WCDMA radio network planning

S-72.4210 PG Course in Radio Communications

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Outline

- Introduction
- WCDMA radio network planning process
- Coverage enhancing methods for WCDMA networks
- Maximizing WCDMA network capacity
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Introduction
WCDMA has changed radio network planning

- WCDMA technology has set new requirements to radio network planning
- Multiservice environment (CS, PS) with different service requirements
- All frequency dependent elements have to be updated and taken into account during planning (antennas, cables, power amplifiers, low noise amplifiers, filters, combiners…)
- WCDMA has a strong impact on radio interface management and thus also GSM-based radio network planning principles and planning and measurement tools need updates
- WCDMA air-interface: Capacity and coverage coupled, Fast power control, Planning a soft handover overhead, Cell dominance and isolation, Vulnerability to external interference
- All the WCDMA cells can use the same frequency -> reuse = 1
- Interworking between WCDMA and GSM has to planned
- The state of WCDMA network is changing fast and it is important to have an immediate feedback loop from the operational network, such as performance measurements
- WCDMA radio network planning is closely related to the optimisation of radio network

Introduction
Differences of GSM and WCDMA network planning

Claimed often: "GSM RF planning is more difficult than WCDMA RF planning"

- Partly true, but
  - WCDMA network serves users with various services (Release 99 PS 8-384 kbps, CS 5.95 – 64 kbps) and the aspects of these services has to be taken into account
  - Many aspects of planning are more closely intertwined to each other in WCDMA
- Also wideband nature of WCDMA (5 MHz) compared to GSM (200 kHz) imposes new criteria in modelling the propagation environment
- Differences occur in coverage and capacity planning (detailed planning phase)
- In GSM
  - Coverage is planned separately after network is dimensioned
  - Capacity and frequency planning is executed simultaneously
- In WCDMA
  - Coverage and capacity are planned simultaneously
  - Capacity requirements and traffic distribution affect coverage
  - Frequency and code planning can be executed separately

Introduction
Differences of GSM and WCDMA network planning

- WCDMA operates in the frequency band of 2100 MHz, which is much more higher than the 900 MHz and 1800 MHz typically in GSM
- Higher user data rates require better signal quality, Eb/No

-> radio propagation in WCDMA is not equivalent to GSM

- Old GSM base station coverage areas are not necessarily valid for WCDMA not being in the most optimum locations for WCDMA coverage
- Possibility to reuse the existing GSM base station sites depends heavily on the implemetation strategy and on the traffic forecasts

-> costs due to implementing new WCDMA base stations

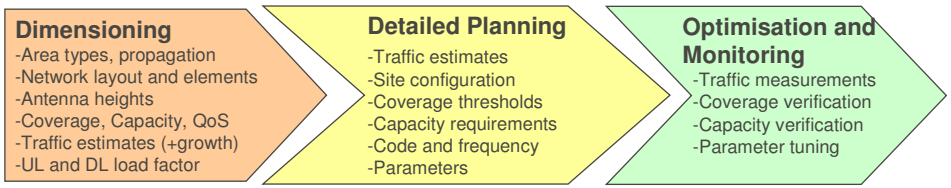
- In low traffic areas, WCDMA planning is quite similar to GSM planning as the load does not have a great impact on coverage
- In high traffic areas, unlike for GSM, there is no clear split between coverage, interference and capacity planning of WCDMA

Introduction
Radio network planning strategies for WCDMA

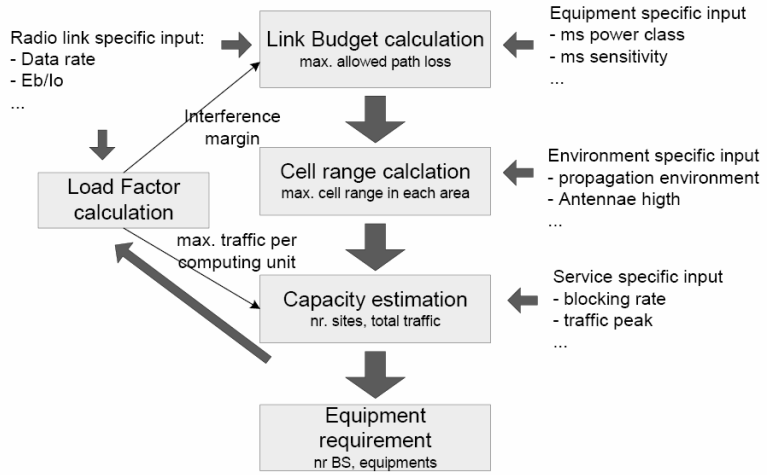
- WCDMA radio network planning strategy must be done before actual planning is started
- Overall layout of the radio network and the evolution path should be decided in order to reach the optimal network configuration for quality, capacity, coverage, and cost
- Analysis of existing GSM radio network configuration and needs of WCDMA network for a certain planning area is needed
  - GSM900 used as coverage layer for idle and (E)GPRS service
  - GSM1800 used as capacity layer for voice calls
- Next the WCDMA major topology or layout (antenna heights and site density) must be decided in order to define the radio propagation environment and to fix planning principles
  - Decision what services to enable in WCDMA and what to enable in GSM/(E)GRPS
  - Continuous coverage wherever implemented in order to maintain a consistent service level
  - GSM/(E)GPRS layer used as reference for WCDMA layer when planning
  - Co-siting and co-sectorisation approach is preferable for GSM/WCDMA dualmode network layout
  - More WCDMA BTS sites needed to have continuous coverage when using GSM900 sites
  - WCDMA coverage should be equivalent to GSM coverage layer in order to optimize handovers
  - Interworking strategy between GSM and WCDMA need attention

WCDMA radio network planning process
Planning phases

- The overall radio network planning goal is to maximise the coverage and capacity while meeting the key performance indicators (KPIs) and quality of service (QoS)
- Basic WCDMA planning process similar to GSM but detailed planning phases need modifications
- Traffic level has to be considered continuously in WCDMA radio network planning
  - Distribution of traffic between voice and data should be estimated at each base station coverage as accurately as possible
  - Location of users should be known as exactly as possible (hard to forecast)
  - Regional traffic hot spots should be identified
  - Base station locations should be selected so that they are on the traffic hot spots



WCDMA radio network planning process
Dimensioning - Process



WCDMA radio network planning process
Dimensioning - General

- Traffic estimation and growth forecasts based on market analysis (hypothetical data)
  - GSM/(E)GPRS traffic measurements, WCDMA capable UE penetration in NW
- Area to be planned for WCDMA based on the strategy and license requirements
  - Whole country coverage? Percentage of population? Cities with high population?
- Goal is to estimate of the network layout and elements needed
  - Approximate number of necessary base station sites and base stations (also RNCs and core elements)
  - Antenna heights
- The first configuration estimates and requirements for coverage, capacity and quality of service
  - Average values for link budget, cell size, capacity, and initial network configuration are estimated
  - The capacity requirements and the overall quality of service targets determine the selection of the RAN transport network and the transport interfaces of base stations and RNC
- The coverage area for one cell is a hexagonal configuration estimated from: $S = K \cdot R^2$
  - S = coverage area, R = maximum cell range, K = Constant accounting for the sectors, K(Omni)=2.6
- In this phase a fixed load is assumed for all base stations within the planned area
- Load level can be estimated using UL and DL load factors based on capacity estimates
- MS Excel can be used as a basic dimensioning tool for example to license applications
- GSM operators can use dimensioning to estimate the service capability of existing network
- More exact values for individual sites are calculated in the detailed planning phases

WCDMA radio network planning process
Dimensioning – Link budget

- Link budget must be calculated for different service profiles and environments, and cell-breathing phenomenon must be taken into account in coverage threshold settings and cell range calculations
- Better link budget leads to lower TX power levels, low interference, high capacity

UMTS UL Link budget (Speech)	
TX	
Mobile max power = 0.125W (dBm)	21
Body loss - Antenna gain (dB)	2
EIRP (dBm)	**19**
RX	
BTS noise density (dBm/Hz) =Thermal noise density + BTS noise figure	-168
RX noise power (dBm) =-168+10*log(3840000)	-102,2
Interference margin (dB)	3
Noise + interference (dBm)	-99,2
Process gain (dB), 12.2k voice =10*log(3840/12.2)	25,0
Required Eb/No for speech (dB)	5
Antenna gain (dBi)	17
Cable and connector losses (dB)	3
Fast fading margin (dB) =slow moving mobile	4
RX sensitivity (dBm)	**-129,1**
Total available path loss (dB)	**148,1**
Dimensioning	
Log normal fading margin (dB)	7
Indoor / In-vehicle loss (dB)	0
Softhandover gain (dB)	3
Cell edge target propagation loss (dB)	**144,1**
Okumura-Hata cell range (km) L=137.4+35.2LOG(R)	**1,55**

WCDMA radio network planning process
Dimensioning – UL load factor

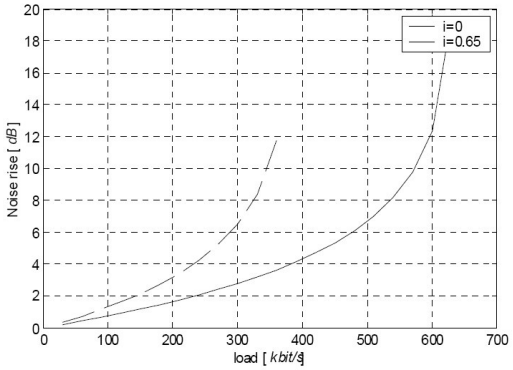
- UL load factor describes the amount of increase of the interference (noise rise) due to the multiple access

η_{ul}	Uplink load factor, generally uplink load of 0.5 – 0.7 is used in dimensioning
N	Number of users
vj	L1 activity factor of user j (0.67 for voice ul, 0.63 for voice dl, 1.0 for data)
Rx_Eb/No_j	Received EbNo of user j
W	WCDMA chip rate; 3.84 Mcps/s
R_j	Data rate of user j
A_j	Power rise of user j due to power control
i	Ratio of other to own cell interference. In uplink, the value depends on the BTS sectorisation:

Micro omni: 25% - 55%

Macro cell:

- Omni: 55%
- 2-sector: 55%
- 3-sector: 65%
- 4-sector: 75%
- 6-sector: 85%



$$\eta_{UL} = \sum_{j=1}^{j=N} v_j \frac{Rx\_E_b / No_j}{W / R_j} \times (1 + a_j \times i)$$

Noise rise (dB) = - 10 LOG (1-η_{UL})

WCDMA radio network planning process
Dimensioning – DL load factor

- The interference degradation margin in downlink to be taken into account in the link budget due to a certain loading

  Loading = - 10 LOG (1-η_{DL})

- DL load factor: $\eta_{DL} = \sum_{i=1}^{I} \left[\frac{\rho_i R_i v_i}{W} \left((1-\alpha_i) + \sum_{\substack{n=1, \\ n \neq m}}^{N} \frac{LP_{mi}}{LP_{ni}} \right) \right]$

LP_{mi} is a link loss from the serving BS m to MS i,
LP_{ni} is the link loss from another BS n, to MS i,
ρ_i is the transmit $\frac{E_b}{I_0}$ requirement for MS i, including soft HO combining gain an the average power rise due to the fast power control,
N number of BS,
I number of connections in a sector,
α_i orthogonality factor.

The other to own cell interference in downlink $i_{DL} = \sum_{\substack{n=1, \\ n \neq m}}^{N} \frac{LP_{mi}}{LP_{ni}}$

WCDMA radio network planning process
Detailed planning - Configuration planning

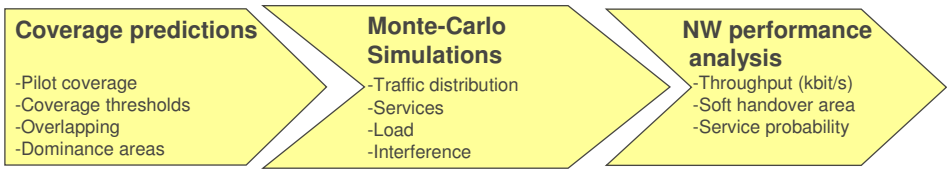
- Target is to find the optimum configuration of BTS in each site in planning area or nominal configuration for different parts of the planning area
- Several factors to be considered:
  - Propagation environment (macro, micro, indoor cell)
  - Site characteristics (indoor, outdoor, wall, mast)
  - Required capacity and coverage
  - BTS antenna configuration has strong impact on interference level and on capacity
- Planner must select optimum combination among several options to fill quality requirements
- Main tool is link budget and cell size calculations
- Result of configuration planning is a detailed base station configuration and a list of antenna line elements for different network evolution phases and the maximum uplink and downlink pathloss information for coverage predictions

WCDMA radio network planning process
Detailed planning - Coverage and capacity planning

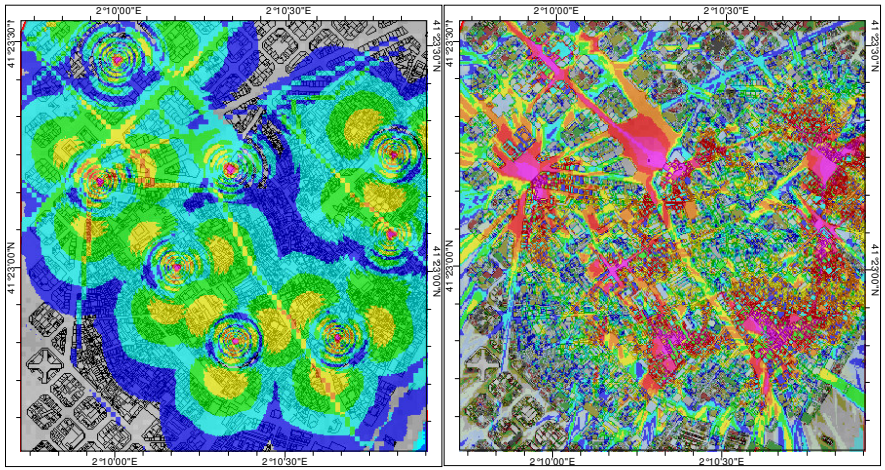
- Combines the use of link budget calculations with path loss predictions and interference analysis
- Objective for coverage is to obtain the ability of the network to ensure availability of services in the entire service area
- WCDMA coverage planning can be done as in GSM by using pathloss information and prediction models such as Okumura-Hata if there is no other traffic (one user only) and thus no interference in the radio network
- When traffic is included, cell-breathing occurs and cell range, as well as coverage, is dynamic, based on the load of the network
- Cells' coverage areas are linked to each other as a function of mobile terminal locations
- Maximum load or capacity of the WCDMA network depends on the coverage area (cell overlapping, depth of propagation slope, etc.), base station locations, antenna configurations (height, direction, beam width, tilting, etc.)
- Traffic expectation is important input, but also difficult to define
- Service coverage performance should be specified on a per service and per clutter basis for indoor, outdoor, and in-car environments
- Service quality objectives are defined in terms of call blocking probabilities applied to speech, circuit switched data, and packet switched data

WCDMA radio network planning process
Detailed planning - Coverage and capacity planning

- Coverage prediction with thresholds in order to estimate pilot channel coverage and dominance areas
- System level simulations for a certain cluster of cells to estimate maximum traffic or load of the network in different cells
  - In Monte-Carlo type of simulations a certain number of mobiles are located over a coverage area and distribured homogenously or non-homogenously
  - Results inlude coverage, capacity, and interference-related information (BTS TX powers, max. number of mobiles in each cell, onw-cell-to-other-cell interference)
- Estimated if BTSs are located correctly based on performance analysis
- If changes are made to BTSs locations or to other parameters new simulations are required over the whole cluster of cells



WCDMA radio network planning process
Detailed planning - Coverage and capacity planning

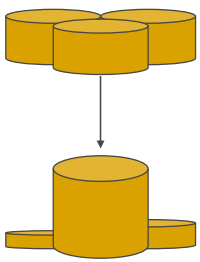


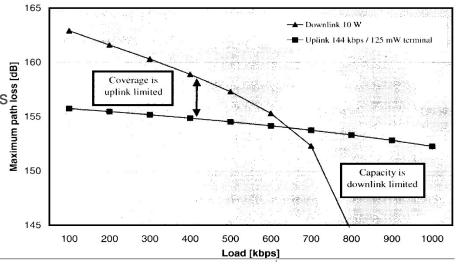
Statistical propagation model

Ray-Tracing propagation model

WCDMA radio network planning process
Detailed planning - Coverage and capacity planning

- Erlang B formula gives too pessimistic results for capacity
- Soft capacity in WCDMA = interference sharing between neighbouring cells
- Cell capacity is determined by:
  - Site location
  - Closeness of the neighbouring cells
  - Geographic distribution of the traffic loading the network
- Outcome of capacity planning and simulations
  - number and location of base station sites
  - configuration of the base station sites
  - capacity and coverage of the base station sites per service
  - throughputs in uplink and downlink
  - number of users per service





WCDMA radio network planning process
Detailed planning - Code and frequency planning

- Simple tasks from a network planning point of view
- Main task for network planning is allocation of scrambling codes for the downlink
  - 512 primary scrambling codes (0-511) to separate cells in DL direction
  - Allocation is executed using planning tools to avoid possibility of errors
- Example scrambling code planning criteria
  - Same scrambling code and frequency with nearby WCDMA cells should be avoided
  - One GSM cell should not have two or more neighbour WCDMA cells with same frequency and scrambling code -> code reuse distance
- Frequency planning has minor importance compared with GSM
- In Finland every 3G (WCDMA) operator has 3 x 5 MHz (UL & DL) carriers
  - Possible to use different cell layers (macro, micro, pico/indoor) in different carriers
  - Hierarchical cell structures available also if needed
  - Intra- and inter-operator Adjacent Channel Interference (ACI) problems should be examined and solved

WCDMA radio network planning process
Detailed planning - Parameter planning

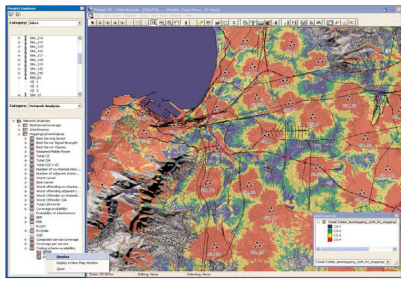
- The purpose of planning parameters is to optimize the usage of radio network and to fully utilise the planned coverage and capacity
- Parameters are planned together with coverage and capacity planning
  - Radio resource management (Admission, Load, Power, Handover control, Packet scheduling)
  - Measurements
  - Idle mode camping
  - Connection establishment
  - Connected mode
- Common channel (CPICH, P-CCPCH etc…) powers are important
  - Need careful planning, the planning is vital for good coverage and capacity
  - Are relatively large compared to dedicated channel powers
  - Are not power controlled since they need to be decoded everywhere in the cell area
- Usually default or vendor recommended values are used for the network launch
- Optimisation of different parameters are needed still because networks are different and exactly same parameter values cannot be used for some example (SHO, ISHO etc…)

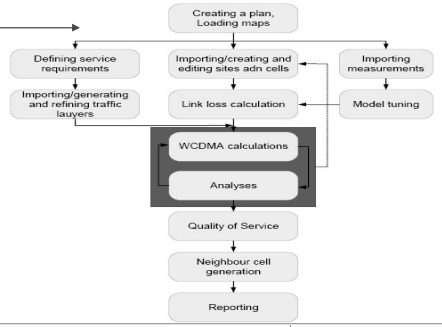
WCDMA radio network planning process
Optimization and monitoring

- WCDMA like GSM network require continuous optimization and monitoring because mobile users' locations and traffic behavior vary constantly
- Measurements -> Analysis -> Updates to configurations and parameters
- Optimization and monitoring is to check that the planned coverage, capacity and quality has been reached with efficient resource usage and KPIs operator has defined are met
- Network element monitoring with counters, measurements with scanner and test mobile
- KPI monitoring and field measurements are needed for optimization
  - Traffic, deviation, mixture
  - Soft handover overhead (usually lower than 40%)
  - Average TX power (e.g. MS transmission power)
  - Average RX power
  - Call establishment success, packet call delay
  - Dropped calls
  - Interference (Pilot pollution due to high-elevation sites with RF large coverage)
  - Overload situations (lack of element capacity, interference)
  - Handovers per cell (soft handovers, hard handovers, Inter-system handovers
  - Throughput and delay with packet switched services (Web, FTP, MMS, Streaming, PoC)

WCDMA radio network planning process Planning environment and tools

- WCDMA planning must be supported by different SW and HW tools during different planning phases to allow planner to optimise the BTS configurations, antenna selections and directions in order to meet coverage, capacity, QoS with minimum costs
- During detailed planning, an advanced GUI planning tool based on digital maps is needed to get reliable coverage predictions
- Tools must have interfaces to measurement systems and the network in order to import and export data (measurement, and traffic import, parameter and plan export)
- Tools must support RNP work flow





Coverage enhancing methods for WCDMA networks

- Coverage is limited by UL due to the lower TX power of mobile and BTS RX-sensitivity
- Mast head amplifiers reduce the the composite noise figure of the base station receiver
  - Uplink link budget is improved and the service coverage improved
  - Problems if cell is already DL limited -> DL capacity decreases more
- Active antennas include the low noise amplifier as an integrated part of the antenna itself
- Antennae bearing and tilting can reduce the interference leakage further
- Higher-order receive diversity not generally feasible to deploy with more than 4 branches
- Sectorisation improves both system capacity and service coverage at the same time
  - Antenna selection and placing is a critical part of planning
- Repeaters provide a solution for extending the coverage of an existing base station
  - Problems if repeated cell is already DL limited -> DL capacity decreases more
- Adding more sites is expensive
- Enhance RX –sensitivity leads usually to higher equipment cost
- Multi-user detection and interference cancellation in the future

Maximizing WCDMA network capacity

- DL capacity is considered more important than UL, asymmetric traffic
- Due to the less multipath microcell capacity better than macrocell
- Adding frequency layers for WCDMA brings more capacity
- Power splitting between frequencies
- Adding cells and sites is expensive and more possible interference
- Power splitting between sectors (one power amplifier for all sectors)
- Sectorisation (every sector has its own power amplifier)
- Transmit diversity
- Lower bit rate codecs for speech (AMR 5,95 – 12.2 kbps supported)
- Multibeam antennas
- Indoor cells with better interference isolation -> more capacity
- Network evolution with features like HSDPA, HSUPA, MIMO

Summary

- WCDMA network radio planning has the same basic philosophy as GSM radio network planning but varies in detailed planning (capacity and coverage)
- Coverage and capacity planning are related in WCDMA
- Code planning is unique to WCDMA, frequency planning is unique to GSM
- WCDMA frequency planning is simple as all the cells use same frequency
- WCDMA link budget covers the same basics as GSM, but uses different parameters and depends on changes in data rate and spreading factor used for different services
- Interference estimation is crucial already in the coverage prediction phase
- WCDMA system performance cannot be determined analytically and thus link-level and system simulations are needed to define performance in different scenarios
- In WCDMA capacity planning it must be remembered that service data rates depend on the distance from base stations
- Base station locations, number of sectors, antenna directions and configurations are important and need to be considered together in WCDMA network
- Optimization and monitoring are of great importance in WCDMA

Preferences

- Dinan, Kurochin, Kettani, “UMTS Radio Interface System Planning and Optimization”, Bechtel Telecommunications Technical Journal, 2002.
- Laiho, Wacker, Novosad, “Radio Network Planning and Optimisation for UMTS”, John Wiley & Sons, 2002.
- Lempiäinen, Manninen, “UMTS Radio Network Planning, Optimisation and QoS management”, Kluwer Academic Publishers, 2003.
- Holma, Toskala, “WCDMA for UMTS”, John Wiley & Sons, 2004.

Homework

- Calculate the UL link budget for indoor user of 384 kbps packet switched service according to following parameter values:
  - Frequency = 1950 MHz
  - MS TX power = 24 dBm
  - MS antenna height = 1.5 m
  - MS antenna gain = 2.5 dBi
  - MS body loss = 1.5 dB
  - BTS noise figure = 6 dB
  - Interference margin = 3 dB
  - Required Eb/No for 384 kbps = 1.7 dB
  - BTS antenna height = 30 m
  - BTS antenna gain = 13 dBi
  - Cable and connector losses at BTS = 2 dB
  - Fast fading margin (PC headroom) = 3,7 dB
  - Log normal fading margin = 7 dB
  - Indoor loss = 12 dB
  - Soft handover gain = 2 dB
  - K (Omni) = 2.6

- What is the maximum UL pathloss (dB)?
- What is the maximum cell coverage area with hexagonal approximation and using Okumura-Hata model (Slide 13)?
- Explain how could radio network planner enhance the UL coverage for the user? Justify 3 enhancements briefly with max couple of rows.