HSDPA radio network planning

S-72.4210 PG Course in Radio Communications

Tommi Heikkilä (45444T)
Outline

• Introduction
• HSDPA Deployment
• HSDPA Cell Planning
• Summary
• References
• Homework
Introduction

HSDPA (High Speed Downlink Packet Access)

• Described in 3GPP Release 5 specifications
  – Enhances peak download data rate from current 384 kbps up to a theoretical maximum downloading peak rate of 14.4 Mbps (10.7 Mbps with ¾ coding rate)
  – Aimed for interactive and background services but streaming is also considered

• HSDPA brings benefits for both operators and end-users
  – Higher data rates for end-users
  – Larger and cost efficient capacity in the radio network
  – Opportunity to deliver services - existing ones and new ones - at a lower cost of bit

• Requires investments to R99/R4 UMTS (WCDMA) network
  – Affects radio network HW and SW, core network SW, and transmission network HW
  – Can be deployed using small upgrades, not required for all BSs, RNCs
  – Does not require a completely new network structure
  – Protecting the current investments made to the network
Introduction

HSDPA Basics

- In order to reduce Round Trip Time (RTT) new features have been implemented in BS, closer to the air interface

  - **Adaptive Modulation and Coding (AMC)**
    - Depending on UE channel conditions (CQI)
    - QPSK, 16QAM
    - Coding rate (1/4 – 3/4)
    - Data rate adapted on 2 ms time basis

  - **Fast Retransmission**
    - Hybrid Automatic Repeat reQuest (HARQ)
    - UE soft-combines data
    - Reduced RTT

  - **Fast Packet Scheduling (PS)**
    - Scheduling of users on 2 ms time basis

- New radio channels included for HSDPA
  - DL: HS-(P)DSCH, HS-SCCH
  - UL: HS-DPCCH

- It is important to note that downlink HSDPA is a shared data channel
  - End user throughput depends on the number of the other users on the same HSDPA cell
  - Capacity planning and dimensioning of HSDPA is different to non-real time (NRT) DCH bearer
Introduction
Key Network Impacts and Investments of HSDPA

- Increased processing power (H/W)
- RF power allocation to HSDPA
- Management of new device categories & signalling ch.
- Software upgrade

- Additional backhaul bandwidth to support higher data rates
- Additional capacity
- Software upgrade
- Additional capacity
- Extended QoS field for HSDPA devices (for data rates >8 Mbps)

Reference [4]
HSDPA Deployment Process

Assessment of existing R99 network

- Hardware configuration audit used to verify suitability for HSDPA

Analysis of existing R99 network performance

- Field measurement surveys to evaluate HSDPA performance
- Monitor and analyse network performance and used resources
  - Average used BS power for existing traffic
  - Mixed or separate carrier for HSDPA?
  - BS processing card, RNC, and Iub usage
  - Need for new elements?
  - SHO areas and overhead analysis provide information for planning HSDPA mobility and performance

HSDPA performance target definition and selection of deployment strategy

- Several design and upgrade options for coverage and capacity
- Depends on strategy and traffic load in existing R99 network
- When, how and where HSDPA is deployed into the network

Configuration and capacity planning

- Iub interface and Base Station configurations based on
  - Selected HSDPA deployment strategy
  - Cell average throughput requirements
  - For each Base Station
    - Carrier configuration (single or multi?)
    - HSDPA capable HW for traffic processing
    - Iub capacity and ATM or IP configurations
  - RNC
    - Feature activation and management on cell basis
    - HW processing capacity, interface capacity

Definition of parameter sets for HSDPA capable cells

- Parameter values should be chosen according to the dimensioning calculations and the approach chosen for HSDPA service quality
- Different for different site types
- Values should be updated as the traffic load evolves
HSDPA Deployment Coverage Options – Full Coverage

- Reduced UL coverage may arise due to interference
  - Interference issues need a lot of attention
- Mobility has to work well
  - Optional features may be required from vendors
- Inefficient radio and transmission capacity allocation
- Expensive to allocate HSDPA in all cells
  - Not suitable for cost efficient operation in the initial roll-out of HSDPA

Reference [3]
HSDPA Deployment Coverage Options – Hotspot and Cluster Coverage

- HSDPA allocated for already high R99 NRT DCH usage areas
  - Based on UMTS and GSM network traffic measurements
- Some mobility features needed but not necessarily for the basic operation
  - HSDPA <-> DCH transitions need support from vendors
  - Cluster coverage may need some mobility support
- Cost efficient for HSDPA roll-out as the capacity is added to those cells having highest possibility for HSDPA traffic

Reference [3]
HSDPA Deployment Coverage Options – Indoor Coverage

• Can potentially offer high average HSDPA throughput
  – Dedicated carrier frequency is useful
• Performance depends on SINR (Signal to Interference and Noise Ratio) conditions as in macro cells
  – Good isolation (=Geometry factor) from the macro cell layer
• Implementation options: Active or passive DAS, Repeaters, Indoor pico cells
• High number of antennas connected to the DAS (Distributed Antenna System) leading to cable losses
  – High power need to be assigned to HSDPA
• HSDPA indoor link budget should take into account the following
  – Low downlink transmit power radiated by the DAS
  – High orthogonality reducing the level of the cell’s interference
  – Lack of soft handover gain
  – No fast fading margin due to no power control
  – Reduced slow fading margin
  – Potentially high level of inter-cell interference from the macro cell layer
HSDPA Deployment
Layering Options – Single Layer (1 Carrier)

• Shared UMTS carrier for HSDPA and R99 DCH traffic
  – BS power shared for CCH, R99 DCH, and HSDPA traffic

• Effect on R99 DCH users must be considered
  – Suitable for cells with low to medium R99 traffic
  – Traffic measurement data required for decisions
  – R99 DCH traffic QoS should not decreased due to the introduction of HSDPA into the network -> some prioritisation rules needed
  – CPICH Ec/No degradation -> UEs might camp on GSM

• Cost efficient solutions
  – Initial network set-up for most operators
  – No extra costs such as amplifiers, filters, combiners etc… needed for implementing additional carriers to BTSs
HSDPA Deployment
Layering Options – Multiple Layers (2-3 Carriers)

- 1\textsuperscript{st} carrier can be dedicated for R99 DCH traffic
- 2\textsuperscript{nd} carrier can be fully or partly allocated for HSDPA enhanced capacity and performance
  - More carriers are added to high traffic areas (Hotspots/Cluster)
  - Based on traffic predictions and measurements
  - Dedicated carrier if there is high R99 traffic in the area
- BS power resources for R99 DCHs better guaranteed
- HSDPA users directed or handed over to a second carrier
- Additional BS equipment needed for 2\textsuperscript{nd} carrier -> costs
- Fully dedicated HSDPA carrier is not a practical solution with the current handover and load control features vendors are offering
- Multiple mixed carriers with R99 & HSDPA traffic would be cost efficient solutions for the operator but vendors do not have adequate service and load sharing features
HSDPA Cell Planning

General

• Aims to the best HSDPA coverage, capacity and performance
  – Depends on radio propagation and SINR conditions
  – Clear dominance areas and good cell isolation
  – Not too large SHO areas (HSDPA does not work in SHO)

• Geometry factor is one of the most important parameters affecting the HSDPA throughput
  \[ G = \frac{I_{or}}{I_{oc}} \]
  – Own cell total wideband received power, \( I_{or} \)
  – Other cell total received power plus noise power, \( I_{oc} \)

• R99 network should be planned well for high HSDPA performance
  – Interference from neighboring sites should be limited
  – Not too excessive soft or softer handover (SHO) areas
  – SHO overhead more crucial for HSDPA than for R99 traffic

• High-rise overlay sites on the same carrier should also be avoided

• The best HSDPA performance is achieved in line of sight scenario
HSDPA Cell Planning

BS Power Usage

- HSDPA can use the remaining output power not used by R99 DCHs
- Implies possibilities for a more efficient usage of the available BS output power

- To achieve good performance in a WCDMA network all parameters determining interference levels need to be well tuned
- Increased average BS output power can increase the inter cell interference in WCDMA, and can then impact the overall system capacity

Reference [3]
HSDPA Cell Planning
Air Interface Dimensioning

• The most important dimensioning target for HSDPA is the average throughput
  – Depends on the amount of power allocated for HSDPA

• How much power should be allocated for HSDPA?
  – Enough to achieve the HSDPA throughput targets
  – Some power should be reserved for R99 DCH traffic

• HSDPA downlink data is carried on a shared channel
  – Different variables have to be considered in HSDPA dimensioning as in NRT DCH data bearer dimensioning
HSDPA Cell Planning
Air Interface Dimensioning - Coverage and Throughput

• HSDPA can enable a wider coverage than R99 due to the adaptive modulation, coding and the fast scheduler in the BS
  – Works at the cell border of a R99 DCH, but the user throughput can vary significantly

• Throughput is not a single concept in HSDPA
  – Average HSDPA cell throughput for single users
  – Minimum throughput at the cell edge for a single user
  – Average HSDPA users throughput

• HSDPA coverage can be understood as a combination of these and all of them can have different dimensioning targets

• The average HSDPA cell throughput and the minimum throughput at the cell edge for a single user are not dependent on the number of simultaneous HSDPA users in the cell
  – Commonly used to set the dimensioning target for HSDPA coverage

• HSDPA throughput depends directly on the radio channel conditions
  – Changing rapidly all the time due to the fast fading of the radio channel (BS uses link adaptation)
  – The achieved throughput is different in every TTI (2 ms)

• Average throughput in a certain location can be estimated if the average SINR is known
HSDPA Cell Planning
Air Interface Dimensioning – UL Link Budget

- Normal WCDMA UL link budget calculation
  - Coverage is uplink limited
- The UL data of the HSDPA connection is carried on an associated DPCH, which is a normal NRT data bearer
  - 64, 128 and 384 kbps usually supported by the vendors in UL
- Additional margin is required in the UL link budget to take into account the power requirements of HS-DPCCH
  - Depends on the UL bearer data rate

Reference [3]
HSDPA Cell Planning
Air Interface Dimensioning – DL Link Budget

• Using Eb/No or Es/No in the link budget would require
  that the bitrate or the number of codes is known
  – Bitrate and number of codes can change in every TTI (2 ms)
• Average SINR allows to create DL link budget for HSDPA
  – Does not depend on bitrate or number codes for HSDPA
  – Can be calculated when HSDPA power, BS total TX power, orthogonality and G-factor are known

\[
SINR = SF_{HSDPA} \times \frac{P_{HSDPA}}{P_{TOT\_TX}} \left[1 - \alpha + \frac{1}{G}\right]
\]

– \(SF_{HSDPA}\) is the Spreading Factor (16)
– \(P_{HSDPA}\) is the allocated transmission power of HS-PDSCH
– \(P_{TOT\_TX}\) is BS total power, including HS-PDSCH and HS-SCCH powers
– \(\alpha\) is the DL orthogonality in certain location in the cell
– \(G\) is geometry factor

<table>
<thead>
<tr>
<th>Base Station</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Max Tx Power (HSDPA)</strong></td>
<td>6.5 W</td>
</tr>
<tr>
<td><strong>Max Tx Power (HSDPA)</strong></td>
<td>38.1 dBm</td>
</tr>
<tr>
<td><strong>Tx Antenna Gain</strong></td>
<td>18 dBi</td>
</tr>
<tr>
<td><strong>Cable Loss</strong></td>
<td>4 dB</td>
</tr>
<tr>
<td><strong>EIRP</strong></td>
<td>52.1 dBm</td>
</tr>
<tr>
<td><strong>Receiver - Handset</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Handset Noise Figure</strong></td>
<td>8 dB</td>
</tr>
<tr>
<td><strong>Thermal Noise</strong></td>
<td>-108 dBm</td>
</tr>
<tr>
<td><strong>Background RSSI</strong></td>
<td>-100 dBm</td>
</tr>
<tr>
<td><strong>Planned DL load</strong></td>
<td>87 %</td>
</tr>
<tr>
<td><strong>Interference Margin</strong></td>
<td>8.9 dB</td>
</tr>
<tr>
<td><strong>Interference Floor</strong></td>
<td>-91.1 dBm</td>
</tr>
<tr>
<td><strong>SINR</strong></td>
<td>2.1 dB</td>
</tr>
<tr>
<td><strong>Service processing gain</strong></td>
<td>12.0 dB</td>
</tr>
<tr>
<td><strong>Rx Antenna Gain</strong></td>
<td>0 dBi</td>
</tr>
<tr>
<td><strong>Body Loss</strong></td>
<td>0 dB</td>
</tr>
<tr>
<td><strong>Receiver Sensitivity</strong></td>
<td>-101.1 dB</td>
</tr>
<tr>
<td><strong>DL Fast Fade Margin</strong></td>
<td>0 dB</td>
</tr>
<tr>
<td><strong>DL Soft Handover Gain</strong></td>
<td>0 dB</td>
</tr>
<tr>
<td><strong>Max. Path Loss</strong></td>
<td>153.2 dB</td>
</tr>
</tbody>
</table>
HSDPA Cell Planning
Air Interface Dimensioning - Coverage and Throughput

Supported effective data rate [Mbps]

Instantaneous per-TTI SINR [dB]

Shannon limit:
$5\text{MHz} \cdot \log_2(1 + \text{SINR}/16)$

QPSK
16QAM

HSDPA link adaptation curve

15 HS-PDSCH allocation
(Rake, Pedestrian-A, 3km/h)

Reference [6]
HSDPA Cell Planning
Key Parameters for HSDPA

- HSDPA transmission power depends on the implementation strategy, HSDPA throughput targets and DCH traffic load
- For a mixed R99 and HSDPA traffic power is around 4 to 7 W
- For a dedicated HSDPA carrier power is around 10 to 12 W
  - Assumed that maximum transmission power of the BS is 20 W
- Power must be high enough to handle traffic and signaling channels
- Radio channel affects to the amount of power needed
- No power control for HSDPA power
- Too low power leads to no or low throughput
- Low cell power can be handled via more codes and lower code rate
- Too high power leads to possible overload situation and interference
HSDPA Cell Planning
Key Parameters for HSDPA

• Admission thresholds for DCH and HSDPA users
• Priority parameters between for DCH and HSDPA users
• Mobility parameters
  – Soft handover (SHO) is not applicable to HSDPA
  – Possible interruptions in the data transmission
  – Option 1, Channel switching between HS-DSCH and DCH (R99/R4)
  – Option 2, Change of serving HS-DSCH cell
  – Separate Soft handover (SHO) parameters can be applied for HSDPA if supported by network vendor
HSDPA Cell Planning
Planning Tools

• Should provide the planner with HSDPA network coverage, quality, and capacity figures
  – HSDPA equipment modelling including modulation schemes and throughputs vs. pilot C/I
  – HSDPA activation at cell or cell group level
  – HSDPA throughput prediction plot
  – CQI prediction plot
  – Ec/No HS-PDSCH prediction plot
  – HSDPA SIR plot

• Can be based on
  – Basic DL power estimates for HSDPA or
  – Monte-Carlo Simulations
    – Accurately model HSDPA capabilities
    – Random user distribution and simulation of HSDPA-related radio channels
    – Simulation provides coverage- and capacity related plots and statistics for use in HSDPA planning

• Atoll, TEMS CellPlanner (Ericsson)
HSDPA Cell Planning
Planning Tools

Max Data Rate [kbps]
- >10000.00
- > 7000.00
- > 5000.00
- > 4000.00
- > 2000.00
- > 1750.00
- > 1500.00
- > 1250.00
- > 1000.00
- > 600.00
- > 300.00
- > 100.00

CQI
- 30.00
- 28.00
- 26.00
- 24.00
- 22.00
- 20.00
- 18.00
- 16.00
- 14.00
- 12.00
- 10.00
- 8.00
- 6.00
- 4.00
- 2.00
Summary

- HSDPA offers high data rates for end-users and cost efficient capacity enhancement to the WCDMA radio network
- HSDPA requires investments to R99/R4 UMTS (WCDMA) network elements
- Before implementing HSDPA the R99 network needs element and performance audit to make sure HSDPA can be efficiently deployed
- HSDPA strategy and performance targets need to be defined before detailed configuration, capacity and parameter planning can be executed
- HSDPA coverage and layering options for specific areas need to be decided by the operator with the costs and vendor feature restrictions in mind
- HSDPA performance depends on radio propagation, SINR conditions, cell dominance area, cell isolation, and SHO overhead
- The most important dimensioning target for HSDPA is the average throughput
- SINR requirement is more useful in link budget than Eb/No requirement
- HSDPA TX power, admission, priority, and mobility parameters are important
References

Homework

• What is the maximum pathloss for HSDPA service?
  – HSDPA transmission power, $P_{\text{HSDPA}} = 5$ W
  – Base station antenna gain = 16.5 dB
  – Base station cable loss = 3 dB
  – Mobile receiver noise figure = 7 dB
  – Planned DL load = 75 %
  – Minimum SINR requirement = 2.5 dB
  – Service processing gain = 12 dB
  – Rx antenna gain = 2 dBi
  – Body loss 1 dB

• Why soft handover gain cannot be used for HSDPA DL link budget?
• Why is SINR useful in HSDPA DL link budget?