The art of mobile testing

HSDPA
High **S**peed **D**ownlink **P**acket **A**ccess

Technology Update

adare GmbH
www.adare.de

Marija Skoda
Email: marija.skoda@adare.de

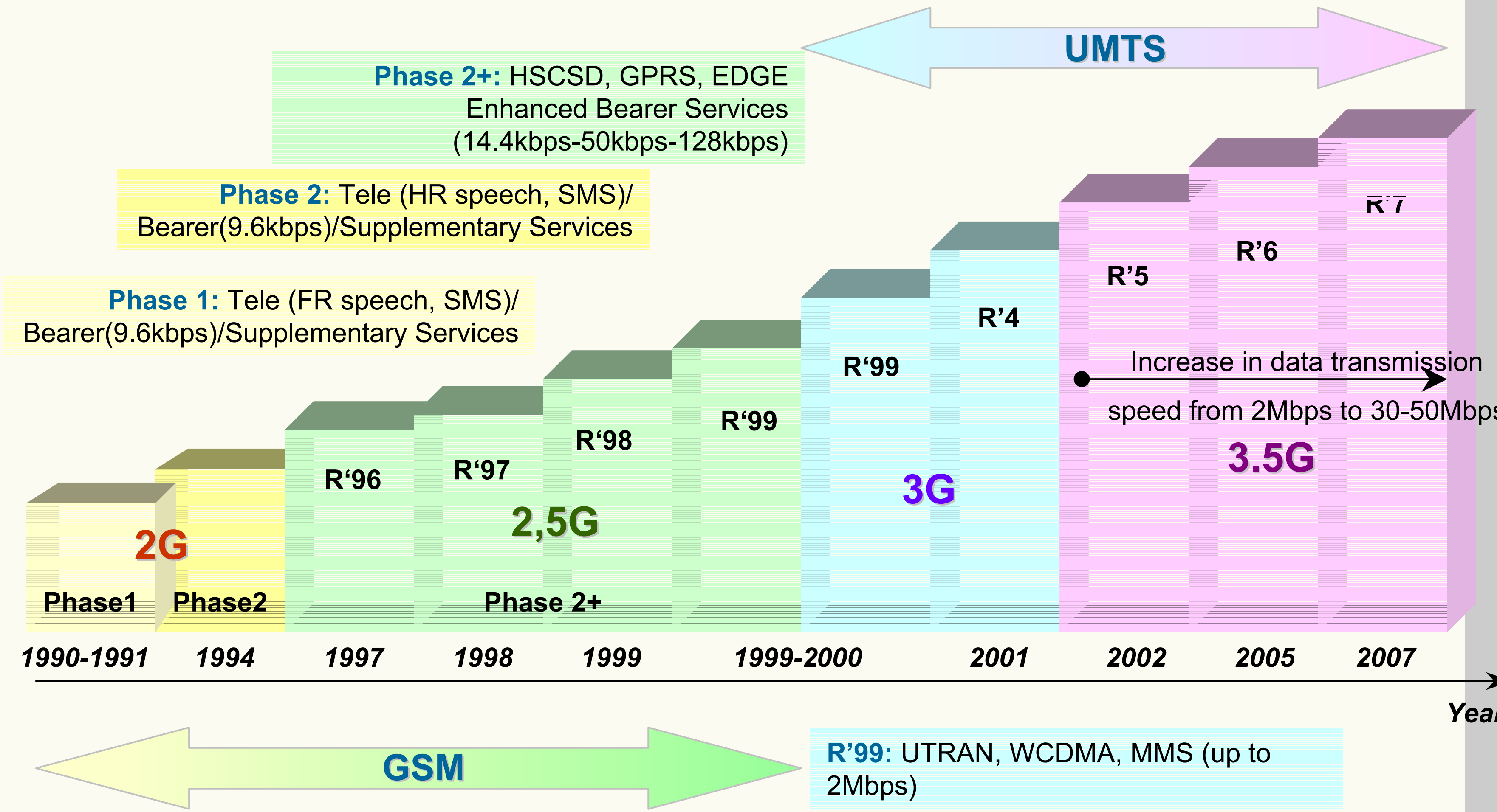
March 2006

HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- Protocol architecture
- HDSPA channels in UTMS Release 5
- Mobility aspects
- Outlook beyond Release 5

The art of mobile testing

Evolution of GSM and UMTS in Europe



R'4-R'7: VHE, IMS, HSDPA, HSUPA, PoC, E-DCH, MBMS, MIMO, WLAN integration

* See the apendix for the abbreviation list

UMTS FDD radio access basics

- Channel bandwidth 5 MHz
- QPSK modulation
- Pulse shaping
- Direct sequence CDMA
- OVSF spreading codes
- Timing structure
- Transmission rate 3.84 Mchip/s
- Frequency reuse = 1
- Soft handover

CDMA – Code Division Multiple Access

OVSF – Orthogonal Variable Spreading Factor

QPSK – Quadrature Phase Shift Keying

CDMA principle

- **CDMA-Code Division Multiple Access:**

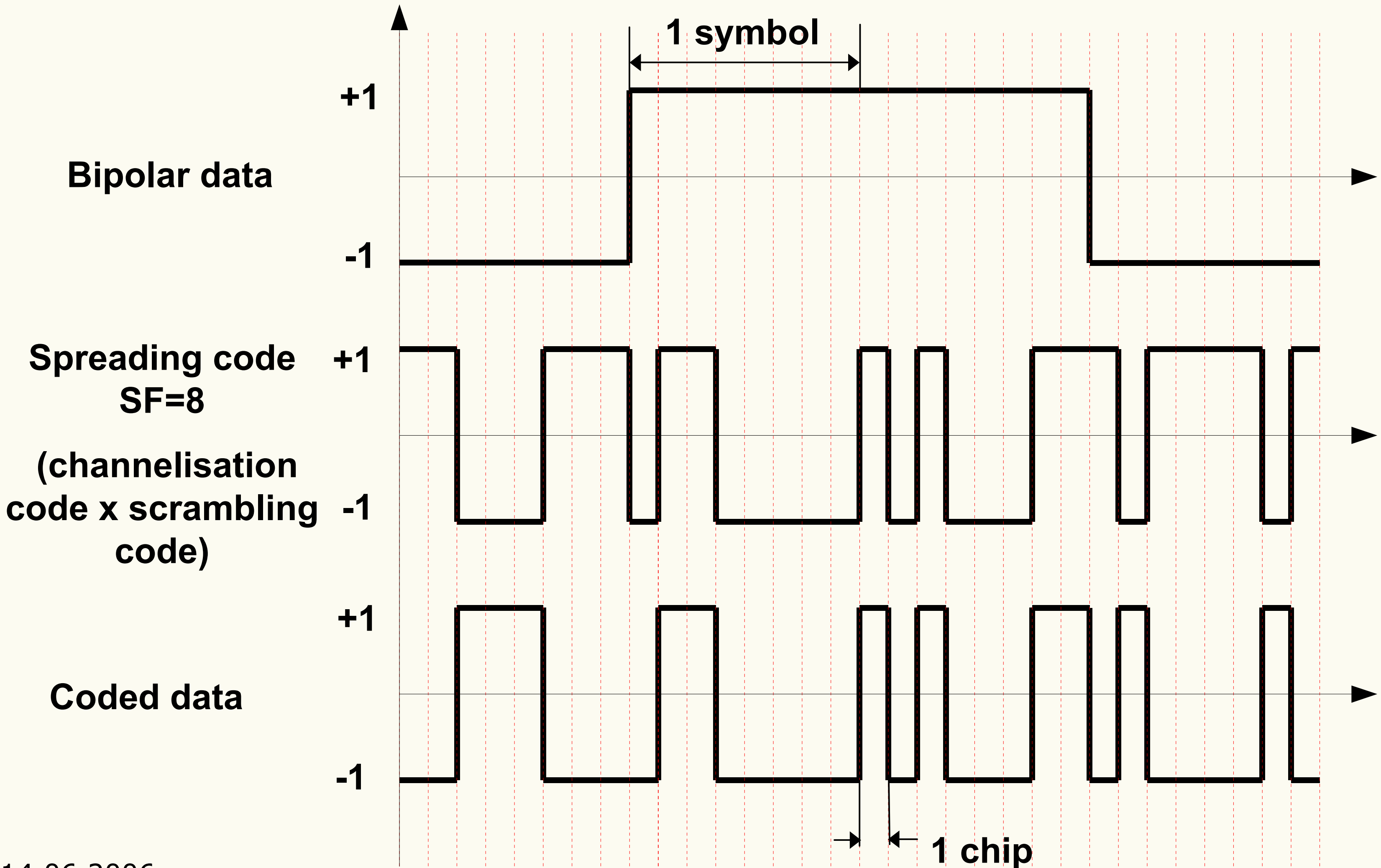
  - Narrow-band signal is **spreaded** with an OVSF code:
    - to increase the signal bandwidth
    - to achieve the orthogonality between signals from the same source

  - Wide-band signal then is **scrambled** with a scrambling code to distinguish between different sources

  - **Spreading factor** SF =Chiprate/Bitrate

- **Near-far problem: - power control necessary to limit the interference between sources**

Spreading example



HSDPA Motivation

- **Reasons to deploy HSDPA:**
  - Saturated voice communication market
  - Growing demand and user expectation for the data services like broadband internet access, streaming, gaming, etc.
  - Competing High Speed wireless technologies
    - WLAN
    - WiMAX
    - 1xEvDo in CDMA 2000

- **Requirements:**
  - Short set-up and transfer delays
  - High system capacity
  - High peak data rates
  - Low mobility (user speed max 3km/h)
  - Low data transfer costs

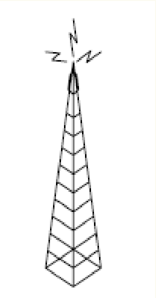
Rel.´99 vs. Release 5

	Release’99	Release 5 - HSDPA
Mode of Transmission	Voice & data over DCH; Max download rate 384 kbit/s, GPRS latency 700 ms	High speed downlink broadcast shared channel for data Support of IP and radio bearers for IP-based services
Network View	Release’99 cells	Release’99 Cells and mixed Rel.’99 – Rel.5 cells e.g. in hotspots

HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- Protocol architecture
- HDSPA channels in UTMS Release 5
- Mobility aspects
- Outlook beyond Release 5

High speed downlink broadcast channel



NodeB

Major objectives:

- **Service aspect:**
  - •Allow higher data rates for users in favourable positions
  - •Decrease latency
- **Network aspect:**
  - •Increase radio efficiency/capacity for data

HSDPA- capable UEs

Technologies for HSDPA support

- **Adaptive Modulation and Coding (AMC)**
- **Hybrid Automatic Repeat Request (H-ARQ)**
- **Fast transmission/retransmission scheduling**

Technologies for HSDPA support

- Adaptive Modulation and Coding (AMC)
- Hybrid Automatic Repeat Request (H-ARQ)
- Fast transmission/retransmission scheduling

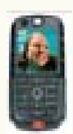
AMC principle

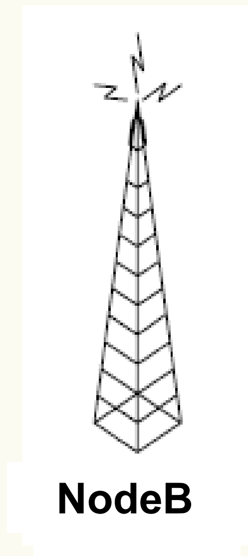
Release '99

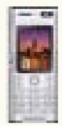
Power level: α

Modulation: QPSK

Turbo Code R=1/3





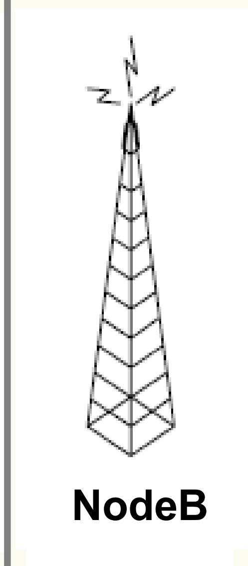


Power level: β

Modulation: QPSK

Turbo Code R=1/3

HSDPA

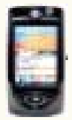


Power level: α

Modulation: 16-QAM

Turbo Code R=1/3,

rate matching: 3/4



Power level: α

Modulation: QPSK

Turbo Code R=1/3,
rate matching: 1/4

Adaptive Modulation and Coding (AMC)

- **Main principle – to dynamically modify**
    - Signal modulation and
    - Coding scheme

  to compensate the variations in cannel conditions

- **Benefits:**
  - Increased average cell throughput
  - Reduced interference variation
  - Higher data rates for users in favourable positions

- **Effective in a combination with scheduling techniques**

Data throughput

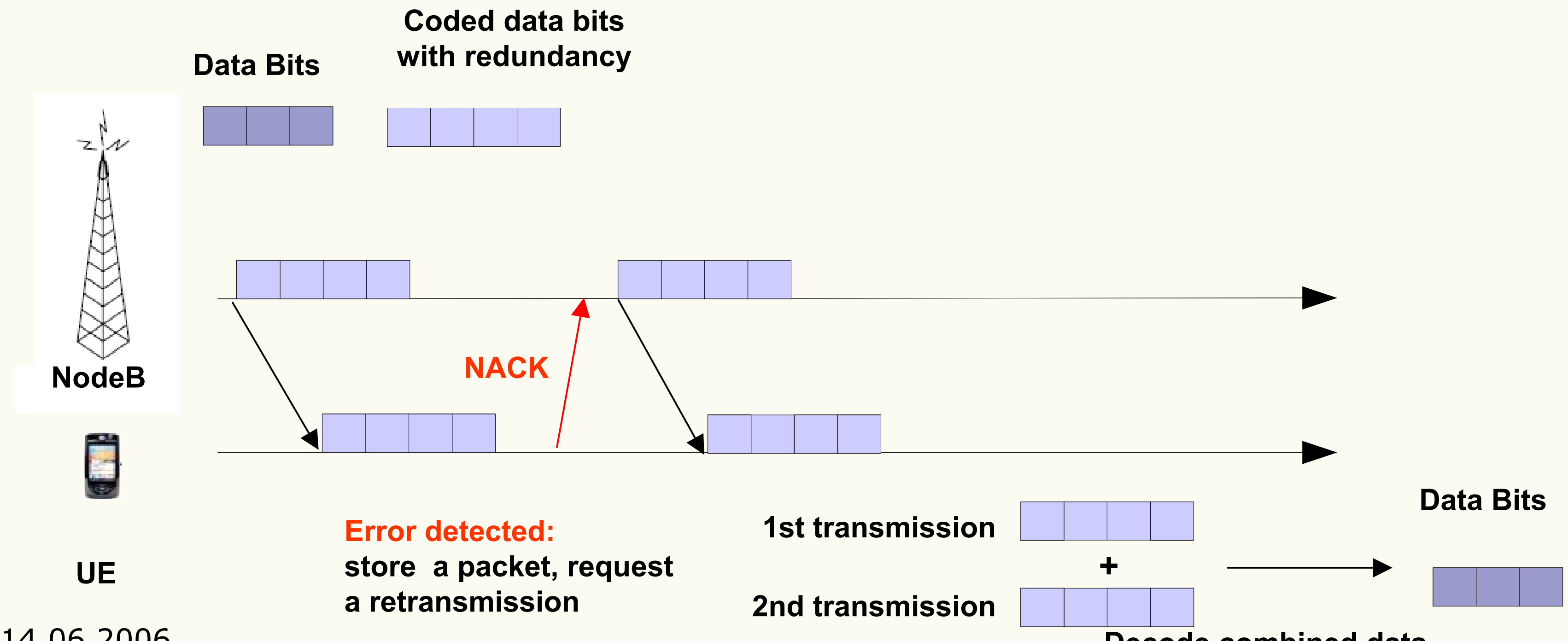
Modulation	Coding Rate	Throughput in kbps (1 code of SF=16)
QPSK	1/4	120
	2/4	240
	3/4	360
16-QAM	2/4	480
	3/4	720
	4/4	960

Technologies for HSDPA support

- **Adaptive Modulation and Coding (AMC)**
- **Hybrid Automatic Repeat Request (H-ARQ)**
- **Fast transmission/retransmission scheduling**

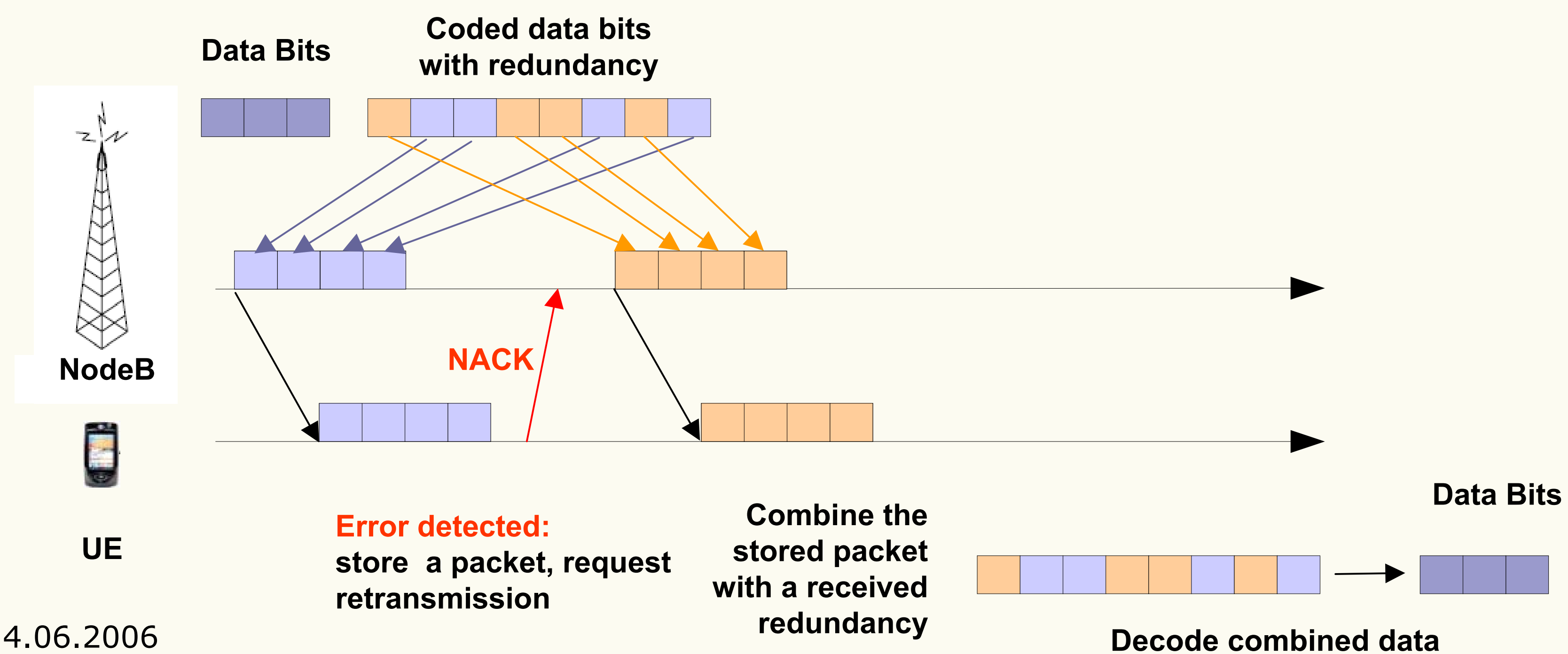
H-ARQ-type-III

- **Chase combining with one redundancy version: the data are retransmitted with a little redundancy. The retransmitted signal is weighted by SNR and then combined with the first received signal.**



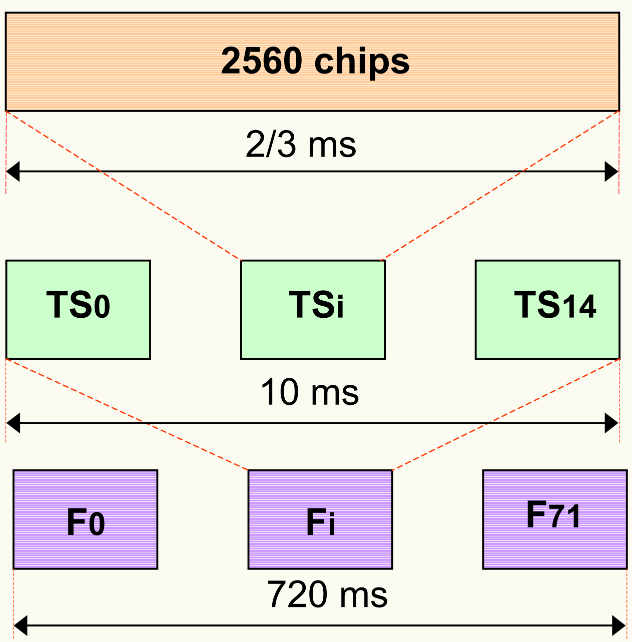
H-ARQ-type-II

- **Incremental redundancy:** only **correction** data to the original data is retransmitted. The additional redundant data will be sent **incrementally** if NACK is received



Timing structure Rel’99

- **In UMTS Rel’99 the transmission time interval for transport channels is always multiple to 10 ms (10/20/40/80)**



Time Slot TS

Time slot is the shortest repetitive period

1Frame =15TS

Frame is the shortest transmission duration

Superframe=72F

TTI-Transmission Time Interval

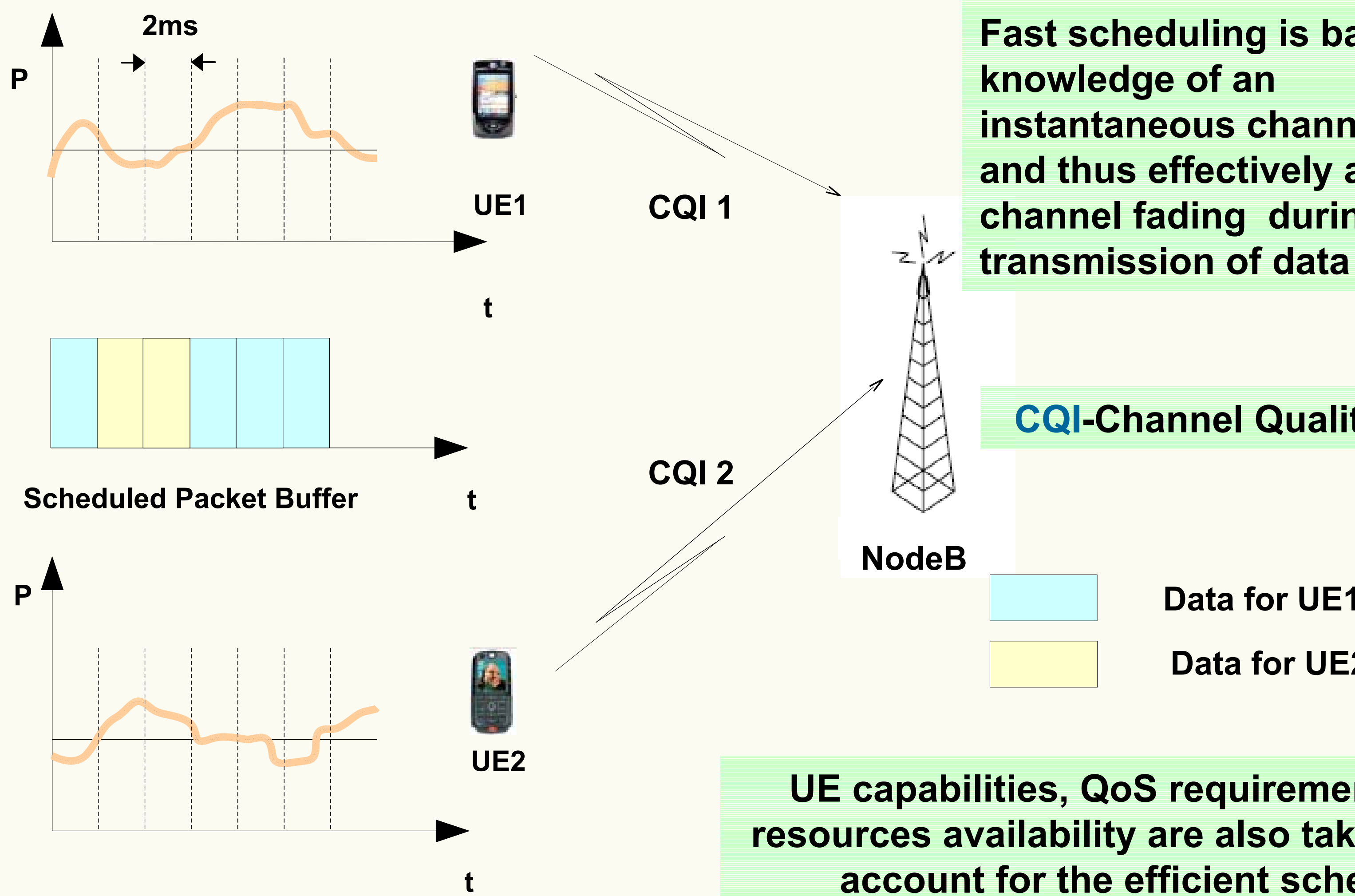
Shorter time transmission interval (TTI)

- **HSDPA introduces short TTI concept, where TTI=2ms**
- **Advantages:**
  - Less probability of an error due to the change of the channel conditions
  - More efficient when packet retransmission is necessary
  - Decreased buffer size

Technologies for HSDPA support

- **Adaptive Modulation and Coding (AMC)**
- **Hybrid Automatic Repeat Request (H-ARQ)**
- **Fast transmission/retransmission scheduling**

Fast and fair scheduling in NodeB



Fast scheduling is based on a knowledge of an instantaneous channel quality and thus effectively avoids channel fading during the transmission of data

CQI-Channel Quality Indicator

UE capabilities, QoS requirements, Uu resources availability are also taken into account for the efficient scheduling

HSDPA - Agenda

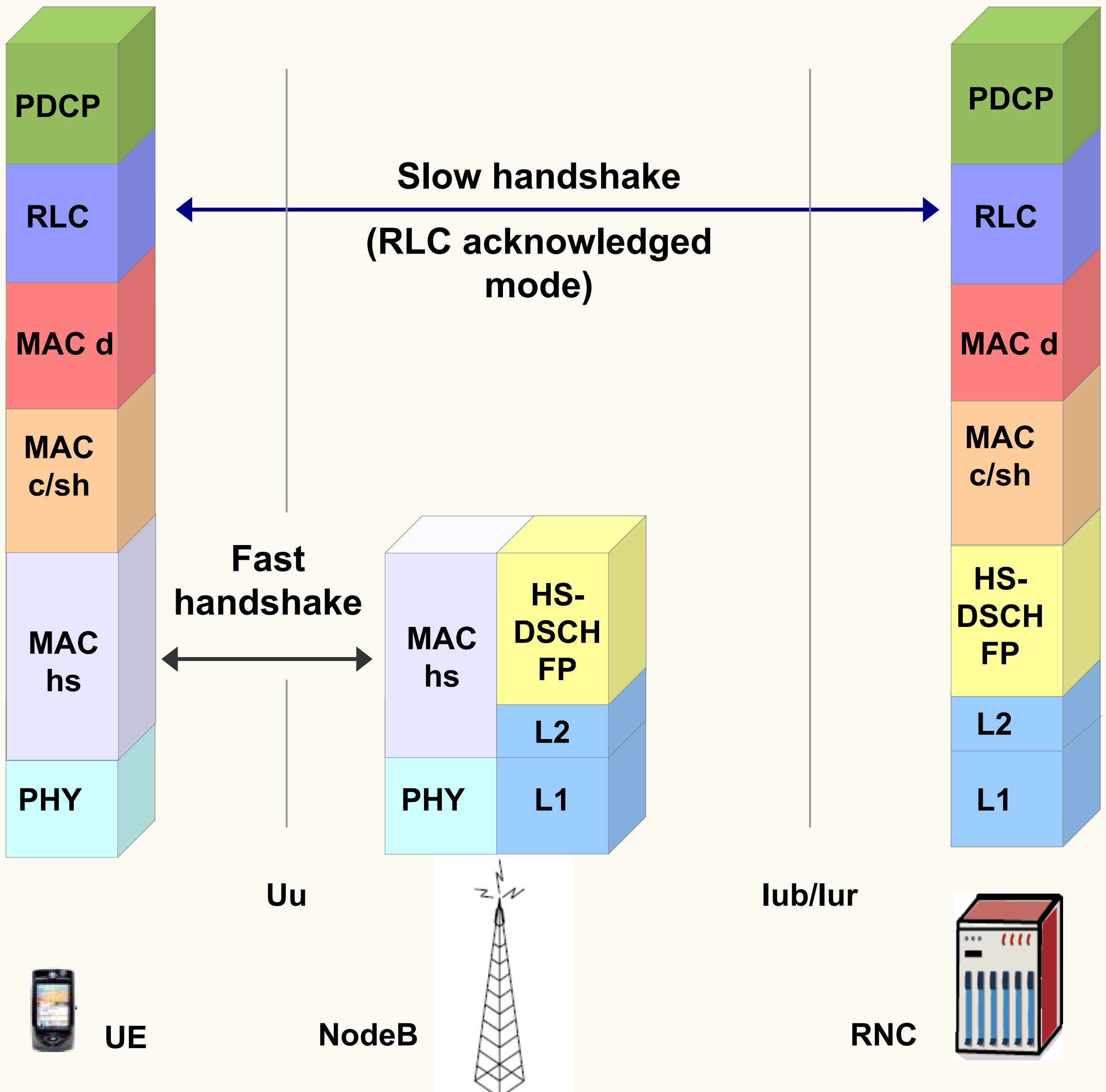
- GSM and UMTS evolution
- Technological approach
- Protocol architecture
- HDSPA channels in UTMS Release 5
- Mobility aspects
- Outlook beyond Release 5

Need for an architectural change to Rel'99

- **ARQ mechanism is placed in RNC**
  - **Disadvantage:** latency time up to 100 ms!
  - **Solution:** move it to node B
  - **Profit:** latency below 10 ms

- **Scheduling is controlled by RNC**
  - **Disadvantage:** important channel measurement information can be delayed
  - **Solution:** move scheduling close to the air interface
  - **Profit:** rescheduling is made within a short time

New protocol entities



Impact on the network

- **New type of cell – Rel’5 cell, complement to Rel’99 cell and ensures HSDPA functioning**

- **New NodeB fast scheduling functionality that takes into account**
  - Buffer status and resource availability
  - QoS and priority
  - UE capabilities and quality feedback

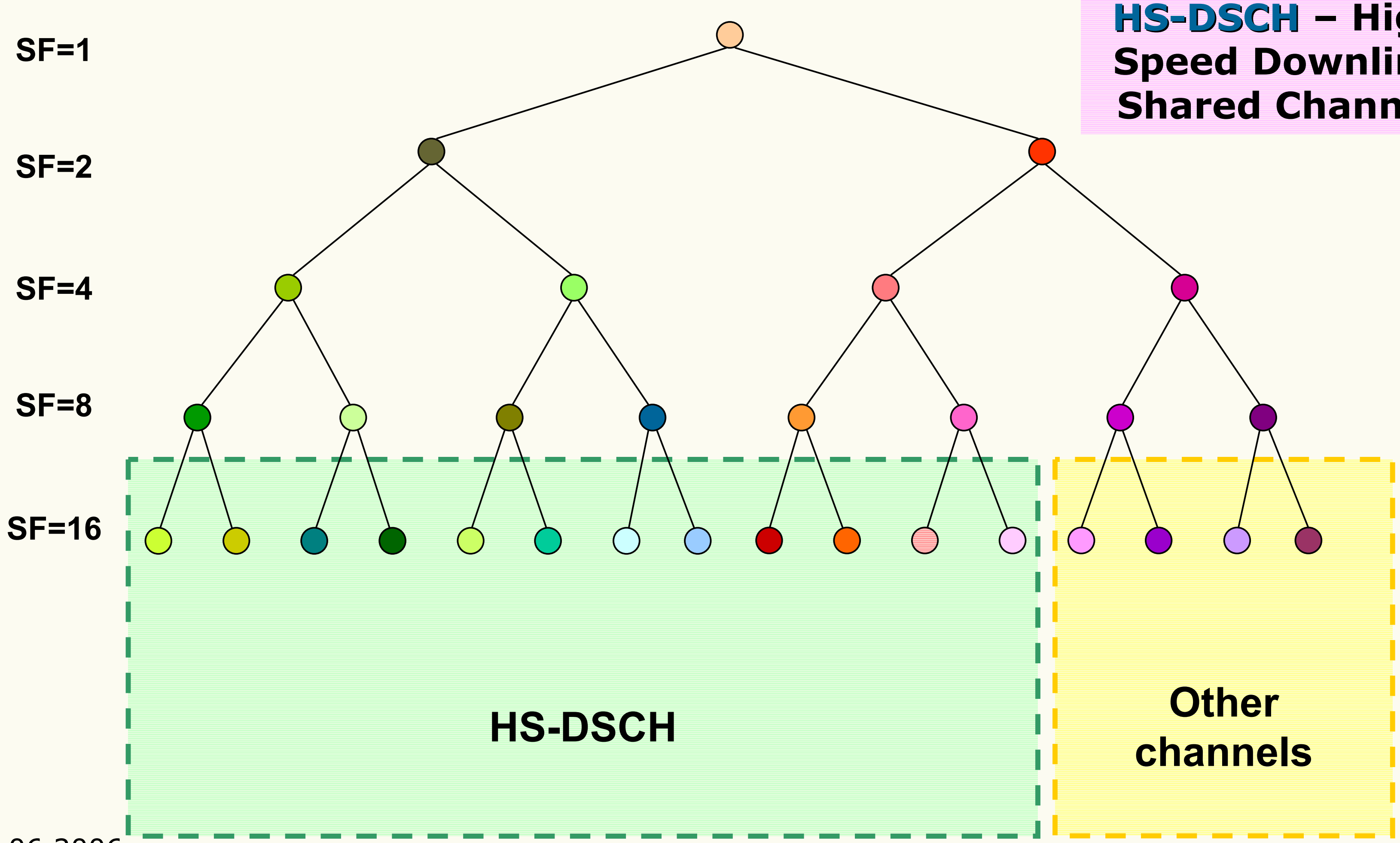
- **Flow control mechanism on the Iub interface**

HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- Protocol architecture
- HDSPA channels in UTMS Release 5
- Mobility aspects
- Outlook beyond Release 5

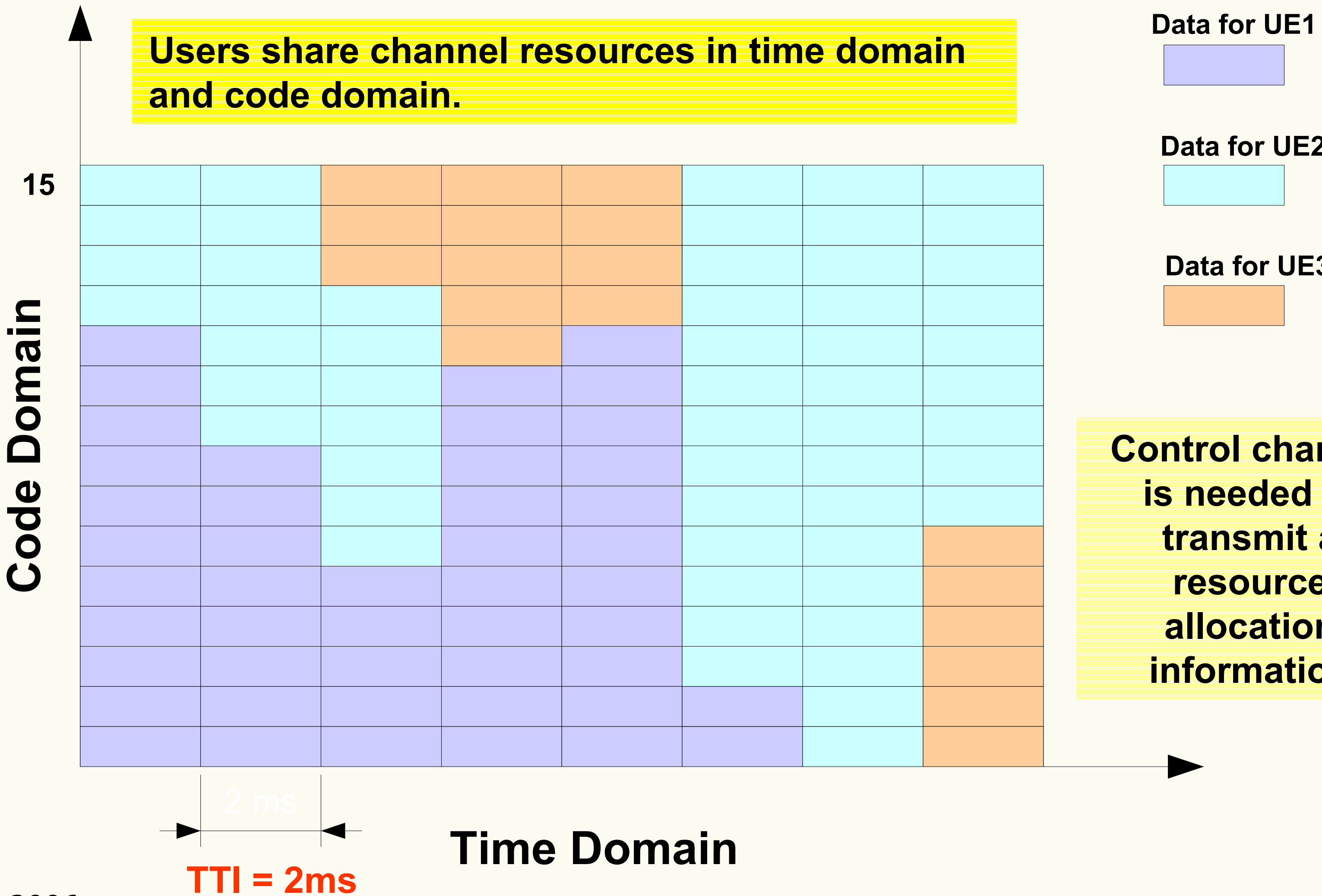
HSDPA code allocation example

HS-DSCH – High Speed Downlink Shared Channel



HSPDA multiplexing

Users share channel resources in time domain and code domain.



Control channel is needed to transmit a resource allocation information

Data throughput

Modulation	Coding Rate	Throughput in Mbps (5 codes)	Throughput in Mbps (10 codes)	Throughput in Mbps (15 codes)
QPSK	1/4	0.6	1.2	1.8
	2/4	1.2	2.4	3.6
	3/4	1.8	3.6	5.4
16-QAM	2/4	2.4	4.8	7.2
	3/4	3.6	7.2	10.7
	4/4	4.8	9.6	14.4

Throughput calculation example

- **Calculate user data throughput in Mbps for a given transmission parameters:**
  - Modulation: 16-QAM
  - Effective code rate: R=3/4
  - Number of allocated codes: N=5
- **Formula:**

$$\frac{\text{Chips per Sec x Number of Bits per Modulation Symbol x R x N}}{\text{SF}}$$

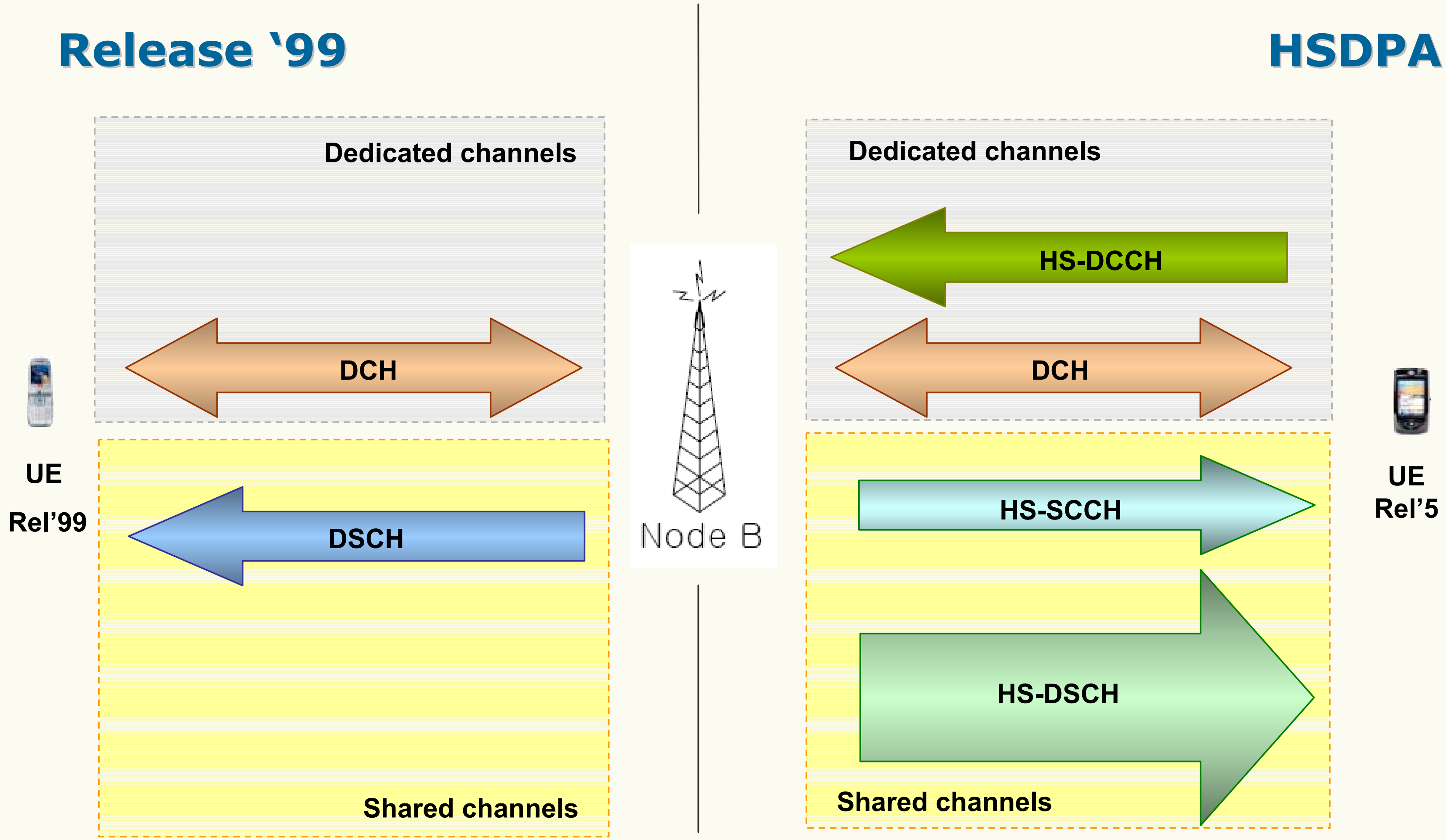
- **Calculation:**

$$\frac{2560 \times 3/2\ \text{ms} \times 4 \times 3/4 \times 5}{16} = 3.6\ \text{Mbps}$$

HSDPA terminal classes

Class	HS-DSCH channels	Min TTI	Modulation	Peak rate Mbps	Soft channel bits
1	5	3	both	1.2	19200
2	5	3	both	1.2	28800
3	5	2	both	1.8	28800
4	5	2	both	1.8	38400
5	5	1	both	3.6	57600
6	5	1	both	3.6	67200
7	10	1	both	7.2	1152100
8	10	1	both	7.2	134400
9	15	1	both	10.8	172800
10	15	2	both	14.4	172800
11	5	1	QPSK	0.9	14400
12	5	1	QPSK	1.8	28800

Channel set comparison



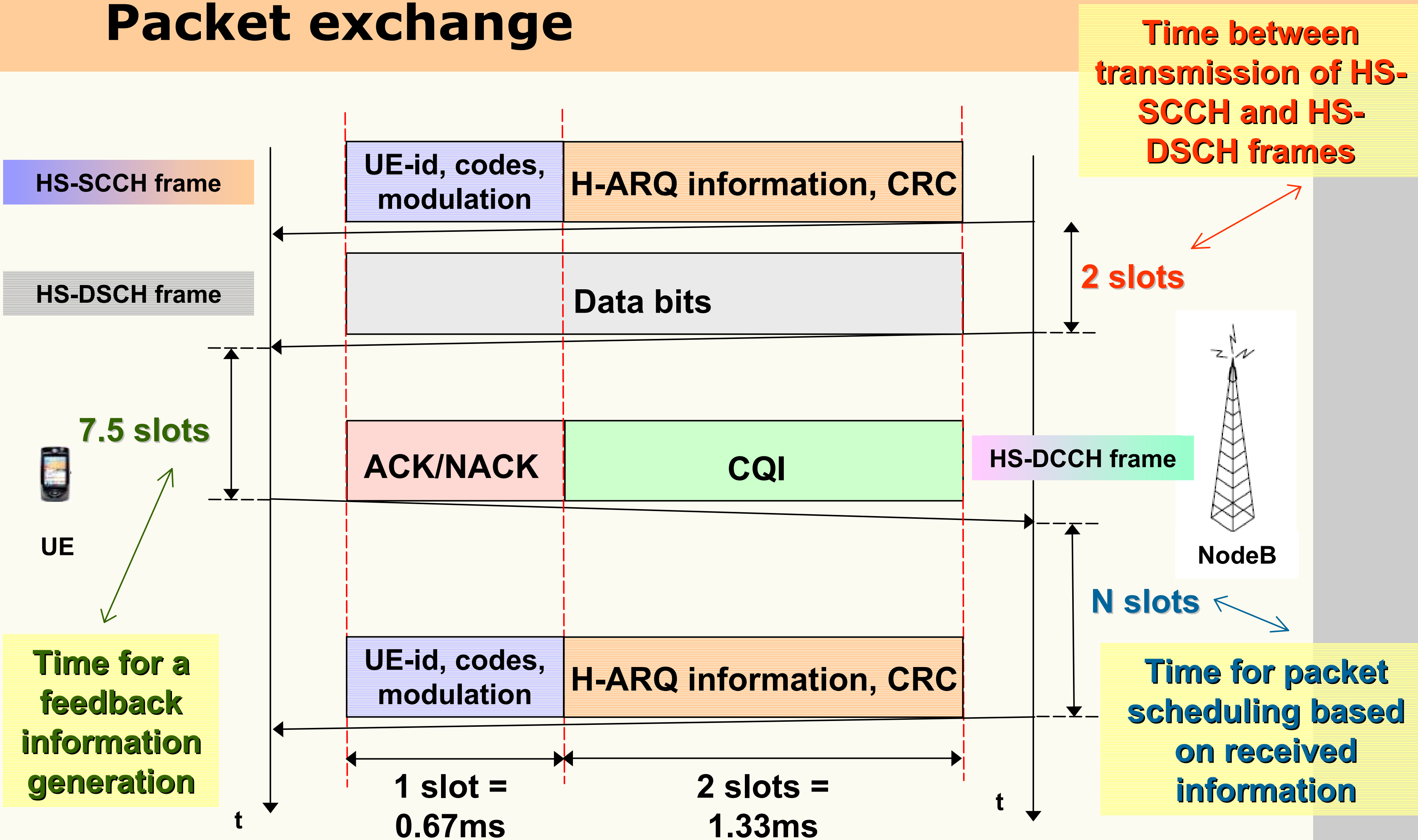
Associated Signalling

- **Uplink:**
  - Fast link adaptation (AMC) signalling
  - H-ARQ signalling

- **Downlink:**
  - UE-Id for a given HSDPA TTI
  - Transport Format and Resource Indicator (TFRI):
    - TB set size
    - Channelisation codes
    - H-ARQ information
  - Relative CPICH to HSDPA power ratio (for TTI)

CPICH – Common Pilot Channel

Packet exchange



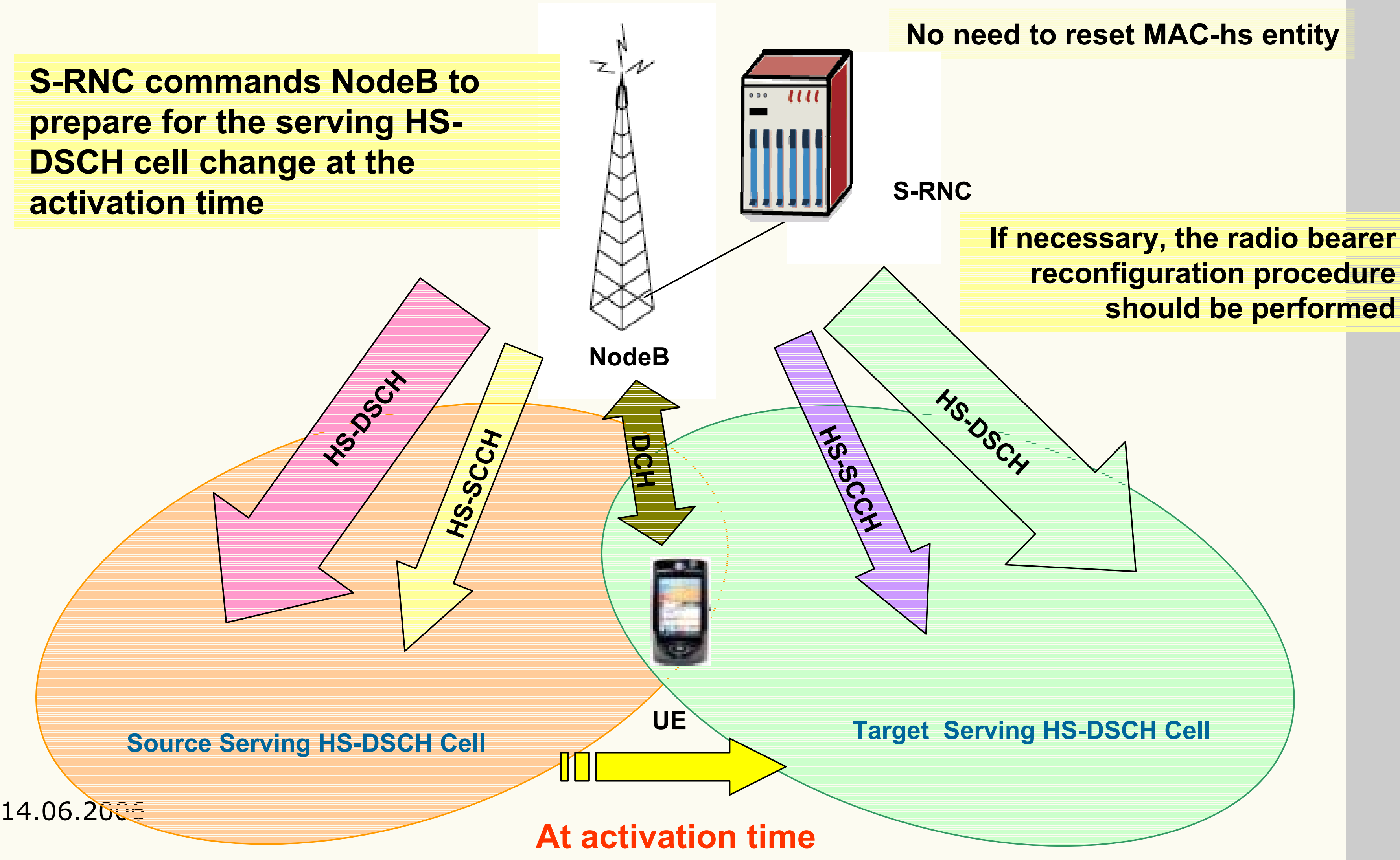
HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- Protocol architecture
- HDSPA channels in UTMS Release 5
- Mobility Aspects
- Outlook beyond Release 5

Mobility management

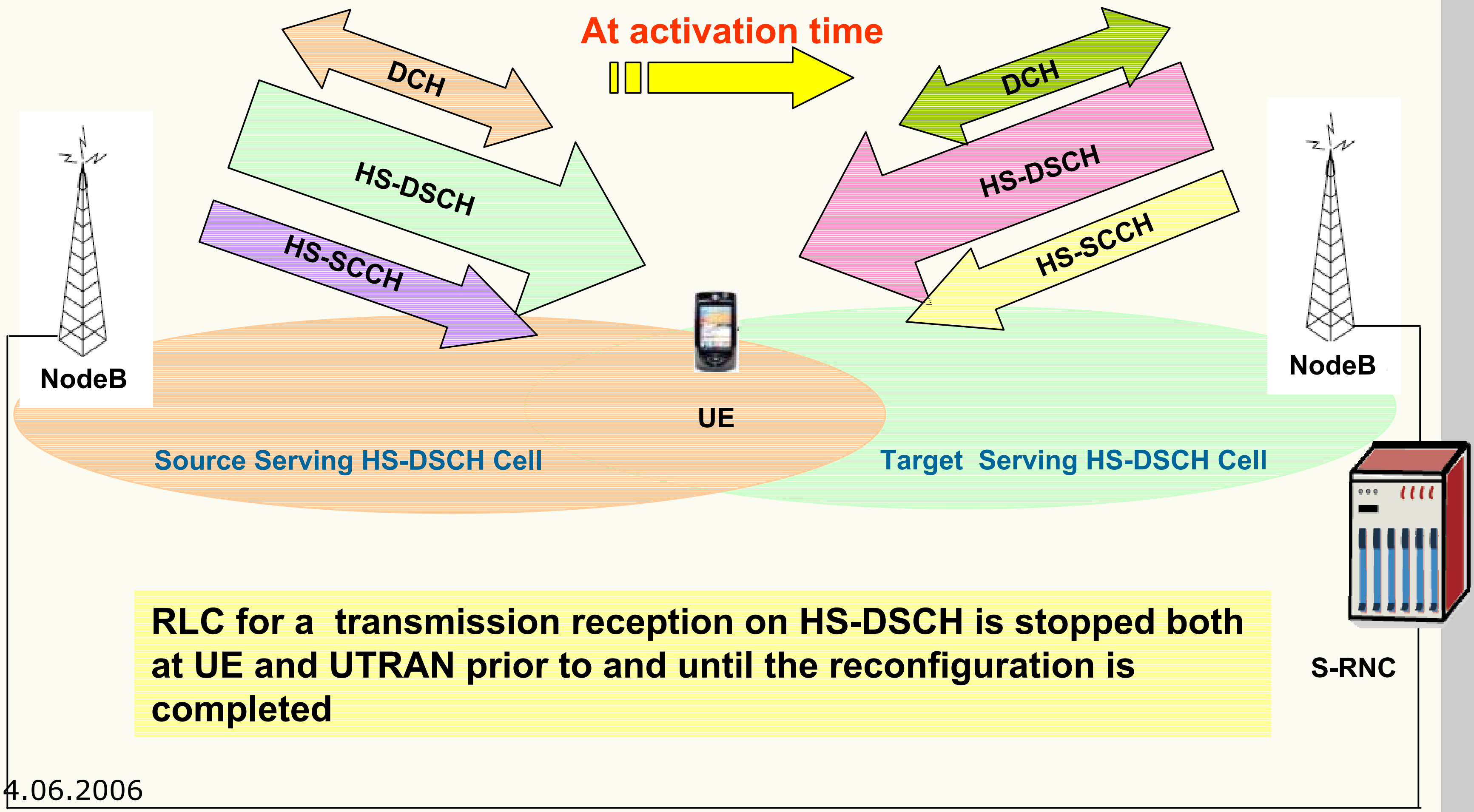
- **Only hard handover for HSDPA transmissions**
- **HSDPA handover types:**
  - Intra NodeB handover
  - Inter NodeB handover
  - HS-DSCH to Dedicated Channel handover

Intra-NodeB HSDPA handover



Inter-NodeB HSDPA handover

Transport channel reconfiguration message includes MAC-hs reset flag



RLC for a transmission reception on HS-DSCH is stopped both at UE and UTRAN prior to and until the reconfiguration is completed

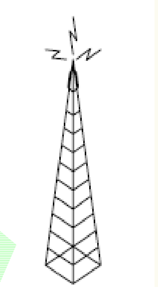
HSDPA - Agenda

- GSM and UMTS evolution
- Technological approach
- HDSPA channels in UTMS Release 5
- Protocol architecture
- Physical layer modifications
- Outlook beyond Release 5

High speed downlink broadcast channel

Major objectives:

- Service aspect:
  - Higher data rated for users in favourable positions
  - Decrease delays
- Network aspect:
  - Increase throughput in the uplink
  - Downward compatibility to Rel’99, Rel’4 and Rel’5
  - Soft handover

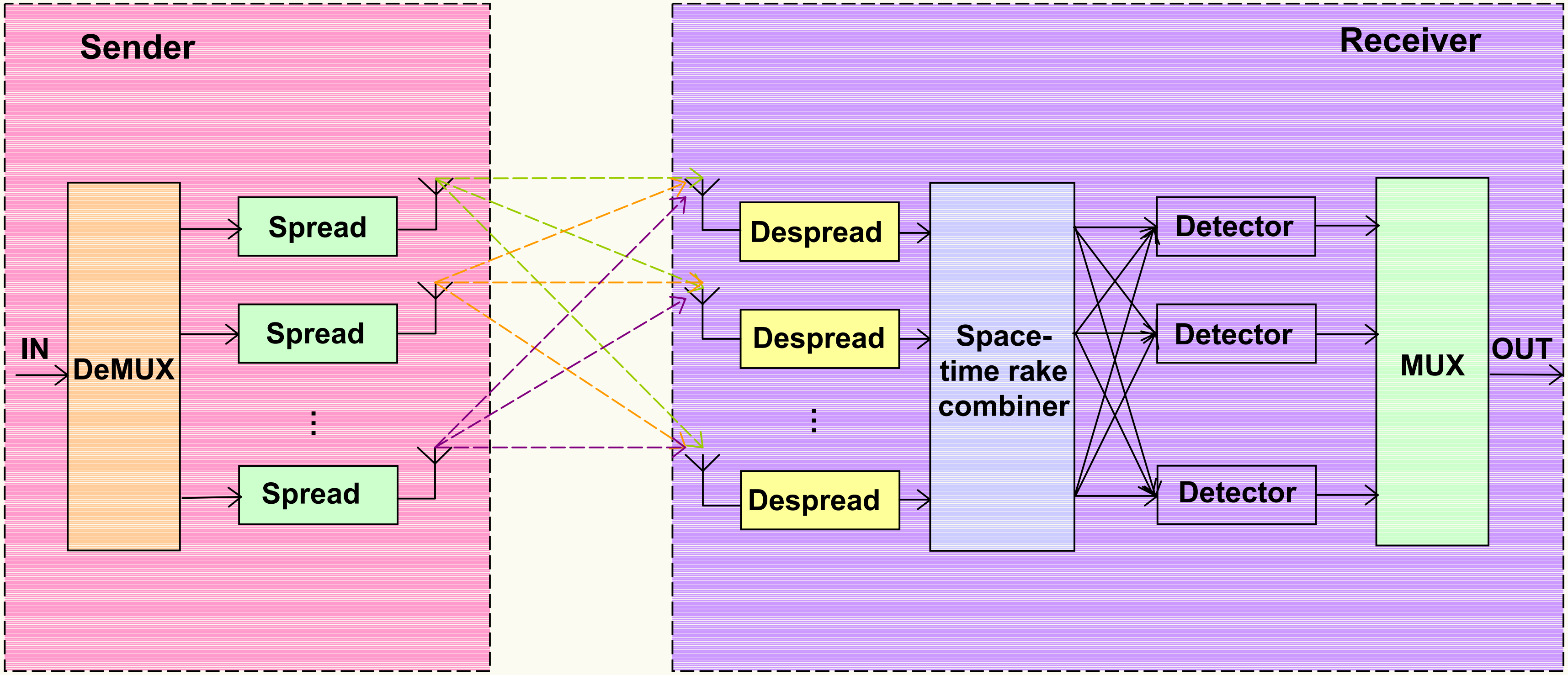


NodeB

HSUPA- capable UEs

Need to deploy an Enhanced Dedicated Channel (E-DCH) in UL/DL for UE for scheduling and H-ARQ operations

MIMO example



MIMO technique allows to achieve higher data rates either:

when using the same spreading code on different antennas attaining better channel quality by improved antenna transmit and receive diversity

HSPDA in Germany, Sample March 2006

Commercial offer T-Mobile (1,8 Mbit/s), large city coverage
Tariff example:

5 € p.m. Data Connect
+
35 € p.m.
Option web'n'walk
i.e. incl. 5 GB (quasi-flat)
+
1 € p.d. used

Notebook card 1 €
24 month contract

UEs availability:

Today:
Only notebook cards
(1,8 Mbit/s)

HSDPA Mobiles announced for Summer:
e.g. BenQ EF 91
(3,6 Mbit/s)

Vodafone: - Home zone DSL-like tariff e.g. 36 €, incl.5 GB p.m.
- Surcharge for mobility

Questions and Discussion

Thank you