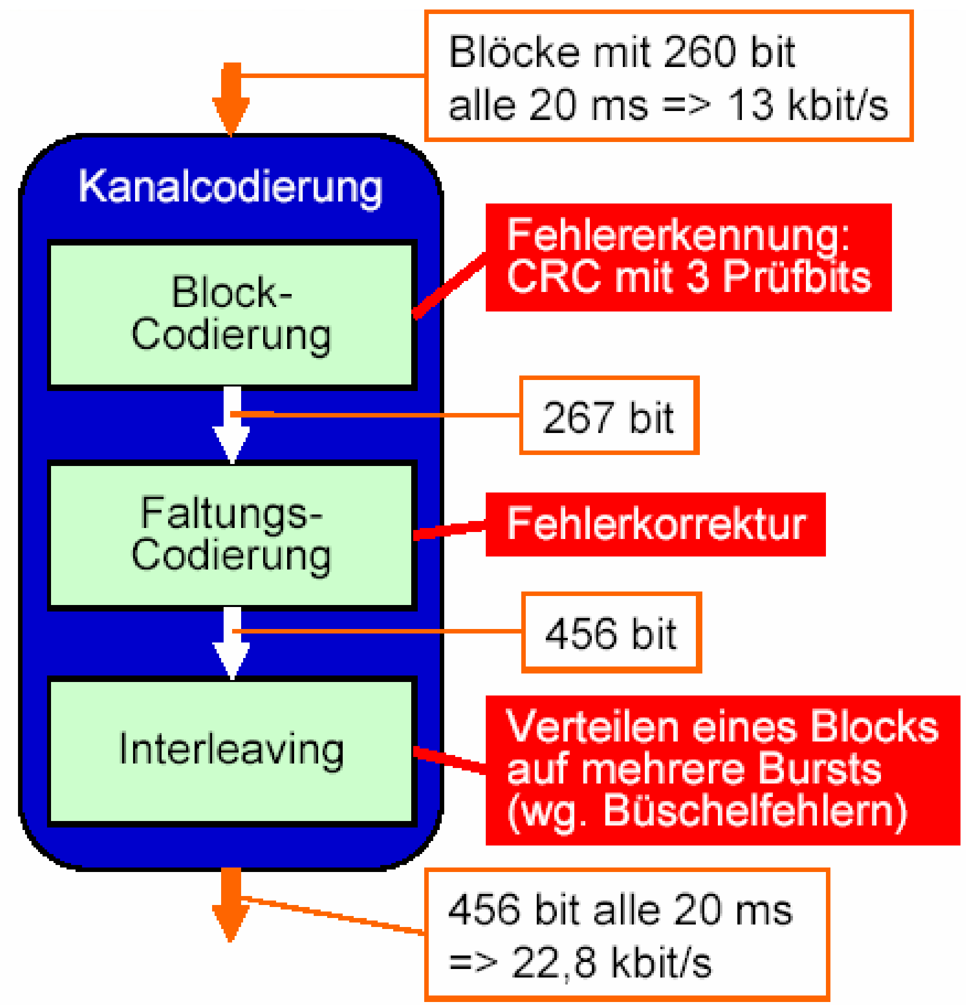


- RPE-LTP Codec
  - Regular Pulse Excitation - Long Term Prediction - Linear Predictive Coder
  - had been chosen from a set of voice codecs (through listening trials)
- Error Concealment
  - faulty frames are replaced with predictively calculated frames
- Discontinuous Transmission (DTX)
  - if voice pauses are detected, nothing will be transmitted (Voice Activity Detection, VAD)
  - background noise is measured continuously and is created artificially at the receiver side (Comfort Noise)

Source Coding - Codec Variants

- Full Rate Codec (RPE-LTP)
  - originally used codec for GSM
  - 260 Bit per 20ms → 13 kbit/s (compression factor 8)
  - used in the full rate channel (TCH/F, 22,8 kbit/s)
- Half Rate Codec
  - voice quality comparable to Full Rate Codec; but significantly worse in case of non-voice signals (e.g. waiting loop music, …)
  - 6,5 kbit/s (compression factor 16)
  - used in the half rate channel (TCH/H, 11,4 kbit/s) → doubling of the traffic capacity possible by use of Half Rate Codecs
  - not widely applied by network operators
- Enhanced Full Rate Codec
  - Algebraic Codebook Excited Linear Predictive Coder (ACELP)
  - 244 Bit per 20 ms → 12,2 kbit/s (compression factor 8,5)
  - used in the full rate channel (TCH/F, 22.8 kbit/s)
  - better voice quality than the original full rate codec
- Adaptive Multi-Rate Codec (AMR)
  - different rates possible: between 12,2 kbit/s and 4,75 kbit/s
  - used in the half or full rate channel (depending on the rate)
  - in-band signaling to adjust the rate

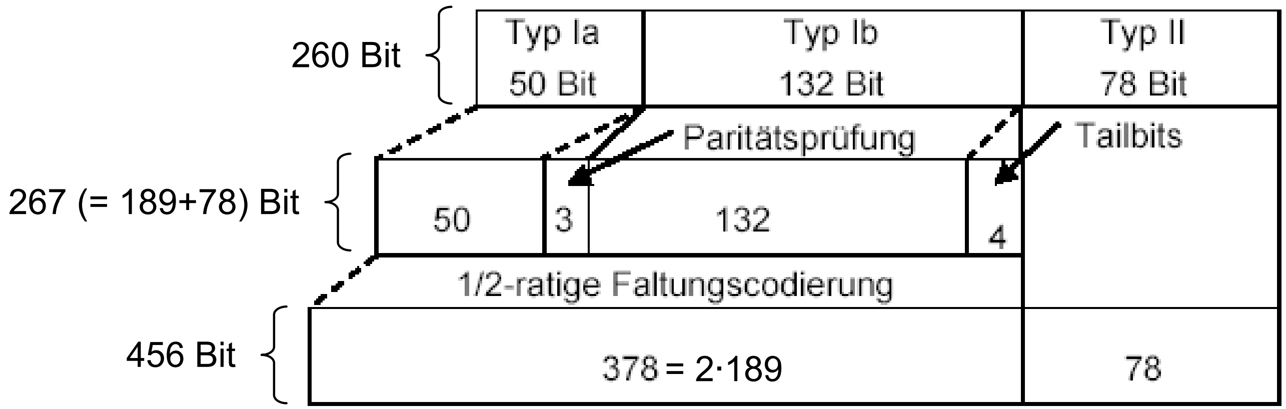
Channel Coding



- Block coding for error detection
  - cyclic code
  - classification of bits: only the 50 most important bits are protected
- Convolution coding for error correction
  - code rate ½ → the encoded bit sequence is twice as long as the original
  - only the 185 most important bits are protected
- Interleaving
  - uniform distribution of burst errors (caused e.g. by fast fading) to several data blocks → better error correction
- Different channel coding schemes are applied for different logical channels

Channel Coding - Details

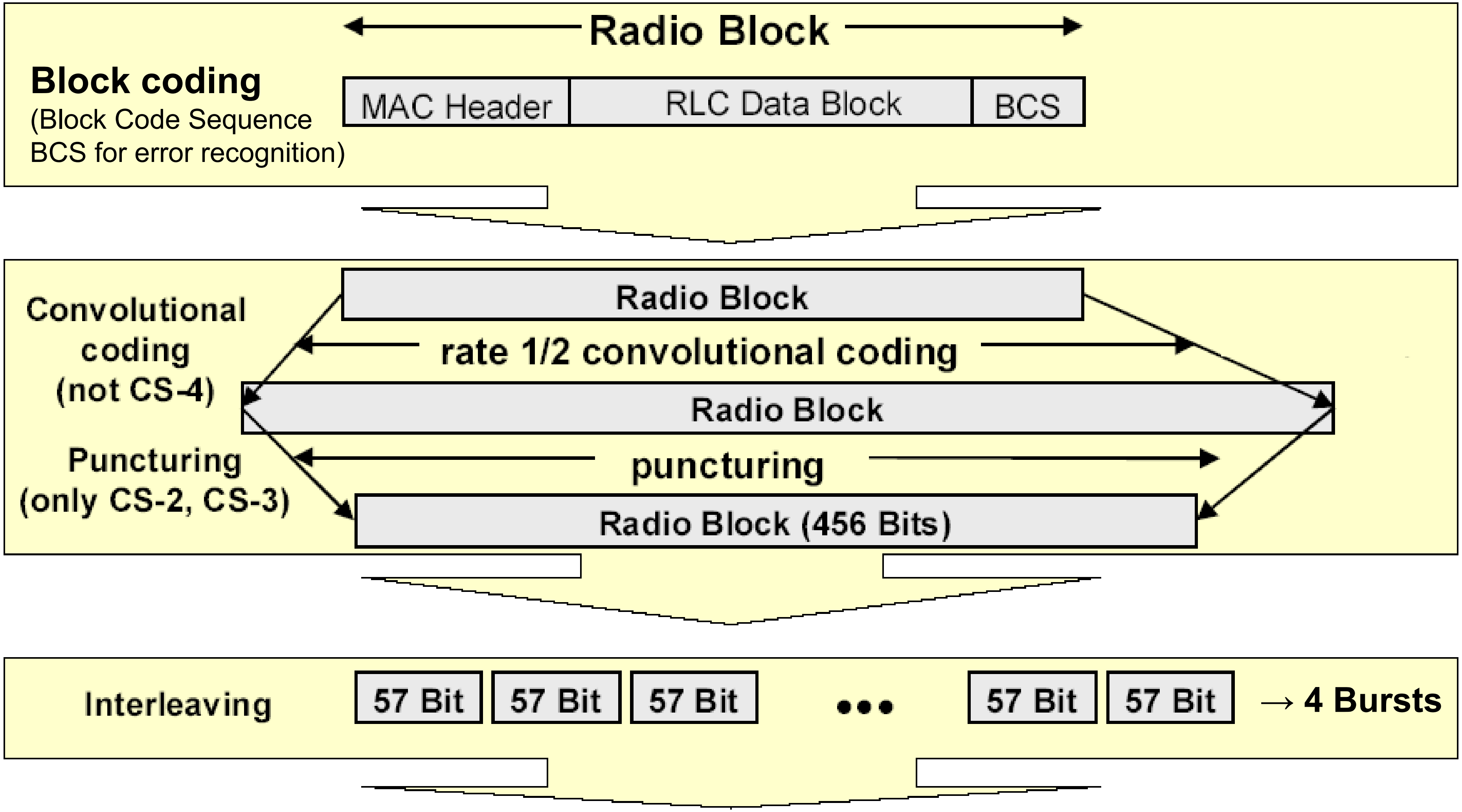
- Grouping of voice bits into three protection classes
  - depending on the importance for the voice quality, the error protection is lower or higher
  - in case of error detection during parity check the block is not forwarded to the decoder



- Interleaving
  - 456 bits (resulting from channel coding) are mapped "block diagonal" to 8x57 bits; the mapping of consecutive bits into different blocks is performed according to the following rule:
    - $i = k \bmod 8$
    - $j = (49 \cdot k) \bmod 57$; $k = 0 \ldots 455$
  - longer interruptions and block errors are distributed in time

Bit aus Kanalcoder (k)	Block (i)	Bitposition im Block (j)
0	0	0
1	1	49
2	2	41
3	3	33
4	4	25
5	5	17
6	6	9
7	7	1
8	0	50
9	1	42
10	2	34
11	3	26
12	4	18
13	5	10
14	6	2
...	...	...

Channel Coding - Extensions for GPRS



Allocation of PDCH for at least 1 Radio Block → at least 4 Normal Bursts

Channel Coding - GPRS Coding Schemes

Coding Scheme	Code Rate	Radio Block*	Coded Bits	Punctured Bits	Data Rate kbit/s
CS-1	1 / 2	181	456	0	9,05
CS-2	≈ 2 / 3	268	588	132	13,4
CS-3	≈ 3 / 4	312	676	220	15,6
CS-4	1	428	456	0	21,4

Coding schemes with different redundancy

bundling 1..8 TS

max. 171,2 kbit/s

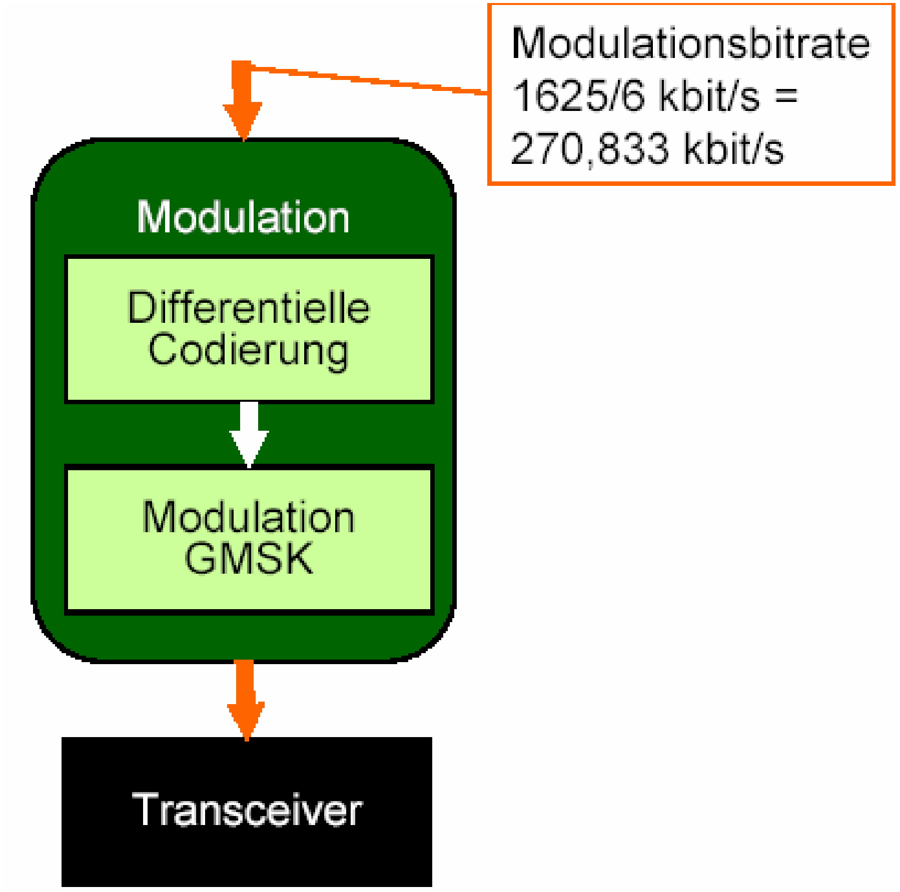
* Radio Block without Uplink State Flag (USF) and Block Check Sequence (BCS)

User Data Encryption

- Main task of Encryption
  - ensures privacy: protection against eavesdropping at the radio interface
- Principle:
  - protection of user data with a subscriber specific key

$\Rightarrow$ covered in the chapter "GSM Security Concept"

Modulation



- Gauß Minimum Shift Keying (GMSK)
  - 1st step: filtering with a Gaussian low pass filter
    - advantage: small transmit power density spectrum
    - but: sensitive wrt. inter-symbol interference → equalization required
  - 2nd step: continuous phase modulation
- GMSK Properties
  - small transmit power density spectrum → low neighbor channel interference
  - constant signal envelope → allows amplifier without high linearity requirements (i.e. simple, cheap amplifiers with low energy consumption)