WCDMA Theory

Dallas – 04 May 2006

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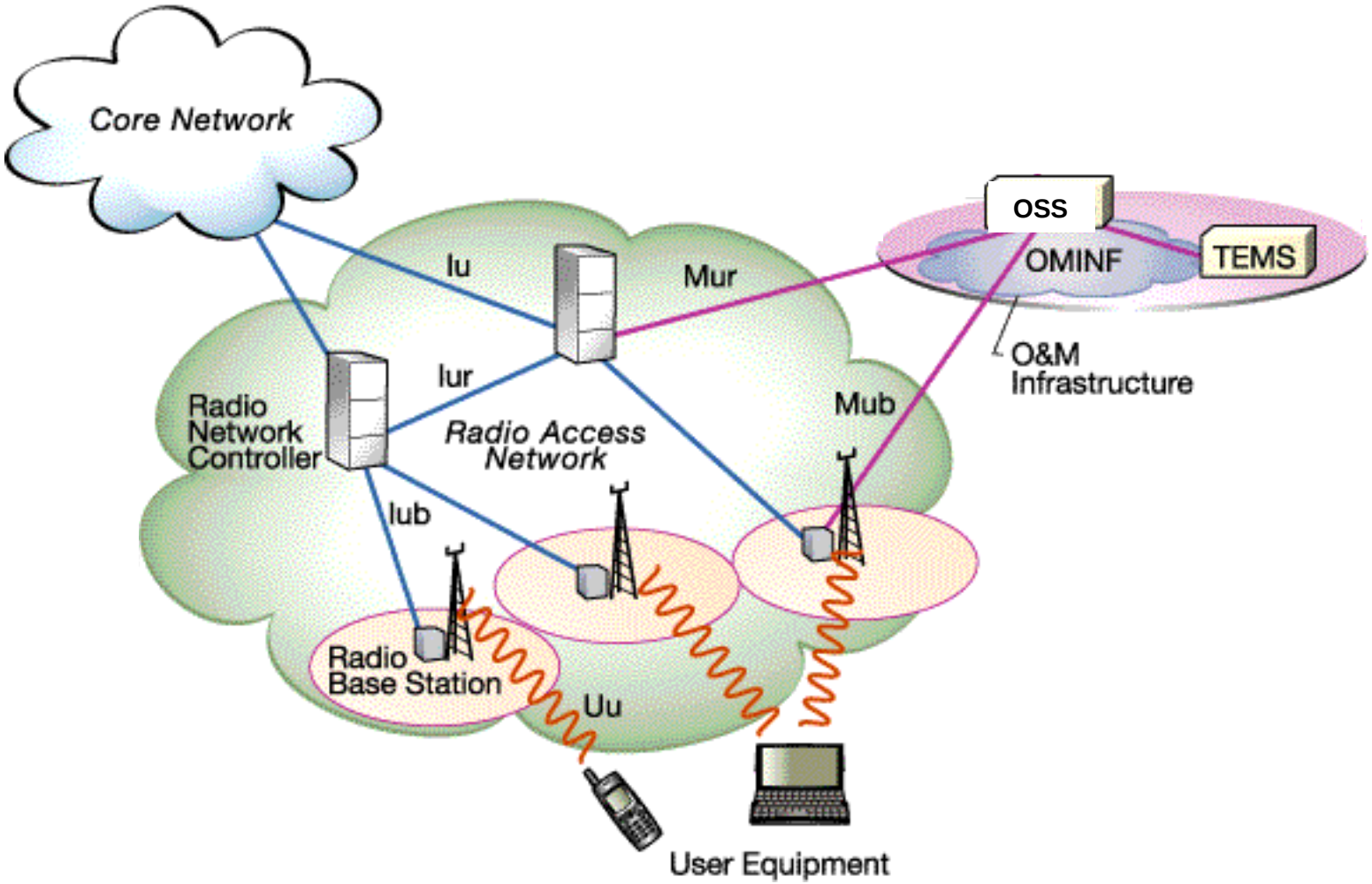
ERICSSON

TAKING YOU FORWARD

Agenda

- **UTRAN architecture**
- Multiple access techniques (DS-CDMA)
- Spreading codes (Channelisation and Scrambling)
- Fast link adaptation (Power and Rate control)
- Soft Handover
- Capacity limitation and cell breathing
- Rake receiver
- UE states
- Services (Bearers)
- Channels in WCDMA (logical, transport, physical)

UTRAN Architecture



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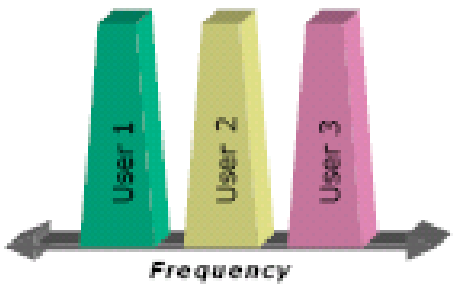
Multiple access techniques

Frequency
Division
Multiple
Access



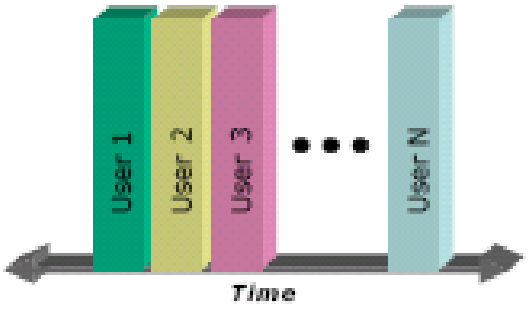
Each User has a unique **frequency**

(1 voice channel per user)

All users transmit at the same time

AMPS, NMT, TACS

Time
Division
Multiple
Access



Each User has a unique **time slot**

Each Data Channel has a unique **position within the time slot**

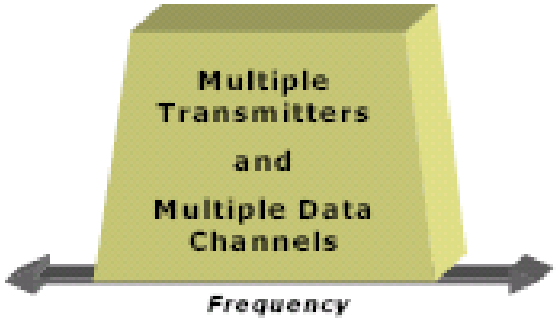
Several users share the same frequency

IS-136, GSM, PDC

Spread
Spectrum
Multiple
Access

/

Code
Division
Multiple
Access



Each Transmitter has a unique **Scrambling Code**

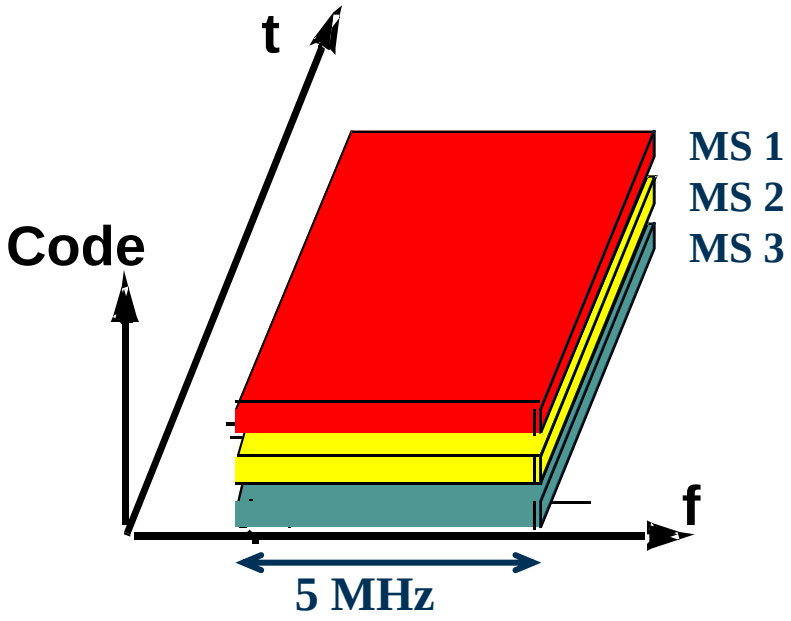
Each Data Channel has a unique **Channelization code**

Many users share the same frequency *and* time

IS-95, cdma2000, WCDMA

Direct Sequence - Code Division Multiple Access (DS-CDMA)

- Separate users through different codes
- Large bandwidth
- Continuous transmission and reception



- **WCDMA (5 MHz)**
- IS-95 (1.25 MHz)
- CDMA2000 (1.25, 3.75 MHz)

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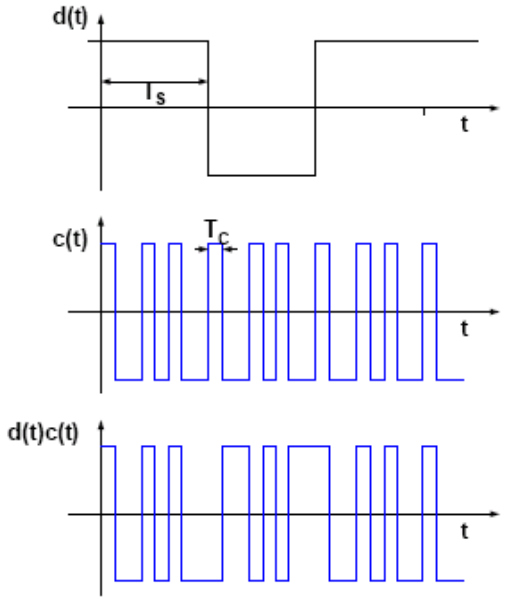
Spreading principle

- ✓ User information bits are spread into a number of chips by multiplying them with a spreading code
- ✓ The chip rate for the system is 3.84 Mchip/s and the signal is spread in 5 MHz
- ✓ The Spreading Factor (SF) is the ratio between the chip rate and the symbol rate
- ✓ The same code is used for de/spreading the information after it is sent over the air interface

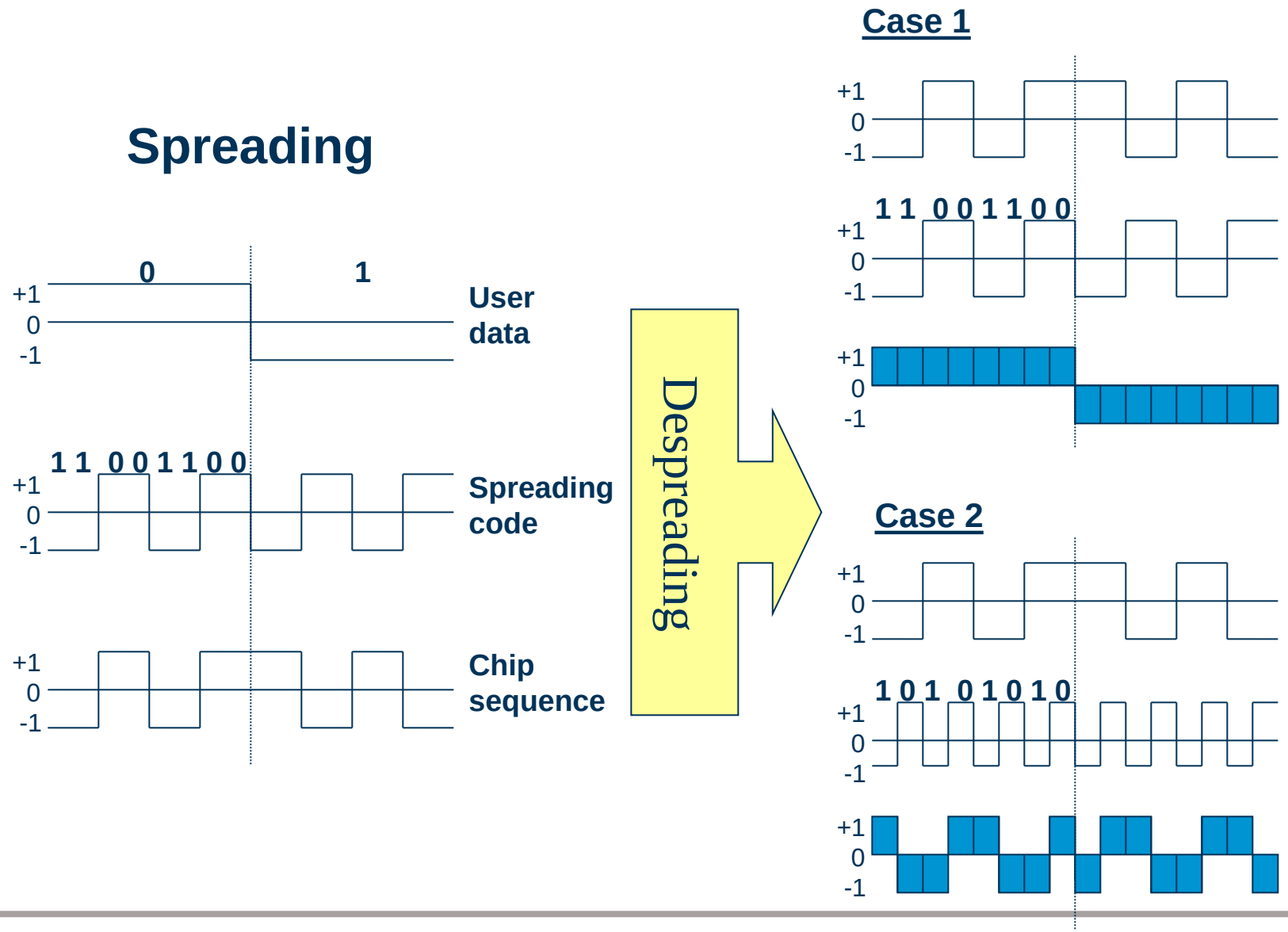


Information signal

Spreading signal

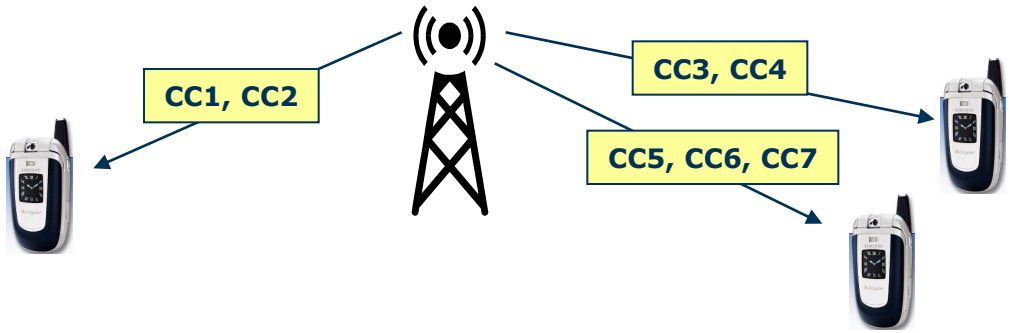
Transmission signal

Spreading principle

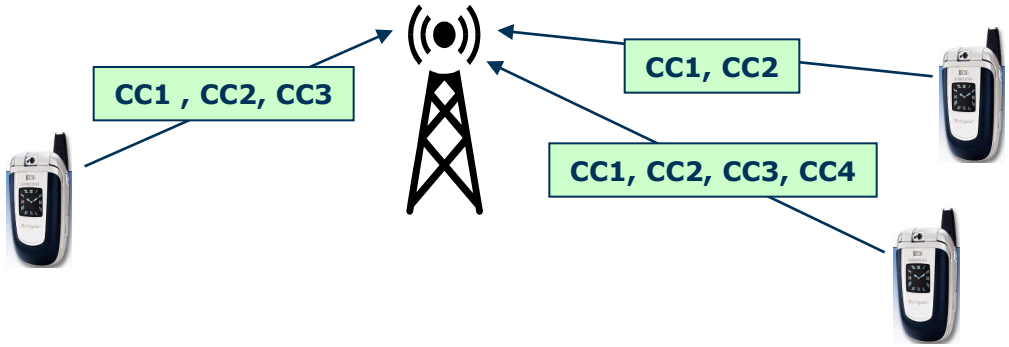


Channelization Codes

- ✓ In the Downlink Channelization Codes are used to distinguish between data (and control) channels coming from the same RBS

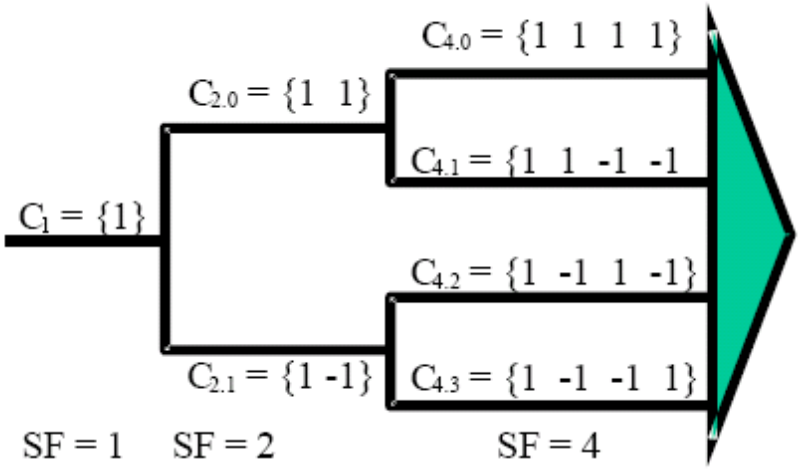


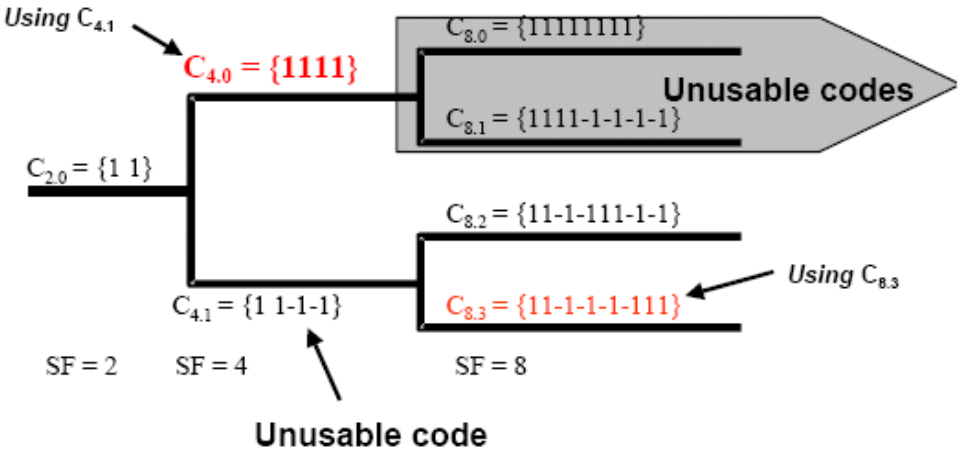
- ✓ In the Uplink Channelization Codes are used to distinguish between data (and control) channels from the same UE



Channelization Codes

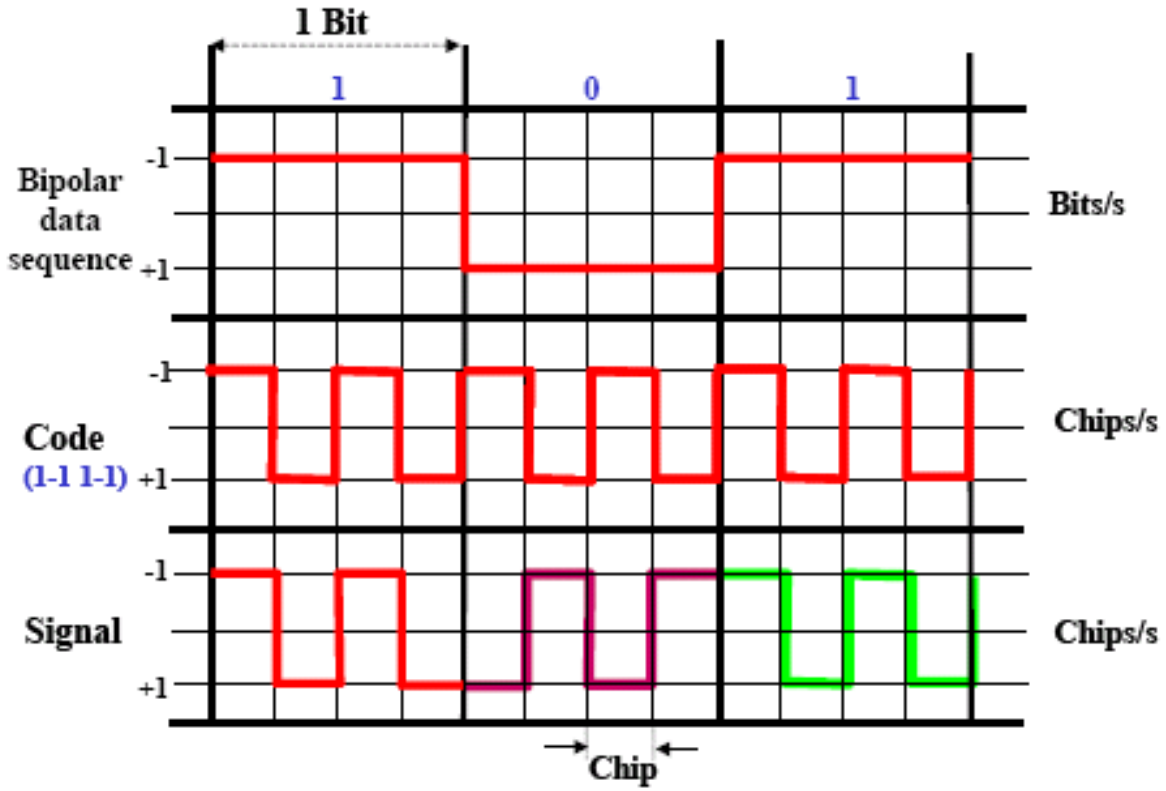
- ✓ Channelization Codes have different length depending on the bit rate
- ✓ A physical channel may use a certain code in the tree if no other physical channel uses a code from an underlying branch.





Channelization Codes

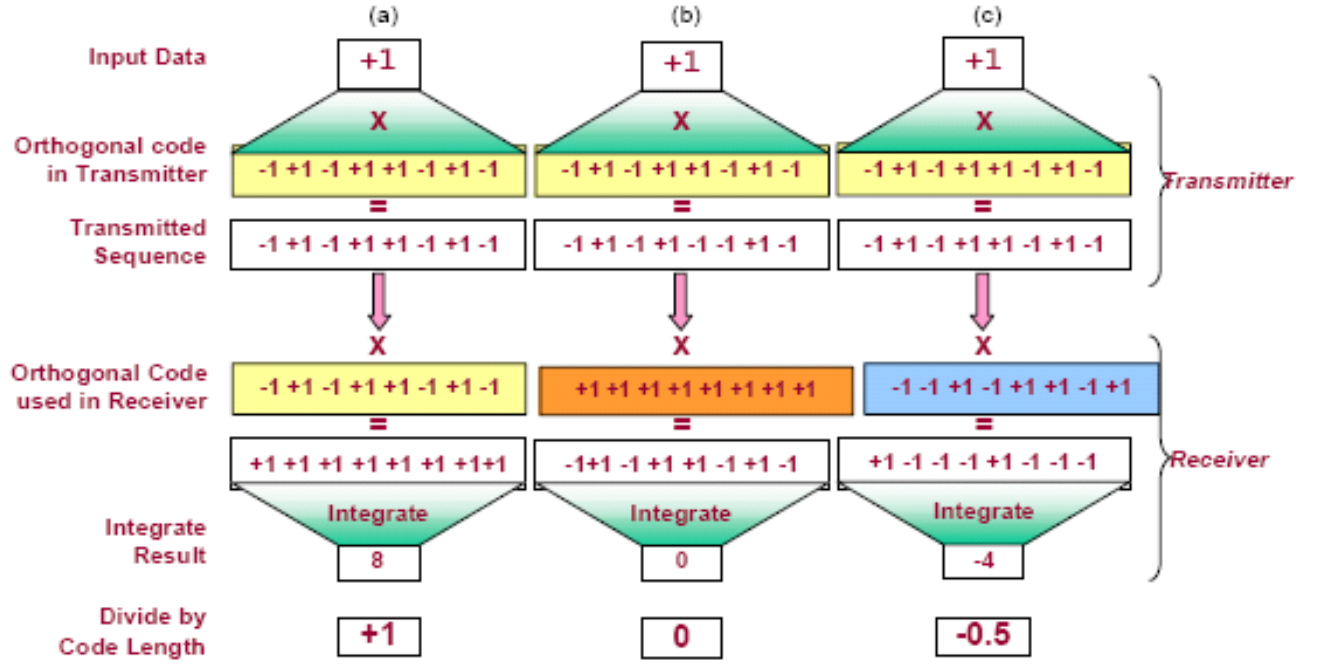
The bit stream is spread into a constant chip rate of 3.84 Mchip/s



Channelization Codes

- ✓Channelization codes are orthogonal (but only if they are synchronized)
- ✓Orthogonal codes have perfect (100%) separation

(a) Same Channelization Code; (b) Different Channelization codes; (c) Same code with non-zero time offset

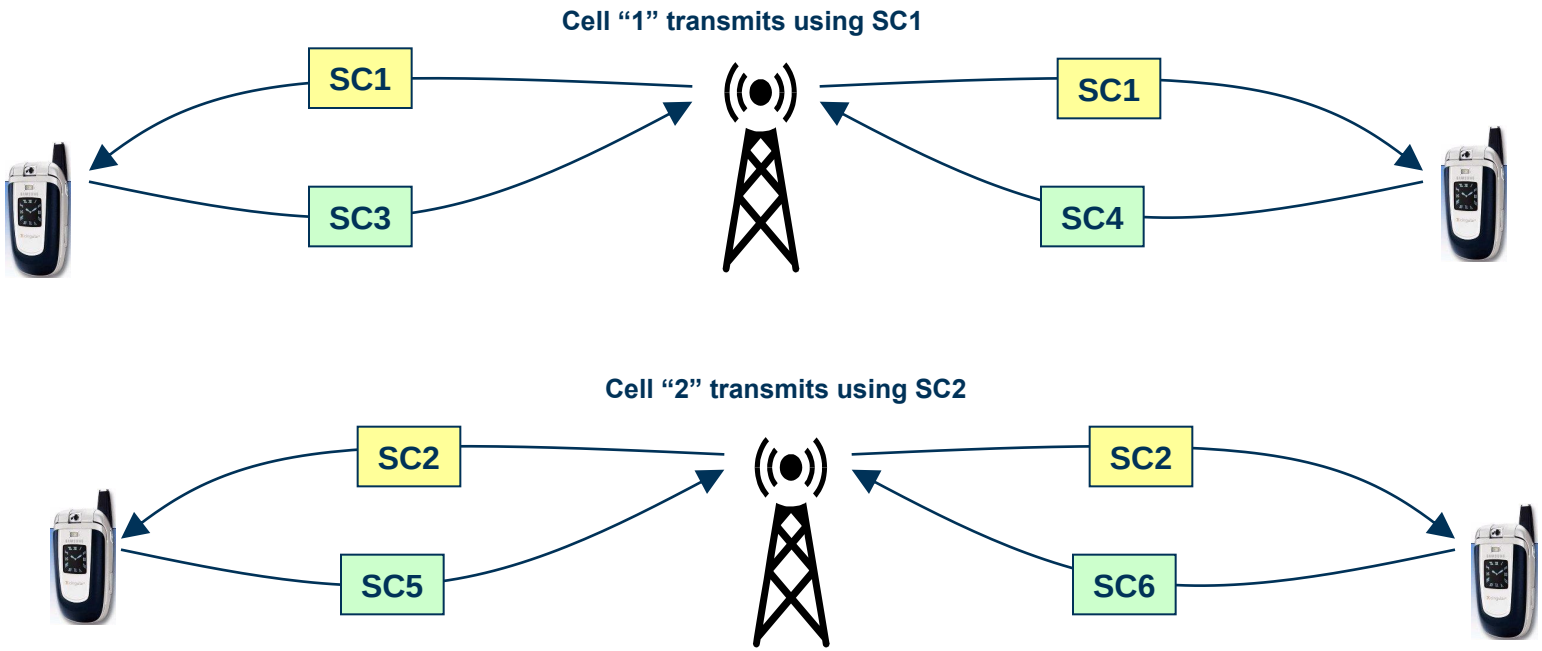


Scrambling Codes

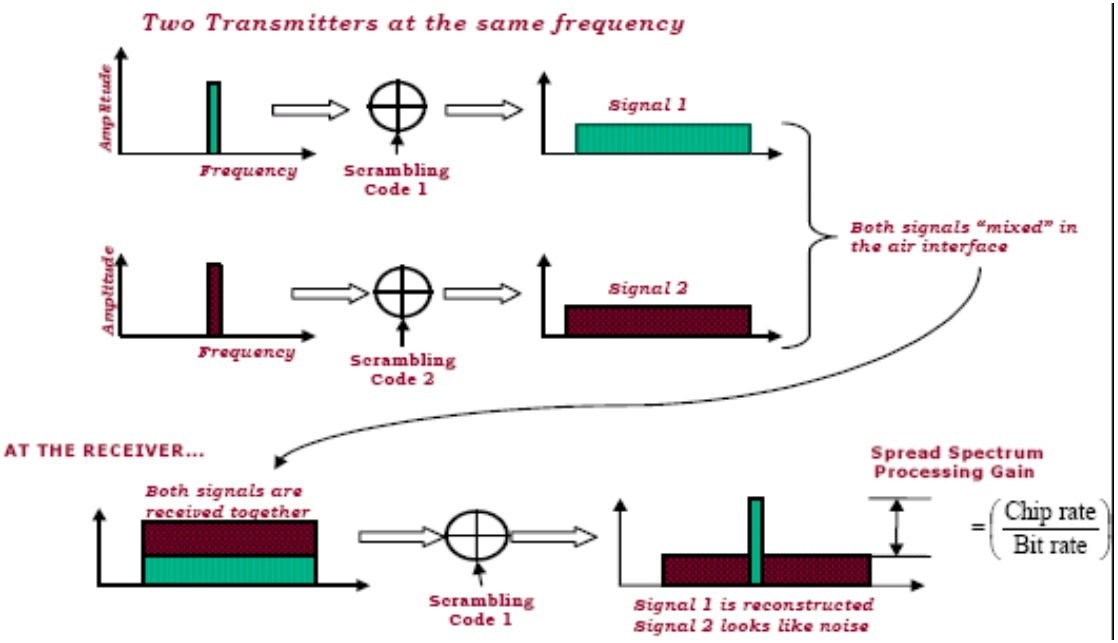
- ✓ After the Channelization Codes, the data stream is multiplied by a special code to distinguish between different transmitters.
- ✓ Scrambling codes are not orthogonal so they do not need to be synchronized
- ✓ The separation of scrambling codes is proportional to the code length – longer codes, better separation (but not 100%)
- ✓ Scrambling codes are 38400 chips long

Scrambling Codes

- ✓ In the Downlink, the Scrambling Codes are used to distinguish each cell (assigned by operator – SC planning)
- ✓ In the Uplink, the Scrambling Codes are used to distinguish each UE (assigned by network)

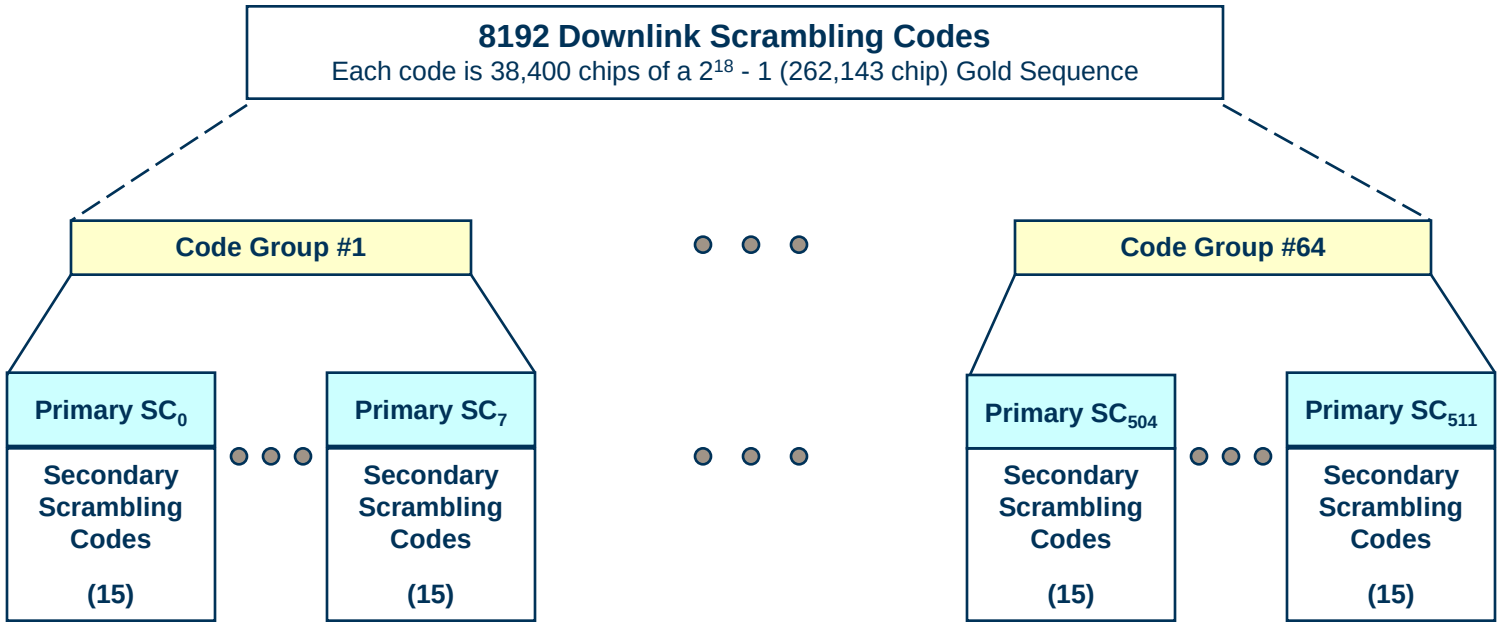


Spread Spectrum gain



Downlink Scrambling Codes

- Used to distinguish Base Station transmissions on Downlink
  - Each Cell is assigned one and only one Primary Scrambling Code (of 512)
  - Secondary Scrambling Codes may be used over part of a cell, or for other data channels



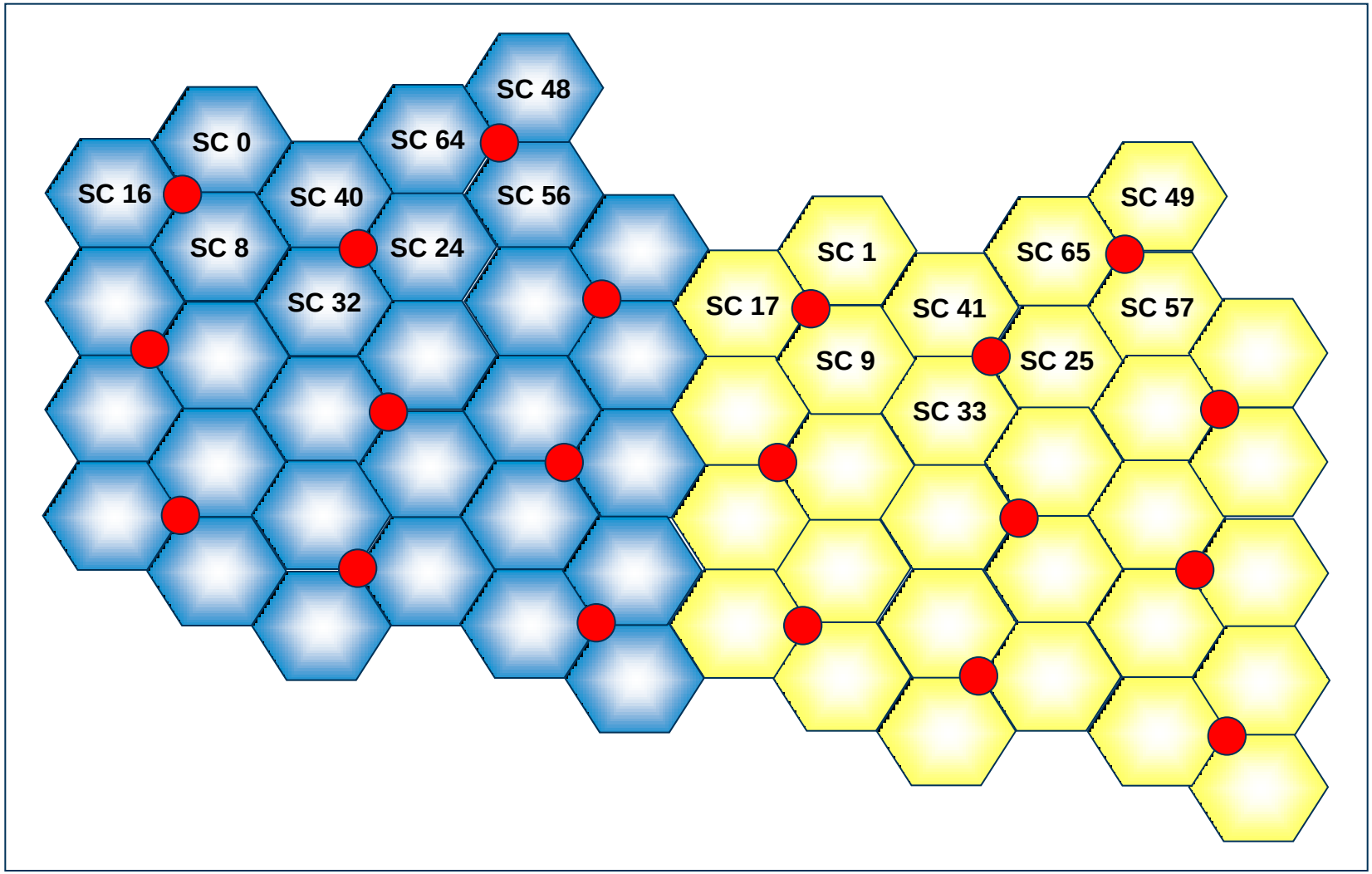
Scrambling Code planning

- SC are organized in Code Groups.
- The first SC in each Code Group differs from the first SC in the subsequent Code Group by a multiple of 8

64 Code Groups

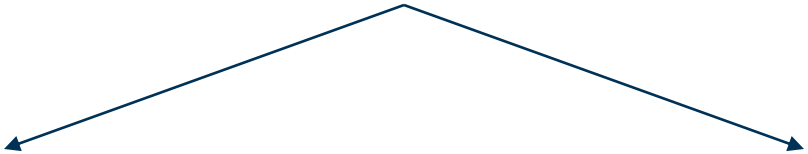
0	8	16	…	…	504
1	9	17	…	…	505
2	10	18	…	…	506
3	11	19	…	…	507
4	12	20	…	500	508
5	13	21	…	501	509
6	14	22	…	502	510
7	15	23	…	503	511

Scrambling Code planning example



Uplink Scrambling Code

Uplink Scrambling Code Type depends on the Application



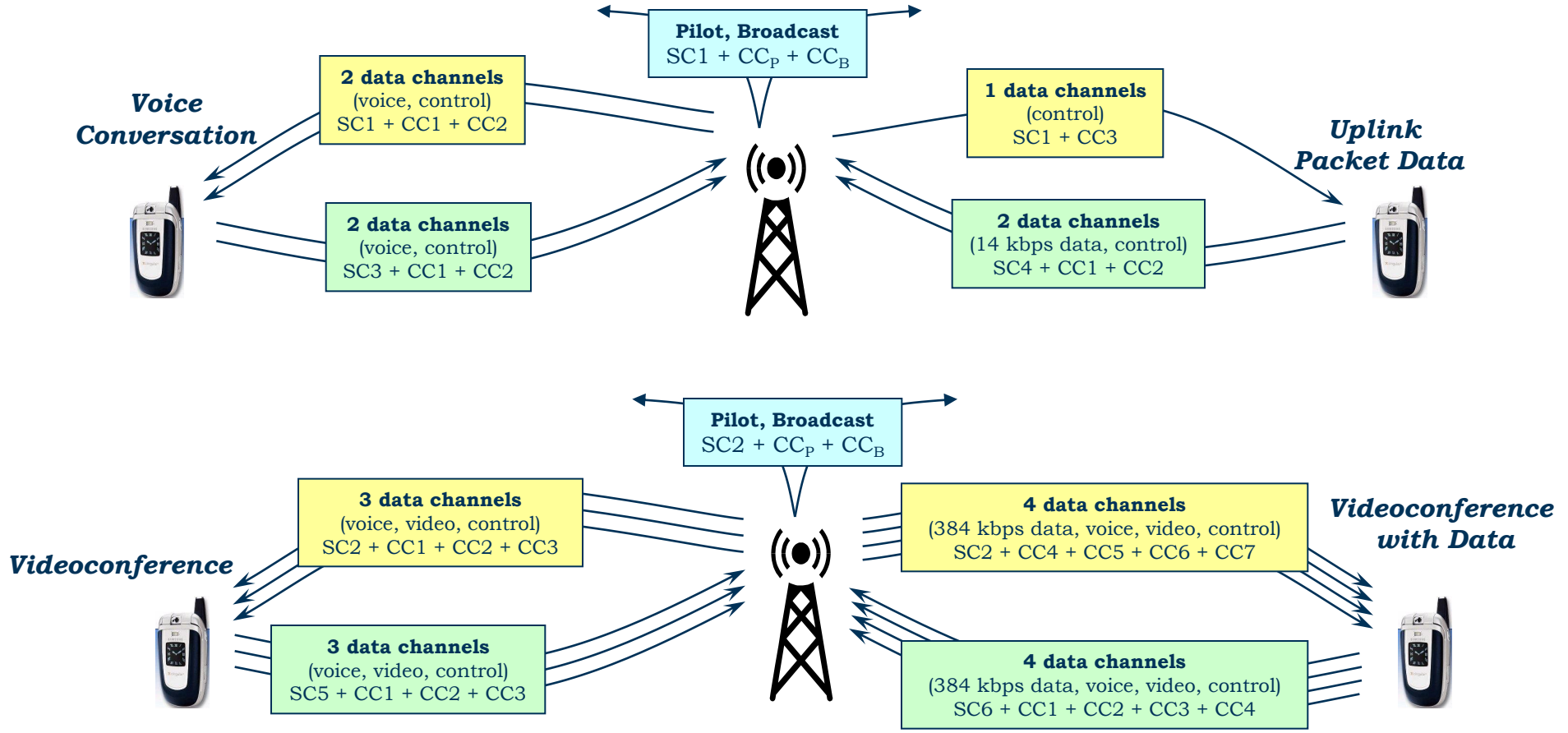
Random Access, Packet Access

- **Cell-specific** Scrambling Code(s)
- Code(s) are assigned by UTRAN
- Code(s) are conveyed to UE via the BCH or FACH
- 8,192 PRACH codes
- 32,768 PCPCH codes
- Code allocation corresponds to the cell's DL scrambling code group

Dedicated Traffic Connection

- **UE-specific** Scrambling Code(s)
- Code(s) are assigned by UTRAN
- Code(s) are conveyed to UE via the FACH
- 2^{24} possible codes

Channelization and Scrambling Codes



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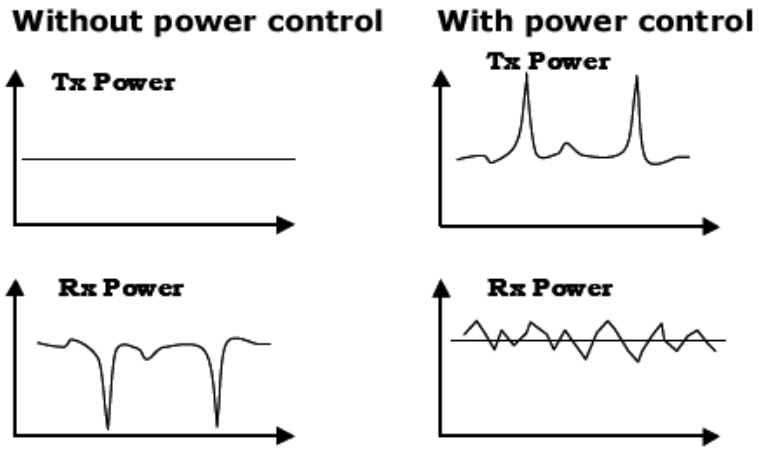
Fast link adaptation

- Radio channel conditions varying significantly due to:
  - Different location
  - Interference level (position and transmission activity)
  - Multi-path fading
  - UE speed
  - ...
- Goal: ensure sufficient received energy per information bit for all communication links
- Power control strategy (Rel.99): adjust transmitted power while keeping the data rate constant
- Rate control strategy (Rel 5): adjust the data rate while keeping the transmitted power constant

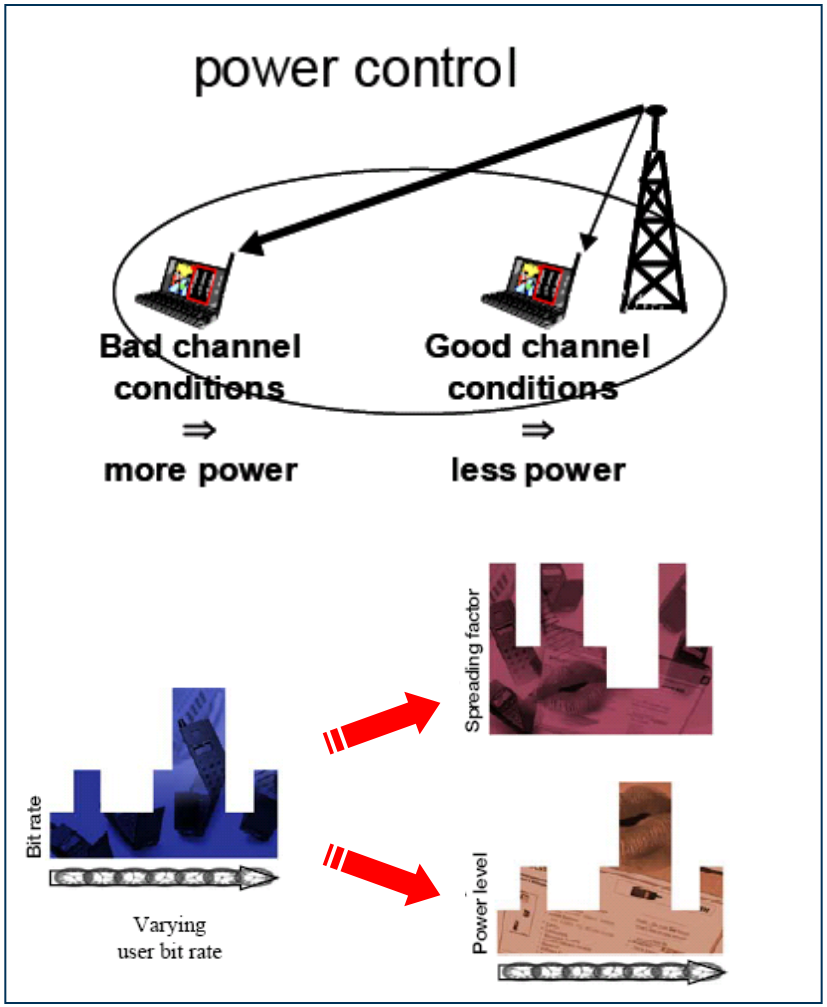
Power control

- Power control is the most important element in WCDMA because many users access and use the same frequency and bandwidth at the same time
- If no mechanism for the UEs to be power controlled to the same level at the RBS, the UE that is closer to the base station could easily overshoots another UE at the cell border and block a large part of the cell (near-far problem)
- The signals received by the RBS serving different UEs should be the same independently from their location (pathloss condition)
- Three types of power control:
  - Open loop: used for initial power setting of the UE at the beginning of the connection
  - Inner loop: used in connected mode (Rel 99) to ensure that the UE transmits just enough to be received to avoid unnecessary interference to other users. It compensates for fast fading
  - Outer loop: used in connected mode (Rel 99) to keep the quality of communication at the required level

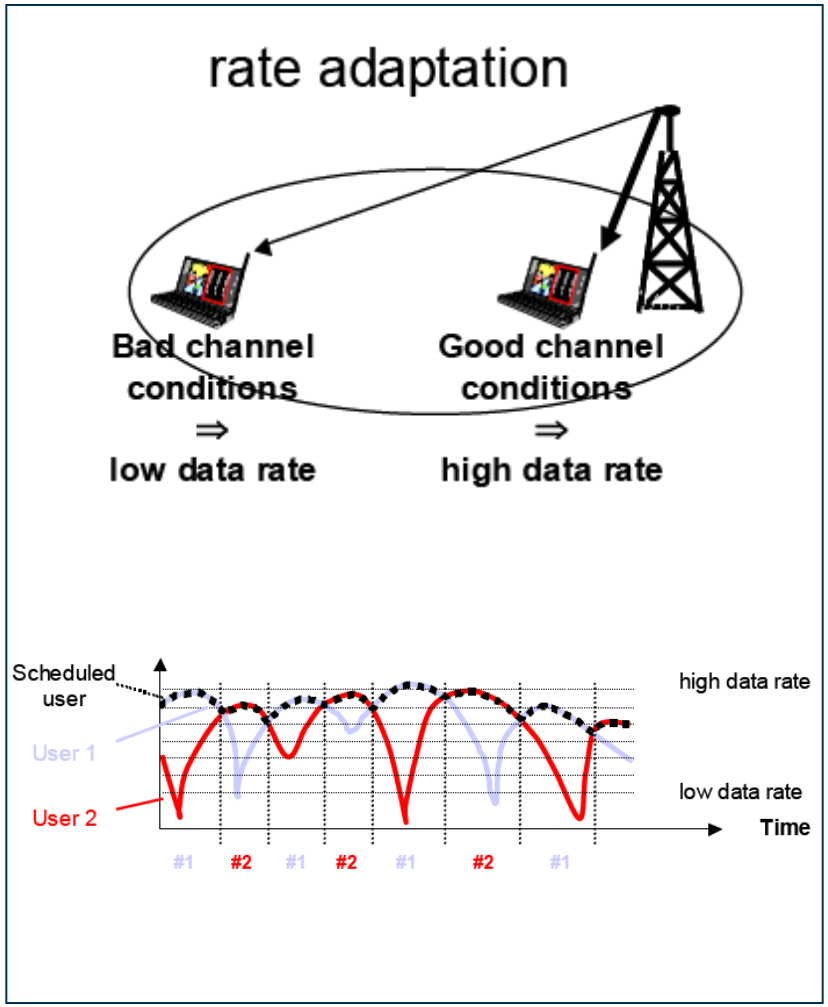


Power control vs data rate adaptation

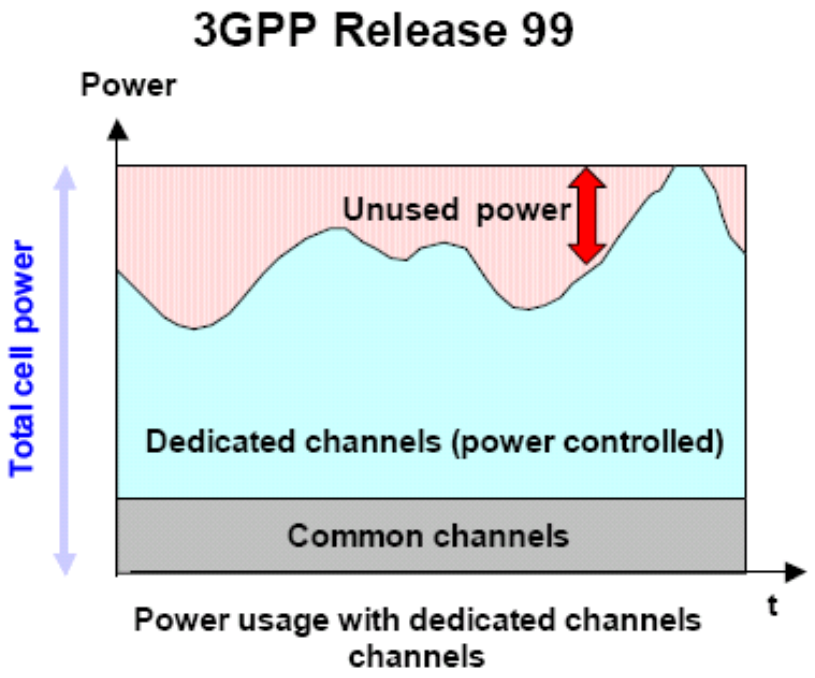
Rel ’99 traffic

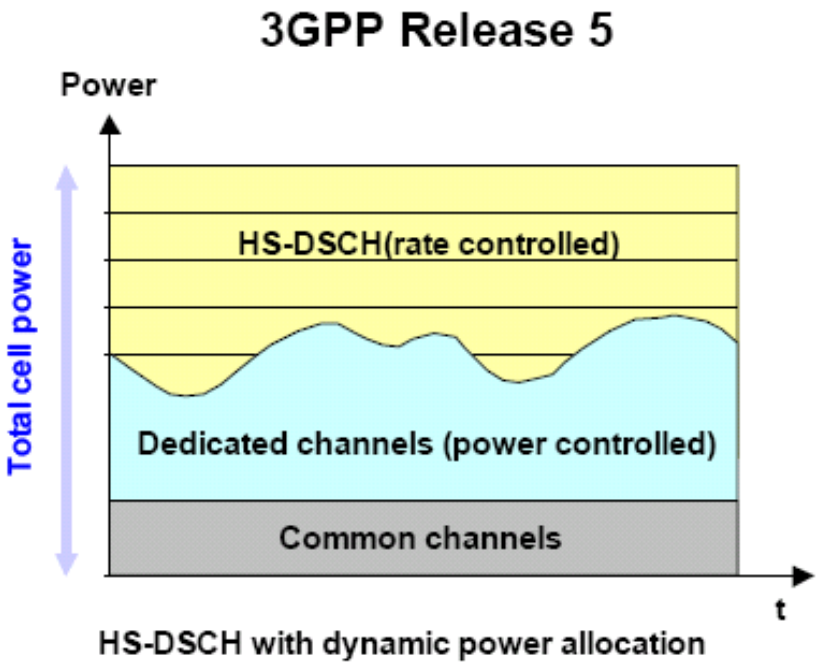


Rel 5 traffic (HSDPA)



Dynamic power allocation





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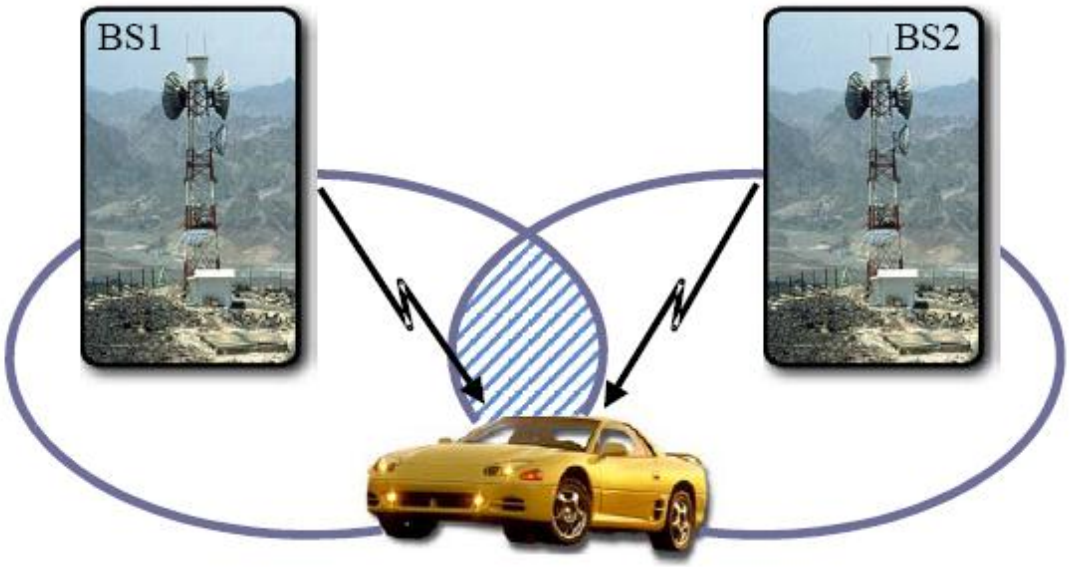
Soft Handover

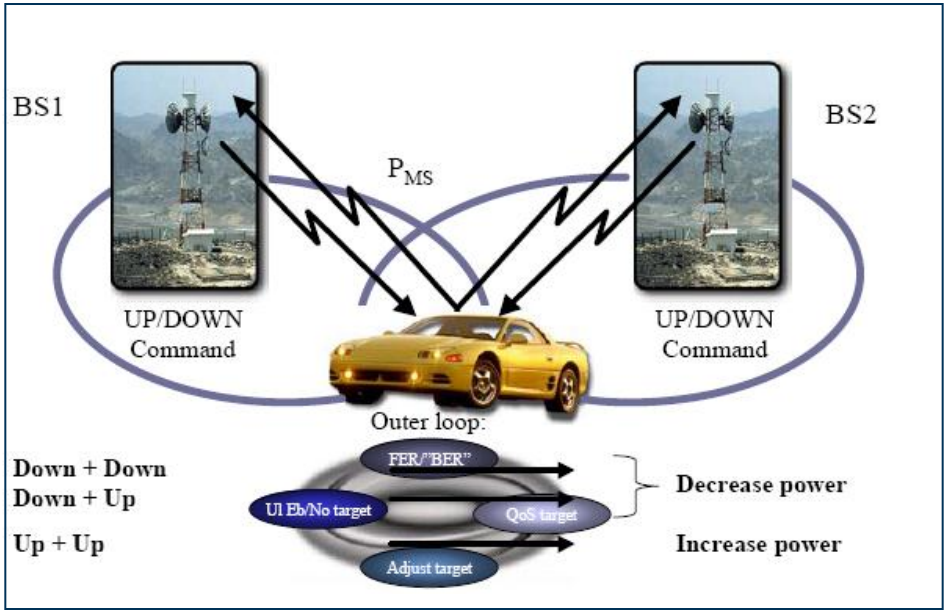
- ✓ Soft/softer handover is important for efficient power control. Without soft/softer handover there would be near-far scenarios of a UE penetrating from one cell deeply into an adjacent cell without being power controlled by the latter.
- ✓ Soft Handover: UE connected to two or more RBSs at the same time
- ✓ Softer Handover: UE connected to two or more sector of the same RBS



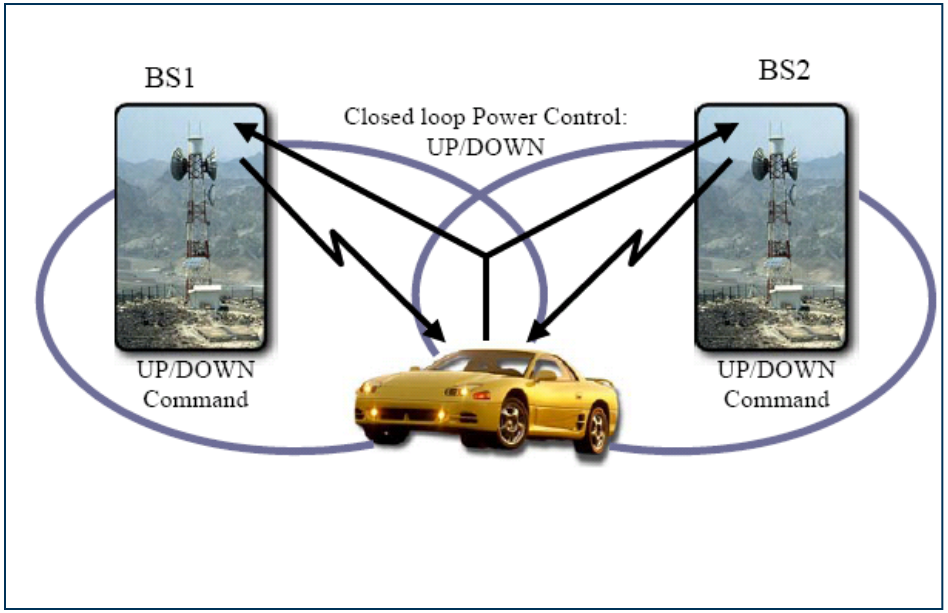
Soft Handover

- ✓ Uplink Power is based on information (TPC bits) from both RBSs to which the UE is connected. The UE will decrease its output power in all cases except when both RBSs send increase power commands.
- ✓ Downlink Power control for both RBSs is based on one signal (TPC bits) from the UE (it does not distinguish between RBSs and the decision is base on the combined output from the RAKE receiver

UL Power control

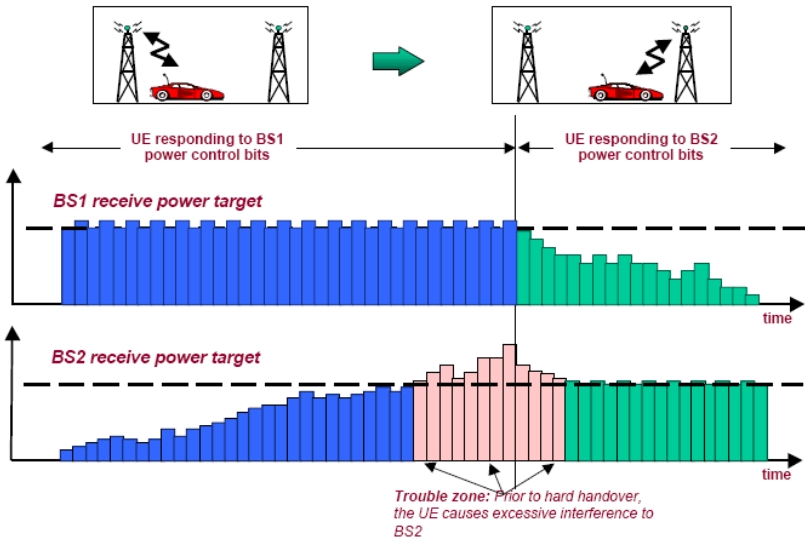


DL Power control

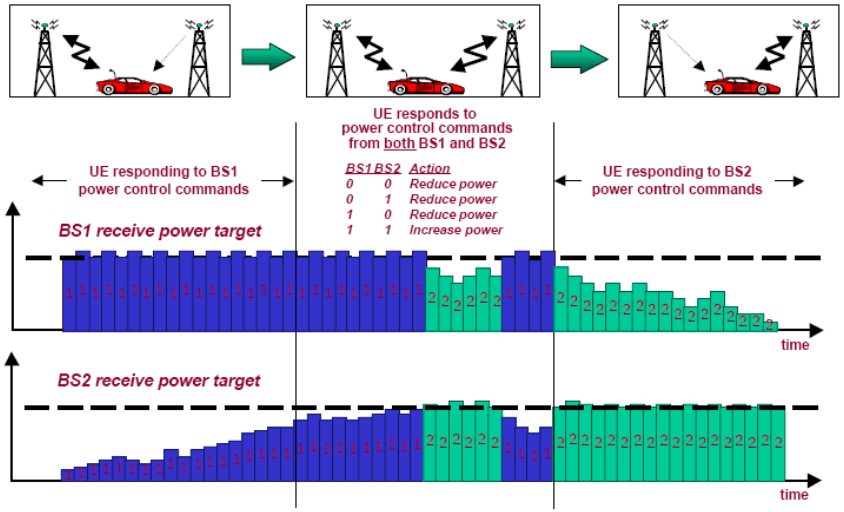


Soft Handover

Power Control without Soft Handover



Power control with Soft Handover



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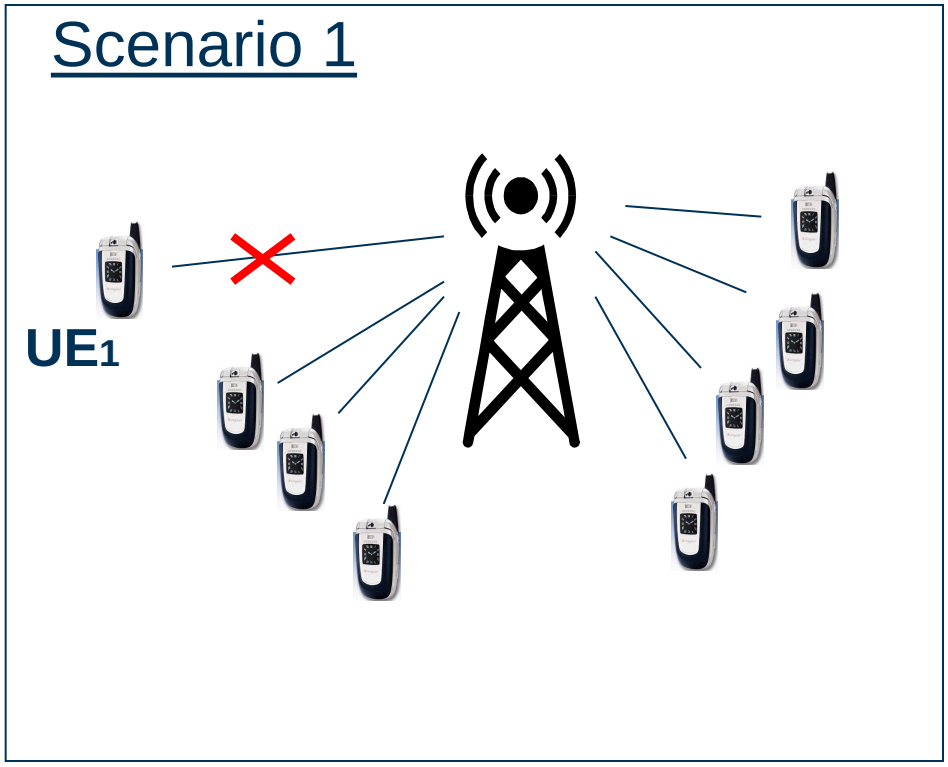
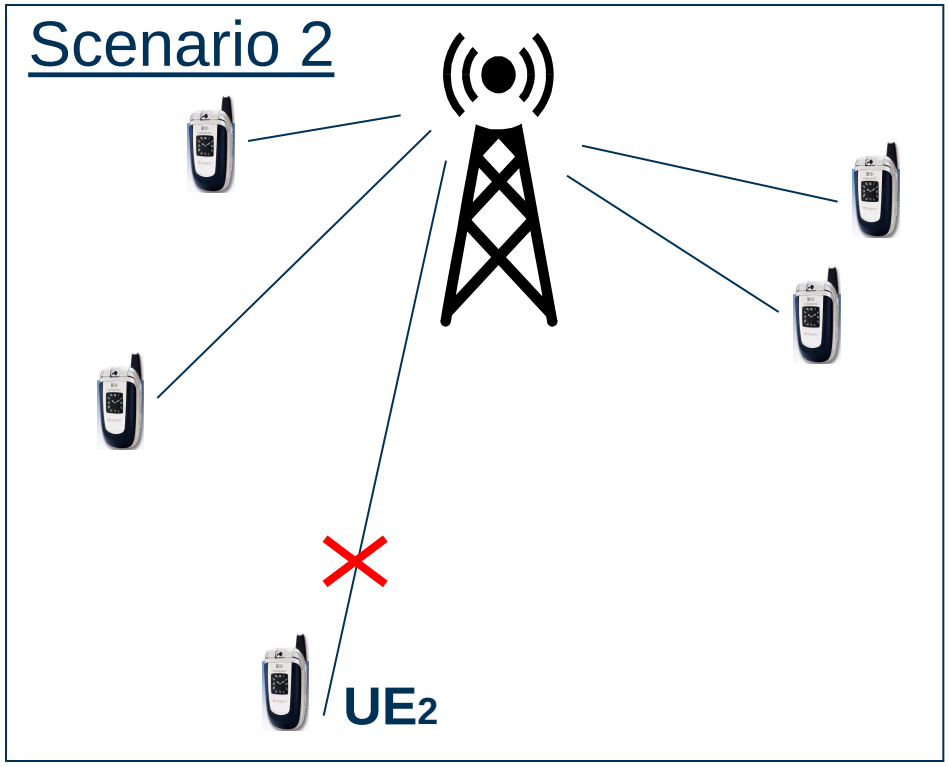
UL/DL capacity limitation

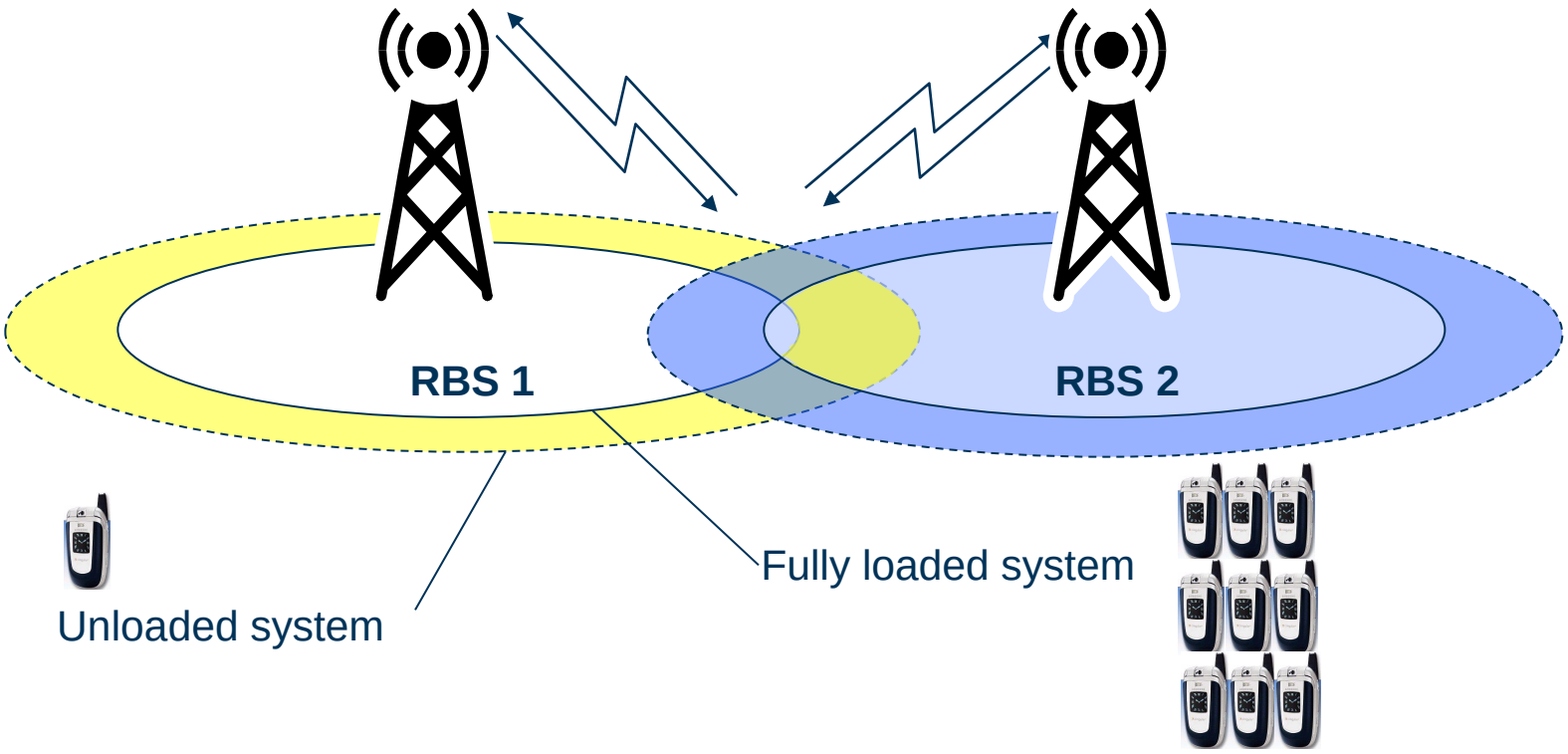
- Scenario 1: Capacity limitation due to UL interference
  - The cell can't serve UE1 because the increase in UL interference by adding the new user would be too high, resulting in a high risk of drops
- Scenario 2: Capacity limitation due to DL power
  - The cell can't serve UE2 because it's using all its available power to maintain the connections to the other UEs





Cell breathing

- ✓ The more traffic, the more interference and the shorter the distance must be between the RBS and the UE
- ✓ The traffic load changes in the system causes the cells to grow and shrink with time



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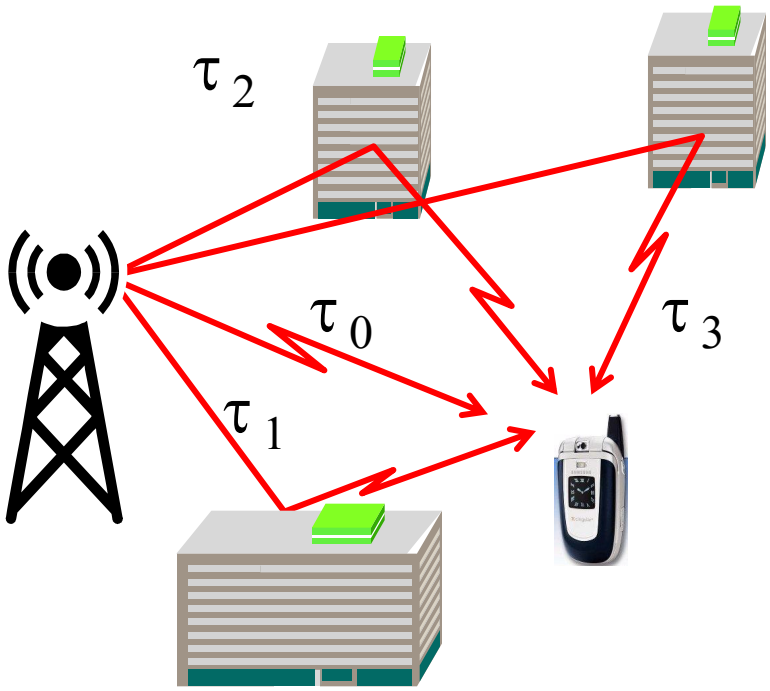
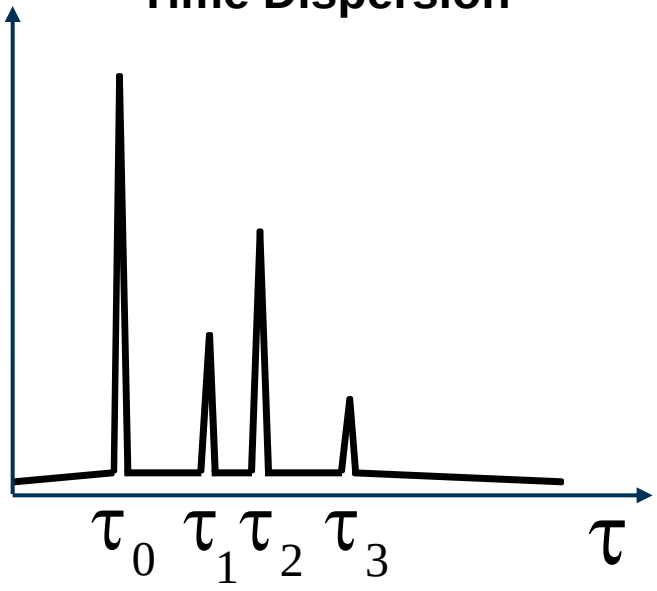
Maximum ratio combining (1/2)

- ✓ Multiple paths possibly cause destructive interference between different replica of the desired signal

Multipath Propagation

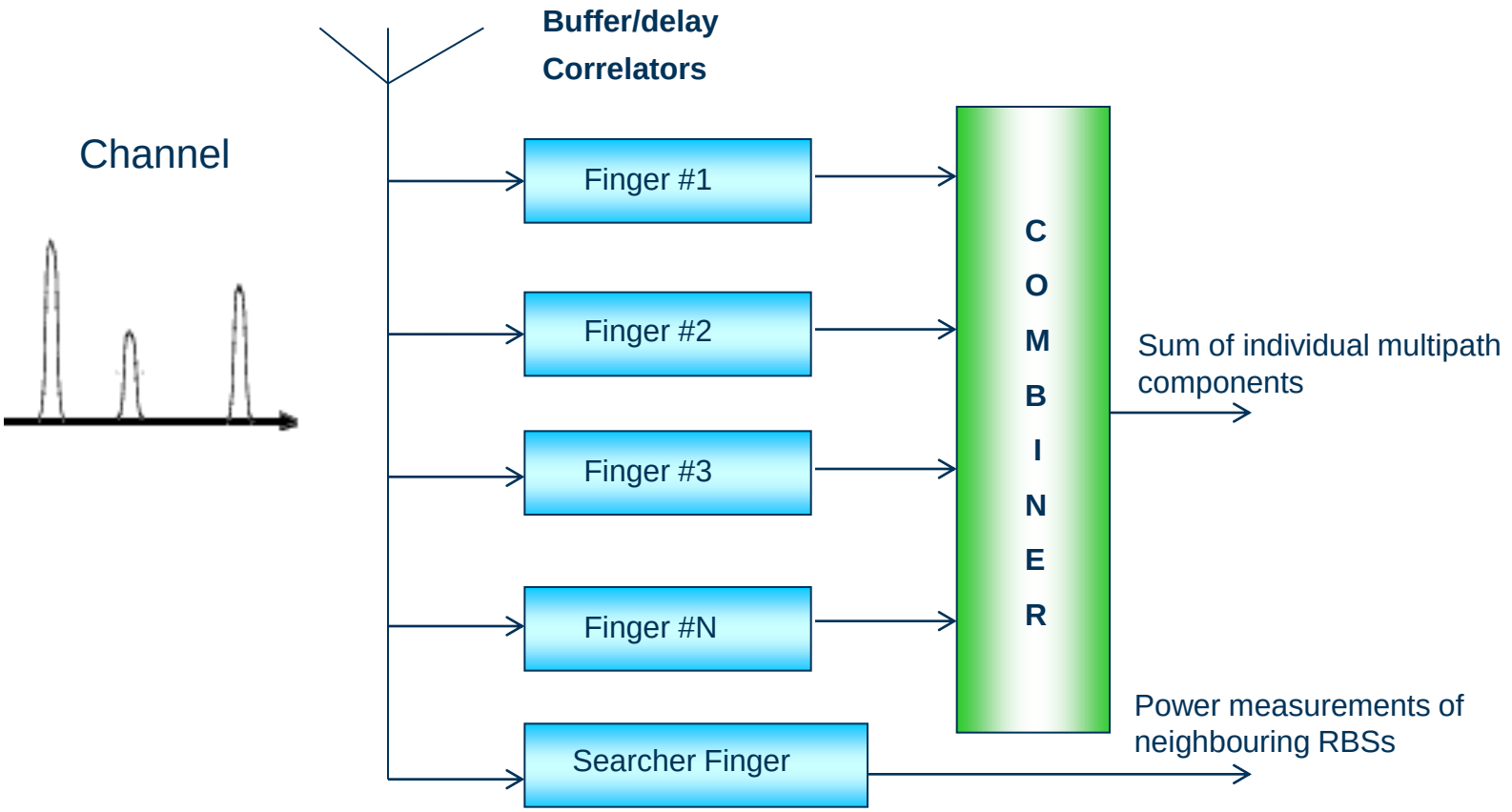


Time Dispersion



Maximum ratio combining – RAKE (2/2)

- ✓ The RAKE receiver is used to overcome the multipath fading. Each finger tracks a different multipath component and other cells during Soft Handover
- ✓ A maximum ratio combining produces the output



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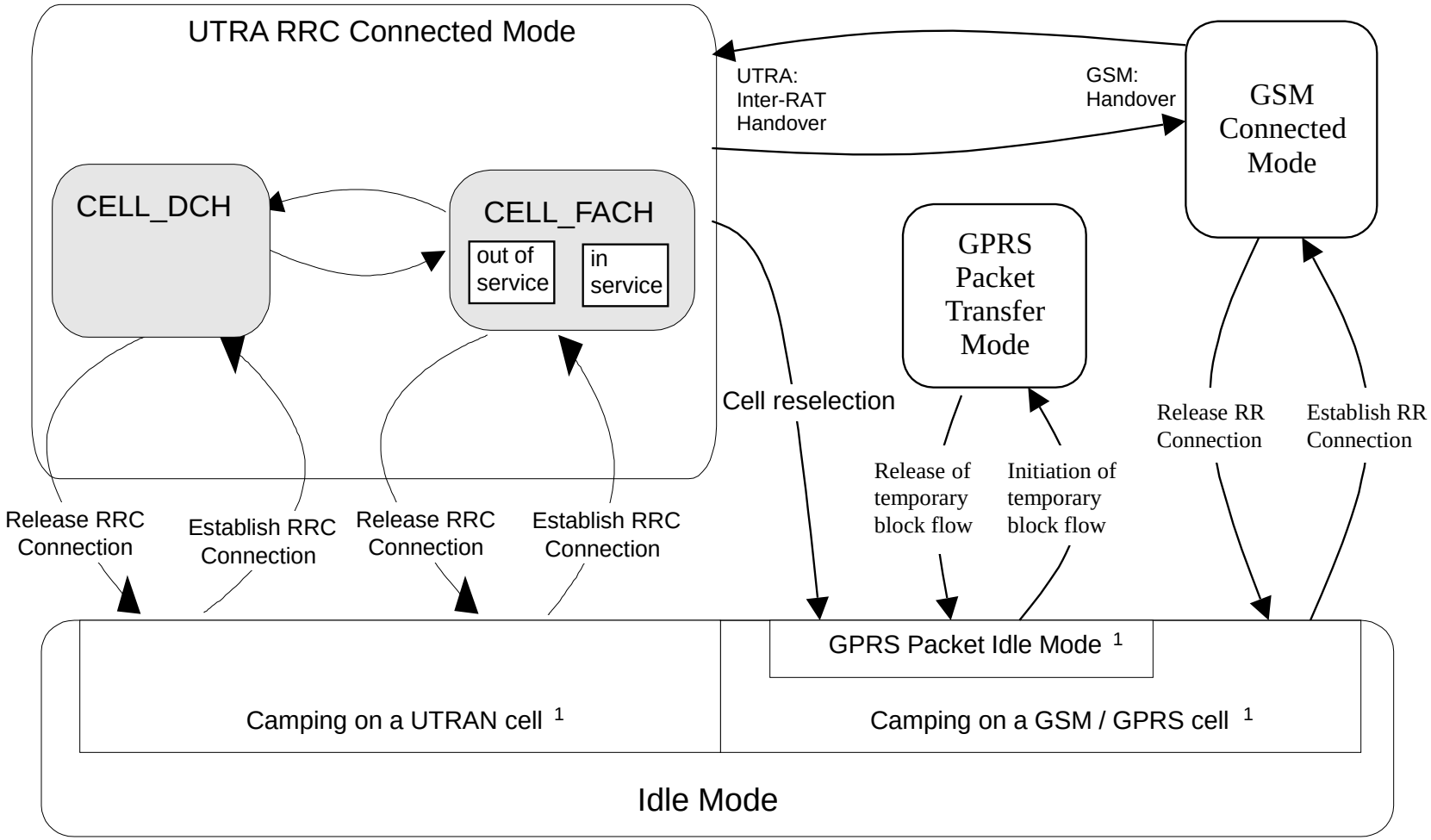
UE states


UTRA RRC Connected Mode
CELL_DCH
CELL_FACH
out of service
in service
UTRA:
Inter-RAT
Handover
GSM:
Handover
GSM
Connected
Mode
GPRS
Packet
Transfer
Mode
Cell reselection
Release RRC
Connection
Establish RRC
Connection
Release RRC
Connection
Establish RRC
Connection
Release of
temporary
block flow
Initiation of
temporary
block flow
Release RR
Connection
Establish RR
Connection
GPRS Packet Idle Mode 1
Camping on a UTRAN cell 1
Camping on a GSM / GPRS cell 1
Idle Mode

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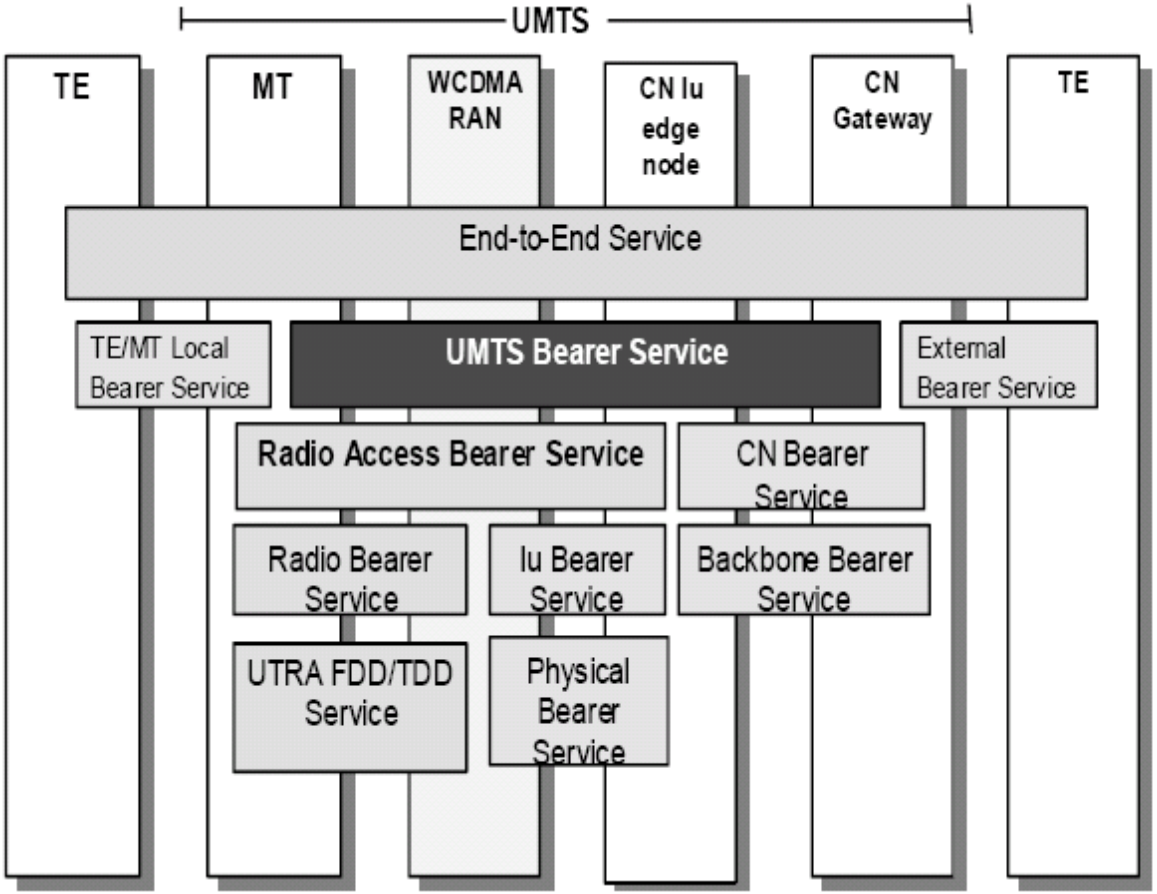
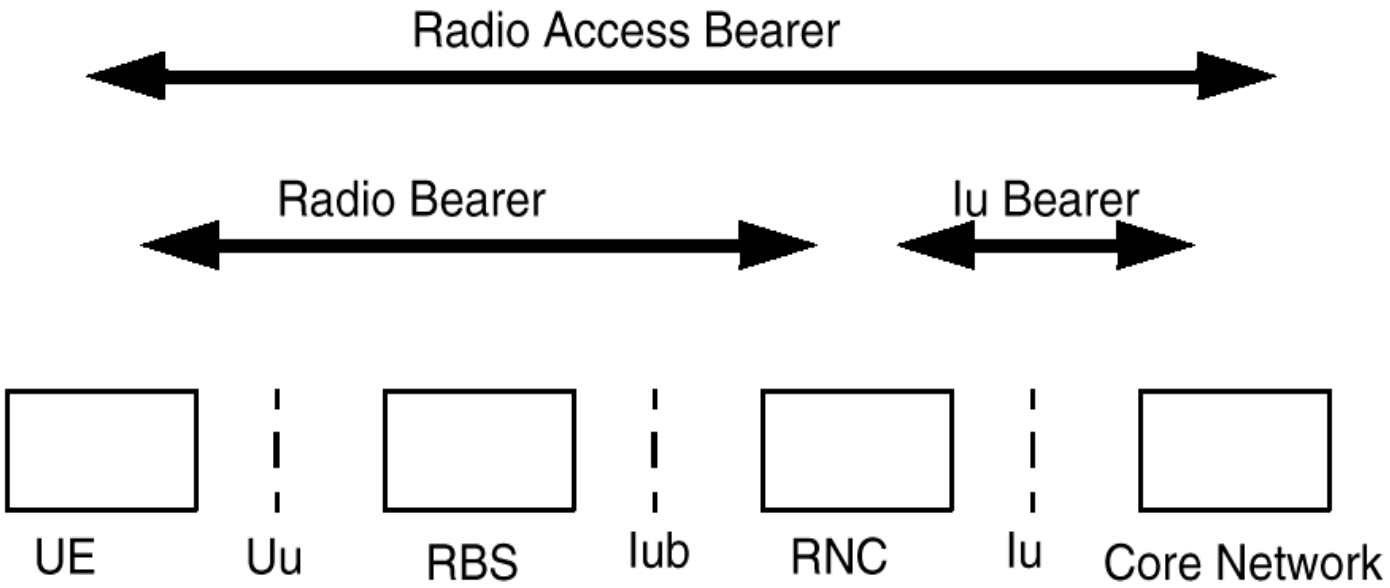
UMTS bearer service



Radio Access Bearer (RAB)

- ✓ A radio access bearer (RAB) connection via UTRAN is realised by two concatenated segments, the Iu bearer connection and the radio bearer connection



RABs

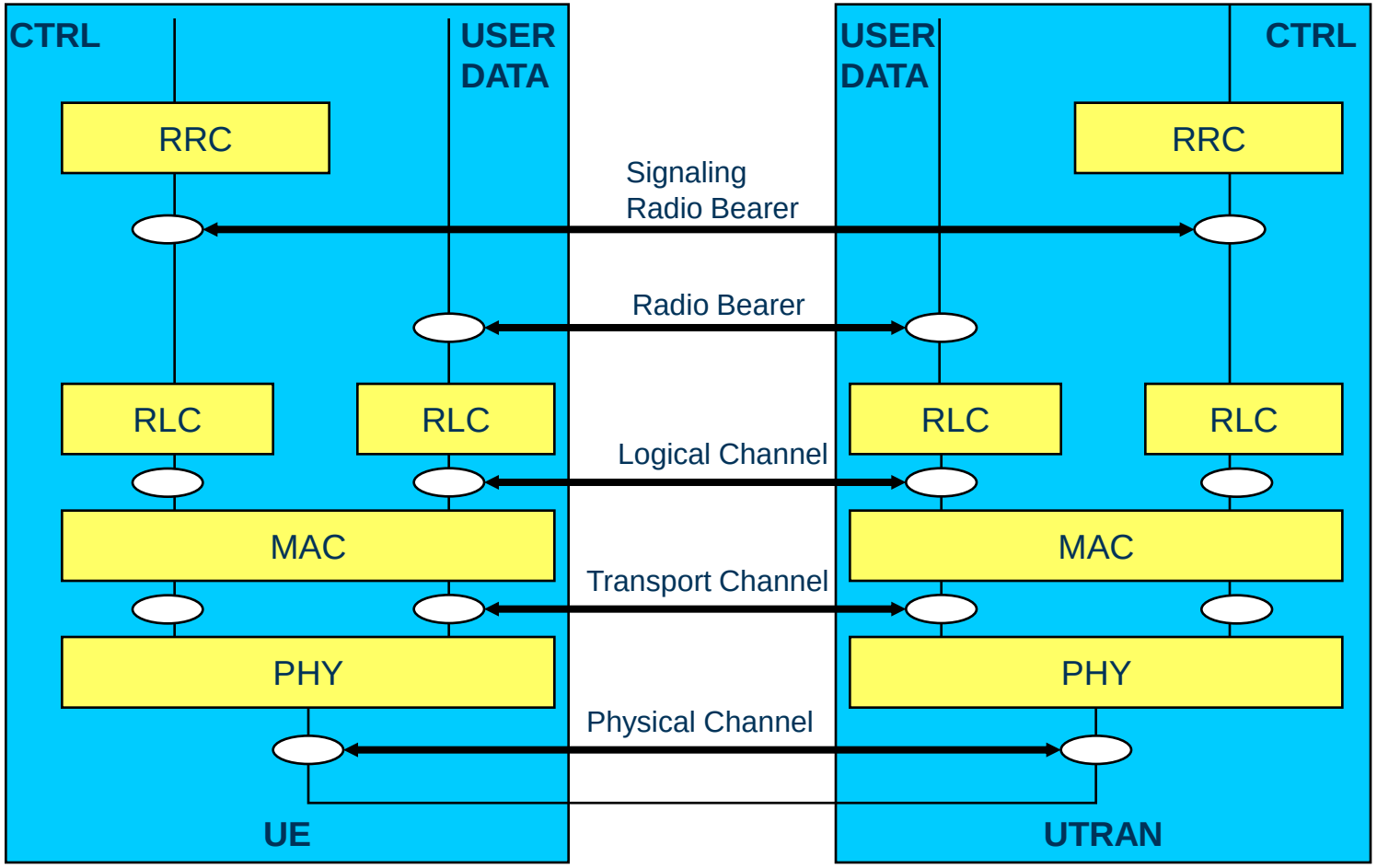
- CS
  - Speech AMR 12.2 kbps
  - Data (Video) 64 kbps
- PS I/B (UL/DL)
  - 64/64 kbps
  - 64/128 kbps
  - 64/384 kbps
  - 128/128 kbps (P5)
- HSDPA
  - 64/HSDPA interactive
  - 384/HSDPA interactive
- Multi-RAB
  - Speech AMR 12.2 kbps + 64/HSDPA (P5)
  - Speech AMR 12.2 kbps + 384/HSDPA (P5)

Agenda

- UTRAN architecture
- Multiple access techniques (DS-CDMA)
- Spreading codes (Channelisation and Scrambling)
- Fast link adaptation (Power and Rate control)
- Soft Handover
- Capacity limitation and cell breathing
- Rake receiver
- UE states
- Services (Bearers)
- **Channels in WCDMA (logical, transport, physical)**

UTRAN Model

- UTRAN OSI Model



WCDMA Downlink Rel ’99

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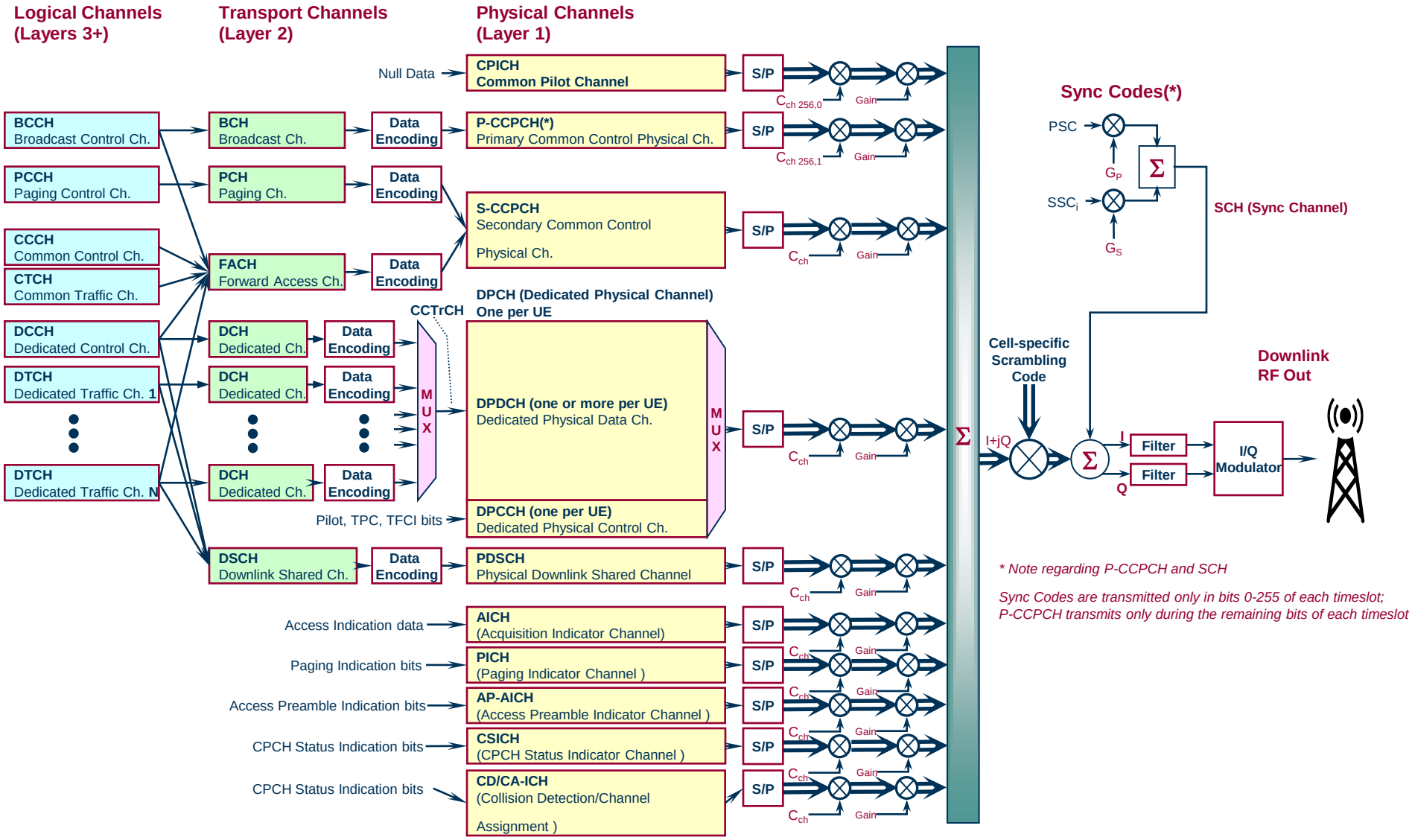
WCDMA Downlink (FDD) – Rel.'99



* Note regarding P-CCPCH and SCH

Sync Codes are transmitted only in bits 0-255 of each timeslot; P-CCPCH transmits only during the remaining bits of each timeslot

Downlink Logical Channels (L3)

- **Control Logical Channels**
  - **BCCH (Broadcast Control Channel)**
    - Broadcasts cell site and system information to all UE
  - **PCCH (Paging Control Channel)**
    - Transmits paging information to a UE when the UEs location is unknown
  - **CCCH (Common Control Channel)**
    - Transmits control information to a UE when there is no RRC Connection
  - **DCCH (Dedicated Control Channel)**
    - Transmits control information to a UE when there is a RRC Connection
- **Traffic Logical Channels**
  - **CTCH (Common Traffic Channel)**
    - Traffic channel for sending traffic to a group of UEs.
  - **DTCH (Dedicated Traffic Channel)**
    - Traffic channel dedicated to one UE

Downlink Transport Channels (L2)

- **Common Transport Channels**
  - **BCH (Broadcast Channel)**
    - Continuous transmission of system and cell information
  - **PCH (Paging Channel)**
    - Carries control information to UE when location is unknown
    - Pending activity indicated by the PICH (paging indication channel)
  - **FACH (Forward Access Channel)**
    - Used for transmission of idle-mode control information to a UE
    - Also used for some user data
- **Dedicated Transport Channels**
  - **DCH (Dedicated Channel)**
    - Carries dedicated traffic and control data to one UE
    - Used for BLER measurements

Downlink Physical Channels (L1)

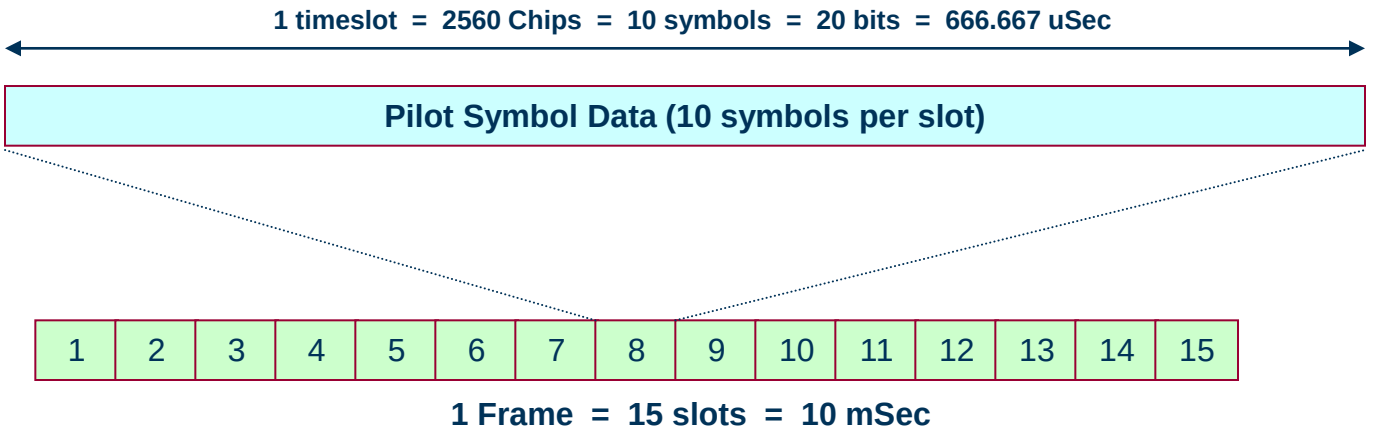
- **Common Physical Channels**
  - **P-CCPCH Common Control Physical Channel (Primary)**
    - Broadcasts cell site information
    - Timing reference for all DL
  - **SCH Synchronization Channel**
    - Fast Synch. codes 1 and 2; time-multiplexed with P-CCPCH
  - **S-CCPCH Common Control Physical Channel (Secondary)**
    - Transmits idle-mode signaling and control information to UEs
  - **CPICH Common Pilot Channel**
- **Dedicated Physical Channels**
  - **DPDCH Dedicated Downlink Physical Data Channel**
  - **DPCCH Dedicated Downlink Physical Control Channel**
    - Transmits connection-mode signaling and control to UEs

Downlink Physical Channels…

- Indicator Physical Channels
  - **AICH (Acquisition Indicator Channel)**
    - Acknowledges that BS has acquired a UE Random Access attempt
    - (Echoes the UEs Random Access signature)
  - **PICH (Page Indicator Channel)**
    - Informs a UE to monitor the next paging frame

Common Pilot Channel

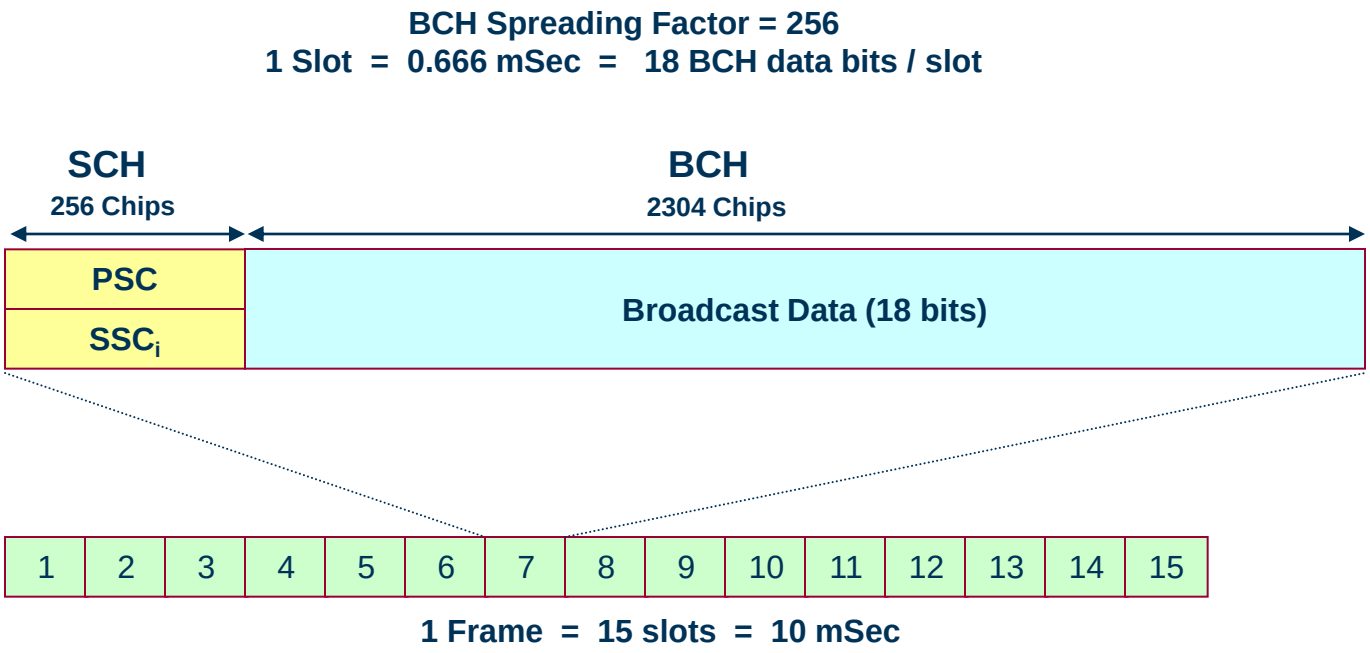
- Downlink CPICH (Common Pilot Channel) ($C_{256,0}$)



- Sends the scrambling code of the cell
- Used for channel estimation

Sync Channel / Primary Common Control Channel

- Downlink SCH / P-CCPCH ($C_{256,1}$)

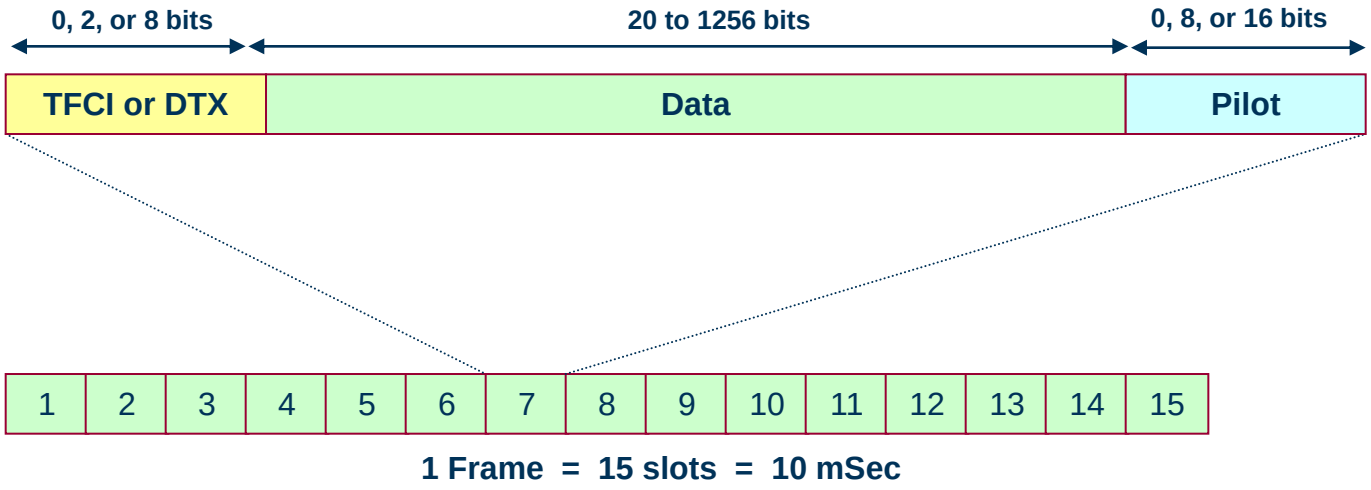


- PSC used for slot synchronization, SSC used for frame synchronization and scrambling code group (16 SSCs in 64 different combinations)

Secondary Common Control Channel

- Downlink S-CCPCH

Spreading Factor = 256 to 4
1 Slot = 0.666 mSec = 2560 chips = 20 * 2^k data bits; k = [0..6]



1 Frame = 15 slots = 10 mSec

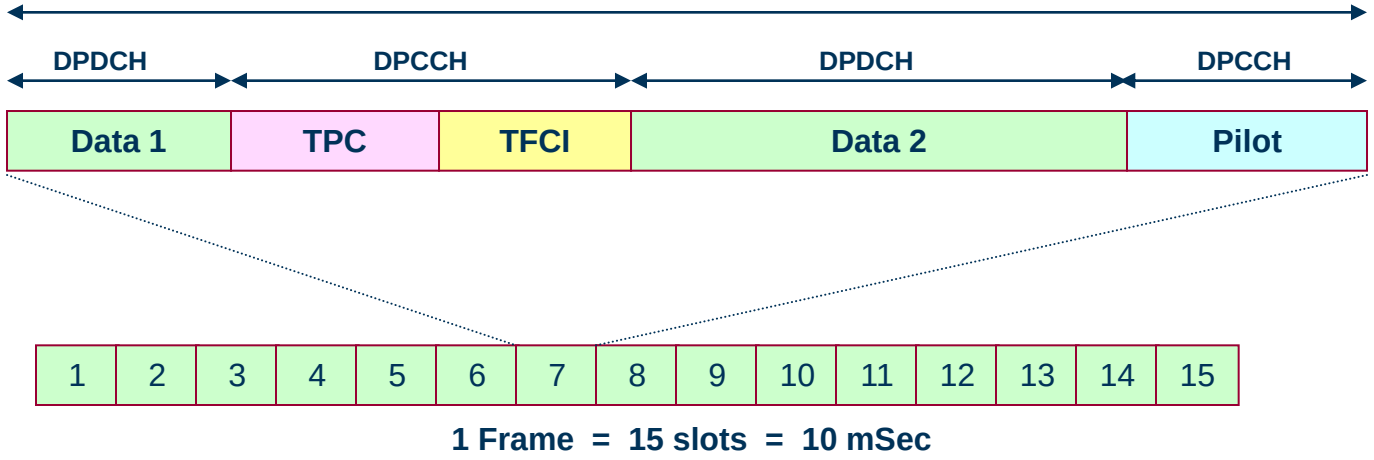
- Monitored by UE in idle mode, but also used in Cell FACH

Dedicated Control/Data Channel

- Downlink DPCCH/DPDCH Frame

1 Slot = 0.666 mSec = 2560 chips = 10 x 2^k bits, k = [0...7]

SF = $512/2^k$ = [512, 256, 128, 64, 32, 16, 8, 4]



1 Frame = 15 slots = 10 mSec

The DPDCH carries user traffic, layer 2 overhead bits, and layer 3 signaling data.

The DPCCH carries layer 1 control bits: Pilot (for SIR measurements), TPC (transmit power control to increase/decrease transmit power, and TFCI

Downlink Inner-Loop Power Control steps of 1 dB, 0.5 dB

WCDMA Uplink Rel ’99

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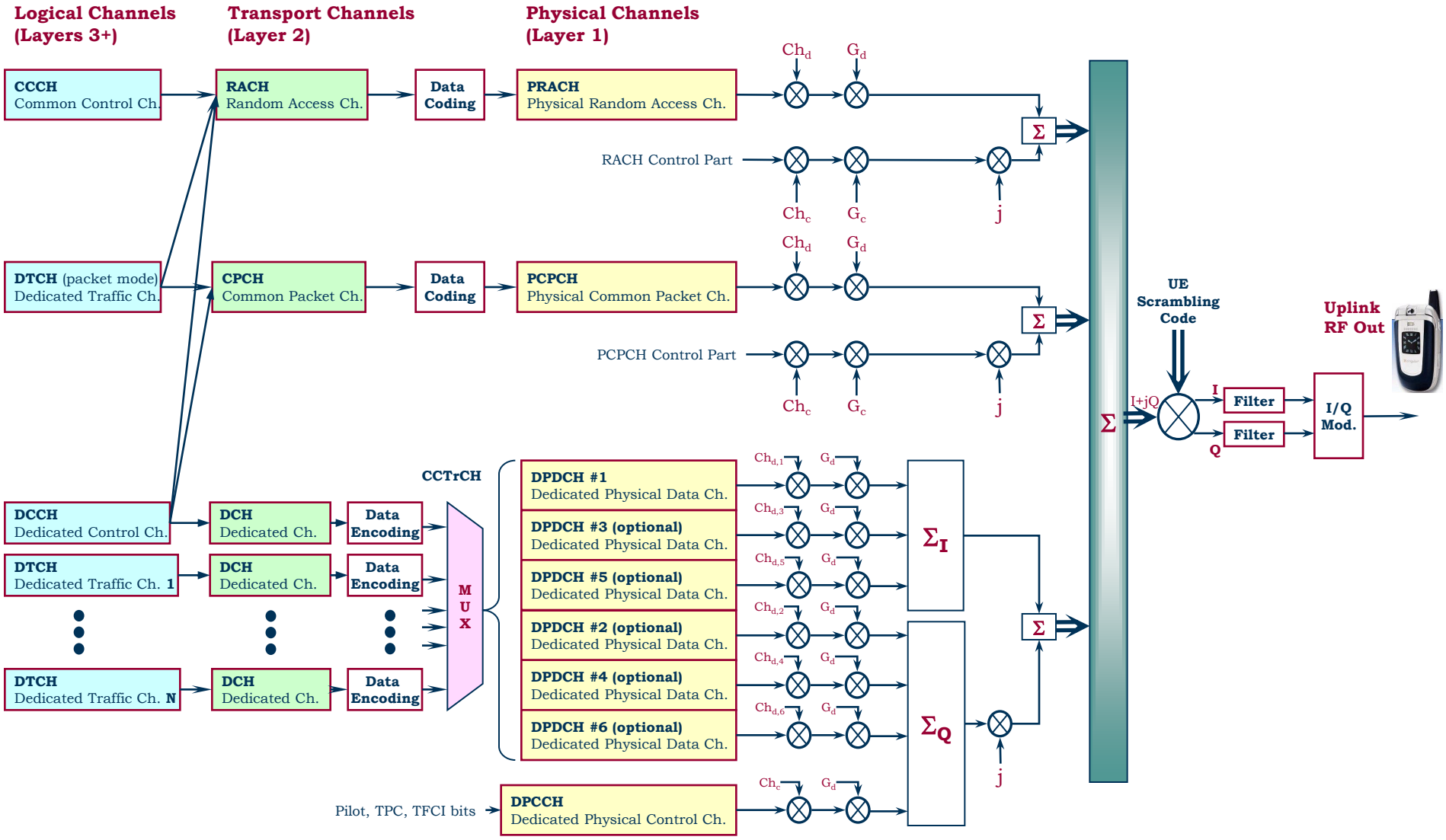
WCDMA Uplink (FDD) – Rel '99



Uplink Logical Channels (L3)

- **Control Logical Channels**
  - **CCCH (Common Control Channel)**
    - Transmits control information to a UE when there is no RRC Connection
  - **DCCH (Dedicated Control Channel)**
    - Transmits control information from a UE when there is a RRC Connection
- **Traffic Logical Channels**
  - **CTCH (Common Traffic Channel)**
    - Traffic channel for sending traffic to a group of UEs
  - **DTCH (Dedicated Traffic Channel)**
    - Traffic channel dedicated from one UE

Uplink Transport Channels (L2)

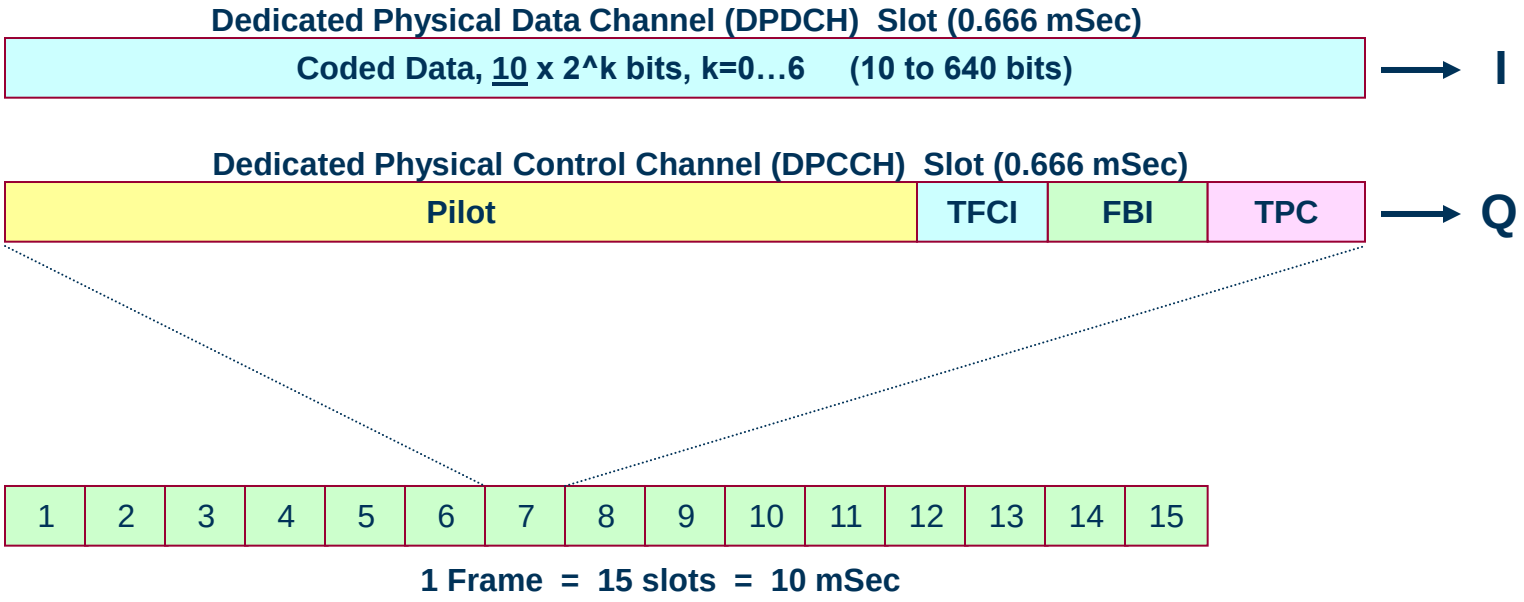
- **Common Transport Channels**
  - **RACH - Random Access Channel**
    - Carries access requests, control information, short data
      - Uses only open-loop power control
      - Subject to random access collisions
- **Dedicated Transport Channels**
  - **DCH - Dedicated Channel**
    - Carries dedicated traffic and control data from one UE
    - Used for BLER measurements

Uplink Physical Channels (L1)

- **Common Physical Channels**
  - **PRACH** **Physical Random Access Channel**
    - Used by UE to initiate access to BS
- **Dedicated Physical Channels**
  - **DPDCH** **Dedicated Uplink Physical Data Channel**
  - **DPCCH** **Dedicated Uplink Physical Control Channel**
    - Transmits connection-mode signaling and control to BS

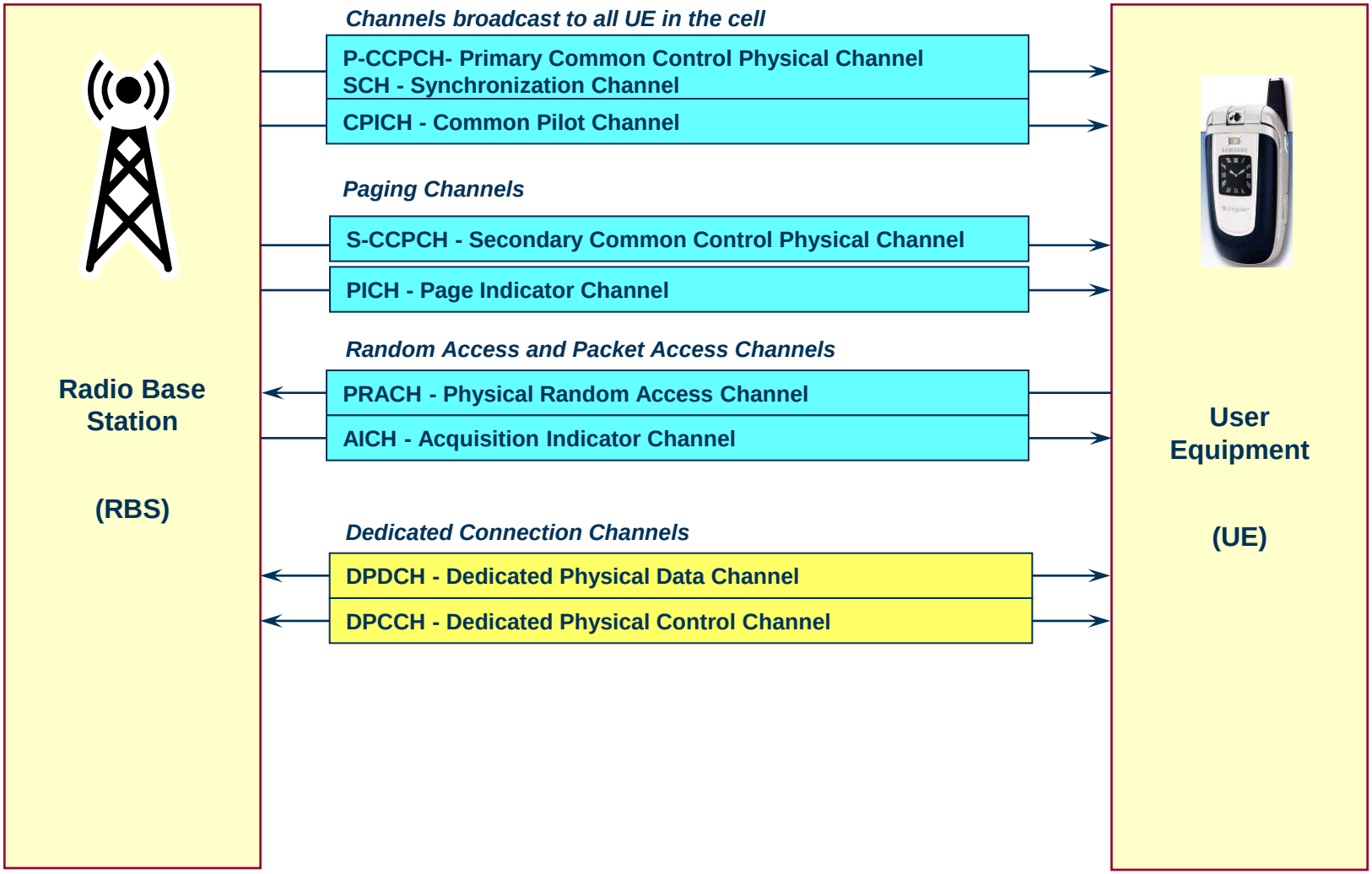
Uplink DPDCH/DPCCH

- Uplink DPDCH/DPCCH



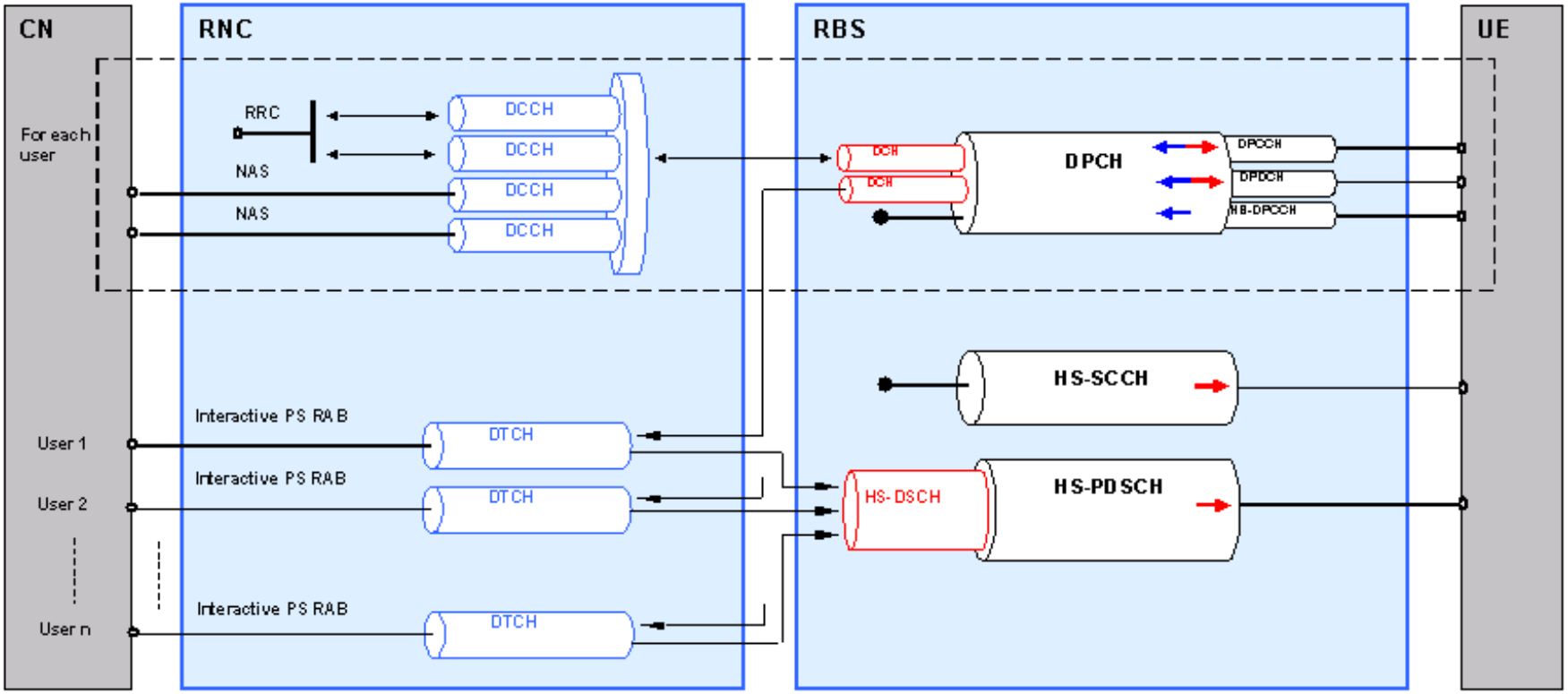
DPCCH: 15 kb/sec data rate, 10 total bits per DPCCH slot	
PILOT:	Fixed patterns (3, 4, 5, 6, 7, or 8 bits per DPCCH slot)
TFCI:	Transmit Format Combination Indicator (0, 2, 3, or 4 bits)
FBI:	Feedback Information (0, 1, or 2 bits)
TPC:	Transmit Power Control bits (1 or 2 bits); power adjustment in steps of 1, 2, or 3 dB

WCDMA Physical Channels



HSDPA channels

HSDPA channels



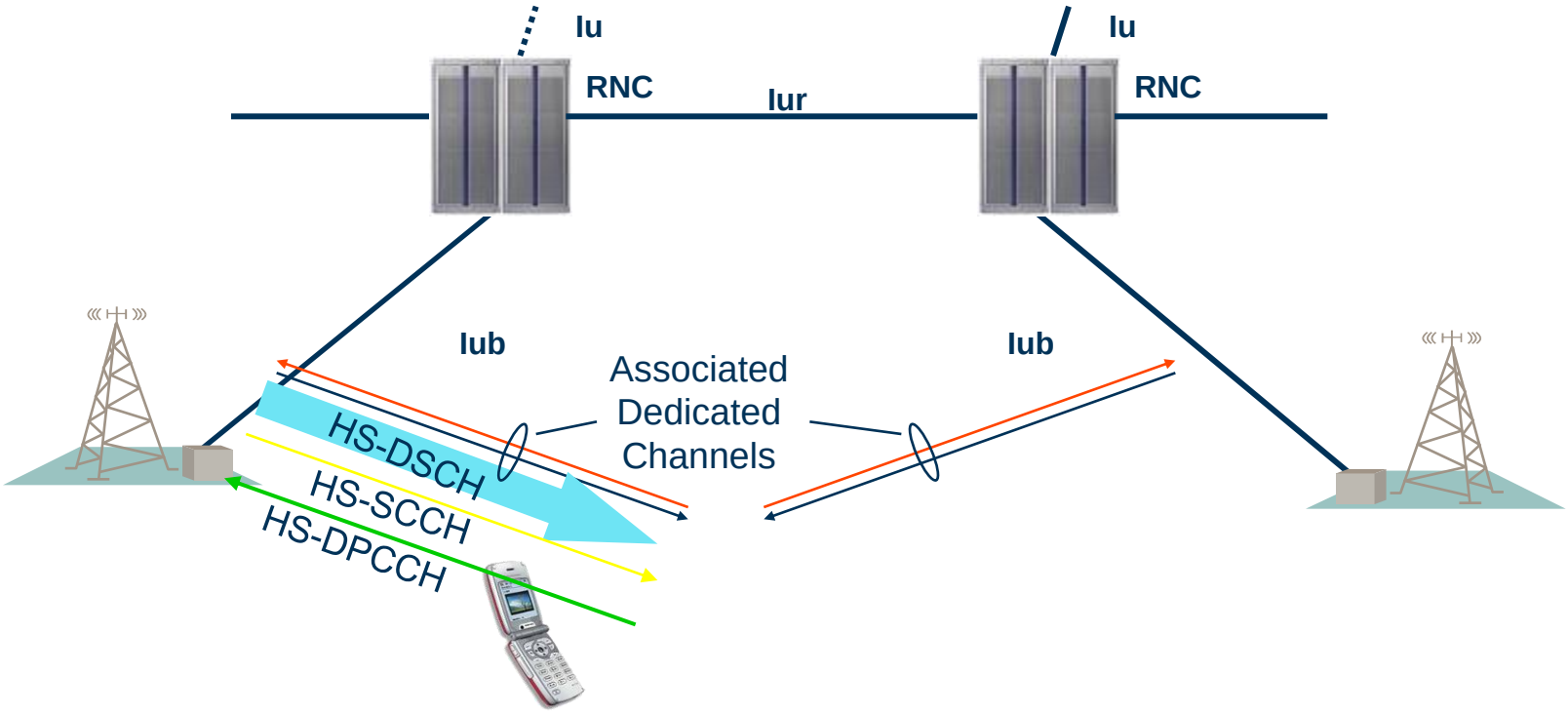
Radio Access Bearers:
- Interactive
- Background

Logical Channels:
- Dedicated Control Channel, DCCH
- Dedicated Traffic Channel, DTCH

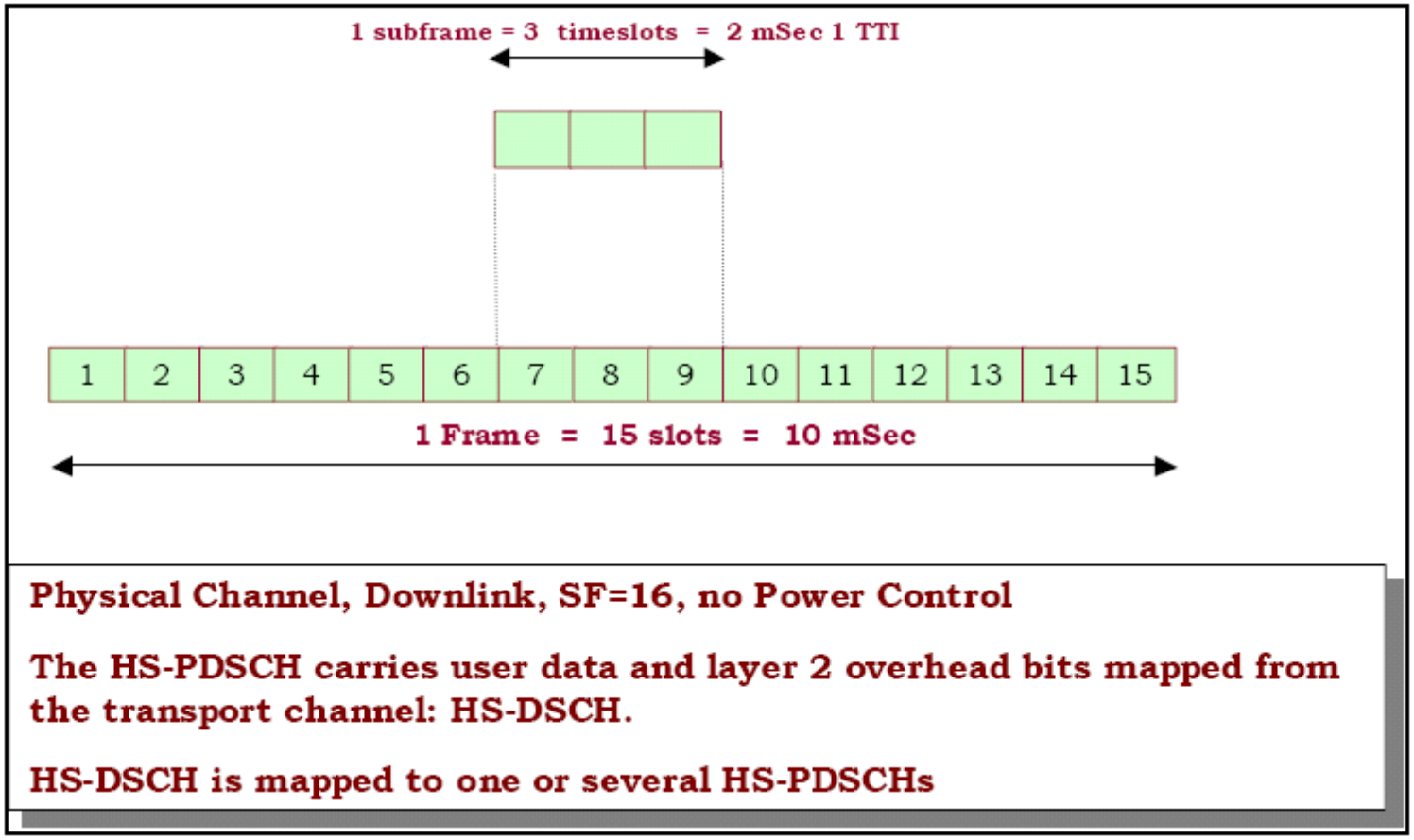
Transport Channels:
- Dedicated Channel, DCH
- High-Speed Downlink Shared Channel, HS-DSCH

Physical Channels:
- Dedicated Physical Channel, DPCH
  - DPCCH, Dedicated Physical Control Channel
  - DPDCH, Dedicated Physical Data Channel
  - HS-DCCCH, HS-DSCH Dedicated Physical Control Channel
- HS-DSCH Shared Control Channel, HS-SCCH
- High-Speed Physical Downlink Shared Channel, HS-PDSCH

HSDPA Channels



HS-PDSCH (Physical, user data)

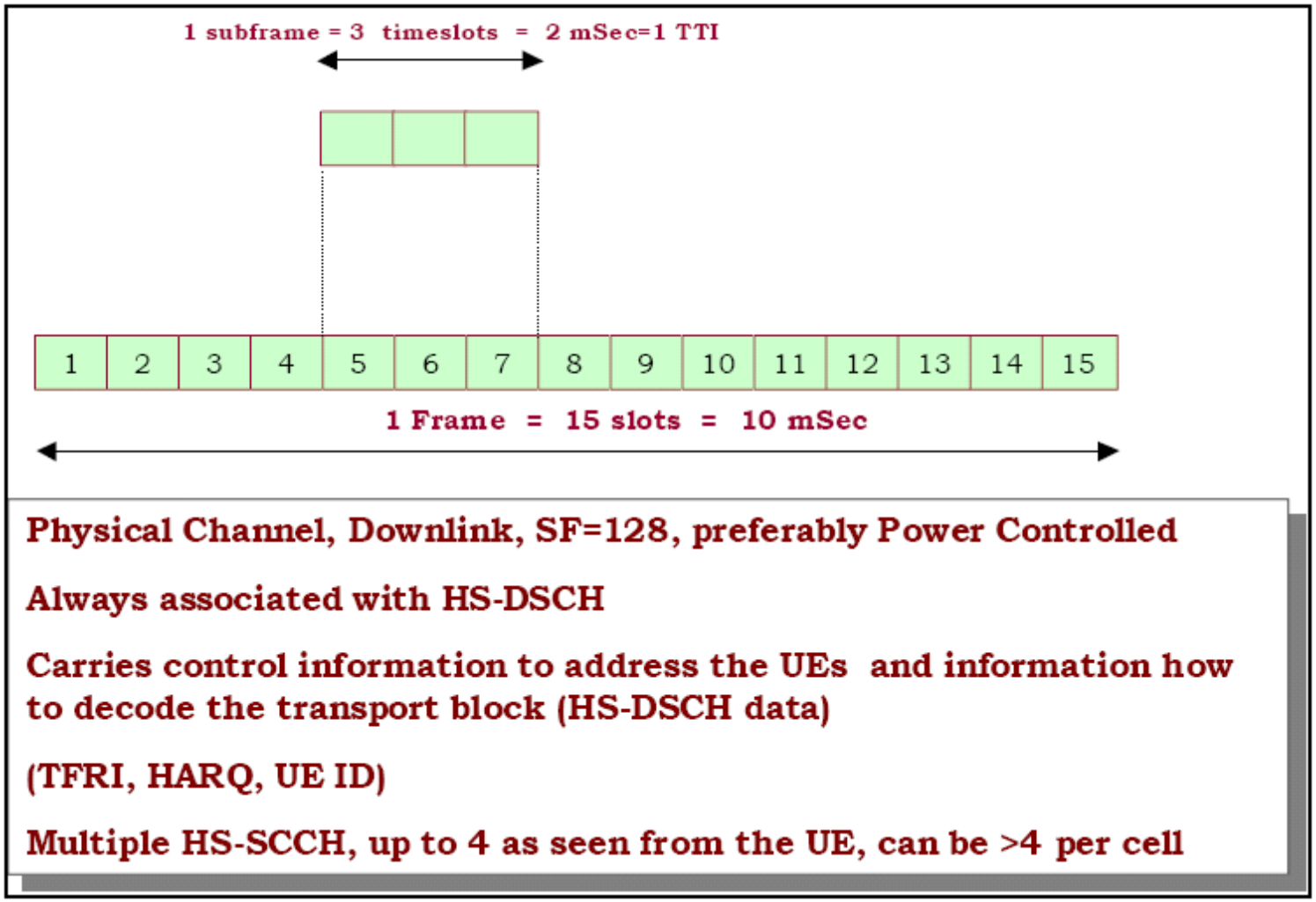


Physical Channel, Downlink, SF=16, no Power Control

The HS-PDSCH carries user data and layer 2 overhead bits mapped from the transport channel: HS-DSCH.

HS-DSCH is mapped to one or several HS-PDSCHs

HS-SCCH (Physical, Shared control)



Physical Channel, Downlink, SF=128, preferably Power Controlled

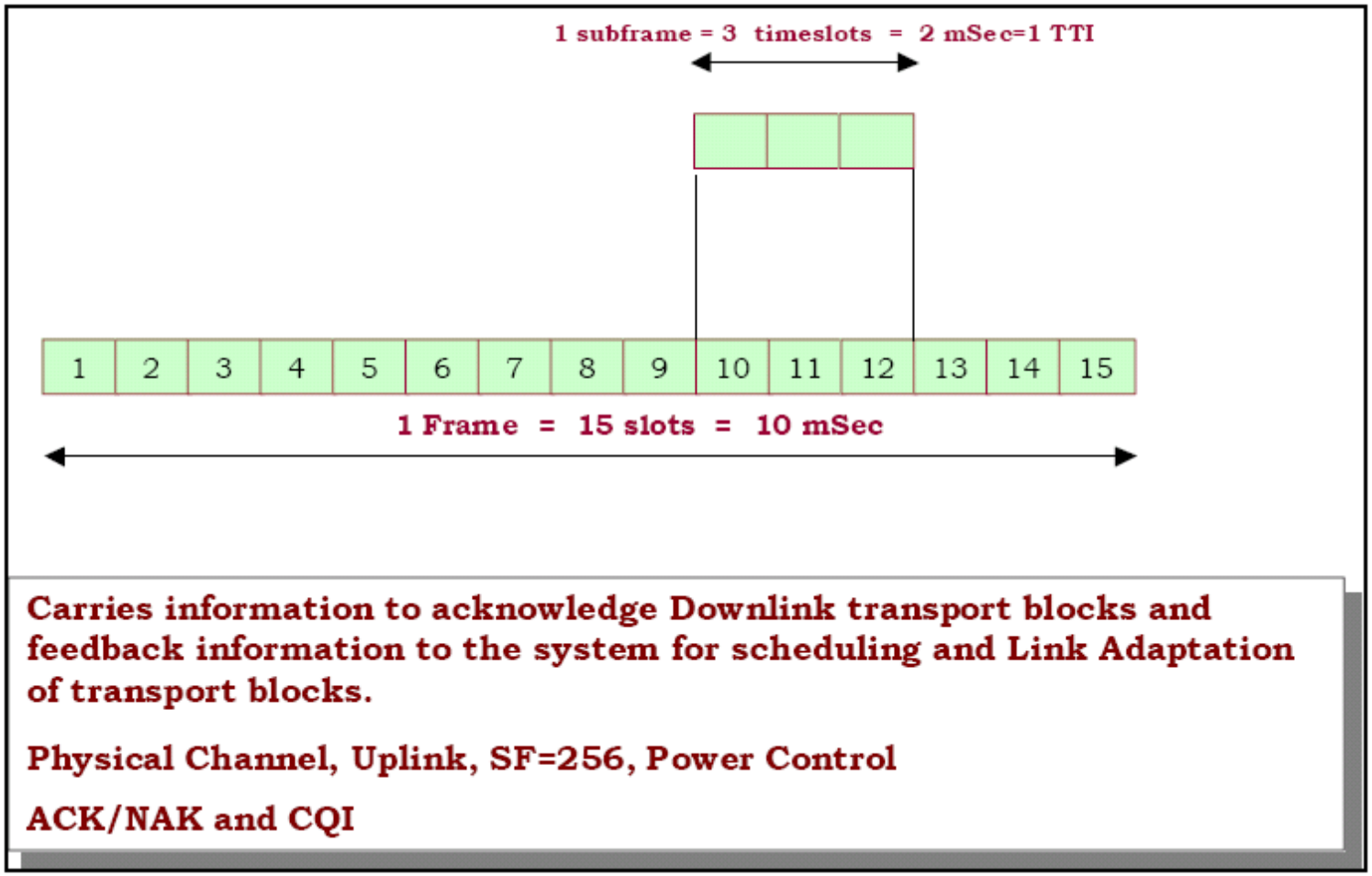
Always associated with HS-DSCH

Carries control information to address the UEs and information how to decode the transport block (HS-DSCH data)

(TFRI, HARQ, UE ID)

Multiple HS-SCCH, up to 4 as seen from the UE, can be >4 per cell

HS-DPCCH (Physical - UL control)



Carries information to acknowledge Downlink transport blocks and feedback information to the system for scheduling and Link Adaptation of transport blocks.

Physical Channel, Uplink, SF=256, Power Control

ACK/NAK and CQI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