Overview of UMTS-WCDMA Technology

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- WCDMA Features
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- WCDAM Air Interface Protocol
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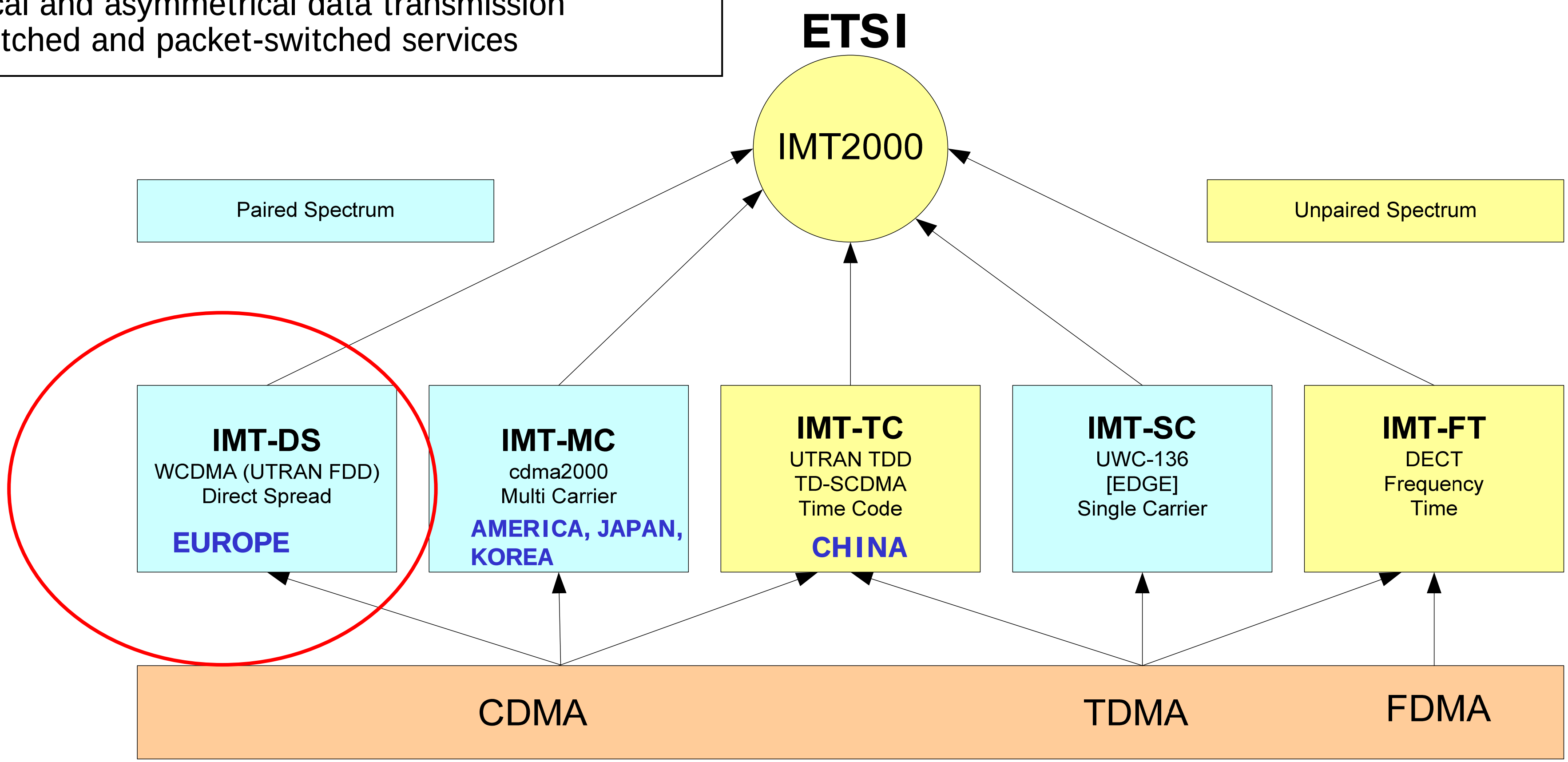
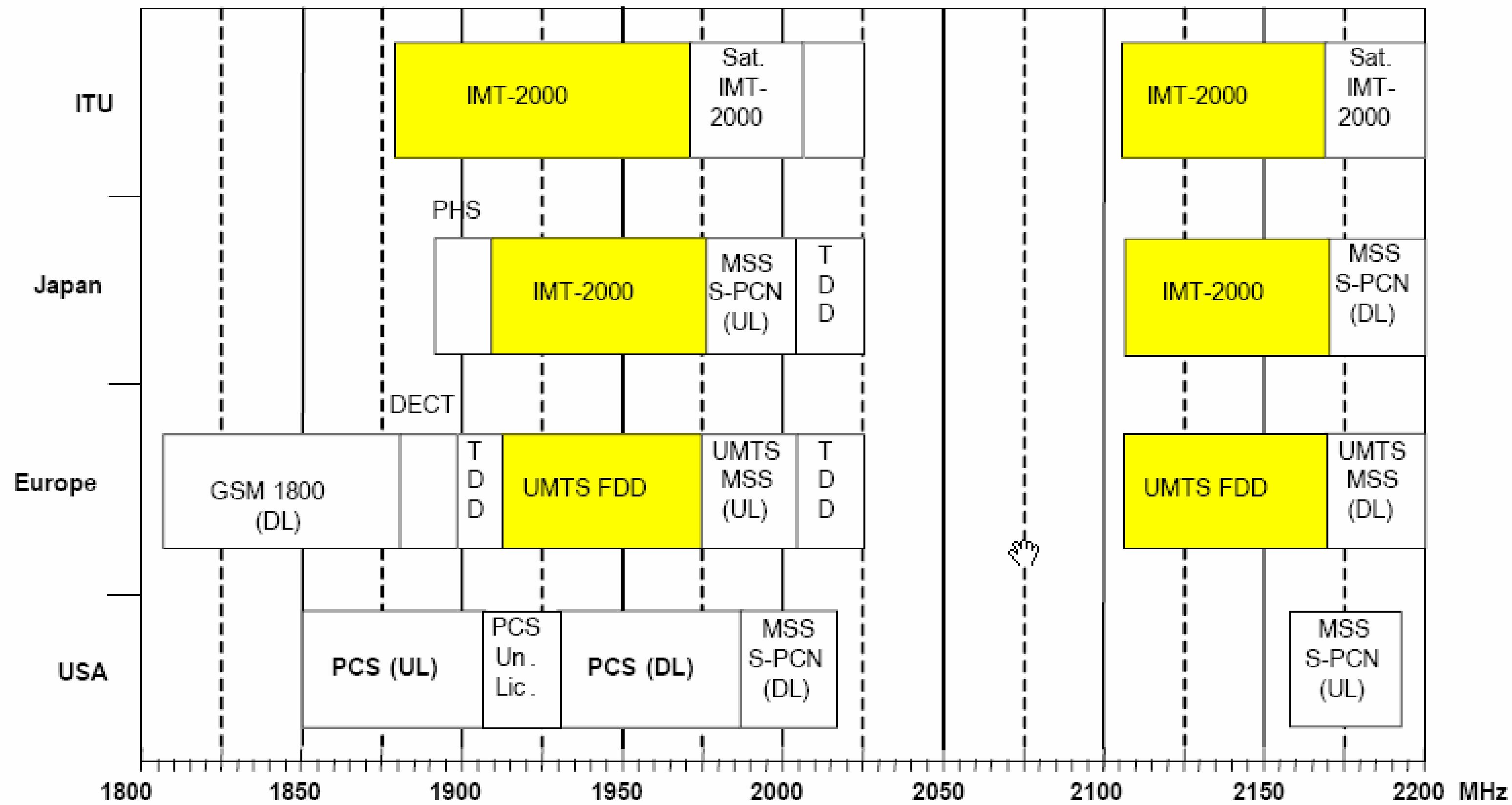
IMT-2000 International Mobile Telecommunications

IMT-2000 International Mobile Telecommunications:

- ITU globally coordinated 3G covering key issues such as frequency spectrum use and technical standards
- high transmission data rates for indoor and outdoor use
- symmetrical and asymmetrical data transmission
- circuit-switched and packet-switched services



3G Frequency Allocation



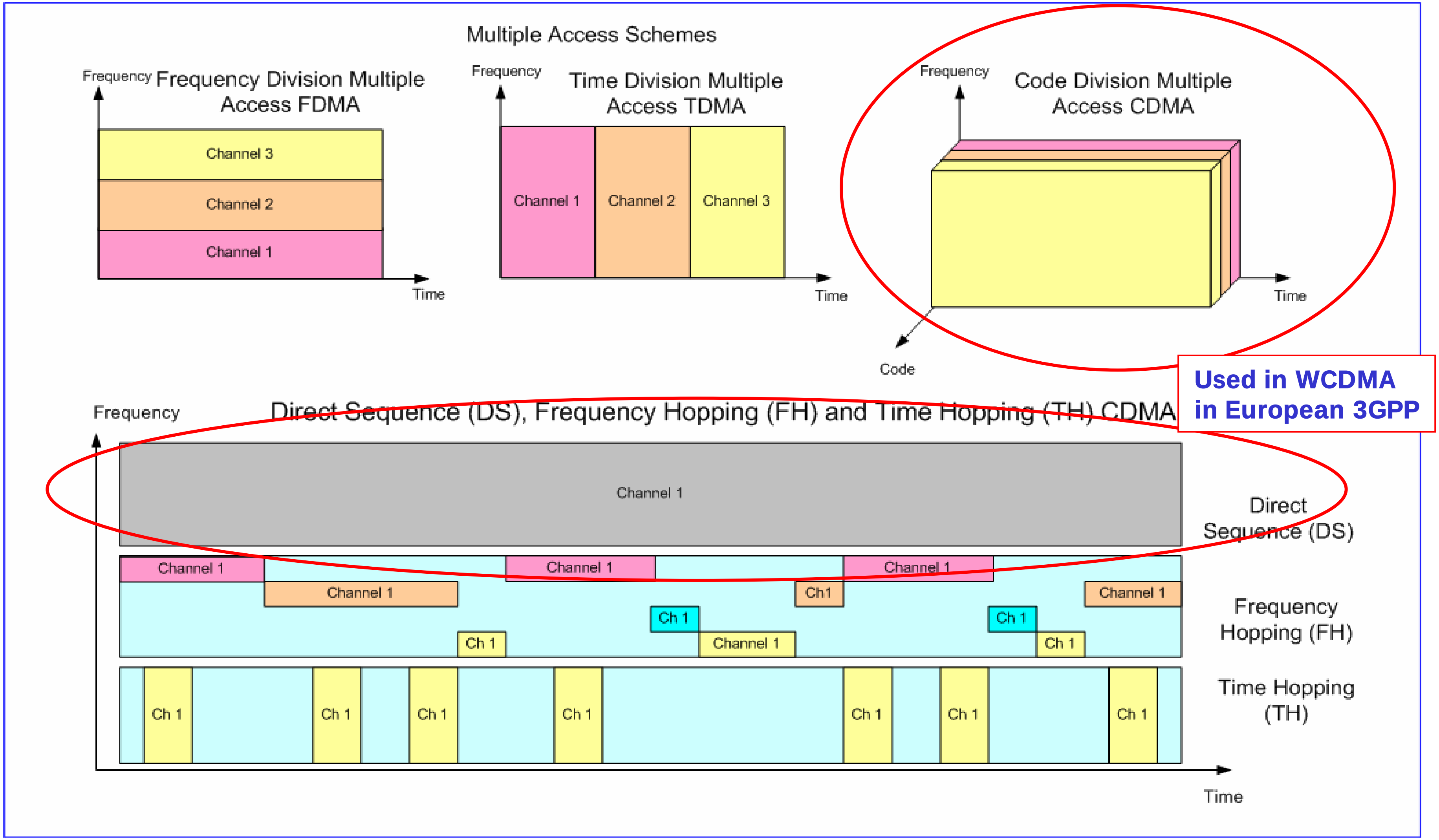
UMTS Frequencies:

- **1920-1980** and **2110-2170** MHz Frequency Division Duplex (FDD, W-CDMA). Ch = 5 MHz, raster = 200 kHz.
- **1900-1920** and **2010-2025** MHz Time Division Duplex (TDD, TD/CDMA). Ch = 5 MHz, raster = 200 kHz.
- **1980-2010** and **2170-2200** MHz Satellite uplink and downlink.

Background: 1G-4G and Network Topology Evolution, Frequency Allocation, Abbreviations

- 1G networks (NMT, C-Nets, AMPS, TACS) are considered to be the first analog cellular systems, which started early 1980s.
- 2G networks (GSM, cdmaOne, DAMPS) are the first digital cellular systems launched early 1990s.
- 2.5G networks (GPRS, cdma2000 1x) are the enhanced versions of 2G networks with data rates up to about 144kbit/s.
- 3G networks (UMTS FDD and TDD, cdma2000 1x EVDO, cdma2000 3x, TD-SCDMA, Arib WCDMA, EDGE, IMT-2000 DECT) are the latest cellular networks that have data rates 384kbit/s and more.
- 4G is mainly a marketing buzzword at the moment. Some basic 4G research is being done, but no frequencies have been allocated. The Forth Generation could be ready for implementation around 2012.
- “UMTS = Universal Mobile Telecommunications System”

Multiple Access and CDMA Classification



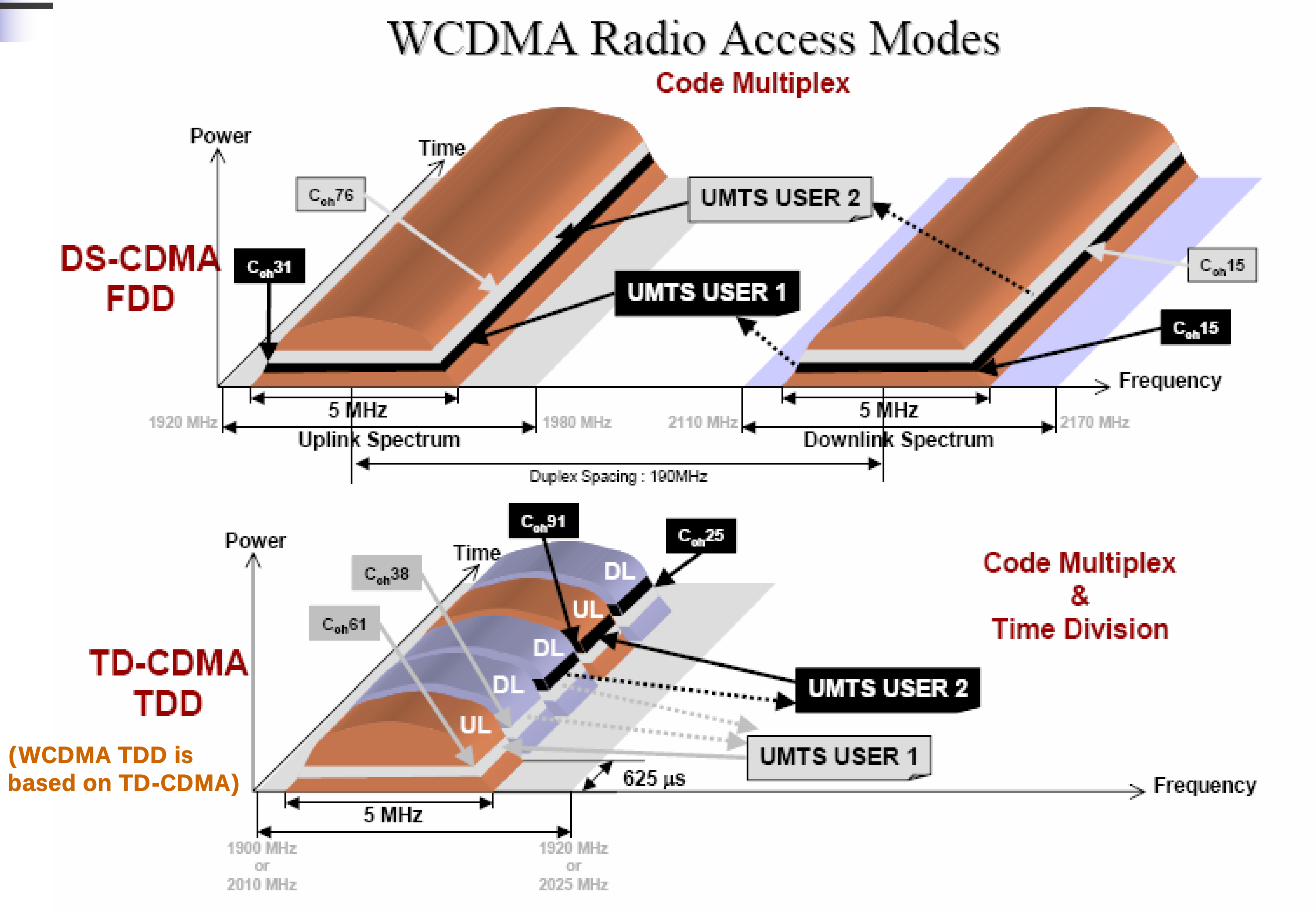
WCDMA Characterictics

- Support two basic modes: FDD and TDD modes
- High chip rate (3.84 Mcps) and data rates (up to 2 Mbps)
- Employs coherent detection on uplink and downlink based on the use of pilot symbols
- Inter-cell asynchronous operation
- Fast adaptive power control in the downlink based on SIR
- Provision of multirate services
- Packet data
- Seamless inter-frequency handover
- Intersystem handovers, e.g. between GSM and WCDMA
- Support for advanced technologies like multiuser detection (MUD) and smart adaptive antennas

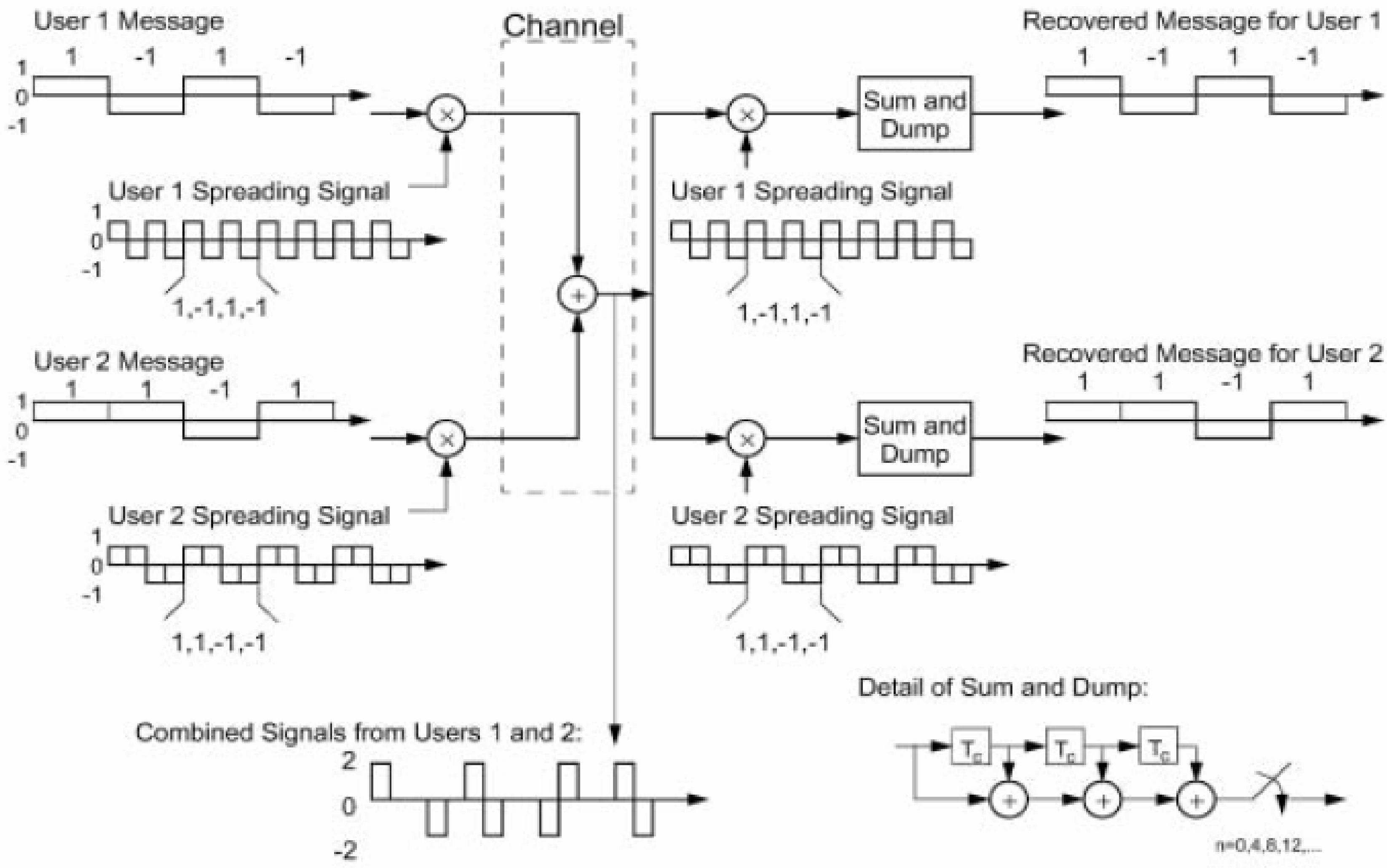
WCDMA Specifications

Channel Bandwidth	5 MHz
Duplex Mode	FDD and TDD
Downlink RF Channel Structure	Direct Spread (DS)
Chip Rate	3.84 Mcps
Frame Length	10 ms
Spreading Modulation	Balanced QPSK (downlink), Dual-channel QPSK (uplink) Complex spreading circuit
Data Modulation	QPSK (downlink), BPSK (uplink)
Channel Coding	Convolutional and turbo codes
Coherent detection	• User dedicated time multiplexed pilot (downlink and uplink) • common pilot in downlink
Channel Multiplexing in Downlink	Data and control channel are multiplexed
Channel Multiplexing in Uplink	• Control and pilot channel time multiplexed • I&Q multiplexing for data and control channel
Multirate	Variable spreading and multicode
Spreading Factors	4-256 (uplink), 4-512 (downlink)
Power Control	Open and fast closed loop (1.6 kHz)
Spreading (downlink)	OVSF sequences for channel separation. Gold sequences 2^{18}-1 for cell and user separation (truncated cycle 10 ms)
Spreading (uplink)	OVSF sequences. Gold sequence 2^{41} for user separation (different time shifts in I and Q channel, truncated cycle 10 ms)
Handover	Soft handover, Inter-frequency handover, etc.

WCDMA Radio Access Modes



Spreading and De-spreading (1)



Spreading and De-spreading (2)

- In WCDMA Spread Spectrum technology the information contents are spread by unique, digital codes (spreading sequences).
- The basic unit of a code sequence is one chip. The rate of spreading code is denominated as **chip rate Rc (chip/s or cp/s).**
- The ratio between the chip rate Rc (cp/s) and the information rate Rb (symb/s) is denominated as **Spreading Factor SF = Rc/Rb.**
- The bandwidth after spreading, B (modulation bandwidth), is in rough terms **SF** times the bandwidth before spreading W: **B ~ SF * W**.
- The bandwidth increases with spreading but spectral power density necessary for transmission decreases. WCDMA needs only very small power densities, often below the level of natural background noise.

Coding (1)

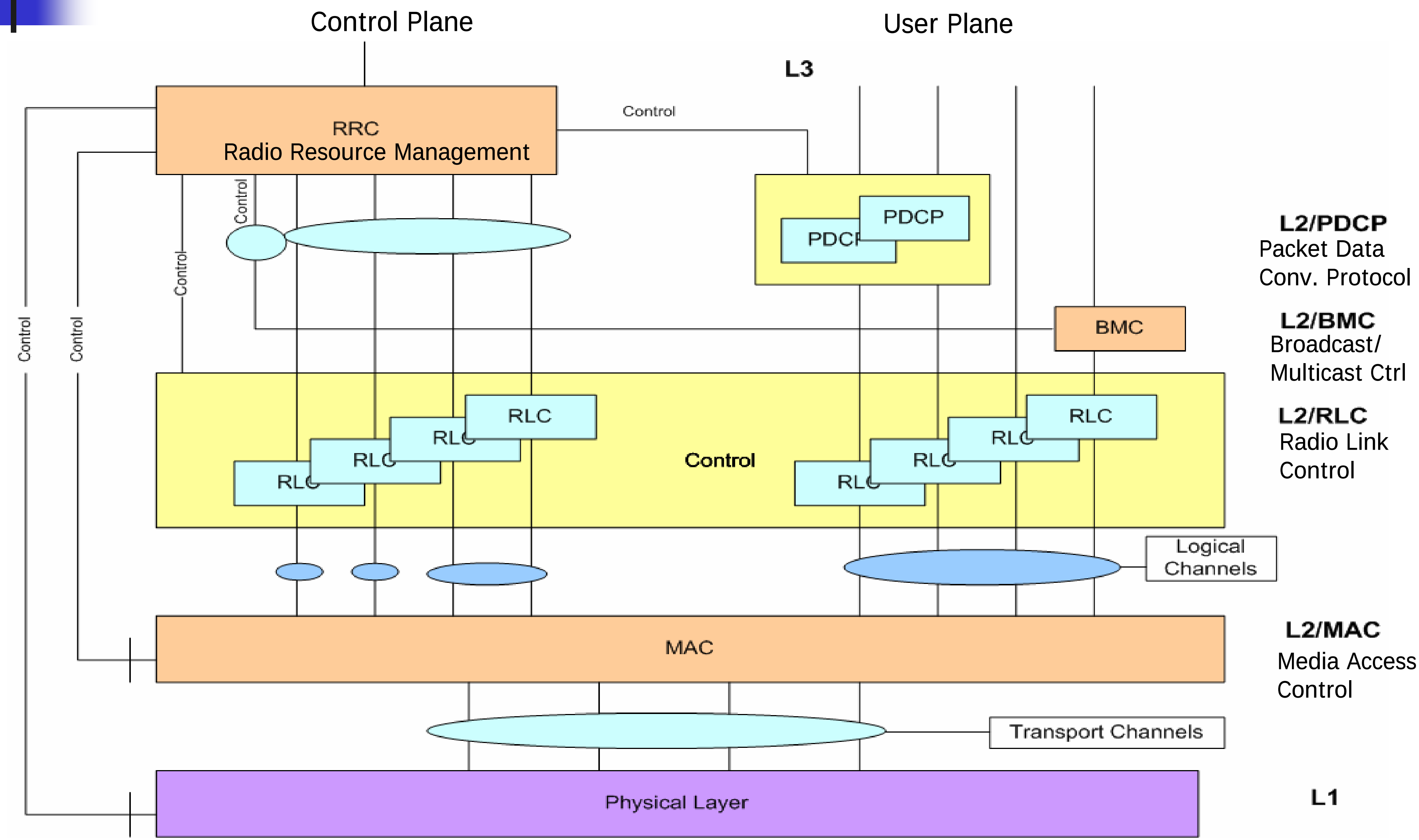
- Physical channel operations:
  - channelization: every bit is transformed into SF number of chips
  - scrambling: scrambling code is applied to the spread signal
- In channelization operation, Orthogonal Variable Spreading Factor (OVSF) codes are used to preserve the orthogonality between the physical channels of connections operating at different rates. Options are Convolutional or Turbo coding.
- The SF depends on the bit rate; high bit rate requires low SF and vice versa
- Each user has its own scrambling code in the uplink

Coding (2)

- Scrambling code is related to a user
- Spreading code is related to the type of service at a given bit rate
- Downlink scrambling code planning:
  - max number of scrambling codes: 2^{18}-1, divided into 512 primary scrambling codes with 15 secondary scrambling codes.
  - each cell has been allocated only one primary scrambling code.
- Downlink spreading code:
  - max number of OVSF downlink spreading codes is 512
  - all users in a cell share the available channelization codes in the OVSF code tree

Air Interface Protocol

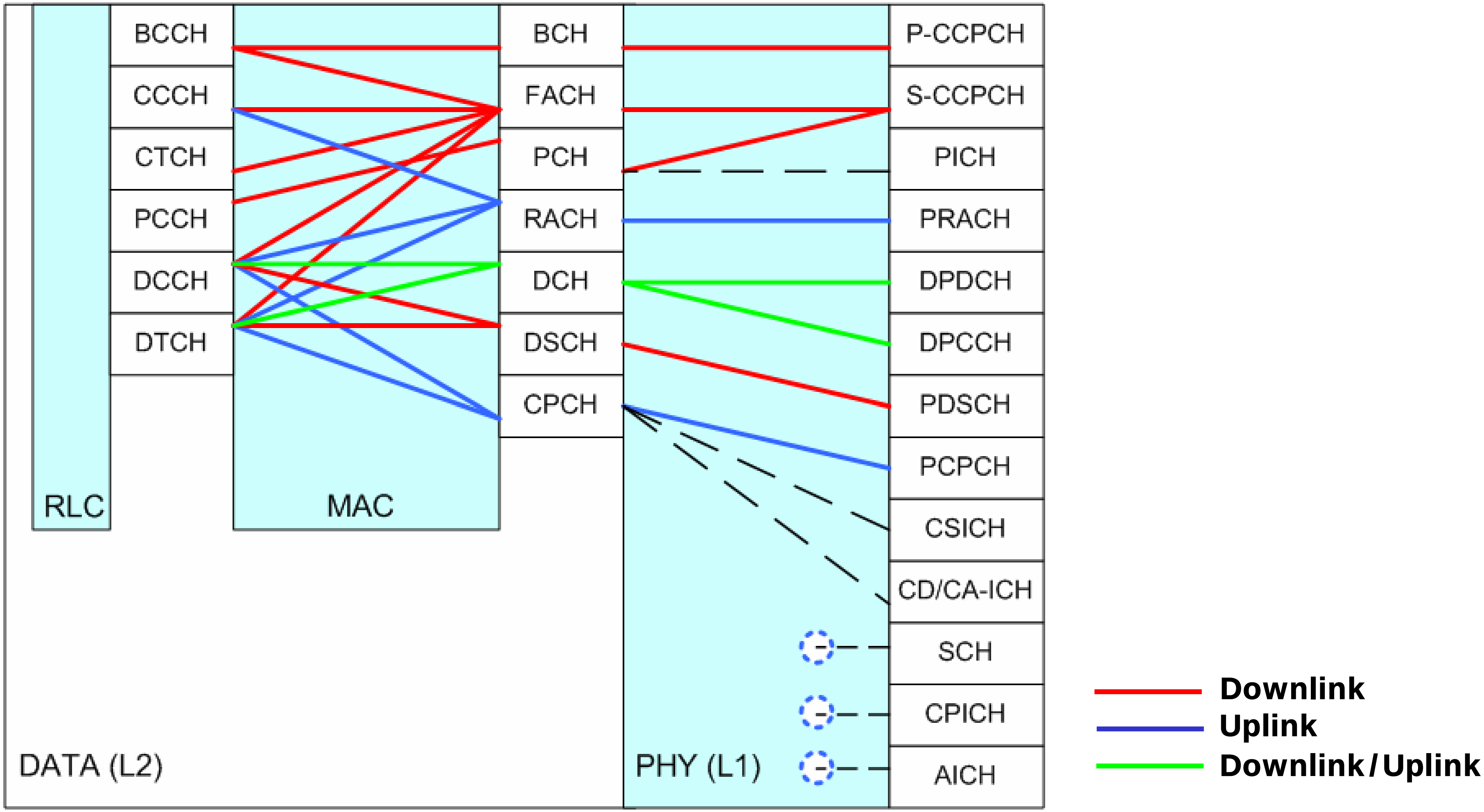
Air Interface Protocol Architecture



Air Interface Protocol Layers

Layer 3	RRC	**Radio Resource Management:** Assignment of radio resource, control of service quality, bearer service management, transmission reports, paging, power control, etc.
Layer 2	PDCP	**Packet Data Convergence Protocol**: header compression in case of TCP/IP, fro example
	BMC	**Broadcast/Multicast Control Protocol:** submission of messages to all or a group of UEs in a cell
	RLC	**Radio Link Control**: segmentation/de-segmentation, error detection and correction, flow control, encryption, etc.
	MAC	**Medium Access Control:** multiplex of logical channels to transport channels, selection of transport type, etc.
Layer 1	PHY	**Physical Layer:** error detection and correction for transport channels, radio measurement and reporting to RRC, splitting and combining data streams for macro diversity and soft handover, adaptation of data rate, synchronization, etc.

Channels in Protocol Architecture



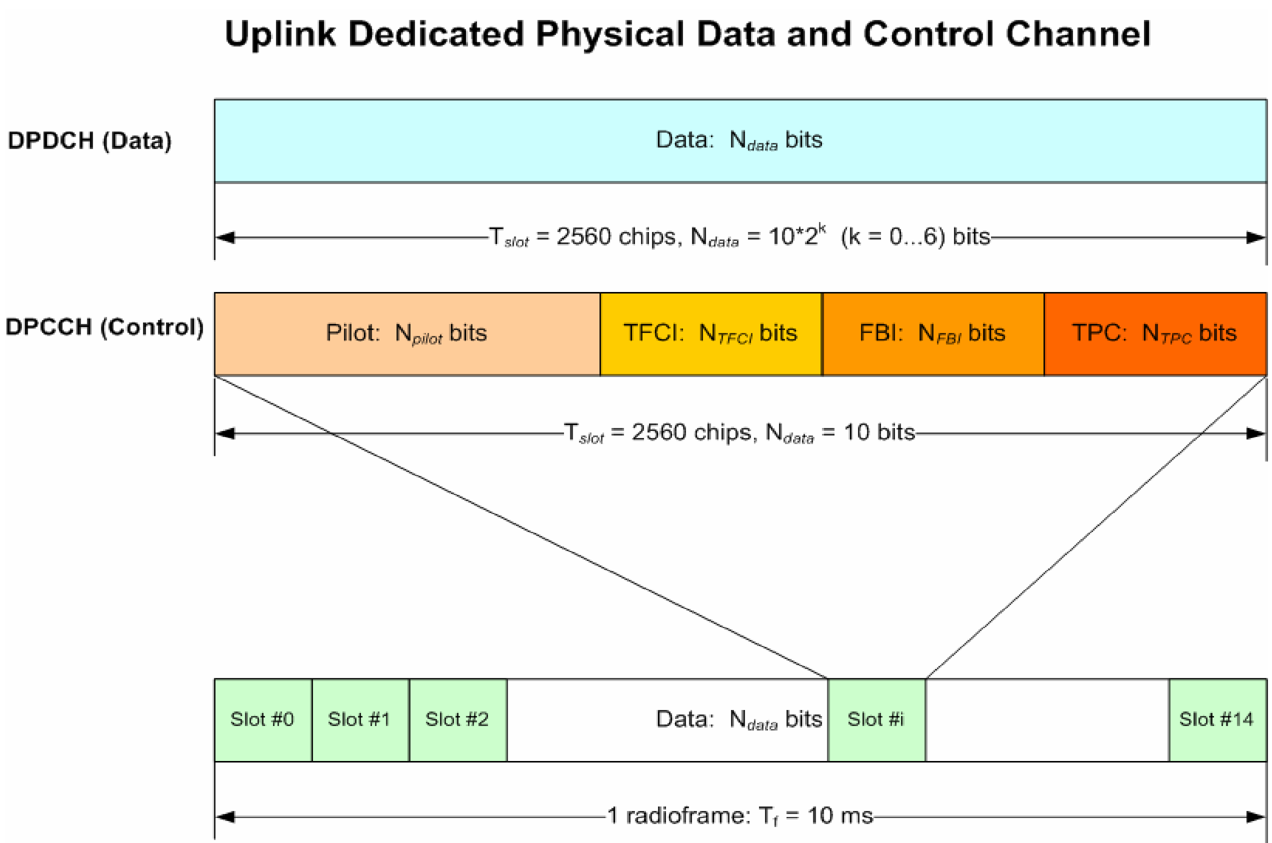
Logical Channels

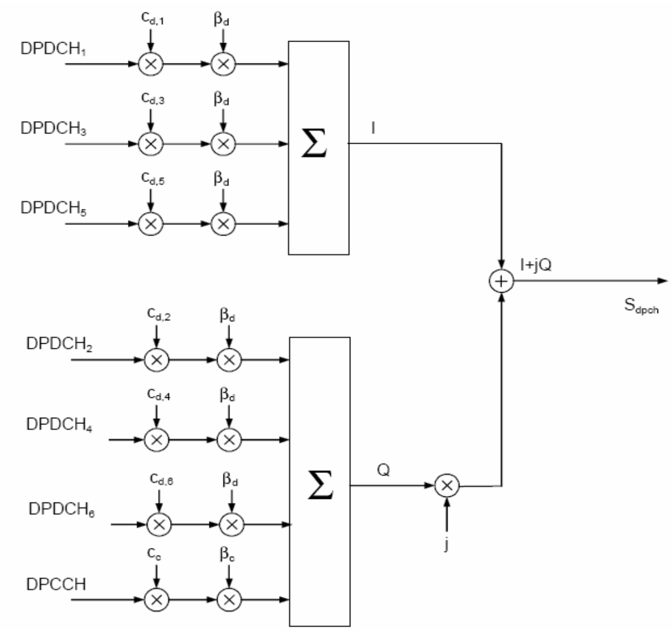
- MAC layer provides data transfer services on logical channels, control and traffic channels:
  - Control channel to transfer control plane information
  - Traffic channels to transfer user plane information
- Control channels
  - Broadcast control channels (BCCH) - downlink broadcast control
  - Paging control channel (PCCH) - downlink paging information
  - Dedicated control channel (DCCH) - dedicated between mobile & network
  - Common control channel (CCCH) - common between mobile & network
  - Shared channel control information (SHCCH) - for UL & DL (TDD only)
- Data channels
  - Dedicated traffic channel (DTCH) - P2P ch. dedicated to one mobile (UL & DL)
  - Common traffic channel (CTCH) - P2MP ch. for unidirectional data

Uplink Physical Channels

Uplink Physical Channels: Frame Structure for Uplink Dedicated Data and Control Channel

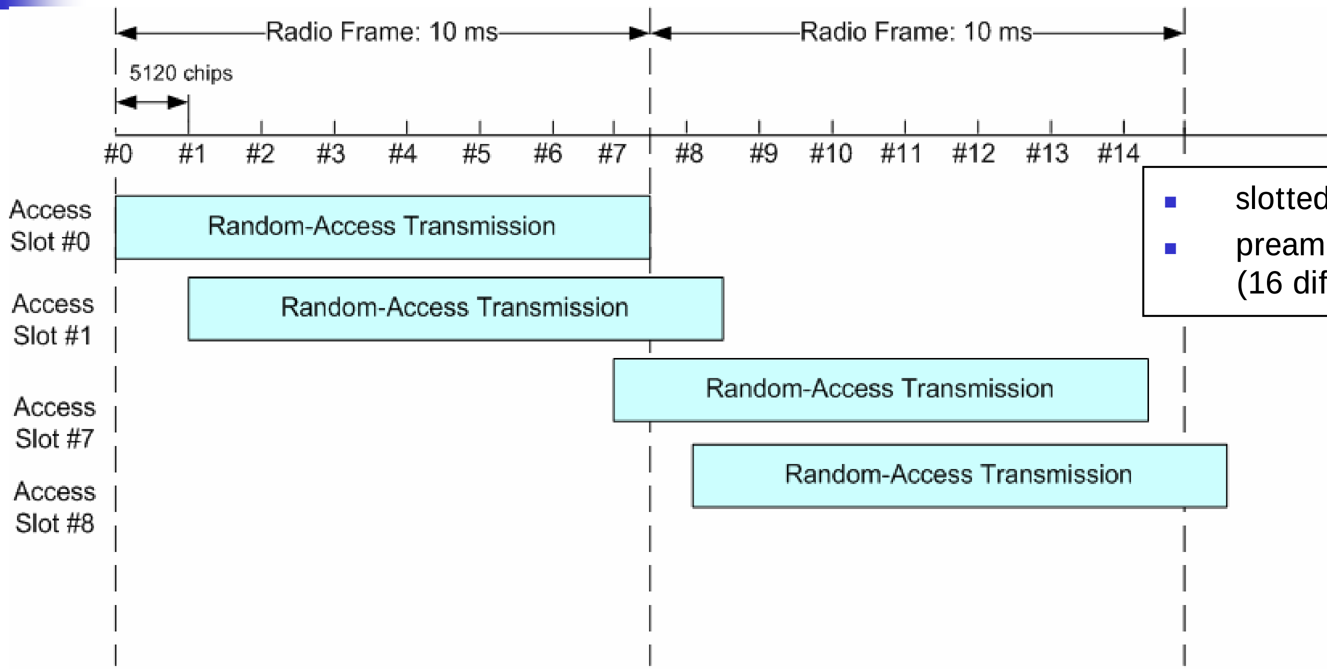
- two dedicated and two common physical uplink channels:
  - uplink Dedicated Physical Data (DPDCH) and Control (DPCCH) Channel
  - uplink Physical Random Access (PRACH) and Common Packet (PCPCH) Channel



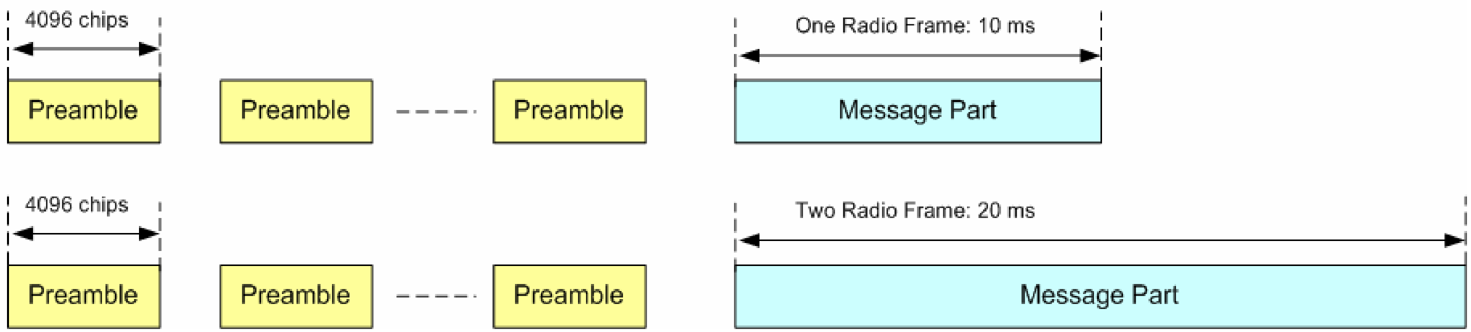


TPC = Transmit Power Control
FBI = Feedback Information
TFCI = Transport-Format Combination Indicator

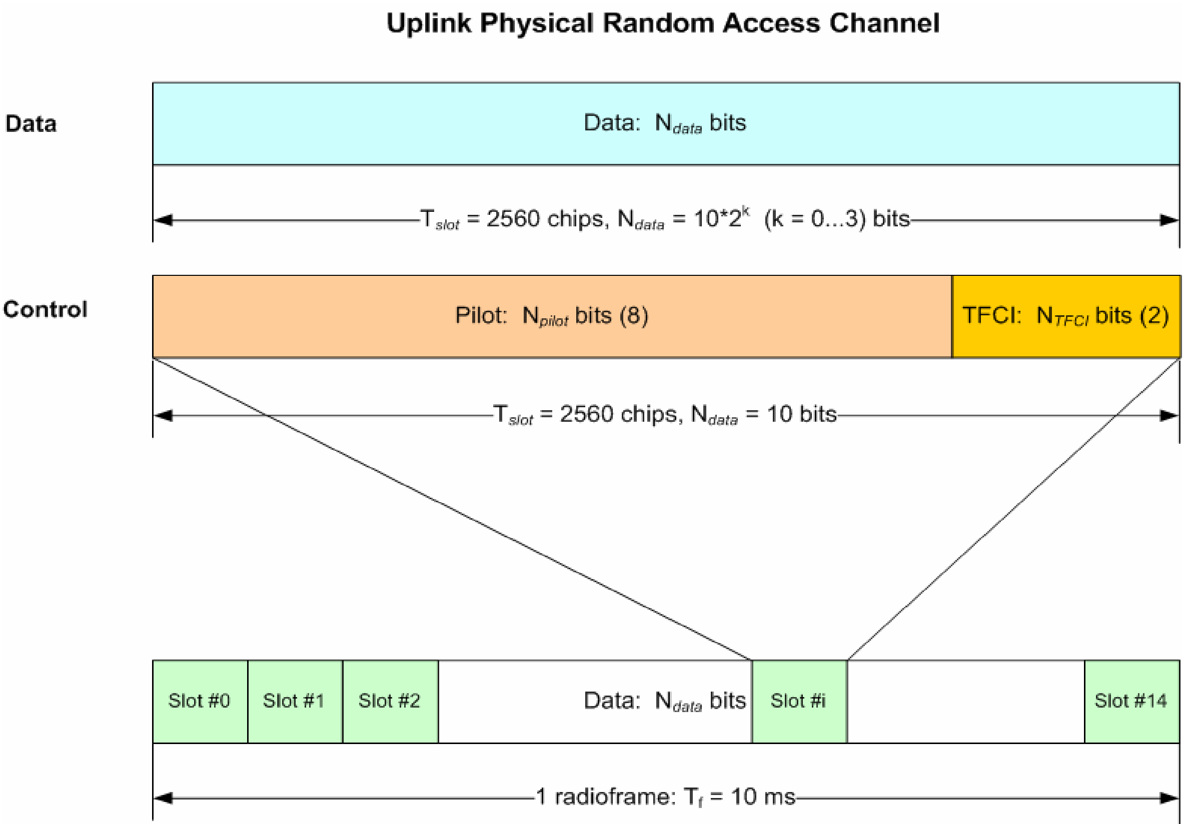
Random Access in Uplink

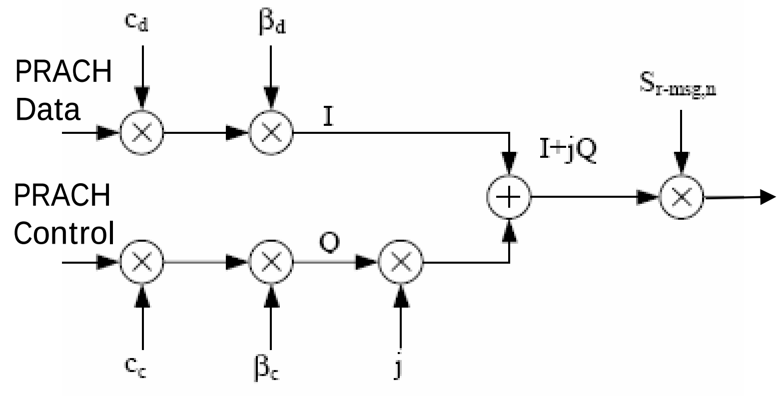


- slotted ALOHA random access
- preamble: 256 repetitions of signature (16 different Hadamard codes)



Uplink Physical Channels: Structure of the Random Access Message Part Radio Frame





- scrambling with 10 ms complex-valued scrambling code

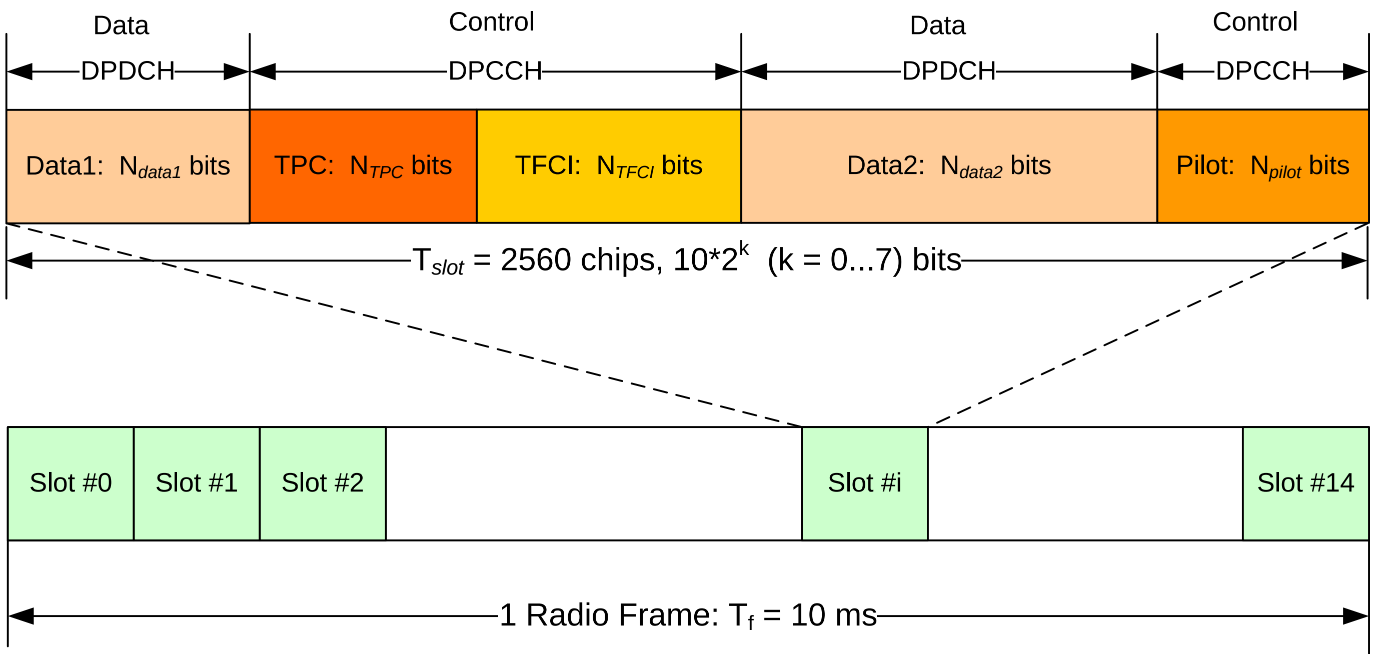
Downlink Physical Channels

Downlink Physical Channels

- Downlink Dedicated Physical Channel (DPCH)
- Physical Downlink Shared Channel (DSCH)
- Primary and Secondary Common Pilot Channels (CPICH)
- Primary and Secondary Common Control Physical Channels (CCPCH)
- Synchronization Channel (SCH)

Frame Structure for Downlink Dedicated Physical Channel (DPCH)

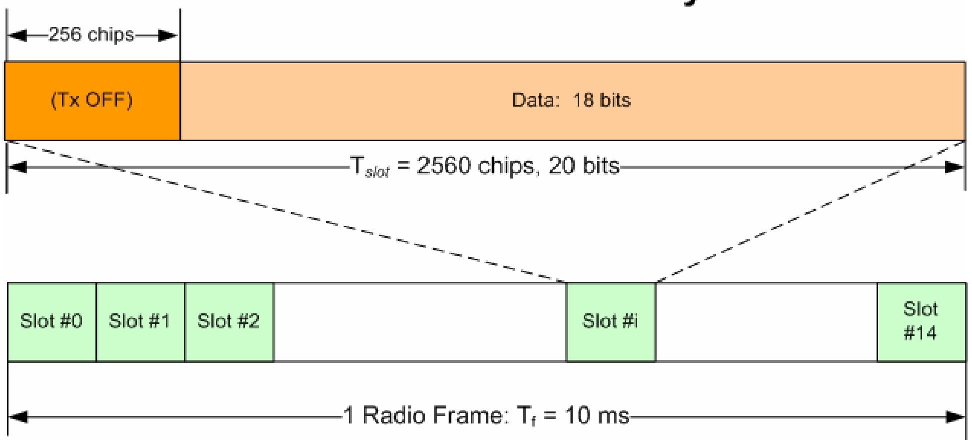
Downlink DPCH Frame Structure



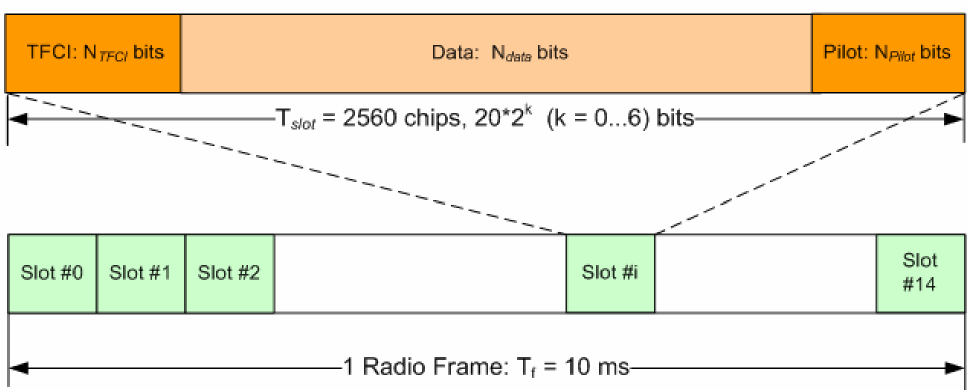
- The dedicated transport channel is sent time multiplexed with control information generated at layer 1 (pilot bits, power-control commands, optional transport format combination indicator)

Primary and Secondary Downlink CCPCH Channels

Frame Structure for Downlink Primary CCPCH

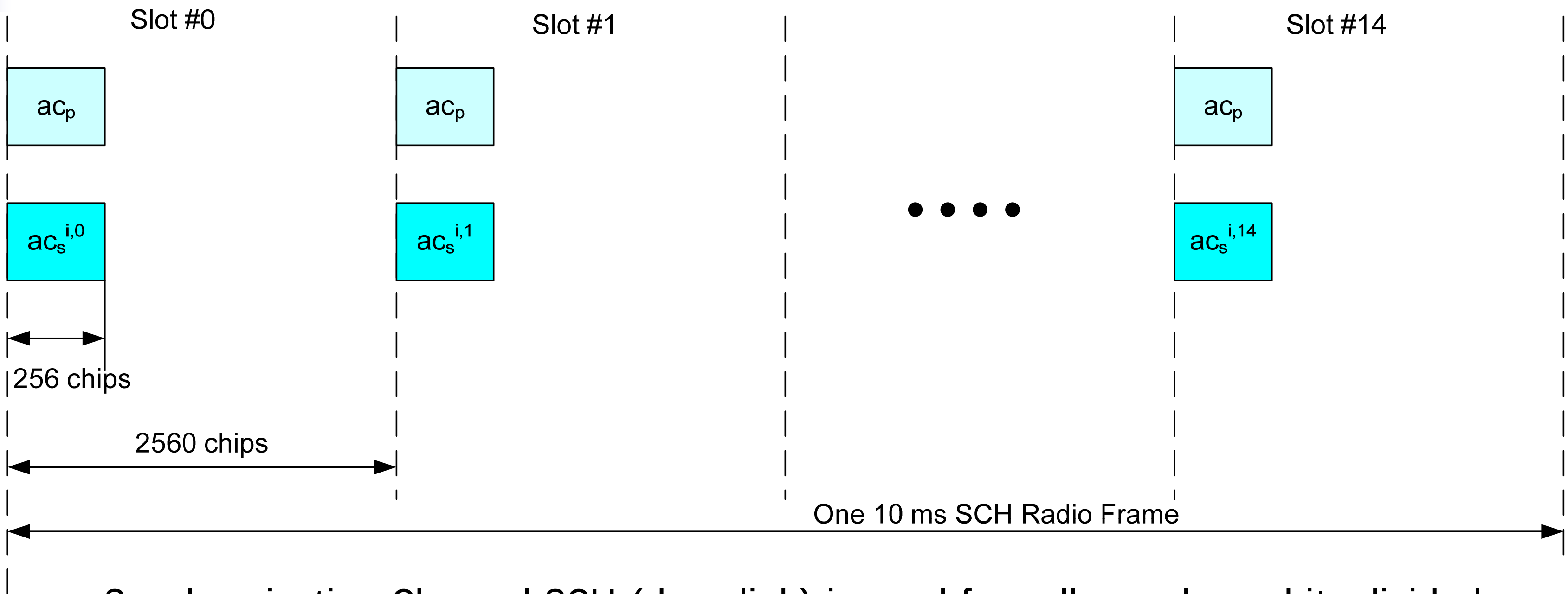


Frame Structure for Downlink Secondary CCPCH



- During Primary CCPCH (P-CCPCH) 256 chips from the start of the frame are not transmitted - that time is reserved for primary and secondary synchronization channels (SCH)
- P-CCPCH differs from DPCH so that no TPC, TFCI or Pilot are not sent
- P-CCPCH is fixed-rate (30 kbps) downlink data channel.
- Secondary (S-)CCPCH is variable rate and is sent only when data available

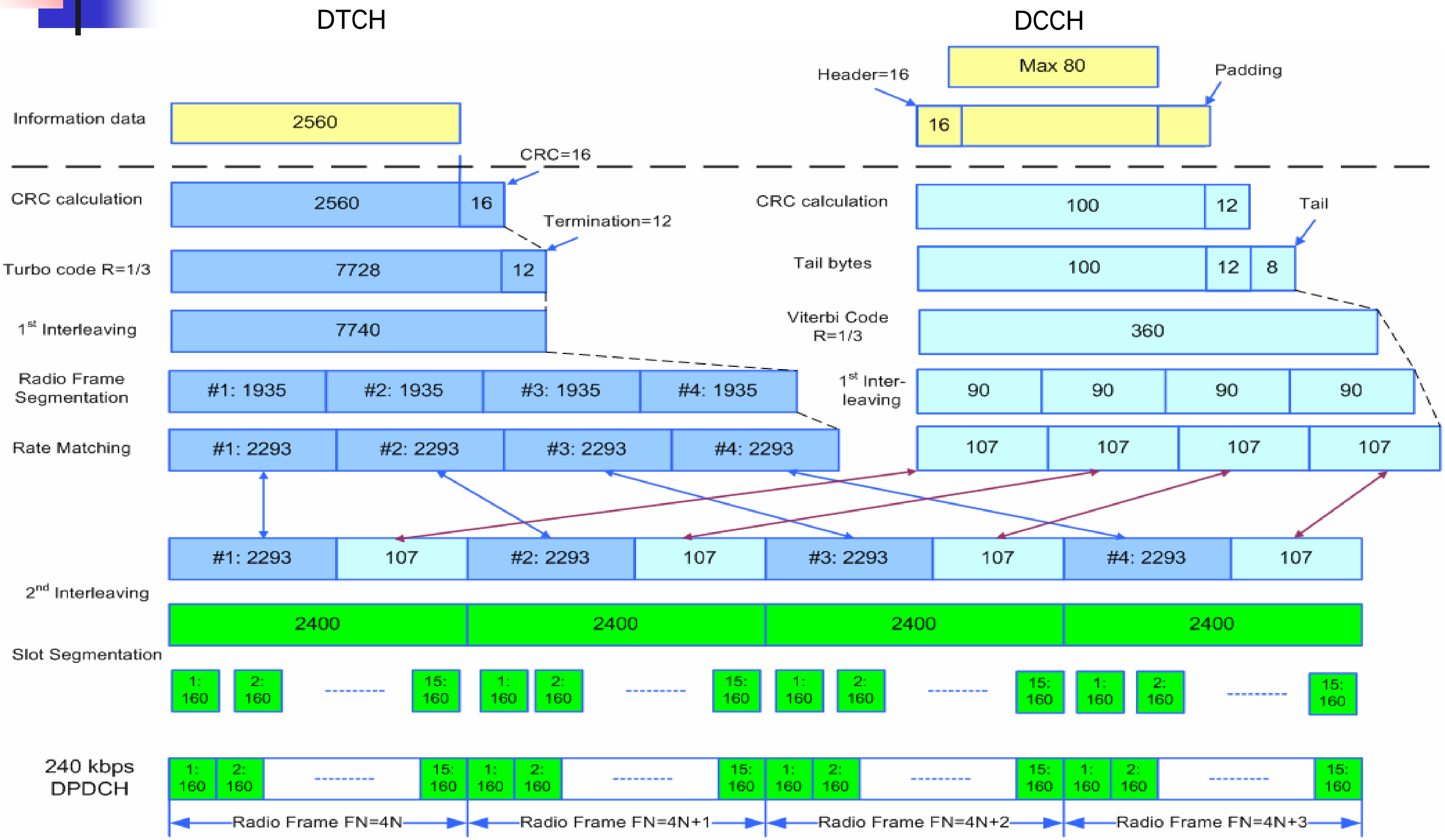
Synchronization Channel SCH

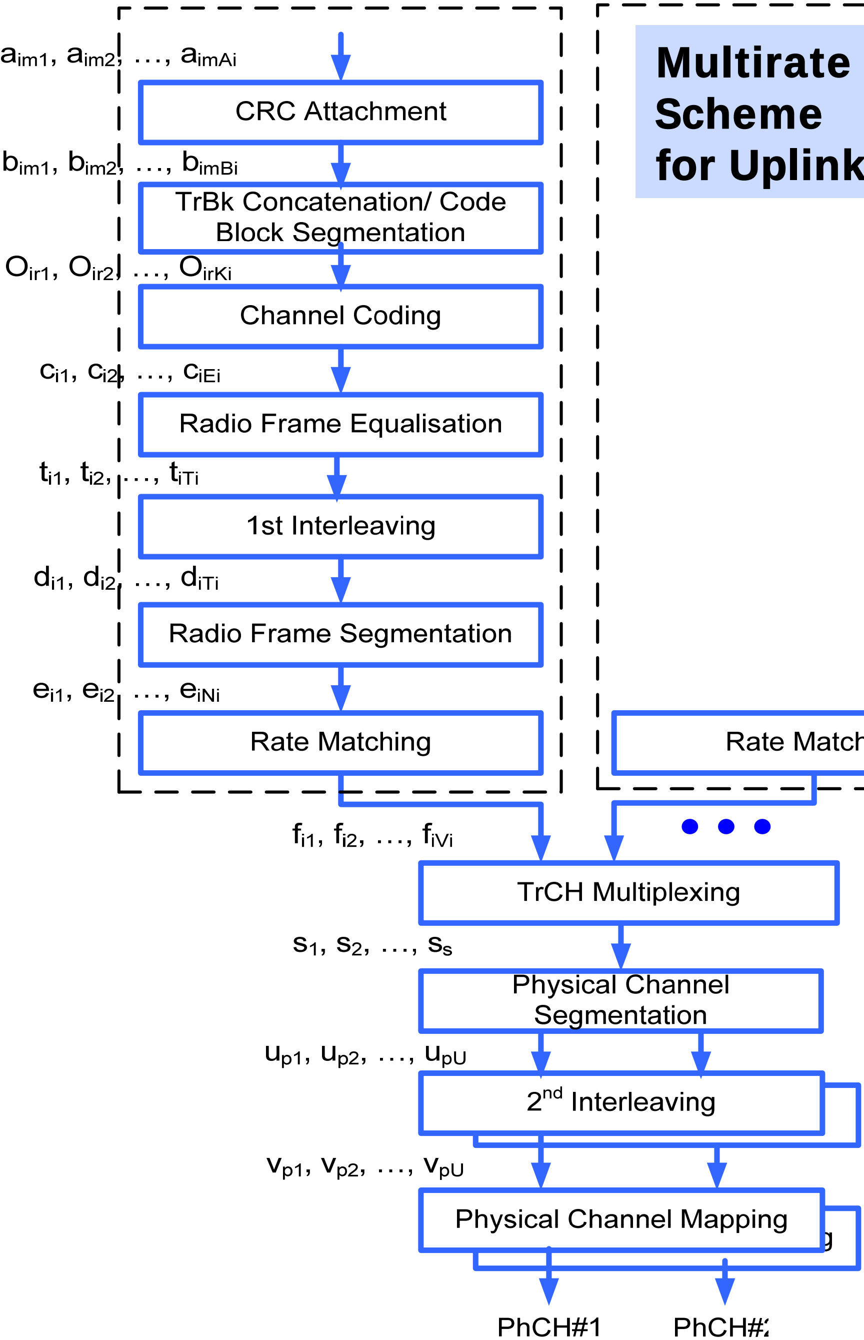


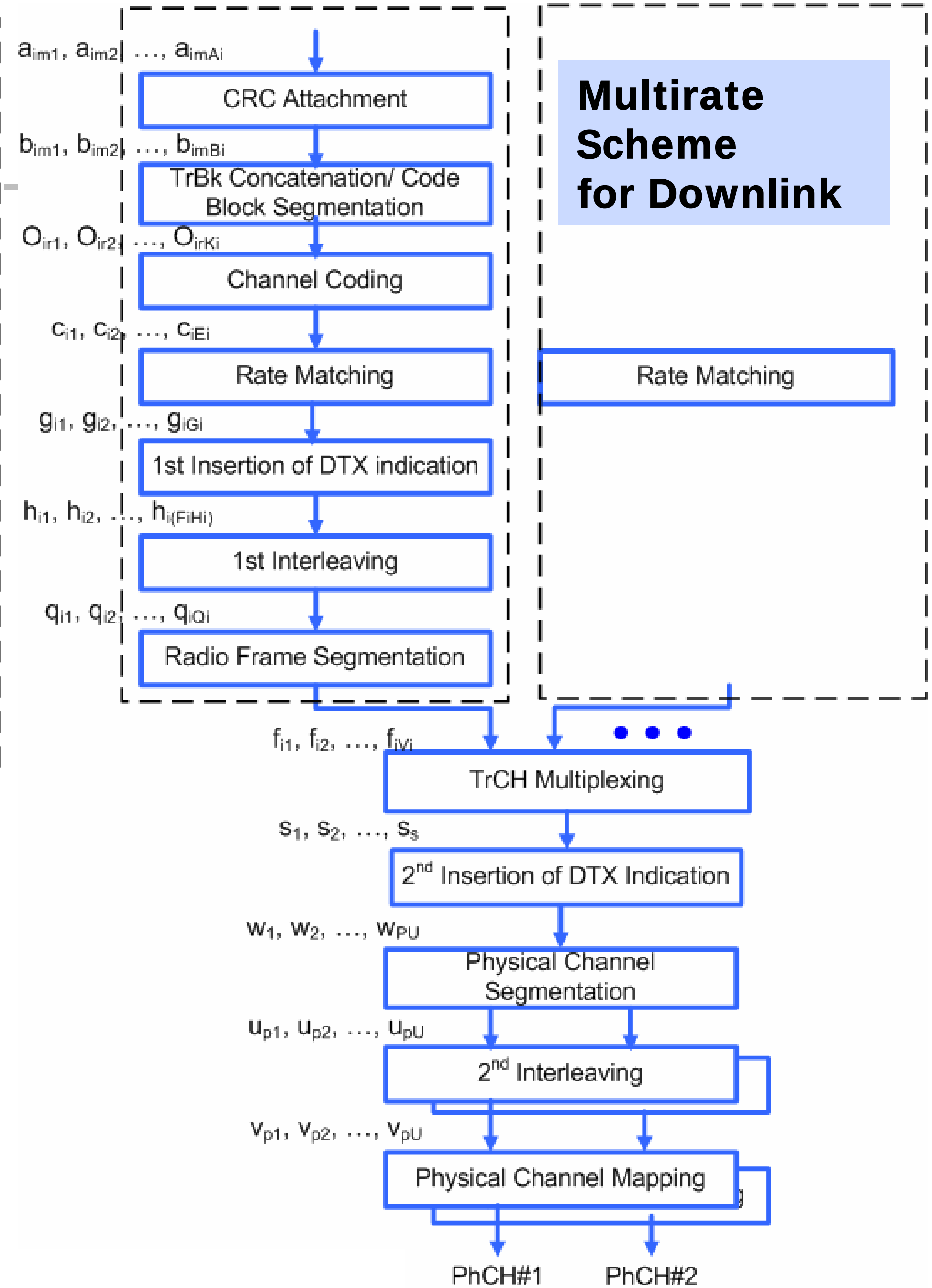
- Synchronization Channel SCH (downlink) is used for cell search, and its divided into two sub-channels
- Primary SCH consists of a modulated code (ac_p) of length 256 chips, repeated once in every slot
- Secondary SCH consists of a modulated code ($ac_p^{i,k}$, i = 0...63 for scrambling code group and k = 0...14 for slot) taken from a set of 16 different codes of length 256
- *a* here is used to modulate the primary and secondary synchronization codes and indicate the presence or absence of STTD encoding in P-CCPCH

Multi-Rate Scheme

Dedicated Transport Channel (DTCH/DCCH) for 64 kbps




Multirate Scheme for Uplink
aim1, aim2, …, aimAi
CRC Attachment
bim1, bim2, …, bimBi
TrBk Concatenation/ Code Block Segmentation
Oir1, Oir2, …, OirKi
Channel Coding
ci1, ci2, …, ciEi
Radio Frame Equalisation
ti1, ti2, …, tiTi
1st Interleaving
di1, di2, …, diTi
Radio Frame Segmentation
ei1, ei2, …, eiNi
Rate Matching
Rate Matching
fi1, fi2, …, fiVi
TrCH Multiplexing
s1, s2, …, sS
Physical Channel Segmentation
up1, up2, …, upU
2nd Interleaving
vp1, vp2, …, vpU
Physical Channel Mapping
PhCH#1


Multirate Scheme for Downlink
aim1, aim2, …, aimAi
CRC Attachment
bim1, bim2, …, bimBi
TrBk Concatenation/ Code Block Segmentation
Oir1, Oir2, …, OirKi
Channel Coding
ci1, ci2, …, ciEi
Rate Matching
Rate Matching
gi1, gi2, …, giGi
1st Insertion of DTX indication
hi1, hi2, …, hi(FiHi)
1st Interleaving
qi1, qi2, …, qiQi
Radio Frame Segmentation
fi1, fi2, …, fiVi
TrCH Multiplexing
s1, s2, …, sS
2nd Insertion of DTX Indication
w1, w2, …, wPU
Physical Channel Segmentation
up1, up2, …, upU
2nd Interleaving
vp1, vp2, …, vpU
Physical Channel Mapping
PhCH#1
PhCH#2

Air Interface Procedures - Cell Search

- Downlink scrambling code and common channel frame synchronization of that cell will be determined during cell search
- All common physical channel timings are related to the timing of P-CCPCH, so only the timing of P-CCPCH need to be found out
- Step 1, Slot synchronization:
  - SCH's primary synchronization code is used to acquire slot synchronization to a cell
  - primary synchronization code is common to all cells, so slot timing of the cell can be obtained by detecting peaks in a single matched filter output
- Step 2, Frame synchronization and code-group identification:
  - now secondary SCH is used to find frame synchronization and identify the code-group of the cells found in the first step. This is done by correlating the received signal with all possible secondary synchronization code sequences and identifying the max correlation value.
- Step 3, Scrambling code identification:
  - Mobile station determines the exact primary scrambling code used by the found cell. The primary scrambling code is identified through symbol-to-symbol correlation over the CPICH with all codes within the group identified in step 2.
  - After the primary scrambling code has been detected, the primary CCPCH can be detected, and the system and cell specific BCH information can be read.

Air Interface Procedures - Handover

- Soft handover
- Softer handover
- Inter-frequency handover
- Handover between FDD and TDD modes
- Handover between WCDMA and GSM

Radio Access Network Technology: Short-Medium Term Evolution

- Targets
  - Better radio performance
  - Support for better UE performance
  - Optimization of the radio access network architecture
- ⇨ Radio Performance
  - Higher spectral density
  - Improved coverage
  - Radio protocol optimization for shorter radio access latencies
- ⇨ UE Performance
  - Support to minimize power consumption
  - Use of high peak rates (up to 20-30 Mbps)
- ⇨ Radio Access Network
  - Joint utilization of 3G and other wireless access technologies (e.g. WLAN)
    - ⇨ Increased capacity
    - ⇨ Very fast access
  - Radio access technologies enabling low cost and power-efficient multi-radio implementations and improved overall performance (data rate, spectral efficiency, capacity and delay) should be studied
  - Radio access network should be further optimized especially for packet data communication

Radio Access Network Technology: Long Term Evolution

- In long term, the performance improvements (spectral efficiency, higher bit rates, shorter delays) of 3GPP radio access should be continued. Long term peak rates are:
  - Up to 100 Mbps in full mobility, wide area deployments
  - Uo to 1 Gbps in low mobility, local area deployments
- The long term spectral efficiency targets are (for best effort packet communication):
  - In a single (isolated) cell, up to 5-10 bps/Hz
  - In a multi-cellular case, up to 2-3 bps/Hz
- The peak data rate targets could be achieved:
  - by gradual evolution of existing 3GPP (UTRAN) and alternate access technologies (e.g. WLAN)
  - Also new access technologies should be considered according to the availability of additional or re-allocated spectrum

Homework

1. What are the main differences between UMTS-WCDMA and CDMA2000?
2. How does cell search happen in UMTS-WCDMA?

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