WCDMA network planning

Outline of the lecture

- Purpose of planning process.
- Peculiarities of 3G network.
- Dimensioning.
- Soft capacity.
- Capacity and coverage planning.
- Dynamic simulations.

Planning

- Planning should meet current standards and demands and also comply with future requirements.
- Uncertainty of future traffic growth and service needs.
- High bit rate services require knowledge of coverage and capacity enhancements methods.
- Real constraints
  - Coexistence and co-operation of 2G and 3G for old operators.
  - Environmental constraints for new operators.
- Network planning depends not only on the coverage but also on load.

Objectives of Radio network planning

- Capacity:
  - To support the subscriber traffic with sufficiently low blocking and delay.
- Coverage:
  - To obtain the ability of the network ensure the availability of the service in the entire service area.
- Quality:
  - Linking the capacity and the coverage and still provide the required QoS.
- Costs:
  - To enable an economical network implementation when the service is established and a controlled network expansion during the life cycle of the network.

What is new

Multiservice environment:

- Highly sophisticated radio interface.
  - Bit rates from 8 kbit/s to 2 Mbit/s, also variable rate.
- Cell coverage and service design for multiple services:
  - different bit rate
  - different QoS requirements.
- Various radio link coding/throughput adaptation schemes.
- Interference averaging mechanisms:
  - need for maximum isolation between cells.
- "Best effort" provision of packet data.
- Intralayer handovers

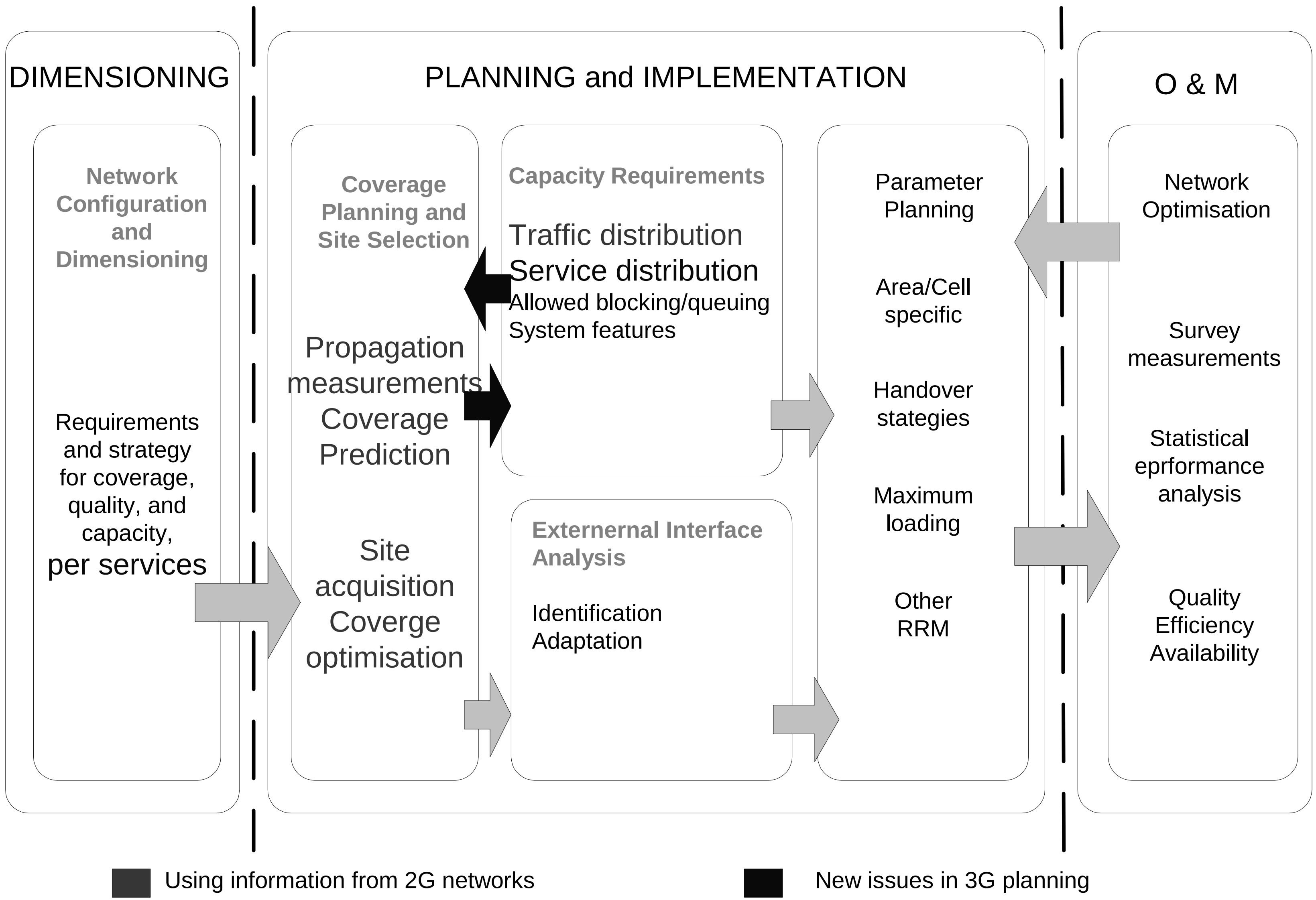
Air interface:

- Capacity and coverage coupled.
- Fast power control.
- Planning a soft handover overhead.
- Cell dominance and isolation
- Vulnerability to external interference

2G and 3G:

- Coexistence of 2G 3G sites.
- Handover between 2G and 3G systems.
- Service continuity between 2G and 3G.

Radio network planning process



Capacity estimation in a CDMA cell

$$-\frac{P_{0,0}}{CIR} + P_{1,0} + \ldots + P_{K_0,0} + \sum_{j=1}^{N} \sum_{k=1}^{K_j - 1} P_{k,j} + \eta = 0$$

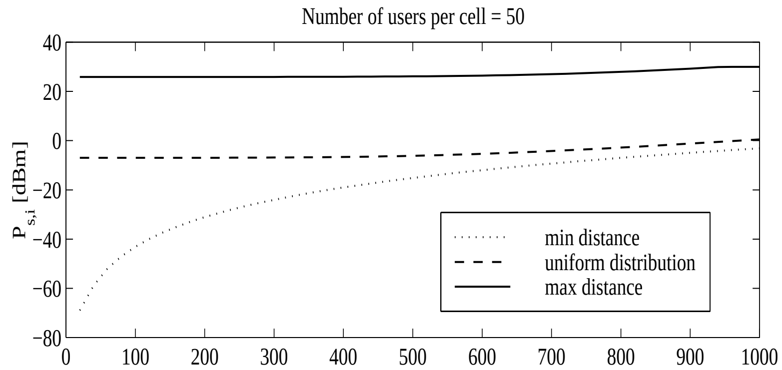
$$P_{0,0} - \frac{P_{1,0}}{CIR} + \ldots + P_{K_0,0} + \sum_{j=1}^{N} \sum_{k=1}^{K_j - 1} P_{k,j} + \eta = 0$$

$$\vdots$$

$$P_{0,0} + P_{1,0} + \ldots - \frac{P_{K_0,0}}{CIR} + \sum_{j=1}^{N} \sum_{k=1}^{K_j - 1} P_{k,j} + \eta = 0$$

Impact of uncertainties to the capacity in the cell

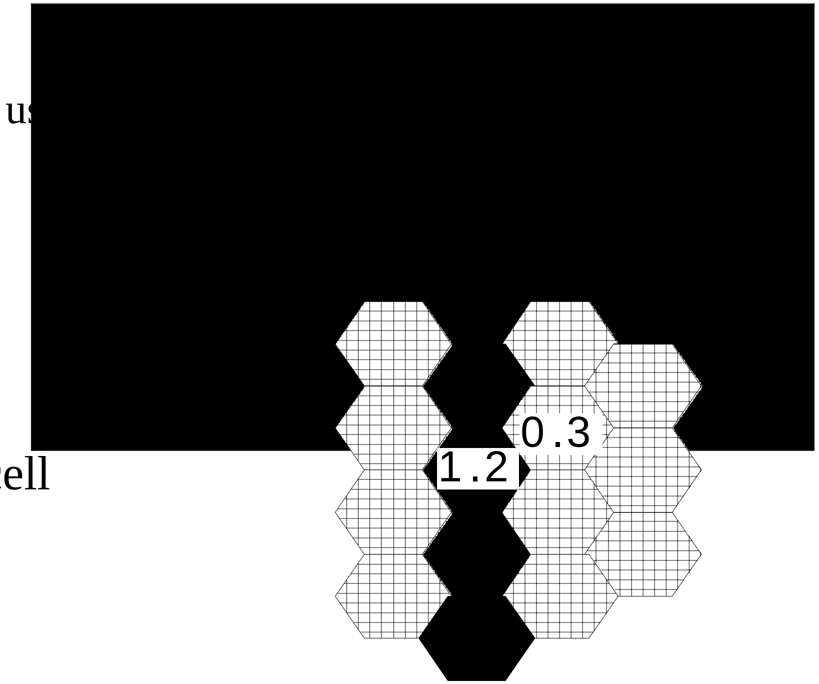
- Location of users in the cell
  - depending where users are located in the cell they get different interference from other cells and capacity varies



- Speed of users
  - target CIR function of speed
  - conditions in the cell vary with users movements
- Data rates
  - n times voice datarate corresponds to n us
    nonuniformity”)

Soft Capacity

- surrounding cells lightly loaded
- less interference to the heavily loaded cell
- capacity to heavily loaded cell can be increased



Conditions for planning

Conditions

- capacity not constant
- separate analysis for UL/DL
- joint coverage/capacity analysis
- HO areas and levels affect directly system capacity
- basic shared resource is power

Objective parameters

- coverage
- capacity (blocking)
- good link quality (BER, FER)
- throughput delay, for packet services

Methods

- preplanned during network planning process
- real time radio resource management
- real time power control

Network planning

Resource reservation for handling expected traffic without congestion.

- – load per cell/sector, handover areas

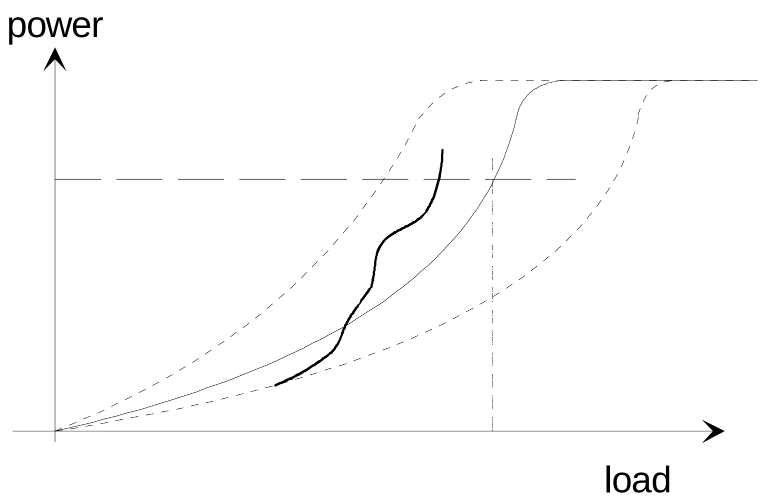
Sets allowable "power budget" available for services

- – load higher than expected
- – load "badly" distributed
- – implements statistical multiplexing

Estimates average power/load, variations

of it are taken care in run time by RRM

- – maximal allowed load versus average load



Planning methods

- Preparation phase.
  - Defining coverage and capacity objectives.
  - Selection of network planning strategies.
  - Initial design and operation parameters.
- Initial dimensioning.
  - First and most rapid evaluation of the network elements count and capacity of these elements.
  - Offered traffic estimation.
  - Joint capacity coverage estimation.
- Detailed planning.
  - Detailed coverage capacity estimation.
  - Iterative coverage analysis.
  - Planning for codes and powers.
- Optimisation.
  - Setting the parameters
    - Soft handover.
    - Power control.
- Verification of the static simulator with the dynamic simulator.
  - Test of the static simulator with simulator where the users actual movements are modelled.

A strategy for dimensioning

Plan for adequate load and number of sites.

- Enable optimised site selection.
- Avoid adding new sites too soon.
- Allow better utilisation of spectrum.

Recommended load factor 30- 70 %

1. Initial phase:

Acquire only part of sites and use coverage extension techniques to fill the gap.

Network expansion:

- Add more sites.
- Add more sectors / carriers to existing sites.

2. Initial phase:

Acquire sites but install part of BSS equipment.

- Allow traffic concentration at RNC level.
- Install less sectors and and less BS.

Network expansion:

- Add more BS/HW/sectors/carriers.

2G operator:

Re-using the infrastructure (Lover cost):

\+ Transmission network.

\+ Sites (masts, buildings, power supplies,…).

Challenges

\- Sufficient coverage for all services.

\- Intersystem handover not seamless.

Green-field operator:

Radio network implementation from scratch.

Renting infrastructure from other operators.

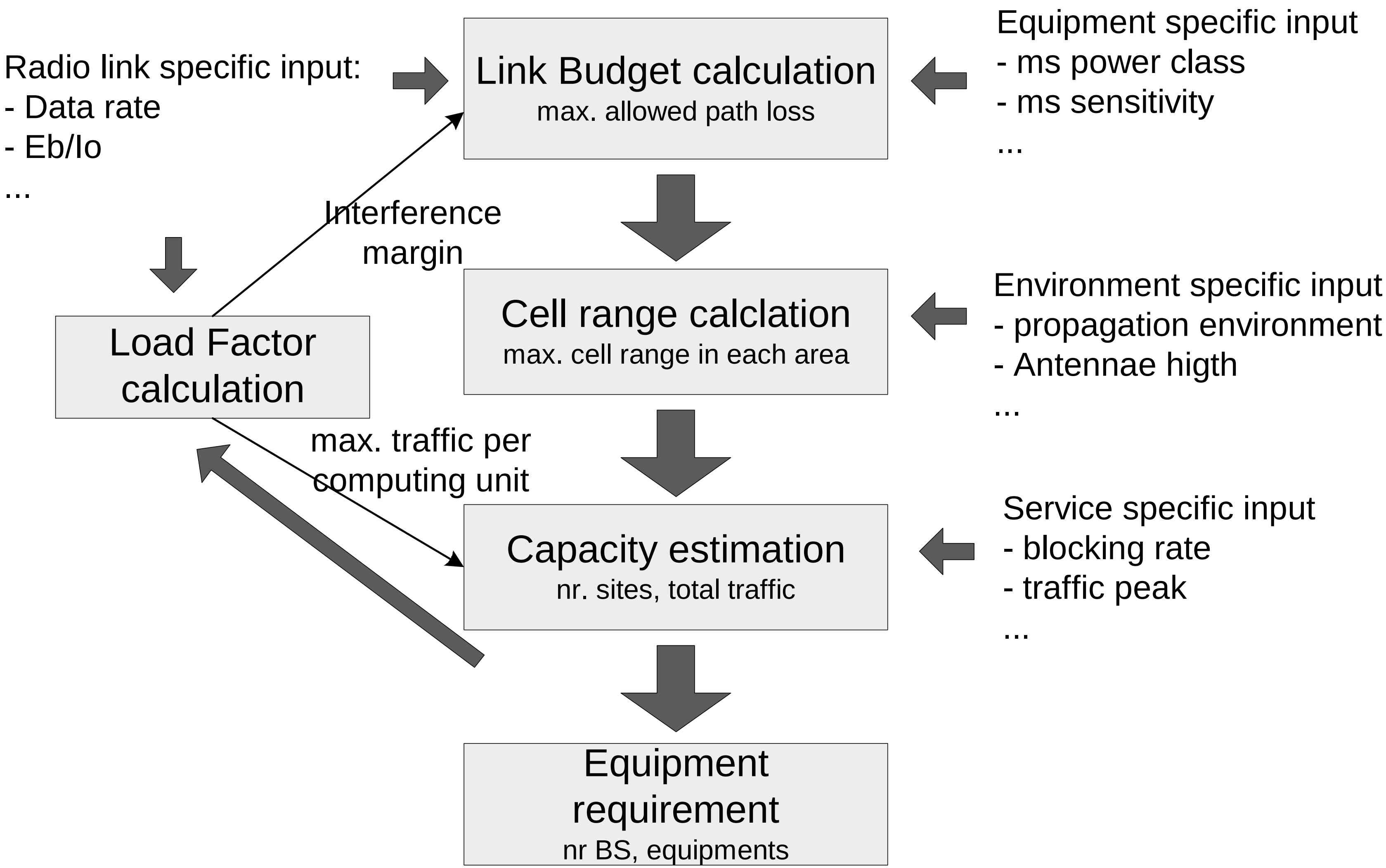
\+ Less limitations easier implementations

\- Higher Cost.

Dimensioning

- Initial planning
  - first rapid evaluation of the network element count as well as associated capacity of those elements.
- Radio access
  - Estimate the sites density.
  - Site configuration.
- Activities
  - Link budget and coverage analysis.
  - Capacity estimation.
  - Estimation of the BS hardware and sites, RNCs and equipments at different interfaces. Estimation of Iur,Iub,Iu transmission capacities.
  - Cell size estimation.
- Needed
  - Service distribution.
  - Traffic density.
  - Traffic growth estimation.
  - QoS estimation.

Dimensioning process



WCDMA cell range

- Estimation of the maximum allowed propagation loss in a cell.
- Radio Link budget calculation.
  - Summing together gains and degradations in radio path.
  - Interference margin.
  - Slow fading margin.
  - Power control headroom.
- After choosing the cell range the coverage area can be calculated using propagation models
  - Okumura-Hata, Walfisch-Ikegami, … .
- The coverage area for one cell is a hexagonal configuration estimated from:

$$S = K \cdot r^2$$

S coverage area.

r maximum cell range, accounting the fact that sectored cells are not hexagonal.

K Constant accounting for the sectors.

Site configuration	Omni	2-sectored	3-sectored	6-sectored
Value of K	2.6	1.3	1.95	2.6

Example of a WCDMA RLB

12.2 kbps voice service (120 km/h, in car)		
Transmitter (mobile)		
Max. mobile transmission power [W]	0.125	
As above in [dBm]	21	a
Mobile antenna gain [dBi]	0	b
Cable/Body loss [dB]	3	c
Equivalent Isotropic Radiated Power	18	d=a+b-c
Receiver BS		
Thermal noise density [dBm/Hz]	-174	e
Base station recever noise figure [dB	5	f
Receiver noise density [dBm/Hz]	-169	g=e+f
Receiver noise power [dBm]	-103.2	h=g+10*log10(3840000)
Interference margin [dB]	3	i
Receiver interference power [dBm]	-103.2	j=10*log10(10^((h+1)/10)-10^(h/10
Total effective noise + interference [	-100.2	k=10*log10(10^(h/10)+10^(j/10))
Processing gain [dB]	25	l=10*log10(3840/12.2)
Required Eb/No [dB]	5	m
Receiver sensitivity [dBm]	-120.2	n=m-l+k
Base station antenna gain [dBi]	18	o
Cable loss in the base station [dB]	2	p
Fast fading margin [dB]	0	q
Max. path loss [dB]	154.2	r=d-n+o-p-q
Coverage probability [%]	95	
Log normal fading constant [dB]	7	
Propagation model exponent	3.52	
Log normal fading margin [dB]	7.3	s
Soft handover gain [dB], multi-cell	3	t
In-car loss [dB]	8	u
Allowed propagation loss for cell ran	141.9	v=r-s+t-u

Load factor uplink

Interference degradation margin: describes the amount of increase of the interference due to the multiple access. It is reserved in the link budget.

Can be calculated as the noise rise: the ratio of the total received power to the noise power:

$$Noise\_rise = \frac{I_{total}}{P_N} = \frac{1}{1-\eta_{UL}}$$

Where η_{UL} is load factor.

Assume that MS k use s bit rate R_k, target $\frac{E_b}{I_0}$ is ρ_k and WCDMA chip rate is W .

$$\frac{W}{R_k}\left(\frac{P_k}{I_{own} - P_k + I_{oth} + N}\right) = \frac{W}{R_k}\left(\frac{P_k}{I_{own} - P_k + i \cdot I_{own} + N}\right) \geq \rho_k,\ k = 1,\ldots,K_n$$

The inequality must be hold for all the users and ca be solved for minimum received signal power (sensitivity) for all the users.

$$P_k\left(1 + \frac{\rho_k R_k}{W}\right) = \frac{\rho_k R_k}{W}(1+i)\,I_{own} + \frac{\rho_k R_k}{W}N$$

$$P_k = \frac{1}{1+\frac{W}{\rho_k \cdot R_k}}(1+i)\cdot I_{own} + \frac{1}{1+\frac{W}{\rho_k \cdot R_k}}N,\ k = 1,\ldots,K$$

Load factor uplink (2)

Interference in the own cell is calculated by summing over all the users signal powers in the cell.

$$I_{own} = \sum_{k=1}^{K_n} P_k$$

$$\sum_{k=1}^{K_n} P_k = \left[\sum_{k=1}^{K_n} \frac{1}{1 + \frac{W}{\rho_k \cdot R_k}} (1+i) \right] \cdot \sum_{k=1}^{N} P_k + \left[\sum_{k=1}^{K_n} \frac{1}{1 + \frac{W}{\rho_k \cdot R_k}} \right] \cdot N$$

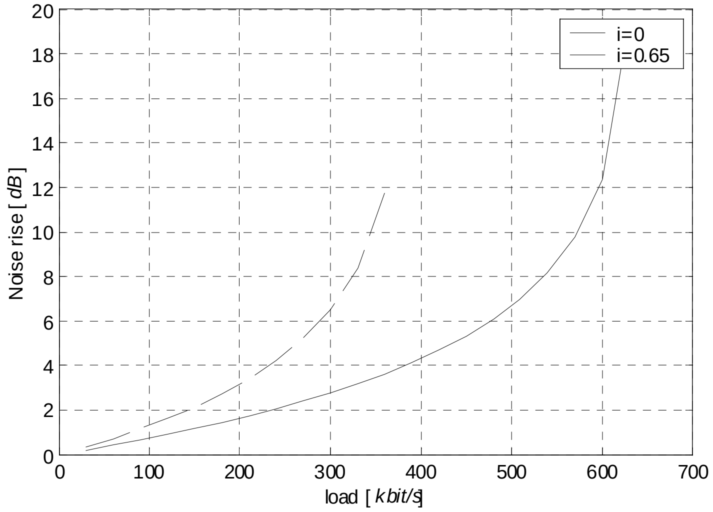
$$\Rightarrow \sum_{k=1}^{K_n} P_k \cdot (1+i) = \frac{N \cdot \left[\sum_{k=1}^{K_n} \frac{1}{1 + \frac{W}{\rho_k \cdot R_k}} (1+i) \right]}{1 - \left[\sum_{k=1}^{K_n} \frac{1}{1 + \frac{W}{\rho_k \cdot R_k}} (1+i) \right]}$$

Load factor uplink (3)

Uplink loading is defined as: $$\eta_{UL} = \sum_{k=1}^{K_n} \frac{1}{1+\frac{W}{\rho_k \cdot R_k}}(1+i)$$

By including also effect of sectorisation (sectorisation gain ξ, number of sectors N_s), and voice activity ν.

$$\eta_{UL} = \sum_{k=1}^{K_n} \frac{1}{1+\frac{W}{\rho_k \cdot R_k}} \nu_k \left(1+i\frac{N_s}{\xi}\right)$$



Noise rise in uplink

Load Factor Downlink

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

$$L = 10\log_{10}(1-\eta)$$

The downlink loading is estimated based on $\eta_{DL} = \sum_{i=1}^{I}\left[\frac{\rho_i R_i \nu_i}{W}\left((1-\alpha_i) + \sum_{\substack{n=1,\\ n\neq m}}^{N}\frac{LP_{mi}}{LP_{ni}}\right)\right]$

- 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 $i_{DL} = \sum_{\substack{n=1,\\ n\neq m}}^{N}\frac{LP_{mi}}{LP_{ni}}$

The total BS transmit power estimation considers multiple communication links with average $\left(\overline{LP_{mi}}\right)$ from the serving BS.

Receiver sensitivity estimation

- In RLB the receiver noise level over WCDMA carrier is calculated.
- The required SIR contains the processing gain and the loss due to the loading.
- The required signal power: $P_r = SNR \cdot N_0 \cdot W$

P_r signal power,
$N_0 \cdot W$ background noise.

$$SNR = \rho \cdot \frac{R}{W \cdot (1-\eta)}$$

- In some cases the noise/interference level is further corrected by applying a term that accounts for man made noise.

Spectrum efficiency

Uplink

- rx_Eb/Io is a function of required BER target and multipath channel model.
- Macro diversity combining gain can be seen as having lower rx_Eb/Io when the MS is having links with multiple cells.
- Inter cell interference *i* is a function of antennae pattern, sector configuration and path loss index.

Downlink

- tx_Eb/Io is function of required BER target and multipath channel model.
- Macro diversity combining gain can be seen as having lover tx_Eb/Io when MS is having radio links with multiple cells.
- Orthogonality factor is a function of the multipath channel model at the given location.
- Planners have to select the sites so that the other to own cell interference *i* is minimised.
  - Cell should cover only what is suppose to cover.

Coverage improvement

- Coverage limited by UL due to the lower transmit power of MS.
- Adding more sites.
- Higher gain antennas.
- RX diversity methods.
- Better RX -sensitivity.
- Antennae bearing and tilting.
- Multi-user detection.

Capacity improvement

- DL capacity is considered more important than UL, asymmetric traffic.
  - Due to the less multipath microcell capacity better than macrocell.
- Adding frequencies.
- Adding cells.
- Sectorisation.
- Transmit diversity.
- Lower bit rate codecs.
- Multibeam antennas.

RNC Dimensioning

- The whole network area divided into regions each handled by a single RNC.
- RNC dimensioning: provide the number of RNCs needed to support the estimated traffic.
- For uniform load distribution the amount of RNCs:

RNC limited by:

- Maximum number of cells: $$numRNCs = \frac{numCells}{cellsRNC \cdot fillrate1}$$

  $numCells$ number of cells in the area to be dimensioned, $cellsRNC$ maximum number of cells, $fillrate1$ margin used to back off from the maximum capacity.

- Maximum number of BS: $$numRNCs = \frac{numBTSs}{btsRNC \cdot fillrate2}$$

  $numBTSs$ number of BS in the area to be dimensioned, $btsRNC$ maximum number of BSs that can be connected to one RNC, $fillrate2$ margin used to back off from the maximum capacity.

- Maximum Iub throughput: $$numRNCs = \frac{voiceTP + CSdataTP + PSdataTP}{tpRNC \cdot fillrate3}$$

  $tpRNC$ maximum Iub capacity, $fillrate3$ margin used to back off from it, $numSubs$ the expected number simultaneously active subscribers.

$$voiceTP = voiceErl \cdot bitrte_{voice}\left(1 + SHO_{voice}\right)$$

$$CSdataTP = CSdataErl \cdot bitrate_{CSdata}\left(1 + SHO_{CSdata}\right)$$

$$PSdtaTP = avePSdata / PSoverhead \cdot \left(1 + SHO_{PSdata}\right)$$

- Amount of type of interfaces (STm-1, E1).

RNC dimensioning (2)

- Supported traffic (upper limit of RNC processing).
  - Planned equipment capacity of the network, upper limit.
  - For data services each cell should be planned for maximum capacity
    - too much capacity across the network. RNC is able to offer maximum capacity in every cell but that is highly un-probable demand.
- Required traffic (lower limit of RNC processing).
  - Actual traffic need in the network, base on the operator prediction.
  - RNC can support mean traffic demand.
  - No room for dynamic variations.
- RNC transmission interface Iub.
  - For N sites the total capacity for the Iub transmission must be greater than N times the capacity of a site.
- RNC blocking principle.
  - RNC dimensioned based on assumed blocking.
  - Peak traffic never seen by the RNC: Erlangs per BS can be converted into physical channels per BS.
  - NRT traffic can be divided with $(1-\mathrm{backoff\_from\_max\_data\_throughput})$.
- Dimensioning RNC based on the actual subscribers traffic in area.

Soft blocking

- Soft capacity only for real time services.
- Hard Blocking
  - The capacity limited by the amount of hardware.
    - Call admission based on number of channel elements.
  - If all BS channel elements are busy, the next call comes to the cell is blocked.
  - The cell capacity can be obtained from the Erlang B model.
- Soft blocking
  - The capacity limited by the amount of interference in the air interference.
    - Call admission based on QoS control
    - There is always more than enough BS channel elements.
  - A new call is admitted by slightly degrading QoS of all existing calls.
  - The capacity can be calculated from Erlang B formula. (too pessimistic).
    - The total channel pool larger than the average number of channels.
  - The assumptions of 2% of blocking. In average 2% of users experience bad quality during the call. (Bad quality for voice 2%, bad quality for data 10%).

Soft capacity

- Soft capacity is given by the interference sharing.
- The less interference coming from neighbouring cells the more channels are available in the middle cells.
- The capacity can be borrowed from the adjacent cells.
  - With a low number of channels per cell
    - A low blocking probability for high bit rate real time users is achieved by dimensioning average load in the cell to be low.
  - Extra capacity available in the neighbouring cells.
    - At any given moment it is unlikely that all the neighbouring cells are fully loaded at the same time.
- Soft capacity: the increase of Erlang capacity with soft blocking compared to that with hard blocking with the same maximum number of channels per cell.

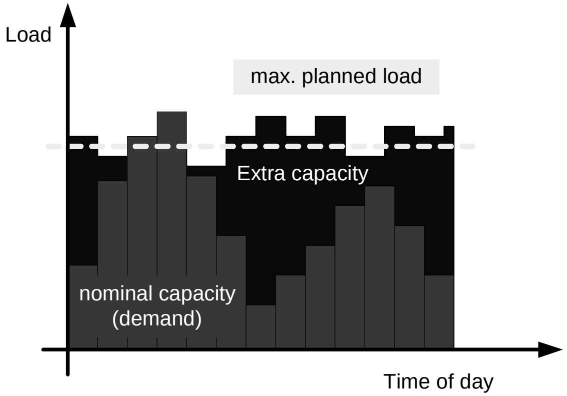
$$SoftCapacity = \frac{Erlang\ capacity\ with\ soft\ blocking}{Erlang\ capacity\ with\ hard\ blocking} - 1$$

Algorithm for estimation:

- Calculate the number of channels per cell, N, in the equally loaded case, based on the uplink load factor.
- Multiply total number of channels by $1+i$ to obtain the total pool in the soft blocking case.
- Calculate the maximum offered traffic from the Erlang B formula.
- Divide the Erlang capacity by $1+i$.

Dimensioning for Voice and Data

- Cell load factor
- Mixing different traffic types creates better statistical multiplexing:
  - Dimensioning for the worst case load is normally not needed if resource pool is large enough.
  - Delay intensive traffic can be used to fill the gaps in loading, using dynamic scheduling and buffering.
- Minimum cell throughput for NRT data should be planned for busy hour loading in order to maintain some QoS.
- By filling the capacity not used by RT traffic we increase loading and in effect go after the free capacity used for soft capacity, cell dimensioning becomes more complex.



Admission control

Prediction of the interference increase

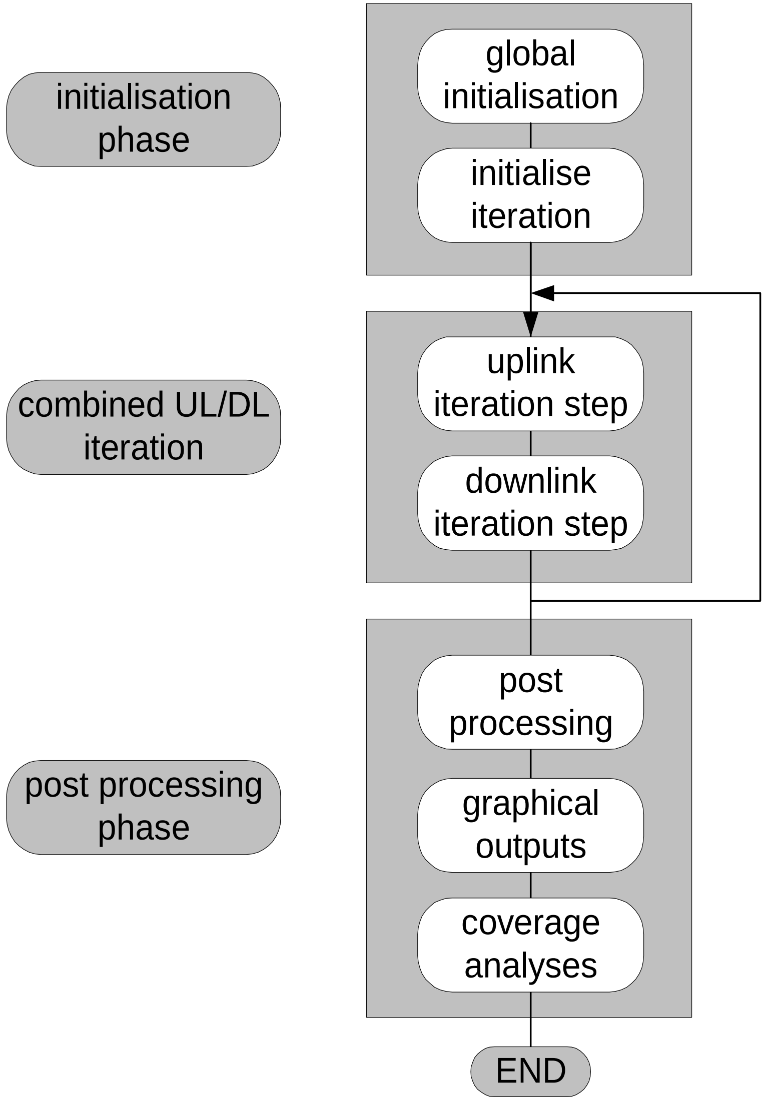
- average bit rate of traffic source
- behaviour of traffic source
- environmental parameters
  - expected average CIR
  - spatial variability

Estimates power increase for UL/DL when new connection is admitted

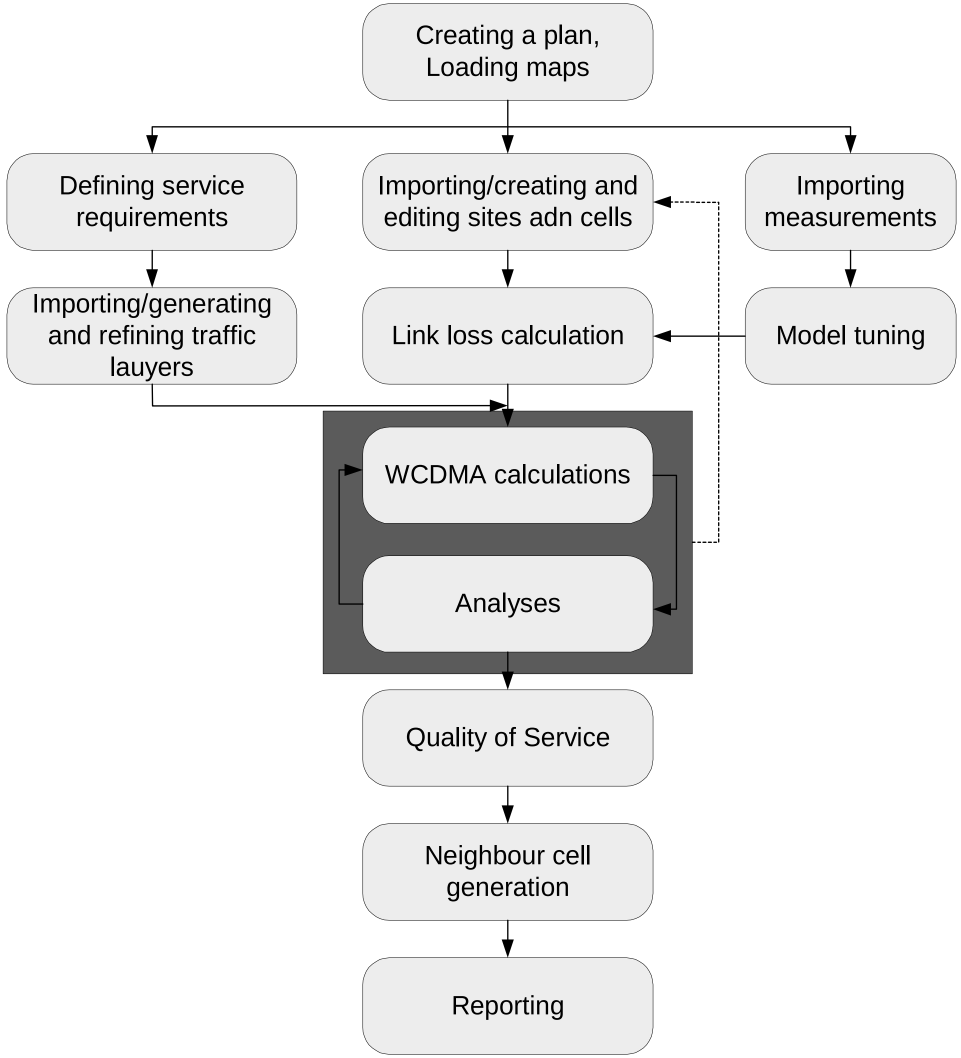
Admission control methods

- admit if possible
- threshold based systems

Detailed planning



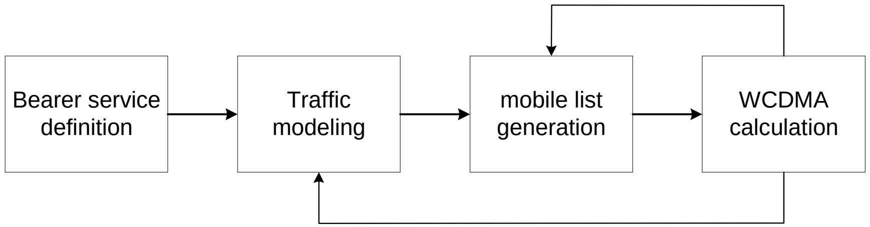
Workflow of a RNP tool



Input data preparation

- Digital map.
  - for coverage prediction.
  - totpoligical data (terrain), morphological data (terrain type), building location and height.
  - Resolution: urban areas $12.5\ m$, rural areas 50-$100\ m$.
- Plan.
  - logical concept combining various items.
    - digital map, map properties, target plan area, selected radio access technology, input parameters, antenna models.
- Antenna editor.
  - logical concept containing antenna radiation pattern, antenna gain, frequency band.
- Propagation model editor.
  - Different planning areas with different characteristics.
  - For each area type many propagation models can be prepared.
  - tuning based on field measurements.
- BTS types and site/cell templates
  - Defaults for the network element parameters and ability to change it.
  - Example BTS parameter template:
    - maximum number of wideband signal processors.
    - maximum number of channel units.
    - noise figure.
    - Tx/Rx diversity types.

Planning

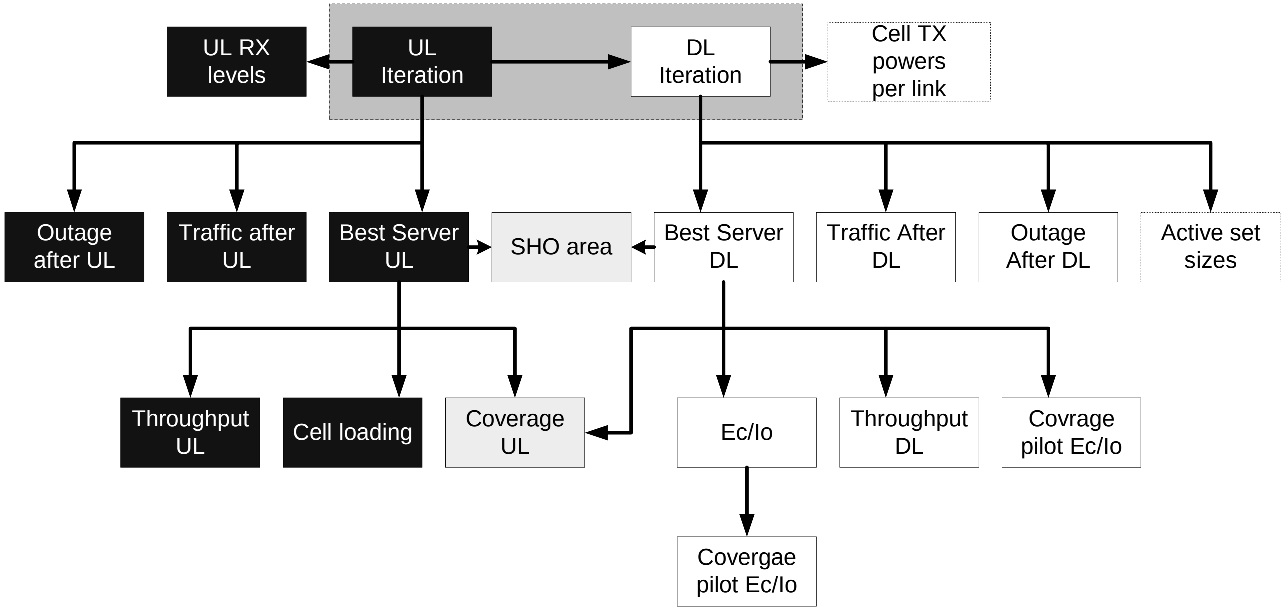


- Importing sites.
  - Utilisation of 2G networks.
- Editing sites and cells.
  - Adding and modifying sites manually.
- Defining service requirements and traffic modelling.
  - Bit rate and bearer service type assigned to each service.
  - For NRT need for average call size retransmission rate.
  - Traffic forecast.
- Propagation model tuning.
  - Matching the default propagation models to the measurements.
  - Tuning functions per cell basis.
- Link loss calculation.
  - The signal level at each location in the service area is evaluated, it depends on
    - Network configuration (sites, cells, antennas). Propagation model. Calculation area. Link loss parameters. Cable and indoor loss. Line-of-sigth settings. Clutter type correction. Topgraphic corrections. Diffractions.
- Optimising dominance.
  - Interference and capacity analysis.
  - Locating best servers in each location in the service area.
  - Target to have clear dominance areas.

Iterative traffic planning process

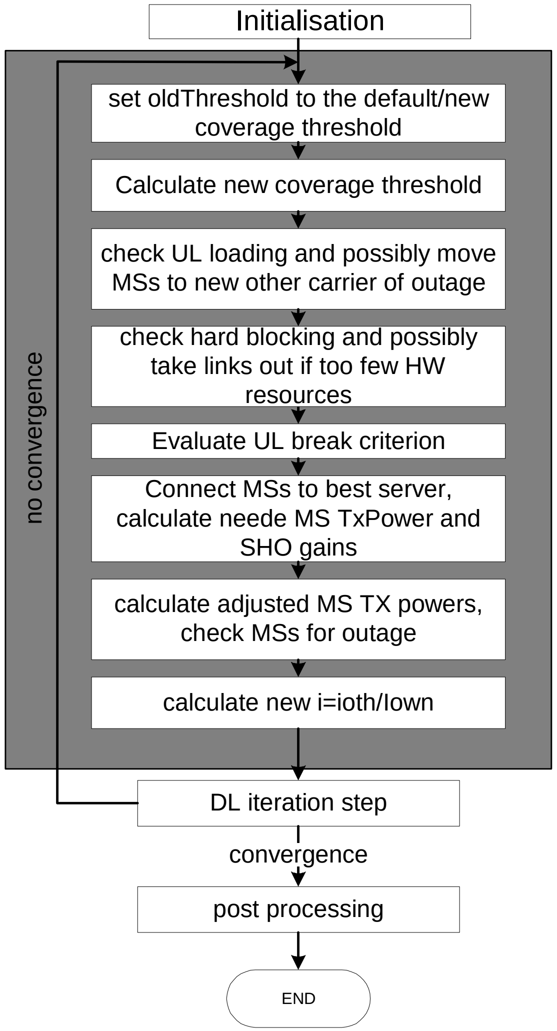
- Verification of the initial dimensioning.
- Because of the reuse 1, in the interference calculations also interference from other cells should be taken into account.
- Analysis of one snapshot.
  - For quickly finding the interference map of the service area.
  - Locate users randomly into network.
  - Assume power control and evaluate the SIR for all the users.
  - Simple analysis with few iterations.
  - Exhaustive study with all the parameters.
- Monte-Carlo simulation.
  - Finding average over many snapshots: average, minimum, maximum, std.
  - Averages over mobile locations.
  - Iterations are described by:
    - Number of iterations.
    - Maximum calculation time.
    - Mobile list generation.
    - General calculation settings.

Example of WCDMA analysis



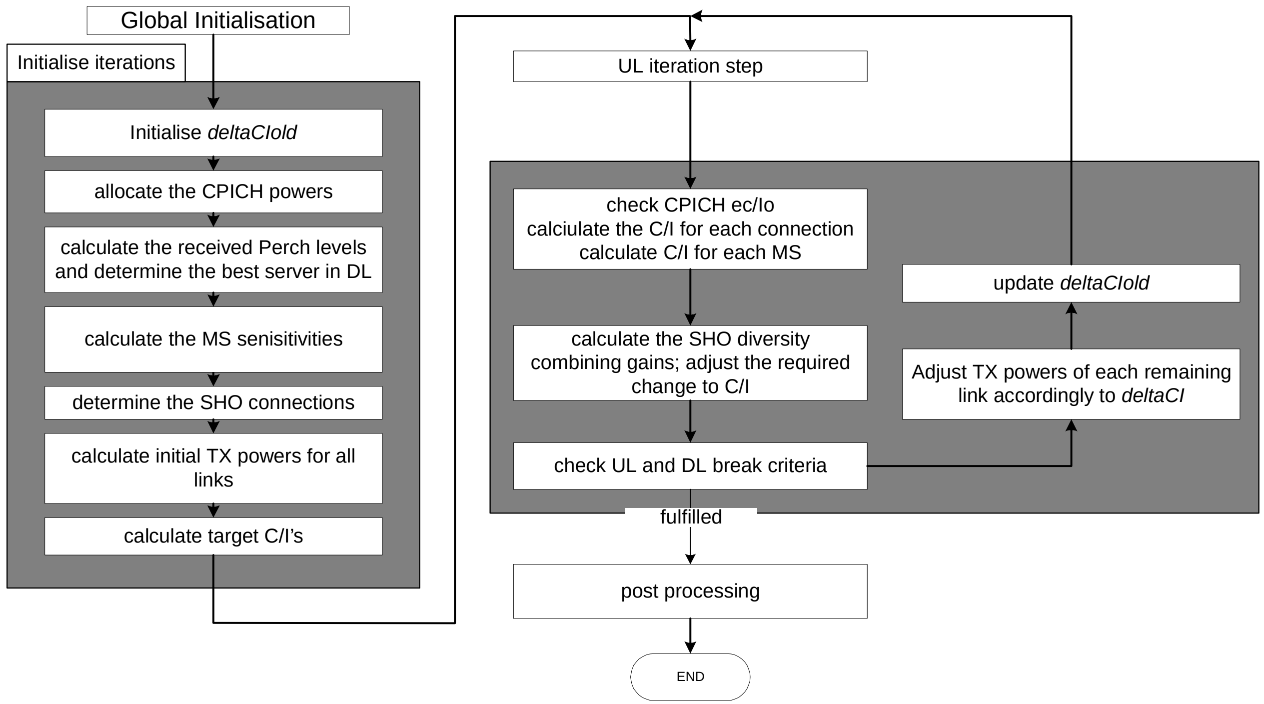
- Reporting:
  - Raster plots from the selected area.
  - Network element configuration and parameter setting.
  - Various graphs and trends.
  - Customised operator specific trends.

Uplink iteration step



- Allocate MS transmit powers so that the interference levels and BS sensitivities converge.
- Transmit power of MS should fulfil required receiver Eb/Io in BS.
  - Min Rx level in BS.
  - Required Eb/Io in uplink.
  - Interference situation.
  - Antennae gain cable and other losses.
- The power calculation loop is repeated until powers converge.
- Mobiles exceeding the limit power
  - Attempt inter-frequency handover.
  - Are put into outage.
- Best server in UL and DL is selected.

Downlink iteration step



- Allocation of P-CPICH powers.
- Transmit power of BS should fulfil required receiver Eb/Io in MS.
- The initial Tx powers are assigned iteratively.

- The target CIR $CIR_{target} = \frac{E_b/N_0}{W/R}$
- The actual CIR

$$\left(\frac{C}{I}\right)_k = \sum_{n=1}^{N} \frac{P_{nk}/LP_{nk}}{(1-\alpha_k)\cdot P_n/LP_{nk} + I_{oth,n} + N_k}$$

- The planning tool evaluates the actual CIR and compares it to the Target CIR

Coverage analysis

UL DCH Coverage

- Whether an additional mobile having certain bit rate could be served.
- The transmit power need for the MS is calculated and compared to the maximum allowed:

$$P_{TX,MS} = \frac{N_0 LP}{\nu(1-\eta)\left(1+\frac{W}{R\rho\nu}\right)}$$

DL DCH Coverage

- Pixel by pixel is checked whether an additional mobile having certain bit rate could be served. Concentration on the power limits per radio link.
- The transmit power need for supporting the link is calculated and compared to the maximum allowed:

$$P_{tx} \geq \frac{\rho R / W}{\sum_{k \in AS}^{N} \frac{\beta_n}{LP_k \left(I_{tot} - \alpha I_k + N_{ms}\right)}}$$

DL CPICH Coverage

- Pixel by pixel is checked whether the P-CPICH channel can be listened.

$$CPICH = \frac{P_{CPICH} / LP}{\sum_{i=1}^{numBSs} P_{TX,i} / LP_i + I_{adjacent\_channel\_CI} + N_0}$$

Dynamic simulation

- Complexity prohibit the usage in actual network planning.
- Is used to verify the planning made by other tools.
- Can consider:
  - power control.
  - soft handover.
  - packet scheduling.
- Good for benchmarking Radio Resource Management.
- Statistic can coverage:
  - Bad quality calls: Calls with average frame error rate exceeding the threshold.
  - Dropped calls: Consecutive frame errors exceed the threshold.
  - Power outage: Power requirement exceeds the available Tx power.

Conclusions

- Cell level results are in good agreement with both, dynamic and static results.
- The outage areas are in the same locations if investigated with different simulations.