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Cellular Network Planning and Optimization
Part XI: HSDPA

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HSDPA

- **HSDPA =** High Speed Downlink Packet Access. Release 5 was the first HSDPA release (2005)
  - As of May 2007, 102 HSDPA networks have commercially launched mobile broadband services in 55 countries
- **HSUPA =** High Speed Uplink Packet Access. Release 6 was the first HSUPA release (2007)
  - First networks launched during 2007
- **HSPA** = High Speed Packet Access = HSDPA + HSUPA

HSDPA

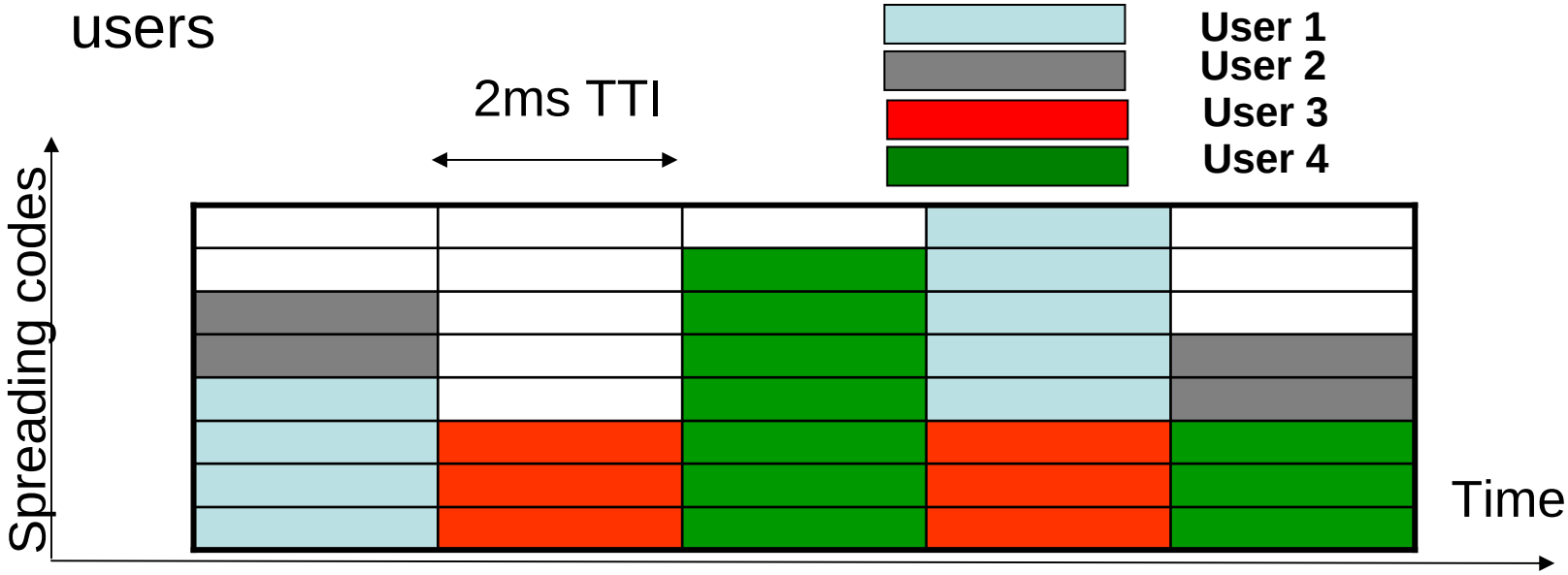
- Data rates
  - WCDMA: Peak data rate 2Mbps, highest practical data rates up to 384kbps
  - HSDPA: Peak data rate 14.4 Mbps, practical data rates up to few megabits
  - Carrier data throughput increased 50-100% compared to WCDMA
- Reduced latency when compared to WCDMA
- Packet switched system
- HSDPA enables possibility to rapidly allocate a large fraction of resources for a specific user

Main changes to WCDMA

- Shared channel transmission introduced
  - HS-DSCH (High-Speed Downlink Shared Channel)
  - Enables dynamic allocation of radio resources between users
- Fast channel-aware scheduling
  - Controls to which user the HS-DSCH transmission is directed
  - Take into account the radio channel conditions
- Adaptive modulation and coding
  - QPSK and 16QAM modulations applied (in WCDMA only QPSK applied)
  - QPSK carry 2 bits and 16QAM carry 4 bits
  - Combination of modulation and coding is decided based on channel conditions
- Hybrid automatic repeat request (HARQ)
  - User data can be transmitted multiple time with different coding
- Two additional control channels (HS-SCCH, HS-DPCCH)
- No fast power control in HSDPA

HS-DSCH

- Shared channel transmission is key character of HSDPA.
  - Part of the DL radio resources are used to serve as a common resource pool
  - These resources are dynamically shared between users



TTI = Transmit time interval

HS-DSCH illustration

HS-DSCH

- There is DSCH already in WCDMA but
  - Power control is applied in WCDMA DSCH
  - Spreading factor is variable
  - Only QPSK modulation
- In HSDPA the HS-DSCH has
  - No power control (link adaptation, channel aware scheduling and HARQ form a more efficient combination)
  - Spreading factor is fixed (SF=16)
  - Number of codes granted for a user can be changed after each 2ms time interval
  - QPSK and 16QAM modulations (64QAM after release 7)
  - Up to 15 parallel codes can be assigned to a user (multi-code operation). Yet, terminals may support only 5 parallel codes.

HS-DSCH vs. DCH

Feature	DCH	HS-DSCH
Variable spreading factor	Yes	No
Fast power control	Yes	No
Adaptive modulation + coding	No	Yes
Fast L1 HARQ	No	Yes
Channel aware scheduling	No	Yes
Multi-code operation	Yes	Yes, extended

Channel aware scheduling

Channel quality information
(CQI, Ack/Nack, TPC)

Data

UE1

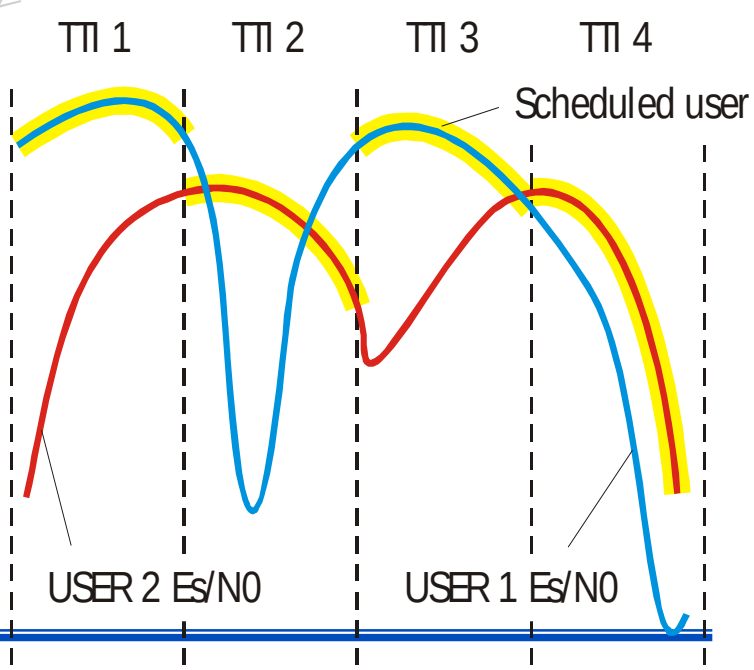
Node-B scheduling can utilize information on the instantaneous channel conditions for each user.

Multi-user selection diversity
(give shared channel to "best" user)

Channel quality information
(CQI, Ack/Nack, TPC)

Data

UE2

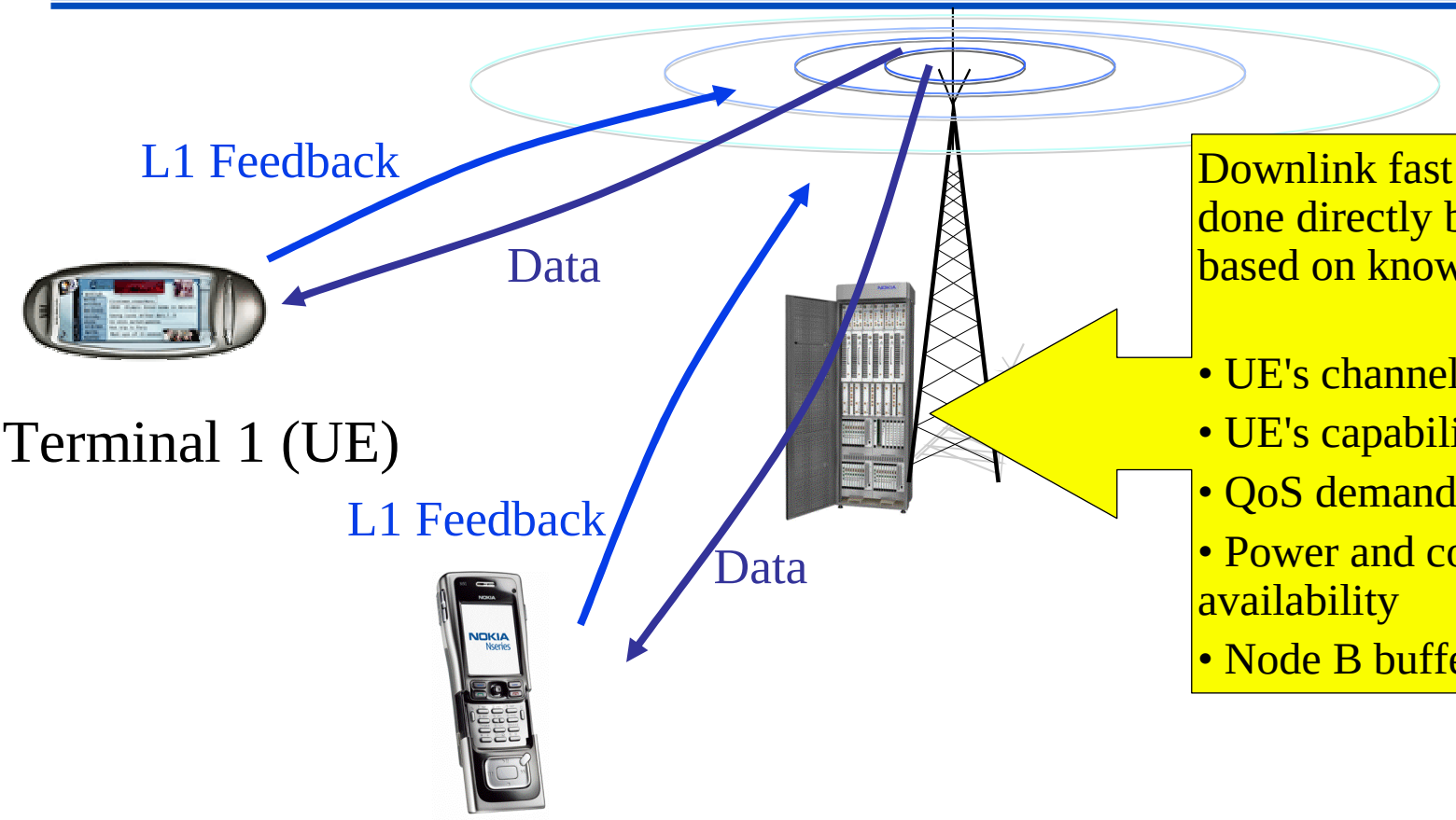


Temporal changes in the channel

Channel-aware scheduling

- Channel aware scheduling is also called as
  - Channel dependent scheduling
  - Fast scheduling
- This scheduling utilize multi-user diversity
  - Different users have different channels
  - We can send to user who has the best channel conditions (figure of previous slide)
  - Yet, in HSDPA we can get best benefit from channel aware scheduling only if delay requirement is not tight
  - While scheduling users we face a trade-off between fairness and capacity
  - Channel aware scheduling gives best performance when there is high load of NRT data.

HSDPA – General Principle



Downlink fast scheduling done directly by Node B based on knowledge of:

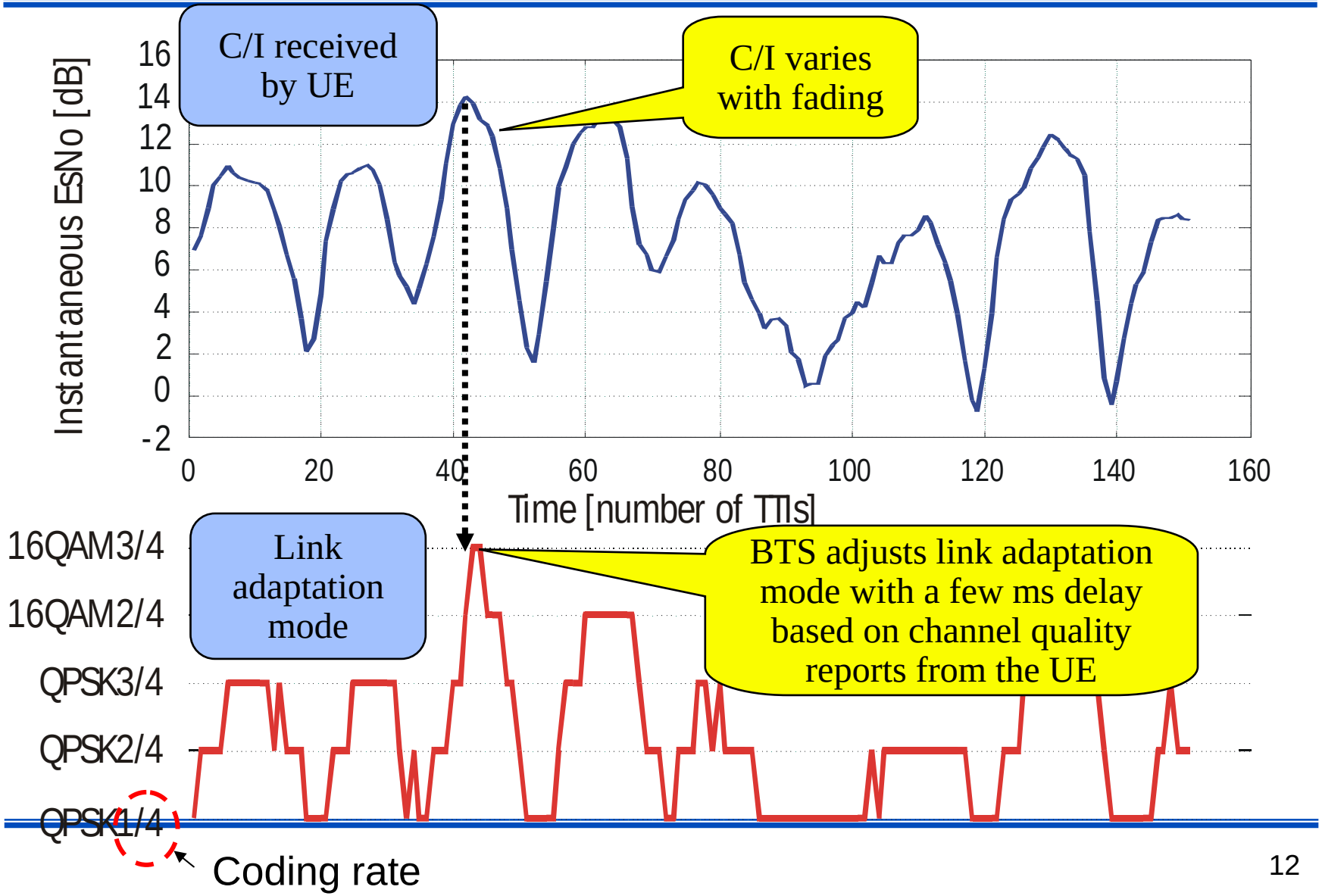
- UE's channel quality
- UE's capability
- QoS demands
- Power and code resource availability
- Node B buffer status

Users may be time and/or code multiplexed

Adaptive modulation and coding

- Variable spreading factor and power control that are used in WCDMA are replaced by adaptive modulation and coding in HSDPA
- In WCDMA downlink power control dynamics is 20dB while in uplink it is 70dB.
  - DL power control dynamics is limited by intra-cell interference (interference between parallel codes).
  - As a result transmitted power to users near the cell centre in unnecessary high.
  - In HSDPA adaptive modulation and coding selects higher order modulation and low coding rate for users near the cell centre => less radio resources are needed for those users and less interference is generated. Also significantly higher data rates are available for users near the cell centre.

Adaptive modulation and coding



HARQ

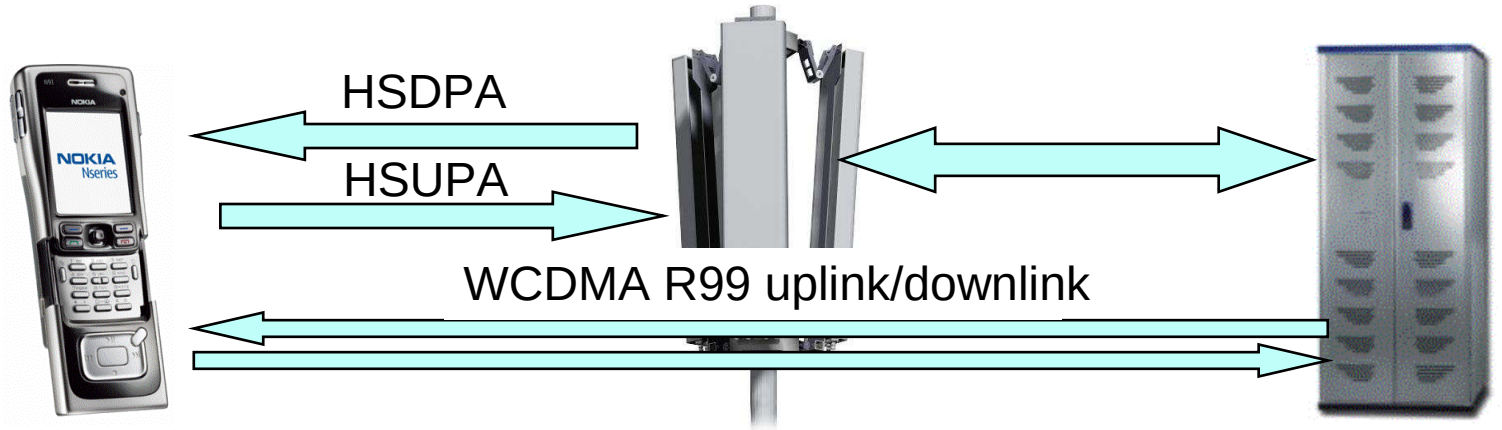
- Hybrid automatic repeat request (HARQ)
  - Highly effective technique that clearly increases the system efficiency
  - In HARQ terminal requests retransmission when data block is erroneously received.
  - Retransmitted and original data blocks are merged using soft combining, i.e. receiver store bits of the first (erroneous) block in a soft form (2 or more bits are used to express a single data bit)
  - The code rate increases with retransmissions. Hence, we may send first packet without coding but in case of retransmission the code rate for first and second packet is ½. If there is still error we can do retransmission again and code rate of three packets drop down to 1/3.
  - For HARQ we need ACK/NACK (acknowledgement, negative acknowledgement) information from terminal. This information is send via HS-DPCCH.

Control channels

- Two control channels introduced in HSDPA
  - Downlink high speed shared control channel (HS-SCCH)
  - Uplink high speed dedicated physical control channel (HS-DPCCH)
- HS-SCCH information for terminal
  - Applied modulation and channel coding
  - Which spreading codes terminal should despread
  - Other information like ARQ process number etc
- HS-DPCCH information for Node B
  - ACK/NACK showing whether packet has been correctly received or not. Used for HARQ.
  - CQI that indicates which transport block size, modulation type and number of codes could be received correctly.

HSPA

- HSPA transfers some functionalities from RNC to NodeB



HSPA scheduling and HARQ retransmission control in base station

WCDMA R99 scheduling and retransmission control in RNC

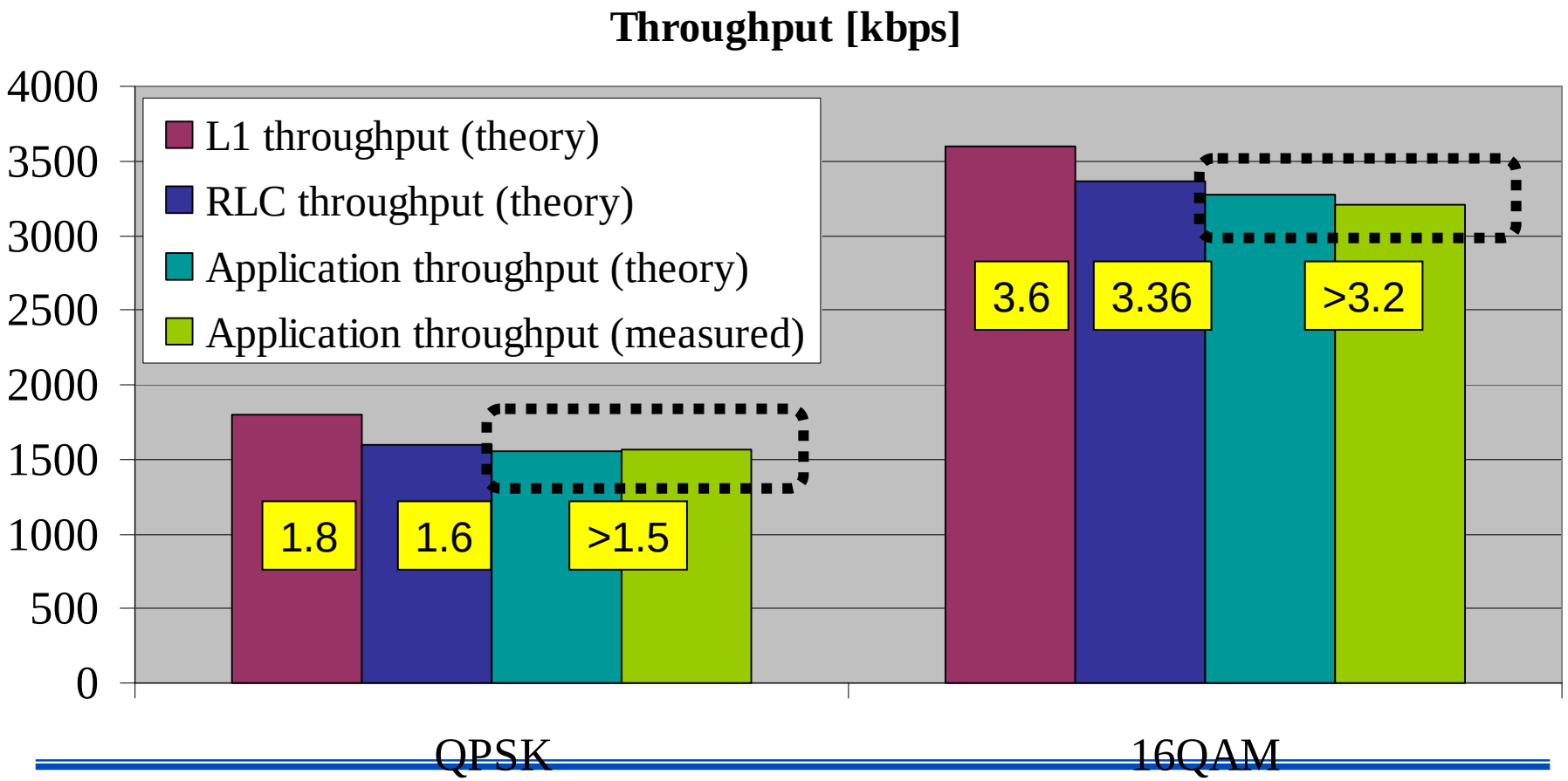
HSDPA – some UE categories

- Theoretical peak bit rate up to 14 Mbps
- 1.8 Mbps and 3.6 Mbps capabilities first in market

Max. number of HS-DSCH codes	Minimum inter-TTI interval	Bit rate	QPSK	16QAM
5	1-3	3.6 Mbps	Yes	Yes
10	1	7.2 Mbps	yes	yes
15	1	10.1 Mbps	Yes	Yes
15	1	14.4 Mbps	yes	Yes
5	1-2	1.8 Mbps	yes	no

HSDPA throughput meets theory

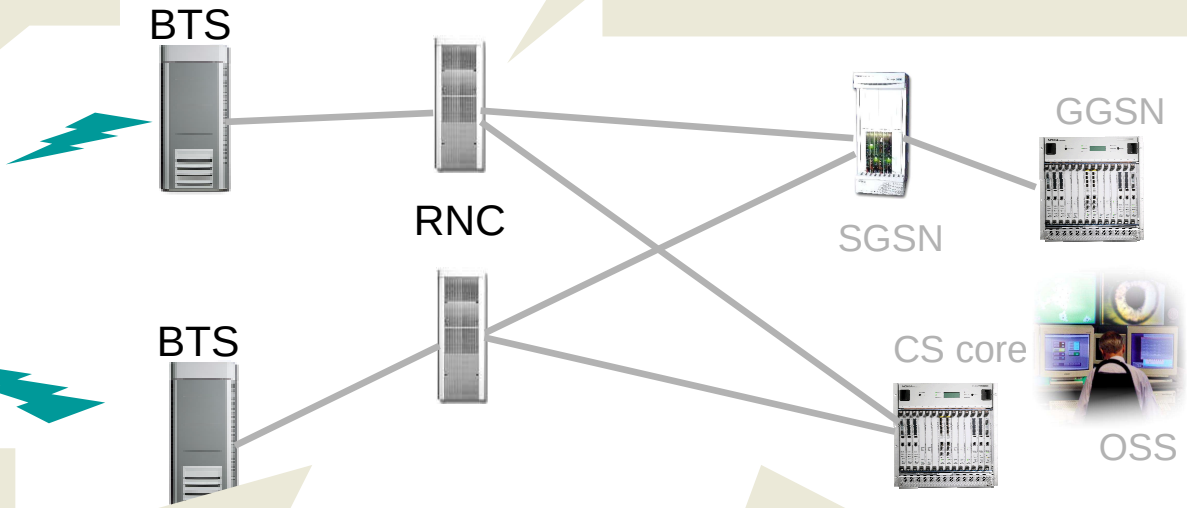
- Maximum bitrates reached in the field



HSDPA network planning

HSDPA air-interface
- Amount of users and traffic ?
- Terminal capabilities in the field?
- Achievable HSDPA capacity?
- Achievable HSDPA coverage?
- Impact on Rel'99 traffic?
- HSDPA mobility

RNC
- RNC SW-upgrade
- RNC capacity and connectivity for HSDPA
- Parameter settings
- IuPS transmission capacity for HSDPA



End-user HSDPA experience
- New services?
- Impact on existing services?
- Service quality, KPI's?
- Service continuity with GSM?
- Provisioning?

BTS & Iub
- BTS SW-upgrade
- BTS HW capacity for HSDPA
- Parameter settings
- Carrier/power allocation
- Iub transmission capacity for HSDPA

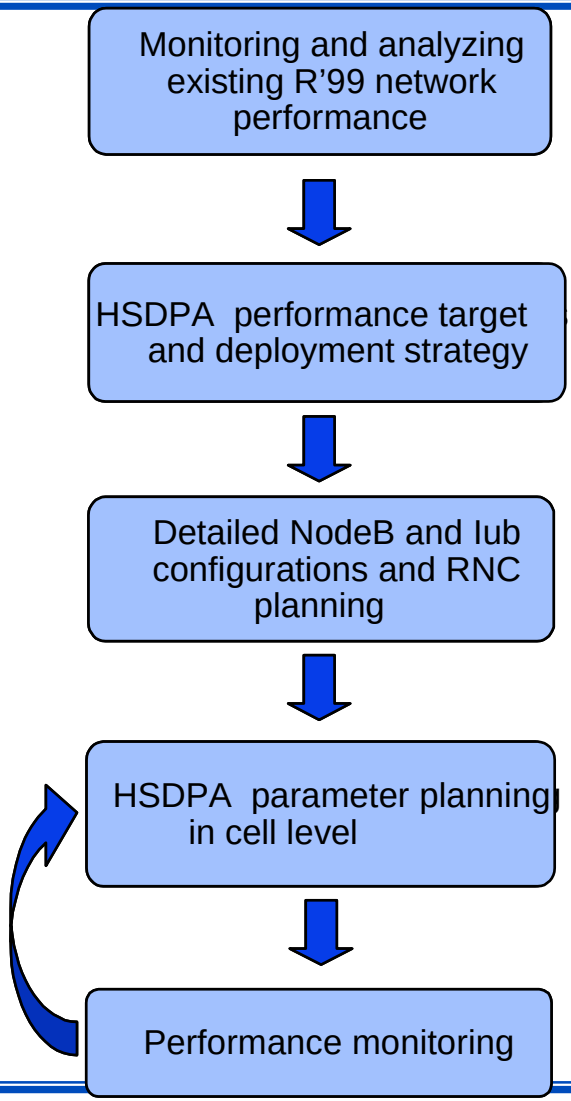
Core network and OSS
- SW-upgrades
- PS/CS core capacity
- HSDPA performance monitoring
- HSDPA troubleshooting

HSDPA dimensioning process

Typical dimensioning steps for HSDPA:

1. Traffic engineering
   - Operator usually defines a traffic mix with QoS targets
   - ⇒ Estimated simultaneous number of connections per bearer/service type
2. Node configurations
   - ⇒ Carrier configuration (1+1+1, 2+2+2, 3+3+3 or etc.)
   - ⇒ Baseband HW configuration
3. Iub configurations
   - Number of NodeBs, carrier configuration and simultaneous number of connections per bearer needed as an input.
   - ⇒ Number of E1 lines per NodeB
4. RNC configurations
   - Iub results needed as an input.
   - Areas that should be covered by one RNC location.
   - ⇒ Number of RNCs and configurations

HSDPA planning process



HSDPA planning process

1. **Monitoring and analyzing existing R99 network performance**
   - Average used NodeB power
   - Average NodeB HW utilization
   - SHO overhead
2. **Dimensioning, preplanning and deployment strategy**
   - Needed NodeB power resources for HSDPA
   - HSDPA strategy: Hot spot or whole area coverage, dedicated or shared carrier
3. **Parameter planning**
   - Parameter priorities and power thresholds
   - Shared carrier
     - Power allocation for HSDPA
   - Dedicated carrier
     - Directed RRC setup for 2nd carrier
   - Mobility
4. **Performance monitoring**
   - Counters and online monitoring