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WCDMA planning and optimization

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Contents

- WCDMA network dimensioning
- WCDMA network planning
- WCDMA network optimization

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Planning target and parameter definition

- Planning targets are agreed between customer/operator and planner
  - Analyzing the quality-cost tradeoff
- Service scenarios should be defined:
  - Which kind of service is to be offered and where
- **Coverage target:** geographical coverage, coverage thresholds, coverage probability
  - Typical coverage probability is 90–95 %
- **Capacity target:** subscriber map based on population map, estimated traffic per user per service, available spectrum
  - Accurate traffic forecasting is required
  - A traffic forecast should be done by analyzing the offered busy hour traffic per subscriber for different service bit rates

Coverage vs capacity

- In WCDMA, coverage and capacity are interrelated
- Dimensioning the coverage has to be planned for a service having a load
  - Used services and their load are input parameters for dimensioning
  - If the network load changes the coverage has to be planned for a new load situation
- WCDMA dimensioning is always a compromise between coverage and capacity.
  - By reducing the maximum load, the coverage can be extended.
  - If more capacity is required the coverage area of an individual cell shrinks, and this increases the number of required network elements

WCDMA Radio Link Budget

Simplified RLB: An example

EIRP = Effective Isotropic Radiated Power, contains transmitted power and antenna gain

BS Transmitter	**BS to MS**
Total transmission power	43 dBm (20 W)
Transmitter antenna gain	15 dBi
EIRP	58 dBm
Margins	
Shadow fading margin	5 dB
Fast fading margin	6 dB
Penetration loss	10 dB
Total Margin	23 dB
MS Receiver	**(Max coverage)**
Receiver sensitivity	-100.7 dBm
System gain	158.7 dB
Allowed propagation loss	135.7 dB

Transmitter characteristics

Channel characteristics

Receiver characteristics

Number that is used to estimate the cell range

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Simplified RLB: Terminology

- dBi = dB(isotropic). It is the forward gain of a certain antenna compared to the ideal isotropic antenna which uniformly distributes energy to all directions.
- dBm = dB(1 mW) is a measured power relative to 1 mW (e.g. 20W is 10*log(1000*20)= 43 dBm
- Effective isotropic radiated power is the amount of power that would have to be emitted by an isotropic antenna (that evenly distributes power in all directions and is a theoretical construct) to produce the peak power density observed in the direction of maximum antenna gain. EIRP can take into account the losses in transmission line and connectors and includes the gain of the antenna.

Simplified RLB

- In link budget calculations we
  - Define transmitter and receiver characteristics. These numbers are system (and product) related.
  - Define margins according to channel properties.
  - As a result we calculate *allowed propagation loss* for the system. This is important number because it is used in the dimensioning of the system.
- Average path loss models are used for system range estimation
  - Once we know the allowed propagation loss and environment (+antenna heights etc), then we can calculate range using a selected average path loss model.
- **See Fundamentals of CNP slides for**
  - Okumura-Hata path loss model (most widely applied outdoor model)
  - Shadow fading discussion: check how shadow fading margin is computed
  - Multipath fading discussion

RLB through simple equations

❖ The Allowed Propagation Loss (APL) can be calculated as follows:

$$
\begin{aligned}
APL &= EIRP - \min\{P_{RX}\} - M_{Total} \\
&= P_{TX} + G - \min\{P_{RX}\} - M_{SF} - M_{FF} - M_{Penetration}
\end{aligned}
$$

Here

$$\min\{P_{RX}\} = \text{Receiver sensitivity [dBm]}$$

$$P_{TX} = \text{Transmission power in BS [dBm]}$$

$$G = \text{BS antenna gain [dBi]}$$

$$M_{SF} = \text{Shadow fading margin [dB]}$$

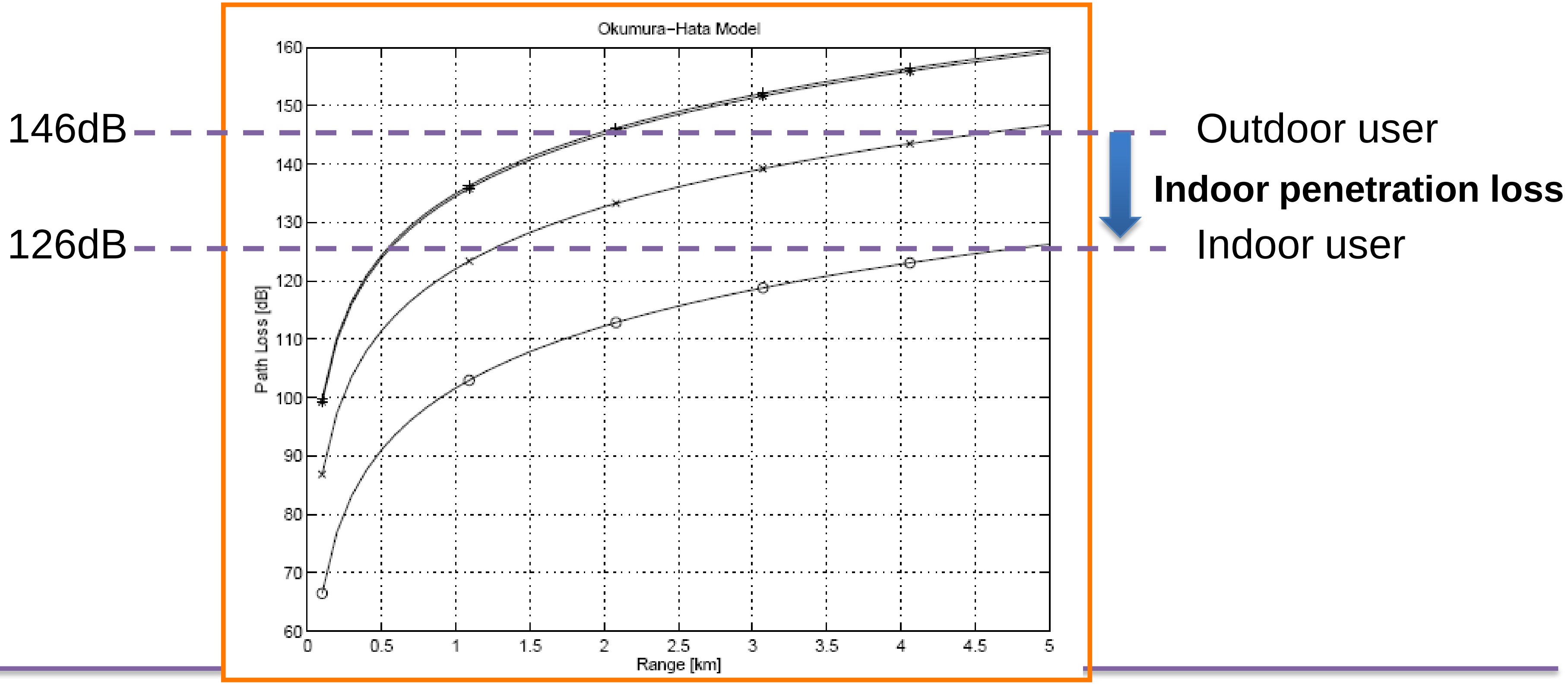
$$M_{FF} = \text{Fast fading margin [dB]}$$

$$M_{Penetration} = \text{Indoor penetration loss [dB]}$$

Penetration loss simply depends on the expected building wall losses.

Example

- Assume that according to RLB the allowed path loss for WCDMA DL speech connection is 146dB. Then cell range in different environment types can be estimated from the figure below. Note that CF=2100MHz and BS antenna height is 30 meters



146dB

126dB

Outdoor user

Indoor penetration loss

Indoor user

Figure 5: Path loss prediction by Hata model in dense city (+), medium size city (*), suburban (x) and open area (o), $h_{\mathrm{BS}} = 30\mathrm{m}$, $h_{\mathrm{MS}} = 2\mathrm{m}$ and carrier frequency is 2100MHz.

WCDMA Link budget, 12.2 kbps speech

		12.2kbps voice, DL		12.2kbps voice, UL	
Target load		0.75		0.5	
Transmitter characteristics	Total transmitter power	20	W	0.125	W
	Transmitter power on TCH	0.348718	W	0.125	W
		25.42474	dBm	20.9691	dBm
	TX antenna gain	17.42531	dBi	0	dBi
	TX cable loss	2	dB	0	dB
	TX Body loss	0	dB	2	dB
	Transmitter EIRP	**40.85005**	**dBm**	**18.9691**	**dBm**
Receiver characteristics and margins	RX antenna gain	0	dBi	17.42531	dBi
	Thermal noise density	-174	dBm/Hz	-174	dBm/Hz
	Receiver noise figure	8	dB	5	dB
	Receiver noise density	-166	dB	-169	dB
	Receiver noise power	-100.157	dBm	-103.157	dBm
	Processing gain	24.97971	dB	24.97971	dB
	Required Eb/No	7	dB	5	dB
	Interference margin	6.0206	dB	3.0103	dB
	Required signal power	-112.116	dBm	-120.126	dBm
	RX Cable loss	0	dB	2	dB
	RX Body loss	2	dB	0	dB
	Diversity gain	0	dB	3	dB
	Fast fading margin	0	dB	3	dB
	Soft handover gain	1	dB	2	dB
	Coverage probability (cell edge)	0.9		0.9	
	Shadow fading std deviation	6	dB	6	dB
	Shadow Fading Margin	7.5	dB	7.5	dB
	Indoor penetration loss	0	dB	0	dB
	Allowed propagation loss	**146.4659**	**dB**	**149.0205**	**dB**

Link budget, TX characteristics

		12.2kbps voice, DL	12.2kbps voice, UL
Target load		0.75	0.5
Transmitter characteristics	Total transmitter power	20 W	0.125 W
	Transmitter power on TCH	0.348718 W	0.125 W
		25.42474 dBm	20.9691 dBm
	TX antenna gain	17.42531 dBi	0 dBi
	TX cable loss	2 dB	0 dB
	TX Body loss	0 dB	2 dB
	Transmitter EIRP	**40.85005 dBm**	**18.9691 dBm**

Network load assumption for dimensioning (target loading)

Target load

- **Target load%**
  - Urban macro DL: 50-60% (heavy traffic and interference)
  - Urban micro DL: 70% (heavy traffic and interference, capacity important)
  - Rural DL, UL: 30-40% (low traffic and interference, coverage important)
  - UL in general: 50%
  - Target load should not be higher than 75% (especially UL is hard to manage when load is high, interference explodes).
- Too low initial target can result as coverage holes and capacity problems, if the traffic proves to be higher than predicted.
- Too high initial target load can result in too dense (and expensive) network. Dense network can also be hard to manage in terms of cell overlapping.
- Currently capacity need is more easily underestimated than overestimated.
- DL load usually bigger than UL load (traffic asymmetry).

TX power

		12.2kbps voice, DL		**12.2kbps voice, UL**	
Target load		0.75		0.5	
Transmitter characteristics	Total transmitter power	20	W	0.125	W
	Transmitter power on TCH	0.348718	W	0.125	W
		25.42474	dBm	20.9691	dBm
	TX antenna gain	17.42531	dBi	0	dBi
	TX cable loss	2	dB	0	dB
	TX Body loss	0	dB	2	dB
	Transmitter EIRP	**40.85005**	**dBm**	**18.9691**	**dBm**

In calculation of TCH transmission power we have used the formula

$$P_{TX,TCH} = \frac{(1 - \text{Control overhead}) \cdot \text{Total TX power}}{\text{Load target} \cdot \text{Maximum number of users}}$$

In this case we have assumed that maximum number of speech users is 65. In WCDMA maximum number of users of a certain service can be estimated through *load equations* or using *system level simulations*.

Load equation discussion can be found after a while.

TX power in BS

- Examples of the control overheads

	Activity [%]	Percentage of the maximum base station power [%]	Power allocation with 20 W. maximum power [W]
Common pilot channel (CPICH)	100	10	2.0
Primary synchronization channel (SCH)	10	6	1.2
Secondary synchronization channel (SCH)	10	4	0.8
Primary common control physical channel (CCPCH)	90	5	1.0
Total common channels	**-**	**~ 15**	**~ 3**

- The maximum number of users for a certain service can be computed using DL load equations (omitted)
- It is important to notice that by decreasing the DL load target the Traffic Channel power can be increased and cell coverage extended.

RX characteristics

Receiver characteristics and margins	RX antenna gain	0 dBi	17.42531 dBi
	Thermal noise density	-174 dBm/Hz	-174 dBm/Hz
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	Coverage probability (cell edge)	0.9	0.9
	Shadow fading std deviation	6 dB	6 dB
	Shadow Fading Margin	7.5 dB	7.5 dB
	Indoor penetration loss	0 dB	0 dB

Receiver noise figure is usually between 5 to 9 dB and BS have better NF. Precise value of this parameter is product specific.

Noise figure represent the loss of the signal power in the receiver RF parts

RX characteristics

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	Shadow Fading Margin	7.5	dB	7.5	dB
	Indoor penetration loss	0	dB	0	dB

Receiver noise density (per Hz) is a sum of receiver noise figure and thermal noise density.

Receiver noise power is equal to receiver noise density x chip rate

RX characteristics

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	Indoor penetration loss	0 dB	0 dB

Processing gain is the chip rate divided by user bit rate

RX characteristics

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	Indoor penetration loss	0	dB	0	dB

Eb/No values can be obtained by link simulations. There are also informative values given in 3GPP specifications. Eb/No values are usually provided by the network vendor

Eb/No

- Ec/Io is defined *before* the signal de-spreading operation and Eb/No *after* de-spreading.
  - Ec/Io can be be determined for the signal ”in the air”
- So Eb/No depends on the service (bit rate, CS/PS, receiving end) & vendor
- Ec/Io is service independent
- Typical Eb/No values
  - 12.2 kbps speech (BLER <7*10^-3) [UL 4-5 dB, DL 7-8 dB]
  - CS 64 kbps data (BER <10^-4) [UL 2-3 dB, DL 6-7 dB]
  - PS Streaming 64 kbps (BER<10^-3) [UL 3-4 dB, DL 7-8 dB]
  - PS data 64 kbps (BLER <7*10^-3) [UL 2-3 dB, DL 5-6 dB]
  - PS data 384 kbps (BLER <7*10^-3) [UL 2-3 dB, DL 5-7 dB]

Interference margin

- Receiver background noise increases in proportion to the number of users.
- This needs to be taken into account in the link budget with a specific interference margin, which is directly related to the loading.

RX characteristics

Receiver characteristics and margins	RX antenna gain	0 dBi	17.42531 dBi
	Thermal noise density	-174 dBm/Hz	-174 dBm/Hz
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	Coverage probability (cell edge)	0.9	0.9
	Shadow fading std deviation	6 dB	6 dB
	Shadow Fading Margin	7.5 dB	7.5 dB
	Indoor penetration loss	0 dB	0 dB

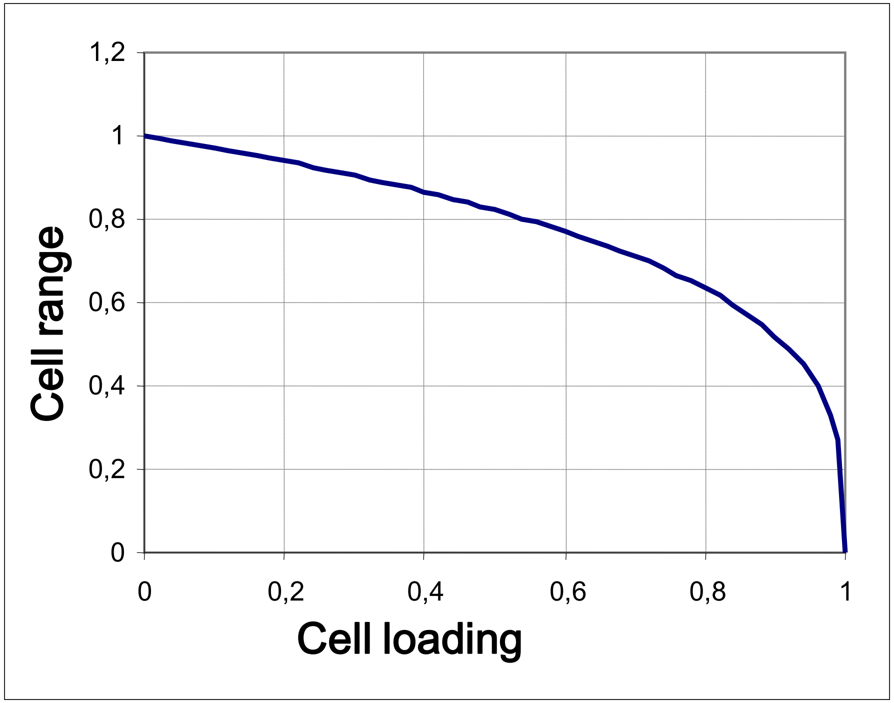
Interference is a function of loading. The value can be obtained from equation

$$\text{Interference margin} = -10 \cdot \log_{10}\left(1 - \text{Target load}\right)$$

This value can be used also in DL. 50% load => 3dB margin, 75% load => 6dB margin

UL Interference margin

Interference binds the capacity and coverage



The more traffic is brought to the cell, more interference is produced

In order to win the interference the terminals have to increase their TX-power

When the interference grows in the cell the most far away terminal from the NodeB cannot win the interference even with the maximum TX-power

New users cannot access the cell from distance

Cell range decreases

RX characteristics

Receiver characteristics and margins	RX antenna gain	0 dBi	17.42531 dBi
	Thermal noise density	-174 dBm/Hz	-174 dBm/Hz
	Receiver noise figure	8 dB	5 dB
	Receiver noise density	-166 dB	-169 dB
	Receiver noise power	-100.157 dBm	-103.157 dBm
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	RX Body loss	2 dB	0 dB
	Diversity gain	0 dB	3 dB
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	Soft handover gain	1 dB	2 dB
	Coverage probability (cell edge)	0.9	0.9
	Shadow fading std deviation	6 dB	6 dB
	Shadow Fading Margin	7.5 dB	7.5 dB
	Indoor penetration loss	0 dB	0 dB

The required signal power (also called as sensitivity) represents the weakest signal that can be received by the receiving antenna.

RX characteristics

Receiver characteristics and margins	RX antenna gain	0	dBi	17.42531	dBi
	Thermal noise density	-174	dBm/Hz	-174	dBm/Hz
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	Required Eb/No	7	dB	5	dB
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	Required signal power	-112.116	dBm	-120.126	dBm
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	RX Body loss	2	dB	0	dB
	Diversity gain	0	dB	3	dB
	Fast fading margin	0	dB	3	dB
	Soft handover gain	1	dB	2	dB
	Coverage probability (cell edge)	0.9		0.9	
	Shadow fading std deviation	6	dB	6	dB
	Shadow Fading Margin	7.5	dB	7.5	dB
	Indoor penetration loss	0	dB	0	dB

Fast fading margin = power control headroom

PC headroom/Fast fading margin

- PC headroom ensures that the UL PC is able to compensate deep fades at cell border.
- PC Headroom is a function of UE speed, and the headroom is largest for relatively slowly moving UEs (<50km/h)
  - Typical value is 3dB for urban area and 4dB elsewhere
  - Depends on assumed SHO gain and Eb/No -values
  - In an operational network, the required PC headroom can vary from 0 to over 8dB.
- PC headroom is usually not needed in the downlink, since all mobile terminals are served simultaneously with comparatively less power than the maximum output power of the node B.

RX characteristics

Receiver characteristics and margins	RX antenna gain	0 dBi	17.42531 dBi
	Thermal noise density	-174 dBm/Hz	-174 dBm/Hz
	Receiver noise figure	8 dB	5 dB
	Receiver noise density	-166 dB	-169 dB
	Receiver noise power	-100.157 dBm	-103.157 dBm
	Processing gain	24.97971 dB	24.97971 dB
	Required Eb/No	7 dB	5 dB
	Interference margin	6.0206 dB	3.0103 dB
	Required signal power	-112.116 dBm	-120.126 dBm
	RX Cable loss	0 dB	2 dB
	RX Body loss	2 dB	0 dB
	Diversity gain	0 dB	3 dB
	Fast fading margin	0 dB	3 dB
	Soft handover gain	1 dB	2 dB
	Coverage probability (cell edge)	0.9	0.9
	Shadow fading std deviation	6 dB	6 dB
	Shadow Fading Margin	7.5 dB	7.5 dB
	Indoor penetration loss	0 dB	0 dB

In soft handover two signals are combined

Soft/Softer handover gain

- Softer/Soft Handover gain results from combining signals either in Node B's RAKE or in RNC. In Downlink signals are combined in UE's RAKE receiver.
- Uplink soft HO gain comes from RNC selection combining. Gain is not achieved as concrete gain in radio interface, but as more stable power control.
- In uplink softer HO maximum ratio combining is performed in Node B's RAKE => gain 1-3 dB
- In downlink Soft HO maximum ratio combining is performed in UE's RAKE => gain 1-2 dB (low complexity receiver used).

RX characteristics

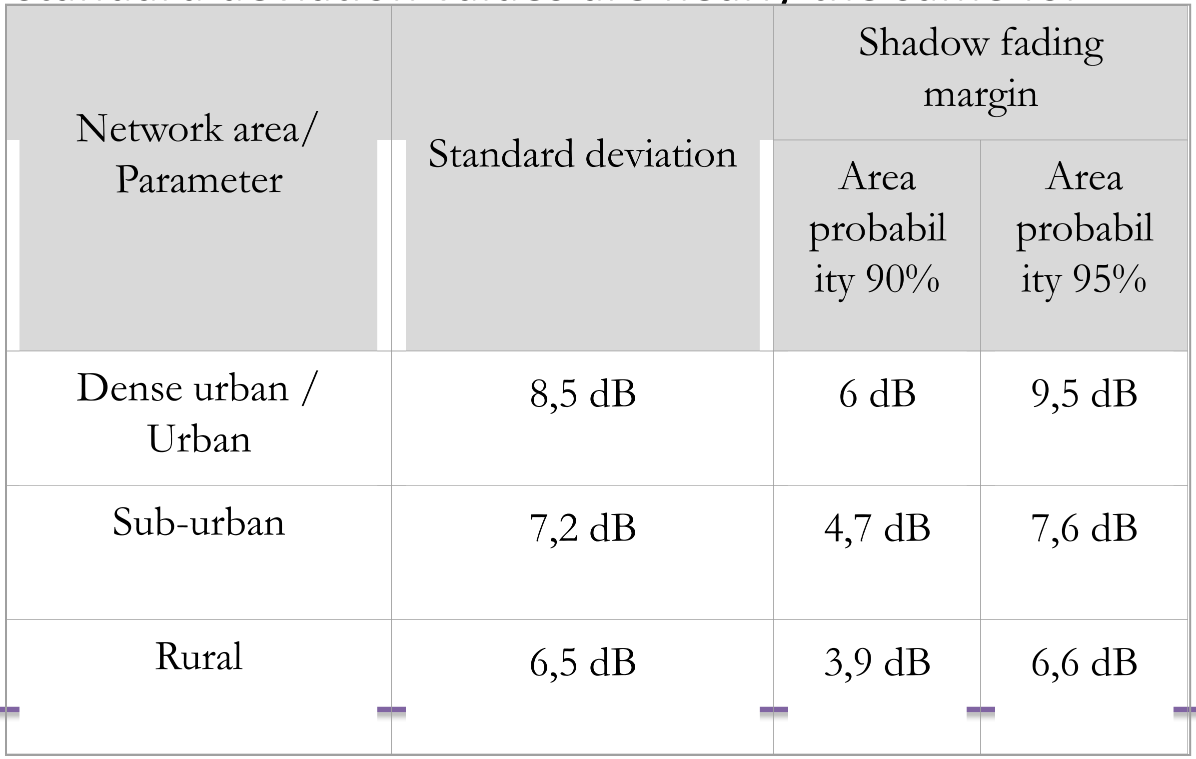
Receiver characteristics and margins	RX antenna gain	0	dBi	17.42531	dBi
	Thermal noise density	-174	dBm/Hz	-174	dBm/Hz
	Receiver noise figure	8	dB	5	dB
	Receiver noise density	-166	dB	-169	dB
	Receiver noise power	-100.157	dBm	-103.157	dBm
	Processing gain	24.97971	dB	24.97971	dB
	Required Eb/No	7	dB	5	dB
	Interference margin	6.0206	dB	3.0103	dB
	Required signal power	-112.116	dBm	-120.126	dBm
	RX Cable loss	0	dB	2	dB
	RX Body loss	2	dB	0	dB
	Diversity gain	0	dB	3	dB
	Fast fading margin	0	dB	3	dB
	Soft handover gain	1	dB	2	dB
	Coverage probability (cell edge)	0.9		0.9	
	Shadow fading std deviation	6	dB	6	dB
	Shadow Fading Margin	7.5	dB	7.5	dB
	Indoor penetration loss	0	dB	0	dB

Shadow fading margin depends on the propagation environment, see next slide

Shadow fading margin (SFM)

- SFM is needed because the buildings and other obstacles between the UE and Node B are causing changes in the received signal level at the receiver
- SFM is taken into account in the WCDMA link budget to assure a minimum signal level with the wanted probability
- According to measurements in live UMTS network, it has been noticed that the practical SFM and standard deviation values are nearly the same for WCDMA and GSM

Some values that are used based on measurements



Network area/ Parameter	Standard deviation	Shadow fading margin	
		Area probability 90%	Area probability 95%
Dense urban / Urban	8,5 dB	6 dB	9,5 dB
Sub-urban	7,2 dB	4,7 dB	7,6 dB
Rural	6,5 dB	3,9 dB	6,6 dB

Cell range

Allowed propagation loss	**146.4659 dB**	**149.0205 dB**

Range (Okumura-Hata path loss model)			Unit
	Carrier frequency	2100	MHz
	BS antenna height	25	m
	MS antenna height	1.5	m
	Parameter A	46.3	
	Parameter B	33.9	
	Parameter C	44.9	
	MS antenna gain function (large city)	-0.00092	
	Path loss exponent	3.574349	
	Path loss constant	137.3351	dB
	Downlink range	1.800742	km
	Uplink range	2.12287	km
	Cell range	**1.800742**	**km**

It seems that WCDMA and GSM 1800 admit pretty same speech coverage (recall that GSM 1800 range is round 1.58 km). Actually if we would have used the same parameters as for GSM 1800 then cell range would have been 1.58 km also for WCDMA. Yet, WCDMA link budget contains much more parameters => more potential error sources in dimensioning.

Link budget, 384kbps data

		384kbps data, DL		384kbps data, UL	
Target load		0.75		0.5	
Transmitter characteristics	Total transmitter power	20	W	0.25	W
	Transmitter power on TCH	5.666667	W	0.25	W
		37.53328	dBm	23.9794	dBm
	TX antenna gain	17.42531	dBi	0	dBi
	TX cable loss	2	dB	0	dB
	TX Body loss	0	dB	0	dB
	Transmitter EIRP	**52.95858**	**dBm**	**23.9794**	**dBm**
Receiver characteristics and margins	RX antenna gain	0	dBi	17.42531	dBi
	Thermal noise density	-174	dBm/Hz	-174	dBm/Hz
	Receiver noise figure	8	dB	5	dB
	Receiver noise density	-166	dB	-169	dB
	Receiver noise power	-100.157	dBm	-103.157	dBm
	Processing gain	10	dB	10	dB
	Required Eb/No	7	dB	3	dB
	Interference margin	6.0206	dB	3.0103	dB
	Required signal power	-97.1361	dBm	-107.146	dBm
	RX Cable loss	0	dB	2	dB
	RX Body loss	0	dB	0	dB
	Diversity gain	0	dB	3	dB
	Fast fading margin	0	dB	4	dB
	Soft handover gain	1	dB	2	dB
	Coverage probability (cell edge)	0.9		0.9	
	Shadow fading std deviation	6	dB	6	dB
	Shadow Fading Margin	7.5	dB	7.5	dB
	Indoor penetration loss	0	dB	0	dB
	Allowed propagation loss	**143.5947**	**dB**	**140.0511**	**dB**

TX power

		384kbps data, DL		384kbps data, UL	
Target load		0.75		0.5	
Transmitter characteristics	Total transmitter power	20	W	0.25	W
	Transmitter power on TCH	5.666667	W	0.25	W
		37.53328	dBm	23.9794	dBm
	TX antenna gain	17.42531	dBi	0	dBi
	TX cable loss	2	dB	0	dB
	TX Body loss	0	dB	0	dB
	Transmitter EIRP	**52.95858**	**dBm**	**23.9794**	**dBm**

Data terminal may have higher TX power

Recall the calculation of TCH transmission power

$$P_{TX,TCH} = \frac{(1-\text{Control overhead})\cdot\text{Total TX power}}{\text{Load target}\cdot\text{Maximum number of users}}$$

Now maximum number of users is only 4 => BS TX power on TCH is high

Receiver characteristics

Receiver characteristics and margins	RX antenna gain	0	dBi	17.42531	dBi
	Thermal noise density	-174	dBm/Hz	-174	dBm/Hz
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	Required signal power	-97.1361	dBm	-107.146	dBm
	RX Cable loss	0	dB	2	dB
	RX Body loss	0	dB	0	dB
	Diversity gain	0	dB	3	dB
	Fast fading margin	0	dB	4	dB
	Soft handover gain	1	dB	2	dB
	Coverage probability (cell edge)	0.9		0.9	
	Shadow fading std deviation	6	dB	6	dB
	Shadow Fading Margin	7.5	dB	7.5	dB
	Indoor penetration loss	0	dB	0	dB

Processing gain is smaller due to higher data rate
Eb/No in UL is also slightly smaller.

Cell range

Allowed propagation loss	**143.5947 dB**	**140.0511 dB**

Range (Okumura-Hata path loss model)			Unit
	Carrier frequency	2100	MHz
	BS antenna height	25	m
	MS antenna height	1.5	m
	Parameter A	46.3	
	Parameter B	33.9	
	Parameter C	44.9	
	MS antenna gain function (large city)	-0.00092	
	Path loss exponent	3.574349	
	Path loss constant	137.3351	dB
	Downlink range	1.496663	km
	Uplink range	1.191201	km
	Cell range	**1.191201**	**km**

Now system is clearly uplink limited (it was downlink limited for speech). Yet this is only problem for symmetric services. Usually 384kbps is used for web browsing which is putting more pressure on DL. If cell dimensioning is done for speech then DL 384kbps coverage may not be a serious problem but capacity becomes soon a bottleneck since system may support only few 384kbps users.

Task

In previous link budgets indoor penetration loss were 0dB. If we assume 20dB penetration loss (usual value), what will be the inter-site distance for the 12.2kbps speech and 384kbps data services assuming a 3 sector sites?

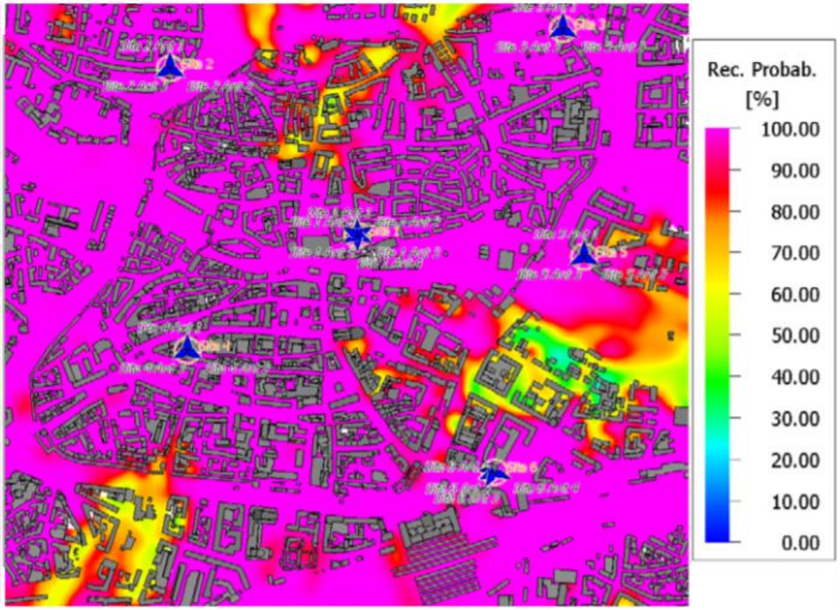
Contents

- WCDMA network dimensioning
- WCDMA network planning
- WCDMA network optimization

WCDMA coverage planning

- The objective is to find optimal locations for base stations to build continuous coverage according to the coverage criteria
    - In coverage limited network, BS location is critical
- Propagation model is selected considering WCDMA technology and customized with model tuning measurements before the coverage planning phase
    - Considering parameters such as frequency, macro/micro cell environment, BTS antenna height
    - Accuracy of the map and the model affects accuracy of the coverage predication

- **First step:** create a preliminary plan based on the calculated number of base stations from the dimensioning phase
- **Second step:** start to find actual base station locations
- **Next step:** to generate updated plan with the actual BS locations



Methods to improve coverage

- Finding optimal BS locations is an important but complicated task as it is a function of various practical factors (coverage criteria, site acquisition, backhaul limitations, …)
- As a result careful iterative recalculation is required with various combinations of parameters until agreed enhanced plan is attained
- Important factors during the coverage planning phase are accuracy of the link budget parameters, BS coordinates and other coverage planning parameters
  - Verification is recommended
  - Same numbers are used from the planning through to the actual BTS
- Different result plots (e.g. composite plot, dominance plot) from network planning tools help us to identify coverage challenges (holes and overlapping)
- Appropriate location updates and parameter fine-tunings are undertaken to address the coverage challenges

Key methods for enhancing coverage

1. Optimize the link budget parameters (e.g. antenna height, antenna gain, BS power, …)
2. Use supplementary hardware (e.g. Booster and mast head amplifier)
   - A booster amplifies the BTS transmission
   - A mast head amplifier strengthens the BTS reception
3. Antenna tilting and azimuth
   - Electrical and mechanical

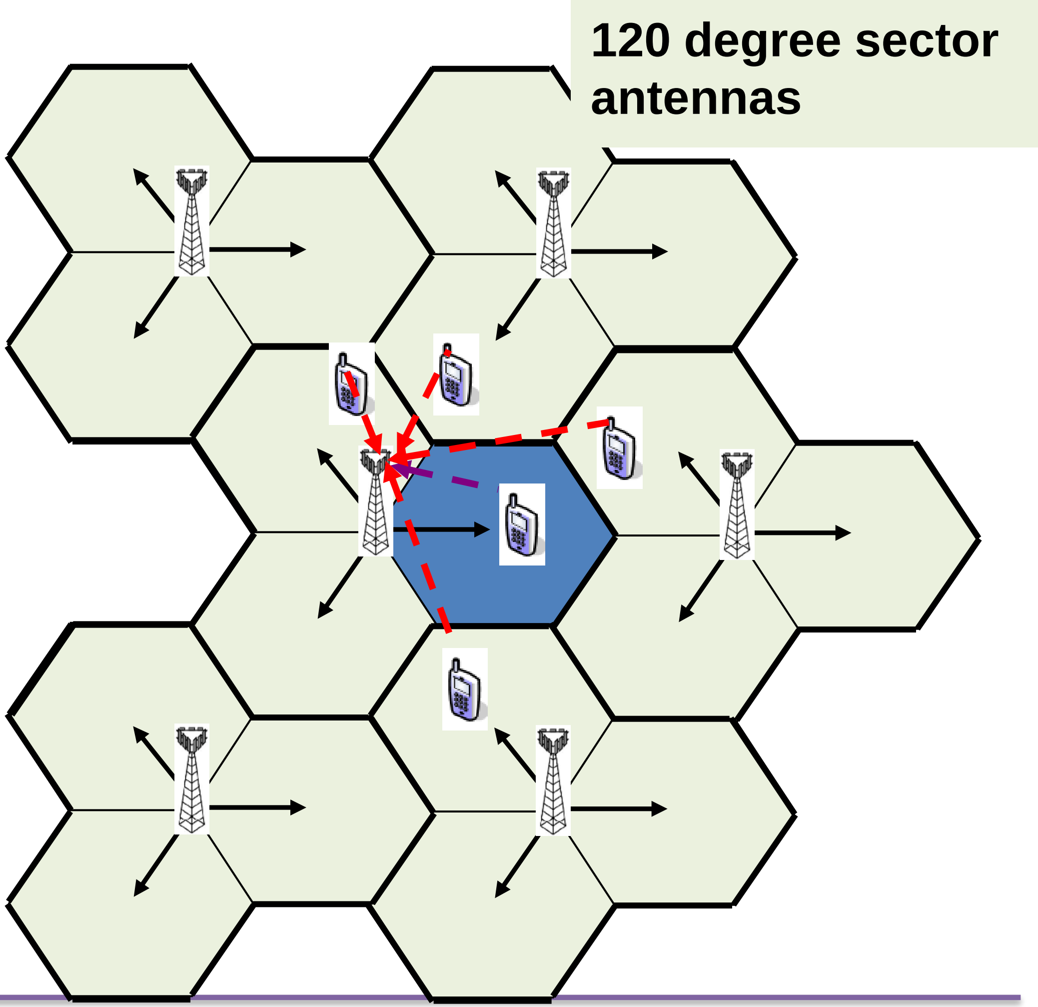
WCDMA capacity planning

- Capacity planning in WCDMA networks is much more complicated than in GSM/EGPRS
- In uplink, capacity planning would need to calculate the interference and the cell capacity
  - The amount of uplink interference has a great impact on the cell capacity and radius
- In downlink, the capacity is determined by the power transmitted by the BS, locations of UE and interference.
- In the WCDMA system, the traffic can be asymmetric in the uplink and downlink directions and thus the load can also be different in either direction.
  - The DL load is, however, higher than the UL load

Uplink load equation

Uplink wideband power

- Illustration: 3 sectors = 3 cells in each site.
- Blue cell = ‘other’ cells, green cell = ‘own’ cell
- All users are separated by scrambling codes
- Signals from different users are uncorrelated
- Path loss and antenna gain attenuates signals from ‘other’ cells



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Uplink load equation (1)

- Important measure that is used in system level investigations is the noise rise (denoted by *NR*) that is defined as a ratio between total received wideband power and AWGN noise power

(3) $$NR = \frac{I_{total}}{P_N}$$ **Definition of uplink noise rise**

our goal is to deduce a formula (load equation) that provides a connection between noise rise and link level parameters.

Uplink load equation (2)

- Consider a single link and denote by Eb/No the received energy per user bit divided by the noise spectral density. We have

$$E_b / N_0 = (\text{Processing gain}) \cdot \frac{\text{Signal power}}{\text{Total received power excluding own signal power}}$$

Hence, the minimum requirement for Eb/No is defined by the processing gain + power that is needed to overcome the interference from other users.

- Eb/No is an important variable since it actually maps the link level performance to the system level performance.

Uplink load equation (3)

- Let us formulate Eb/No mathematically. For a user *j* there holds

(4) $$(E_b / N_0)_j = \frac{W}{\nu_j R_j} \cdot \frac{P_j}{I_{total} - P_j}$$

where

$W = \text{System chip rate}$

$P_j = \text{Signal power of user j}$

$\nu_j = \text{Activity factor of user j}$

$R_j = \text{Bit rate of user j}$

$I_{total} = \text{Total received wideband power} + \text{thermal noise in base station}$

Uplink load equation (4)

- The load generated by *j*th user is

(5) $$\eta_j = \frac{P_j}{I_{total}}$$

- After combining (4) and (5) we find that

(6) $$\eta_j = \frac{1}{1+W/(\nu_j R_j \cdot (E_b/N_0)_j)}$$

This is uplink load generated by a single user

Uplink load equation (5)

- The load generated by N users in the 'own' cell is obtained by summing over (6)

Uplink load equation in isolated cell

$$\eta_{own} = \sum_{j=1}^{N} \eta_j = \sum_{j=1}^{N} \frac{1}{1 + W / (\nu_j R_j \cdot (E_b / N_0)_j)} \qquad (7)$$

Note: If there are e.g. 2 services used in the cell, then load equation is of the form

$$\eta_{own} = \frac{N_1}{1 + W / (\nu_1 R_1 \cdot (E_b / N_0)_1)} + \frac{N_2}{1 + W / (\nu_2 R_2 \cdot (E_b / N_0)_2)}$$

Uplink load equation (6)

- Formula (7) gives only the ‘own cell’ load which is generated by users that are connected to the considered (own) cell. In order to take into account also the load coming from other cells we introduce other-to-own cell interference factor

(8) $$\iota = \frac{\text{Other cell interference}}{\text{Own cell interference}} = \frac{I_{other}}{I_{own}}$$

- In practise other-to-own cell factor may greatly vary in different parts of the network. Now we can write the uplink load equation for non-isolated cell,

Uplink load equation for non-isolated cell

(9) $$\eta = (1 + \iota)\eta_{own}$$

Uplink noise rise (1)

- It is common to discuss on noise rise instead of load. Let us deduce the connection between noise rise and load. The total received wideband power admit the form

$$I_{total} = (1+\iota)\sum_{j=1}^{N} P_j + P_N = \eta \cdot I_{total} + P_N \qquad (10)$$

where last term is the AWGN noise power and we have used equations (2) and (5).

Uplink noise rise (2)

- After combining the definition of noise rise (3) and (10) we obtain the formula

(11) $$NR = \frac{I_{total}}{P_N} = \frac{1}{1-\eta}$$ **Noise rise in terms of load**

Noise rise is usually given in decibels. Thus

(12) $$NR_{dB} = -10\log(1-\eta)$$

Uplink noise rise (3)

- Noise rise of 3 dB is related to 50% load. This is usually limit value when deployment is coverage limited
- Noise rise of 6 dB is related to 75% load. This value is usual upper limit when deployment is capacity limited.
- Load and admission control is monitoring and controlling the noise rise in different cells

Load equation: Parameters

- Suitable value of Eb/No can be obtained from link simulations, measurements or from 3GPP performance requirements.
- Eb/No varies between services and its requirements are coming from the predefined receiver block error rate that is tolerated in order to meet the service QoS.
- Eb/No contains impact of soft handover and power control
  - Example values for multipath channel:
  - 12.2 kbps voice, Eb/No = 4.5 dB (3 km/h), Eb/No = 5.5 (120 km/h)
  - 128 kbps data, Eb/No = 1.5 dB (3 km/h), Eb/No = 2.5 (120 km/h)
  - 384 kbps data, Eb/No = 2.0 dB (3 km/h), Eb/No = 3.0 (120 km/h)

Load equation: Parameters

- **System chip rate W:**
  - 3.84 Mcps for WCDMA (5 MHz bandwidth)
- **Activity factor ν:**
  - Value 0.67 for speech (uplink recommendation)
  - Value 1.0 for data
- **Bit rate R:**
  - Depends on the service, usually up to 400-500 kbps
- **Other-to-own cell interference ι:**
  - Depends on the antenna configuration and network topology
    - Omni-directional antennas $\iota = 0.55$
    - Three-sector cells $\iota = 0.65$
    - ι may greatly vary due to load variations in adjacent cells

Uplink load equations: Example (1)

- **Example.** Plot uplink noise rise curves (in decibels) for
  - 12.2 kbps voice service (all users in the cell use the same service)
  - 128 kbps data services (all users in the cell use the same service)
- Give X-axis of the plot as a function of number of users. All sites in the network admit three sectors (cells) and user mobility is 3 km/h in the first and 120 km/h in the second case.

Uplink load equations: Example (2)

- **Solution.** We use equations

$$\eta_{own} = \sum_{j=1}^{N} \eta_j = \sum_{j=1}^{N} \frac{1}{1 + W/(\nu_j R_j \cdot E_j)} = \frac{N}{1 + W/(\nu \cdot R \cdot E)}$$

$$\eta = (1 + \iota)\eta_{own} \qquad NR_{dB} = -10\log(1 - \eta)$$

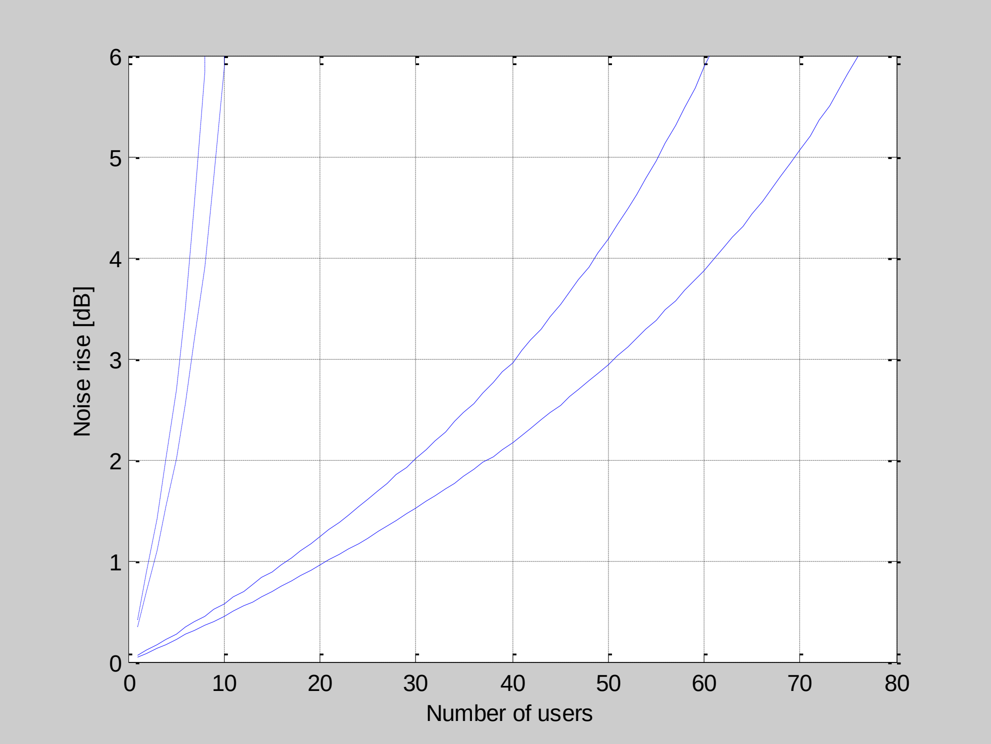
,

Required parameters are

$$W = 3.84 Mcps, \nu = 0.67, R_{voice} = 12.2\text{ kbps}, R_{data} = 128\text{ kbps},$$
$$\left(E_b / N_0\right)_{voice}(3km/h) = 4.5dB, \left(E_b / N_0\right)_{data}(3km/h) = 1.5dB,$$
$$\left(E_b / N_0\right)_{voice}(120km/h) = 5.5dB,$$
$$\left(E_b / N_0\right)_{data}(120km/h) = 2.5dB, \iota = 0.65$$

Uplink load equations: Example (3)

- Requested noise rise plot



12.2 kbps voice service (solid curve) and 128 kbps data service (dashed curve). Lower curves: 3km/h mobility, upper curves: 120 km/h mobility

Uplink load equations: Example (4)

- **Observations:**
  - With 3 dB noise rise system can support in uplink
    - Round 50 (40) voice users when user mobility is 3 km/h (120 km/h)
    - Round 6 (5) data users when user mobility is 3 km/h (120 km/h)
  - With 6 dB noise rise system can support in uplink
    - Round 75 (60) voice users when user mobility is 3 km/h (120 km/h)
    - Round 10 (8) data users when user mobility is 3 km/h (120 km/h)
- **Note:** these are example values that heavily depend on the applied parameters

Downlink load equation

Downlink load equation (1)

- ❖ We start the derivation of the downlink load equation from the so-called pole equation.
- ❖ The baseline assumption is that fast power control is applied. Then UEs are able to obtain exactly the minimum required Eb/No.
- ❖ The link quality equation for the user j in cell m attain the form

Received interference power from ‘other’ node B’s

(13) $$\left(E_b / N_0\right)_j = \frac{W}{R_j} \cdot \frac{P_j}{L_{m,j}} \cdot \frac{1}{(1-\alpha_j)P / L_{m,j} + \sum_{n=1, n\neq m}^{N_{cells}} P / L_{n,j} + P_N}, \quad j = 1,2,\ldots,N_{own}$$

AWGN noise power

Processing gain

Power for user *j*

Received interference power from ‘own’ node B

Downlink load equation (2)

- Parameters in link quality equation are

W = System chip rate

P_j = Required signal power of user j in base station transmission

P = Base station transmission power

$L_{m,j}$ = Path loss between considered base station (index m) and UE

R_j = Bit rate of user j

$L_{n,j}$ = Path loss between nth base station and UE

N_{cells} = Number of cells

Downlink load equation (3)

- In equation (13) first term is the processing gain multiplied by signal power after path loss.

$$\frac{W}{R_j} \cdot \frac{P_j}{L_{m,j}}$$

- The denominator of the second term defines the interference and AWGN noise.
  - First interference term contains the impact of imperfect code orthogonality (due to multi-path fading) which is multiplied by ‘own’ base station power after path loss.

$$(1-\alpha_j)P/L_{m,j}$$

  - The second interference term contains interference coming from other cells.

$$\sum_{n=1, n\neq m}^{N_{cells}} P/L_{n,j}$$

Note: It is assumed that all base stations apply the same transmission power *P*

On orthogonality factor

- In operational network, α is continuously changing
- α is estimated by base station based on UL multipath propagation. According to experience, α for typical WCDMA environments is
  - 0,5 – 0,6 in macro cells
  - 0,8 – 0,9 in micro cells (smaller cells, less multipath)
- Too optimistic α can lead to coverage problems
- Too modest α can lead to inefficient utilisation of DL performance

Base station transmission power (1)

- Let us solve the power that is needed for user j from equation (13). We obtain

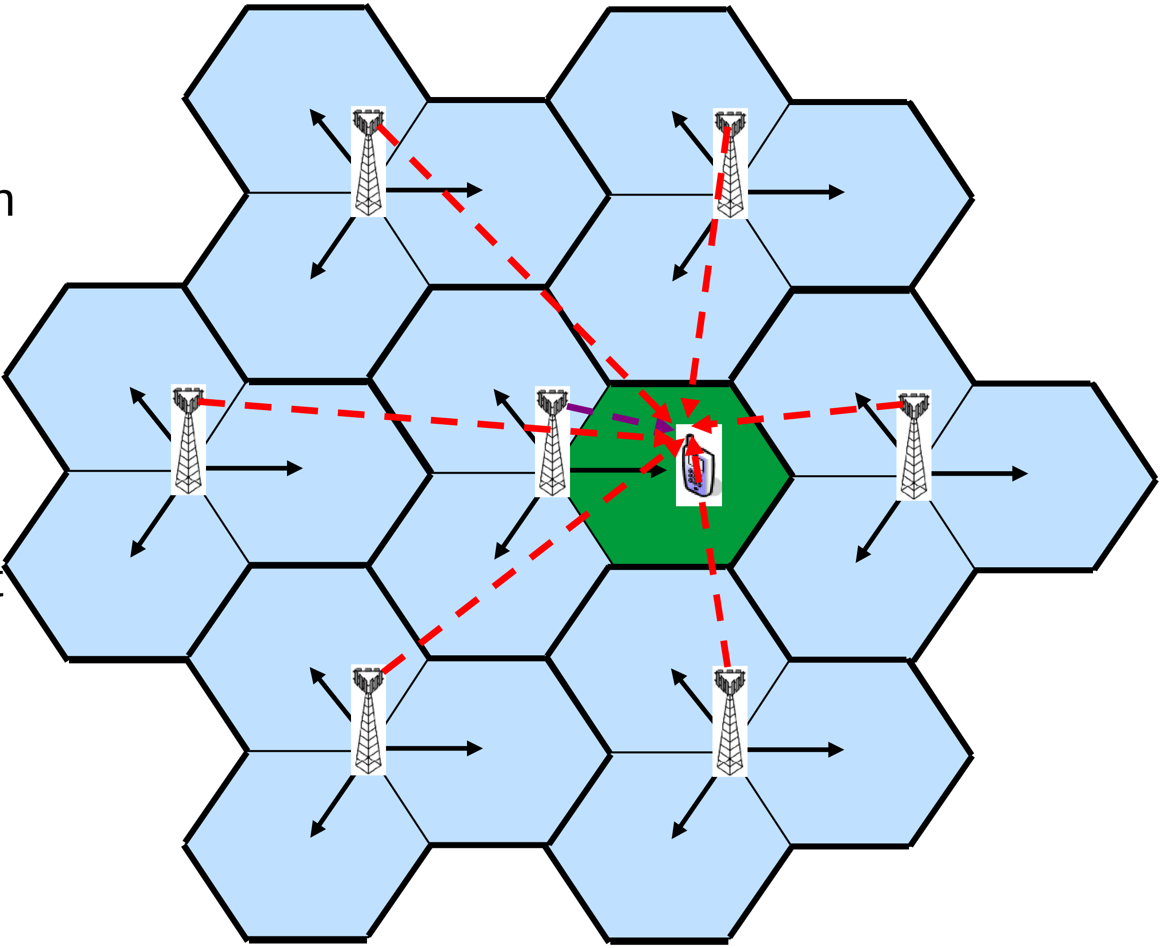
(14) $$P_j = \frac{(E_b/N_0)_j \cdot R_j}{W} \cdot \left(P \cdot (1-\alpha_j) + P \sum_{n=1, n\neq m}^{N_{cells}} L_{m,j}/L_{n,j} + P_N L_{m,j} \right), \qquad j = 1,2,\ldots,N_{own}$$

We note that in downlink other-to-own cell interference is different for different users. We have

(15) $$\iota_j = \sum_{n=1, n\neq m}^{N_{cells}} \frac{P \cdot L_{m,j}}{P \cdot L_{n,j}} = \sum_{n=1, n\neq m}^{N_{cells}} \frac{L_{m,j}}{L_{n,j}}$$

Downlink other-to-own cell interference

- Illustration: 3 sectors = 3 cells in each site.
- Blue cells = ‘other’ cells, green cell = ‘own’ cell
- Other-to-own cell interference depends on the user location
- Cells are separated by scrambling codes
- Shadowing related to different base stations is correlated to some extent
- Path loss attenuates base station signals from ‘other’ cells



Base station transmission power (2)

- Next we sum up powers of different users and take into account the activity factor. Then we obtain the formula

$$(16)\quad P = P\sum_{j=1}^{N_{own}} \frac{(E_b/N_0)_j R_j \nu_j}{W} \cdot \left((1-\alpha_j) + \iota_j\right) + P_N \sum_{j=1}^{N_{own}} \frac{(E_b/N_0)_j R_j \nu_j}{W} L_{m,j}$$

From (16) we solve the required total base station transmission power

$$(17)\quad P = \frac{P_N \sum_{j=1}^{N_{own}} \frac{(E_b/N_0)_j R_j \nu_j}{W} L_{m,j}}{1 - \sum_{j=1}^{N_{own}} \frac{(E_b/N_0)_j R_j \nu_j}{W} \cdot \left((1-\alpha_j) + \iota_j\right)}$$

Required base station transmission power in downlink

Downlink load equation (4)

- In (17) we denote the downlink load by

(18) $$\eta = \sum_{j=1}^{N_{own}} \frac{\left(E_b / N_0\right)_j R_j \nu_j}{W} \cdot \left((1-\alpha_j) + \iota_j\right)$$ **Downlink load equation**

and the downlink noise rise by

$$NR = \frac{1}{1-\eta} \qquad NR_{dB} = -10\log(1-\eta)$$

Base station transmission power (3)

- In decibels the required base station transmission power is of the form (see eq. (17))

(19) $$P_{dB} = (P_N)_{dB} + 10\log\left(\sum_{j=1}^{N_{own}} \frac{(E_b / N_0)_j R_j \nu_j}{W} L_{m,j}\right) + NR_{dB}$$

Required base station transmission power in decibels

- The factors that impact to the required transmission power in base station
  - AWGN noise (first term)
  - Transmission power that is needed to serve own cell users (second term)
  - Transmission power that is needed to overcome the interference (third term). Interference contains contribution from own cell (imperfect code orthogonality) and from other cells.

Base station transmission power (4)

- In downlink it is important to estimate the required base station power.
- Link budget gives the maximum transmission power which is determined by the cell edge users
- However, planning should be based on the average transmission power. This follows from the fact that users are spread all over the cell and wideband transmission is a sum over all signals. Hence, it contains signals to users on cell edge as well as signals to users near the base station.
- The difference between maximum and average path loss is typically 6 dB.

Downlink load equation (5)

- The average load in the cell is given by

(20) $$\bar{\eta} = E\{\eta\} = \sum_{j=1}^{N_{own}} \frac{(E_b / N_0)_j R_j \nu_j}{W} \cdot \left((1-\bar{\alpha}) + \bar{\iota}\right)$$ **Downlink average load equation**

- $\bar{\alpha}$ is the mean orthogonality factor.
  - In ITU Vehicular A channel $\bar{\alpha}$ is round 0.5
  - In ITU Pedestrian A channel $\bar{\alpha}$ is round 0.9
- $\bar{\iota}$ is the mean other-to-own cell interference factor
  - In macro-cell deployment with omnidirectional antennas $\bar{\iota}$ is round 0.55
  - In macro-cell deployment with 3-sector sites $\bar{\iota}$ is round 0.65

SIR/activity values for downlink

- Example values for Eb/No in downlink multi-path channel:
  - 12.2 kbps voice, Eb/No = 6.7 dB (3 km/h), Eb/No = 6.4 (120 km/h)
  - 128 kbps data, Eb/No = 5.3 dB (3 km/h), Eb/No = 5.0 (120 km/h)
  - 384 kbps data, Eb/No = 5.2 dB (3 km/h), Eb/No = 4.9 (120 km/h)
- Recommended activity factor in downlink:
  - Value 0.58 for speech
  - Value 1.0 for data.

Base station transmission power (5)

- In planning the following mean total transmission power in base station is to be used

(21)
$$P_{BS} = \frac{N_{rf} \cdot W \cdot \bar{L} \cdot \sum_{j=1}^{N_{own}} \frac{(E_b / N_0)_j R_j \nu_j}{W}}{1 - \sum_{j=1}^{N_{own}} \frac{(E_b / N_0)_j R_j \nu_j}{W} \cdot \left((1-\bar{\alpha}) + \bar{\imath}\right)}$$

Here N_{rf} is the noise spectral density of the receiver front end. There holds (in linear scale)

(22)
$$N_{rf} = k \cdot T + NF$$

Where k $= 1.381 \cdot 10^{-23}$ J/K is Boltzmann constant, T is temperature in Kelvin and NF is receiver noise figure that is usually between 5 to 9 dB.

Example

- Plot maximum allowed path loss as a function of number of users for 12.2 kbps voice service and for 64 kbps data service when
  - BS transmission power is 40W
  - BS transmission power is 10W

  All sites in the network admit three sectors (cells), users mean mobility is 3 km/h, average orthogonality factor is 0.5, average mobile noise figure is 7dB.

Example

- Solution. We solve mean path loss from equation

$$P_{BS} = \frac{N_{rf} \cdot W \cdot \bar{L} \cdot \sum_{j=1}^{N_{own}} \frac{(E_b / N_0)_j R_j \nu_j}{W}}{1 - \sum_{j=1}^{N_{own}} \frac{(E_b / N_0)_j R_j \nu_j}{W} \cdot ((1-\bar{\alpha}) + \bar{\iota})} = \frac{N_{rf} \cdot \bar{L} \cdot N_{own} \cdot (E_b / N_0) \cdot R \cdot \nu}{1 - \frac{N_{own} \cdot (E_b / N_0) \cdot R \cdot \nu}{W} ((1-\bar{\alpha}) + \bar{\iota})}$$

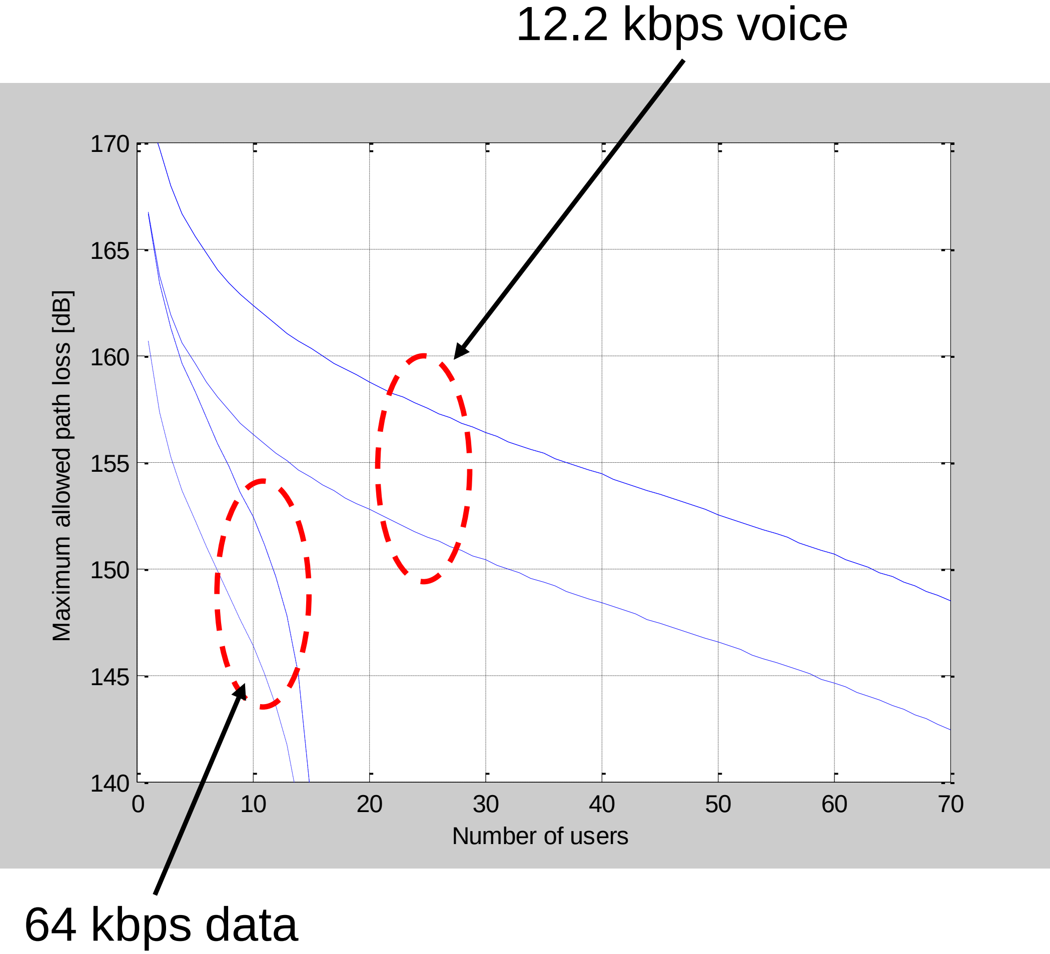
and compute its numeric value for different number of users by substituting parameters

- N_{rf} = -174+7dB, $\bar{\alpha}$ = 0.5, $\bar{\iota}$ = 0.65, ν = 0.58, W = 3.84 Mcps,
- R = 12.2 kbps, R = 64 kbps, Eb/No = 6.7 dB (voice), Eb/No = 5.3 dB (data),
- P_{BS}= 0.85*40W, P_{BS} = 0.85*10W (15% of BS power is spend on control channels)

Finally, we add 6 dB margin to achieved mean path loss. The resulting values are plotted in the figure of the following slide

Example

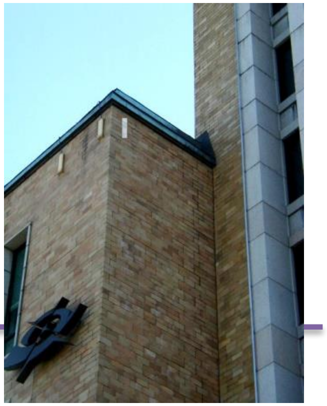
- Observations:
- Number of downlink data users can be increased only slightly by increasing the base station transmission power
- Number of voice users can be significantly increased by increasing the base station transmission power



Important planning aspects

Planning – antenna height

- Since WCDMA performance is interference limited the cell dominance areas should be kept as controlled as possible
- If the antenna is located ”too high” (no proper tilting) then
  - The cell gathers more traffic and external interference and thus the ”effective” capacity is decreased
  - Produced interference decreases the capacity of the surrounding network
  - Also surrounding network’s service propability is negatively effected



$$\bar{\eta} = E\{\eta\} = \sum_{j=1}^{N_{own}} \frac{\left(E_b / N_0\right)_j R_j \nu_j}{W} \cdot \left(\left(1-\bar{\alpha}\right)+\bar{\imath}\right)$$

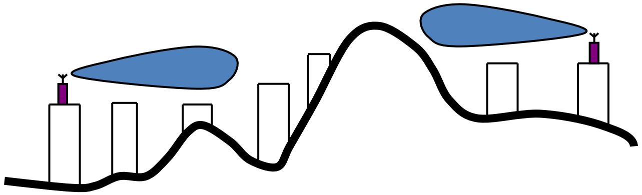
Planning – antenna height

- If WCDMA base station antenna is placed over the rooftop then antenna tilting is needed.

Planning – antenna azimuth

- Natural obstacles and buildings should be used to create good dominance areas for WCDMA cells
- This improves the SHO performance and decreases interference

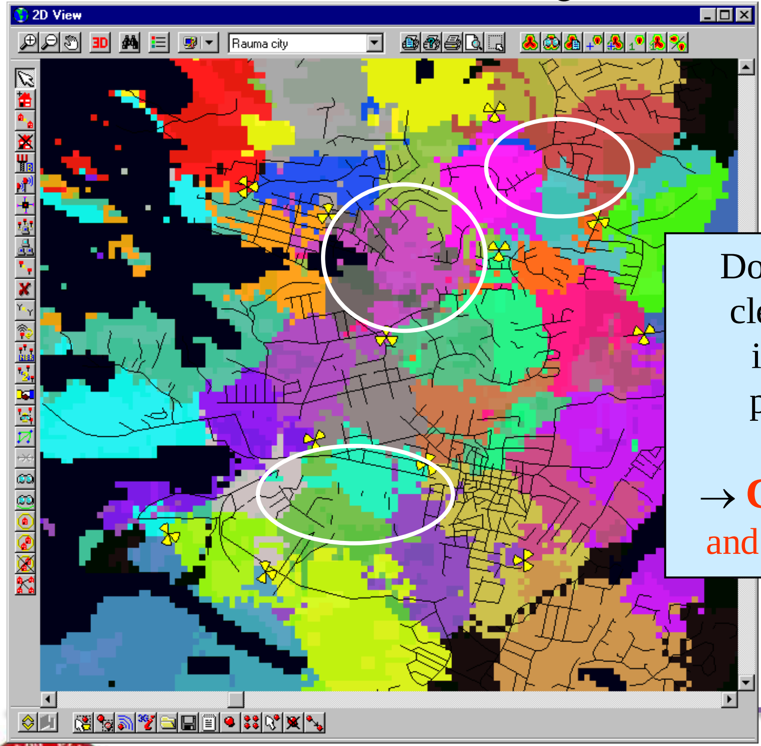
- Example of a UMTS cell, that is naturally bordered (wall effect) by buildings



Planning – antenna height

- When re-using the GSM sites, analysis should be made whether the UMTS antennas should be positioned lower
- This analysis is done with simulations and visiting the site locations in practise

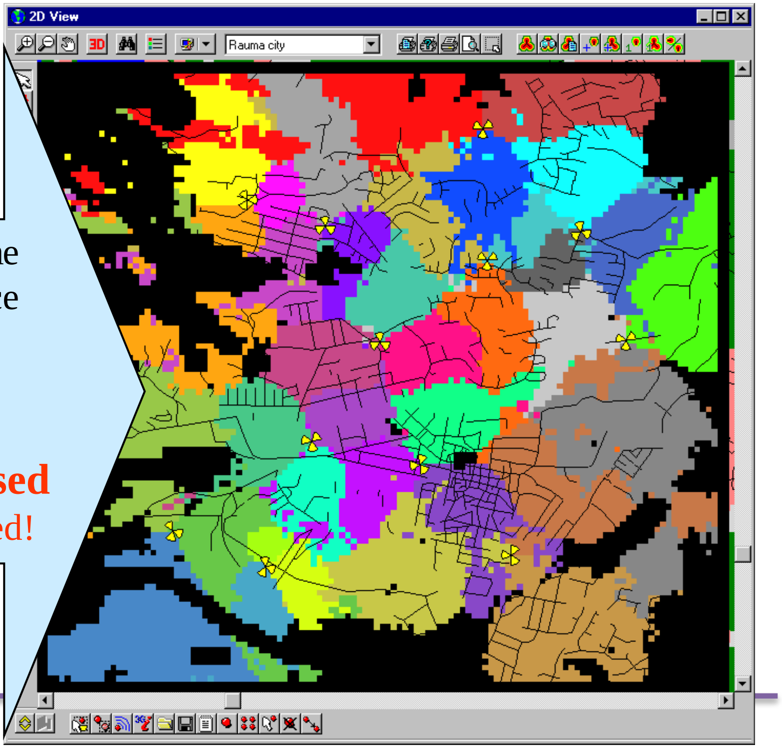
Part of network with re-used few +40meter GSM antenna heights



Dominance areas become clear, so less interference is introduced and HO performance is better.

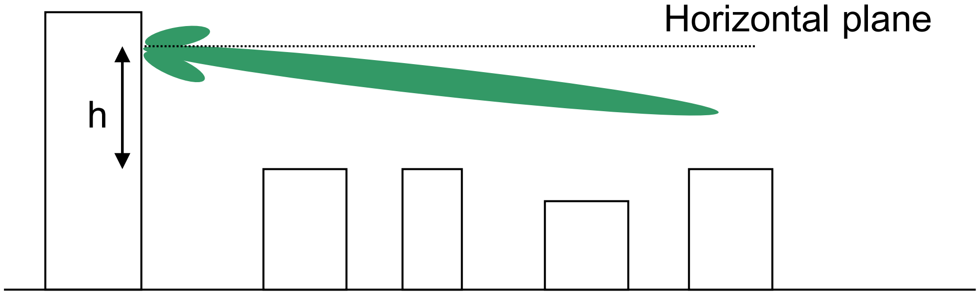
→ **Capacity is increased** and performance enhanced!

High UMTS antenna positions lowered to 25-35m



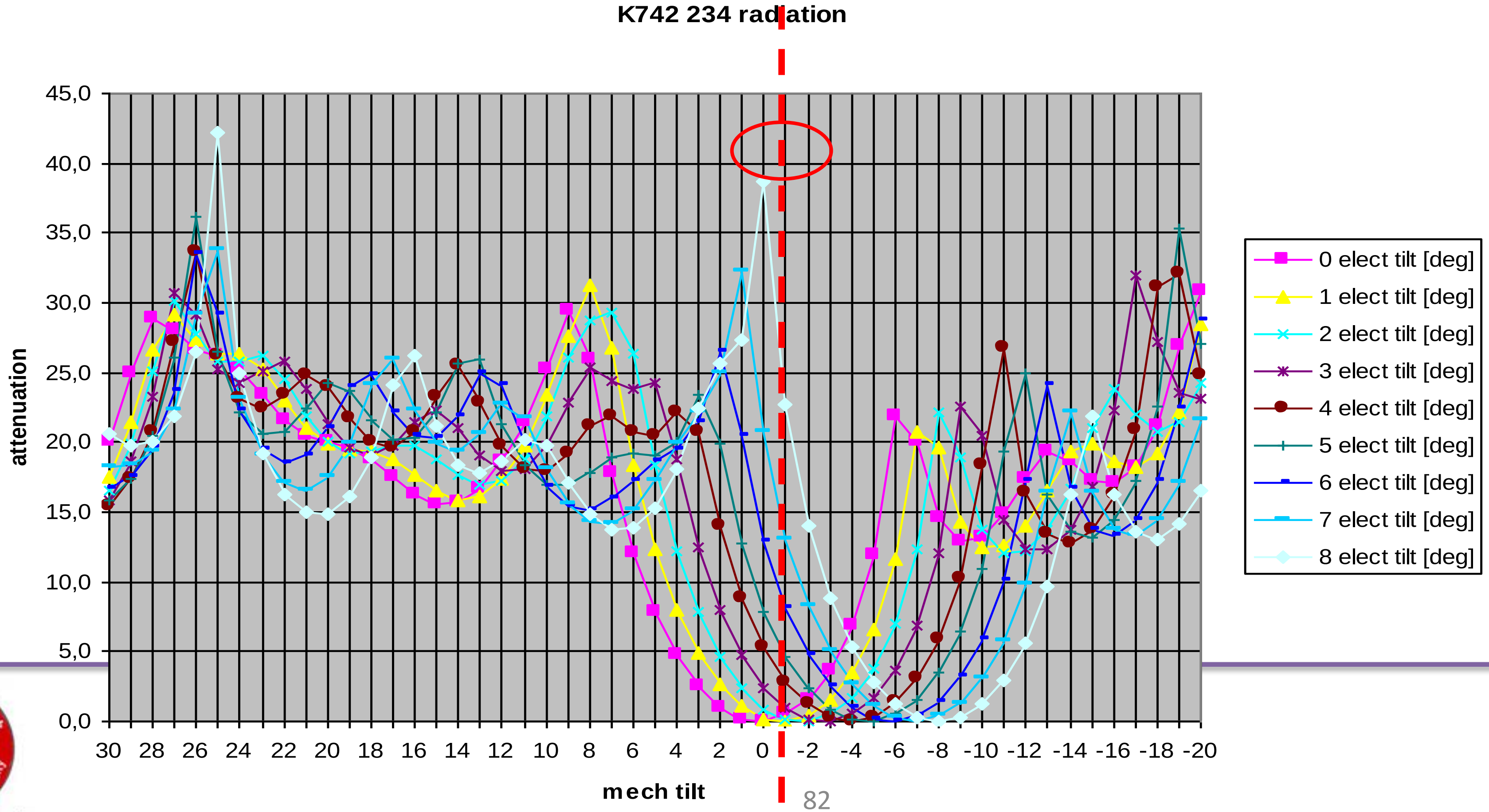
Planning – antenna tilt

- In addition to antenna height, downtilting is very important physical means for interference minimizing in WCDMA
- Basic rule for antenna tilt is that the height of the antenna should be selected with respect to the wanted amount of cell range
- If the cell range with respect to available antennas and their tilting with a feasible amount of tx-power becomes too large to suit the network plan, then the antenna must be lowered
- According to the experience, the analysis should start with the optimum tilting and not by reducing the tx-powers of the cell, which can be optimised after the tiltings are done



Planning – antenna tilt

- It is important to plan the tilting angle according to the antenna characteristics
- Good choice is to tilt antenna such that is the first zero of the antenna radiation pattern is pointed to horizontal direction



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Planning – antenna tilt

- In previous slide the horizontal radiation power of the antenna is set to minimum in order to receive minimum amount of direct interference from the surrounding cells.
- Typically WCDMA macro-cell antenna has the first vertical lobe radiation pattern zero around 7-8deg away from the maximum point (depends on the antenna design), which still allows a reasonable cell size
- The attenuation of the first zero is usually over 20dB compared to the main lobe.
- Usually it is of no use to apply larger tilt than the one that points the first zero to horizon since interference from the antenna increases with larger tilt.
  - This rule of thumb is not necessarily valid in urban (dense) deployments

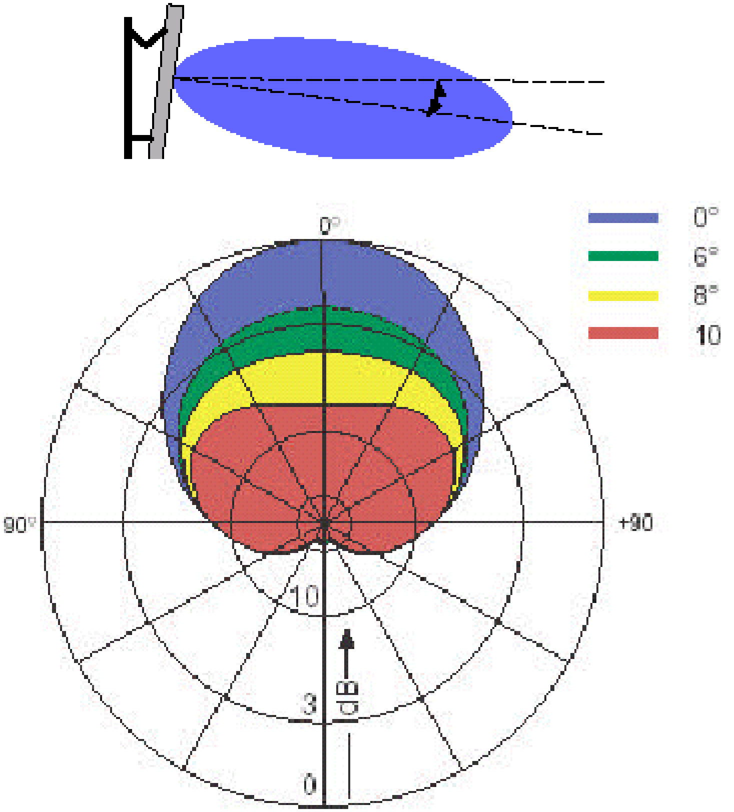
Planning – antenna tilt

Mechanical or electrical tilting?

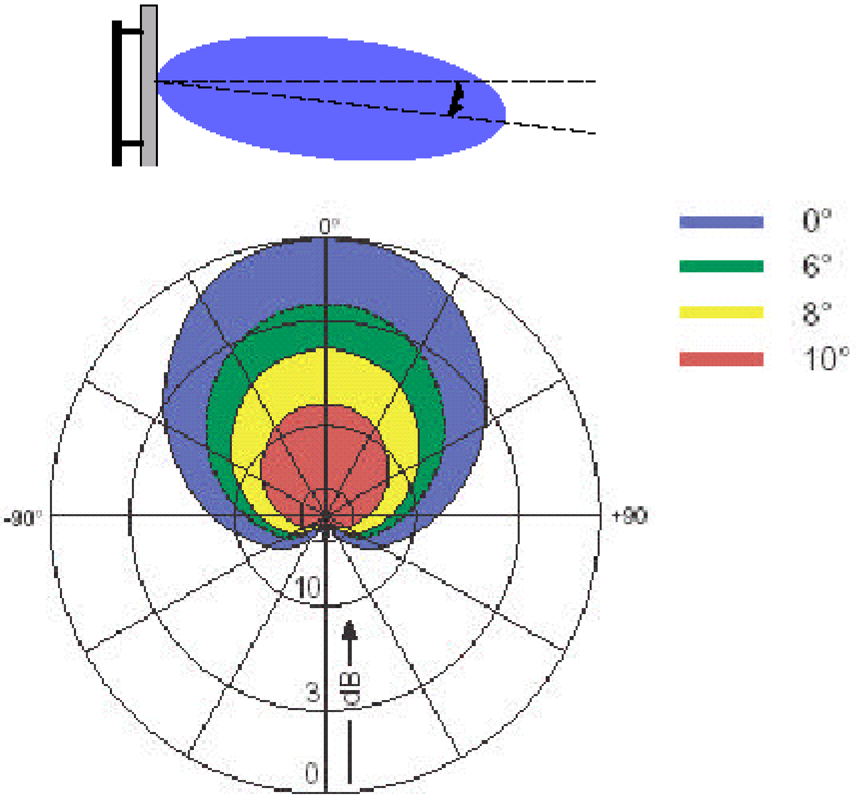
- If there is both electrical and mechanical tilting available, a combination of these two can be combined properly case by case
- Mechanical tilt
  - widens the antenna lobe horizontally, which can be used in some cases
  - does not attenuate the radiation sideways
- Electrical tilt
  - attenuates the radiation also on sideways
- By selecting a combination of these two the first zero of the antenna can be set to horizontal level and the needed amount of power achieved on sideways horizontally if there is a need for it
- When high building is used as a site the antennas can be wall-mounted, so that the needed level of attenuation to the wanted directions are easier to achieve.

Planning – antenna tilt

Mechanical tilt



Electrical tilt



Transmission powers

- Default transmission powers are determined by the equipment vendors.
- In initial phase of the planning
  - Transmission powers of TCHs and CCHs needs to be set
- In DL the power tuning between TCHs and CCHs has effect on network performance
  - More power to CCHs → better channel estimation, which improves the Eb/No performance and thus improves coverage
  - More power to TCHs → better capacity
  - Rule of thumb: 15-20% of DL total power is used for CCHs
- Most important control channel is the primary common pilot channel (P-CPICH)

Transmission powers

- Primary CPICH (P-CPICH) is transmitted continuously with constant power (spreading factor 256, no power control) so it is in fact a significant source of interference.
  - If received P-CPICH is not included in the UE active set, all the power received is interference (this is called as pilot pollution)
- The physical cell range is defined by P-CPICH transmission power
  - The same coverage must be guaranteed for other common channels as well
- The major effects when the pilot power is adjusted
  - The handover behaviour of the network can be changed
  - Load can be divided between cells to certain extent
  - Ability to divide the base station power between cell coverage and capacity.

Transmission powers

- P-CPICH takes typically 5-20% of the node B maximum transmission power
- Clear dominance areas for cells should be ensured with consistent P-CPICH power planning
  - CPICH powers should be planned first, then other SHO parameters
  - Goal is to limit cell overlapping so that the P-CPICH power in the cells outside active set is at least 10dB below the best cell in the active set
- Large differencies in P-CPICH powers of neighbouring cells should be avoided

Transmission powers

- Indicators for P-CPICH power level in practice
  - Other-to-own cell interference (recall load equation discussion)
  - Frequency of active set update messages
  - Dropped calls and throughput
- With low amount of P-CPICH power, the interference produced goes down, but also the robustness of the network is effected negatively.
- Higher amount of P-CPICH power increase signaling and SHO areas as well as produced interference, but the network operation is more robust.

Transmission powers

- Also other control channels beside CPICH need power (for example BCH) to enable correct functioning of the system
- All the other common control channels are powered in relation to the P-CPICH
- The goal of allocating power to the common channels is to find a minimum power level needed for each channel to secure the network operation and to provide the same cell coverage area as with CPICH, but not to waste any capacity left for the traffic channels.

Typical DL power recommendations

Channel	Allocated power
Max power of the Node B	43 dBm
CPICH	Max power – 10dB
PCH	Max power – 11 …13 dB
SCH	Max power – 11 … 12 dB
FACH	Max power – 12 – 13 dB
BCH	Max power – 11 … 13 dB

Recall: Some control channels

- PCH: Paging channel initiates the communication from network side
- SCH: Synchronization channel
- FACH: Forward access channel carries control information to terminals that are known to be located in the given cell. Is used to answer to the UL RACH message.
- BCH: Broadcast channel carries network specific information to the given cell (random access slots for UL, antenna configuration etc)
- PICH: Paging indicator channel is used to provide sleep mode operation for UE
- AICH: Acquisition indicator channel is used to indicate the reception of RACH
- CCPCH: Primary and secondary common control physical channels (P-CCPCH and S-CCPCH) are physical channels that carry BCH, FACH and PCH.

Example: Transmission powers

Channel	Allocated power	Power out of the total common channel powers	Power out of the maximum Node B transmission power (20W)
P-SCH	0,331 W		
S-SCH	0,224 W		
PICH	0,1 W		
AICH	0,126 W		
P-CCPCH	0,245 W		
S-CCPCH	1,165 W		
CPICH	1 W	31 %	5 %
All common Ch	3,191 W	100%	16 %

- P-CCPCH transmitted with activity factor 0,9
- S-CCPCH transmitted with activity factor 0,25
- SCHs transmitted with activity factor 0,1
- AICH, PICH and CPICH are transmitted continuously
- The BCH is transmitted on the P-CCPCH and the FACH and PCH on the S-CCPCH.
- the BCH is transmitted on the P-CCPCH continuously except during the 256 first chips, when the P-SCH and S-SCH are transmitted we can assume 0,1 activity factor for the SCHs and 0,9 for the P-CCPCH.

Transmission powers/DCH’s

- Dedicated channel (DCH) is a transport channel that is mapped to dedicated physical data channel (DPDCH) and dedicated physical control channel (DPCCH)
- The initial power for DPDCH is important because of reliable service set-up
- The initial DCH power is determined by RRM via
  - Spreading Factor
  - Measured Ec/Io on P-CPICH
  - Transmitted power on P-CPICH
  - Service requirements
- Network planning usually needs to plan at least the ”initial DL SIR target” & ”default CPICH power”
- In Uplink the network planning can set initial PC settings, such as ”UL SIR target”, which will effect the power of the first connection

Transmission powers

- The minimum and maximum transmitted code powers can be set per cell (interference & coverage control)
  - It is rather important not to set this maximum power too high. Too high setting of the maximum power will lead to instability in the downlink transmitted carrier power behavior and might effect the quality of the common channels in a cell.
- During the operation, powers allocated per DCH connection can be set according to vendor specific algorithm
  - This is important to the service probability and allows improving of high bitrate services if so decided

Planning only for P-CPICH power in terms of achievable service coverage is not enough, needed DCH power in relation to P-CPICH needs to be set as well.

Transmission powers

- Antenna and transmission power design lead to certain achievable Ec/Io over the network, which in turn depict a certain service level

DCH Ec/Io determines the service coverage!

$$\frac{E_C}{I_O} = \frac{E_b / N_0 \cdot R}{W \cdot (1-\eta)} = \frac{RSCP}{RSSI}$$

RSCP = Received signal code power = received power on one code after despreading. Measured in terminal.
RSSI = Received signal strength indicator = received wideband power on the whole bandwidth. Measured in terminal.

Pilot pollution

- Pilot pollution is faced on a certain area when there is no clearly dominant P-CPICHs over the others.
- The pilot pollution creates an abnormally high level of interference, which is likely to result in the performance problems
  - Increased interference level
  - Poor service quality, decreased throughput or increased delay
  - Decreased service access
  - Frequent changes in Active Set and potential risk for unnecessary handovers.
  - High non-controllable load

Pilot pollution

- Pilot pollution can be (at least partly) avoided by planning the CPICH powers and SHO parameters so that throughout the network there is only 2-3 CPICHs available for the UE's, strong enough to be included in the Active Set.
- All CPICH outside Active Set should be clearly weaker
- Antenna design, height and tilt are selected carefully

Neighbour cell relations

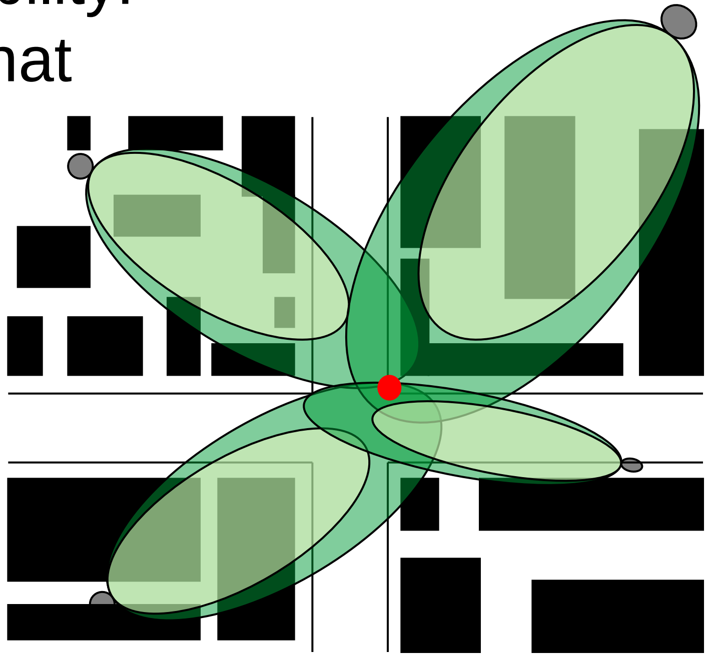
- The Monitored Set is also called as a Neighbour List. This list can be defined in network planning and it can be later changed in network optimization.
- The list of neighbours play an important role since WCDMA is interference limited. Insufficient planning of neighbour relations will lead to unnecessary high interference
  - E.g. if suitable SHO candinate is not in the monitored set and thus it is not selected to active set then it’s turning to a ”pilot polluter”
  - On the other hand, unnecessary neighbours increase signalling and effects the SHO selection negatively
- Accurate neighbour relations planning is much more important than in GSM
  - In GSM it is possible to ”hide” cell planning mistakes by frequency planning, in CDMA the such inaccuracies will effect the system capacity
  - The effort saved in frequency planning is spent in more detailed cell planning

Neighbour cell relations

- The parameters to control the neighbor relations and the algorithms how system evaluates neighbors for cell lists depend on vendor
  - minimum P-CPICH RSCP or Ec/Io
  - Ec/Io margin
  - maximum number of neighbors
- A neighboring set (or monitored set) is defined for each cell
  - Utilize planning tools automatized functions and check with drive tests
  - Optimize according to P-CPICH coverage and SHO parameters
- UE monitors the neighboring set that may contain
  - Intra-frequency monitored list: Cells on the same WCDMA carrier (Soft HO)
  - Inter-frequency neighbor list: Cells on another WCDMA carrier (hard HO)
  - Inter-system neighbor list: For each neighboring PLMN
- Missing neighbor can be detected during drive tests
  - If the best cell shown in the 3G scanner does not enter to the active set then there is a missing neighbor
  - Include the missing cell to neighbor list if it's wanted to the active set or change cell plan

SHO planning

- Soft/Softer HO planning and correct operation is one of the most important means of planning WCDMA networks
- The importance is high because of the high bit rate (pathloss sensitive) and RT (delay sensitive) RABs
- SHO is measured in terms of probability: The percentage of all connections that are in SHO state
- The probability is effected by network planning and parameter settings



SHO planning

- Probability for soft HO should be set to 30-50% and for softer HO to 5-15%, depending on the area
  - Too high SHO% results in excess overlapping between cells → other-cell interference increases → capacity decreases
  - Too high SHO% also leads to poorly utilised network capacity (unnecessary links)
  - With too low SHO% the full potential of network is not utilised and transmission powers cannot be minimized → trouble with interference
- SHO performance is planned with a planning tool and optimised by measurements in live network.
- In early stage SHO % can be planned high, since the traffic density is smaller. With increasing traffic coverage decreases and SHO areas become smaller.
- SHO % can be tuned with related parameters and dominance areas

WCDMA code and frequency planning

- WCDMA code and frequency planning are seen as a simple task from a network planning point of view
- The system takes care of most of the code allocation
- Main task for network planning is the allocation of scrambling codes for the downlink
  - There are 512 set of scrambling codes available
  - The code reuse for downlink is 512
  - Simple planning but usage of planning system is recommended to avoid errors
- Frequency planning has minor importance compared with GSM
- At most the UMTS operators have two or three carriers thus there is not much to plan
- Yet, there are a few key decisions to make:
  - which carrier(s) is used for macro cells?
  - Which carrier(s) is used for micro cells?
  - Any carrier(s) is reserved for indoor solutions?
- When making the decisions the interference aspects should be considered.

Parameter planning

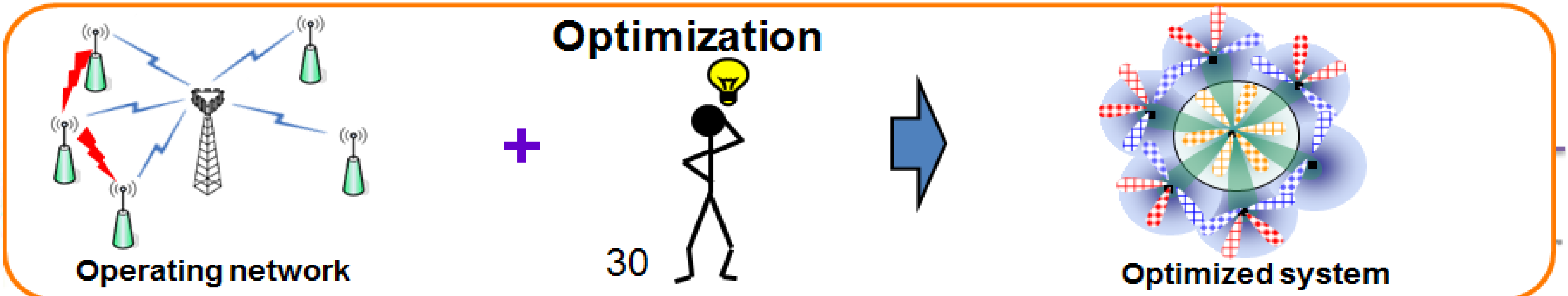
- **Common channel power setting parameters** need to be planned for optimal related operations**.**
- **Home-PLMNSeachPeriodTime** parameter used to set the frequency with which the mobile searches its home PLMN in the automatic selection mode.
    - In the manual mode, the UE gives the user an option to select from a list of found PLMNs where the signal level is considered good enough (RSCP, or received signal code power> −95 dBm)
- **Cell search related parameters: transmit power parameters** for synchronization channels and **timing offset** to make sure that synchronization channels are transmitted at different times in each cell of the same site
- Cell re-selection: measurement criteria and frequency parameters including **Sintrasearch, Sintersearch, SsearchRAT, TmeasureFDD, TmeasureGSM** parameters
- Handover, power control, admission control and other RRM related parameters

Contents

- WCDMA network dimensioning
- WCDMA network planning
- WCDMA network optimization

Optimization overview

- Once planned network is rolled out, optimization takes place to maximize benefits while minimizing capital and operational costs
- Note that operators are worried about their network quality perceived by end user as their competitiveness highly based on it and of course pricing
- Therefore, operators need to continuously monitor quality of their networks and perform appropriate actions to maintain and improve user quality of experience
- Optimization engineers make deep analysis on data collected from monitoring systems to identify required optimization tasks such as
  - Site re-engineering,
  - Parameter tuning,
  - Frequency plan review
- Optimization is a continuous process



WCDMA optimization approach

- Cluster based optimization
  - Network is divided into geographical areas called clusters, each consisting of 10 to 20 sites, based on different methods such as geographical proximity and interference coming in to the cluster from neighboring areas should be minimized
  - Each cluster is optimized to ensure QoS in that area
- Cluster preparation consists of activities that can be done without drive test data:
  - Defining clusters
  - Planning the drive route
  - Radio parameter audit
  - Site configuration check
  - Neighbor list verification
  - Fault management check
  - Cell availability check
- Prior to any drive tests a cluster should have the majority of its sites integrated be operational and available.

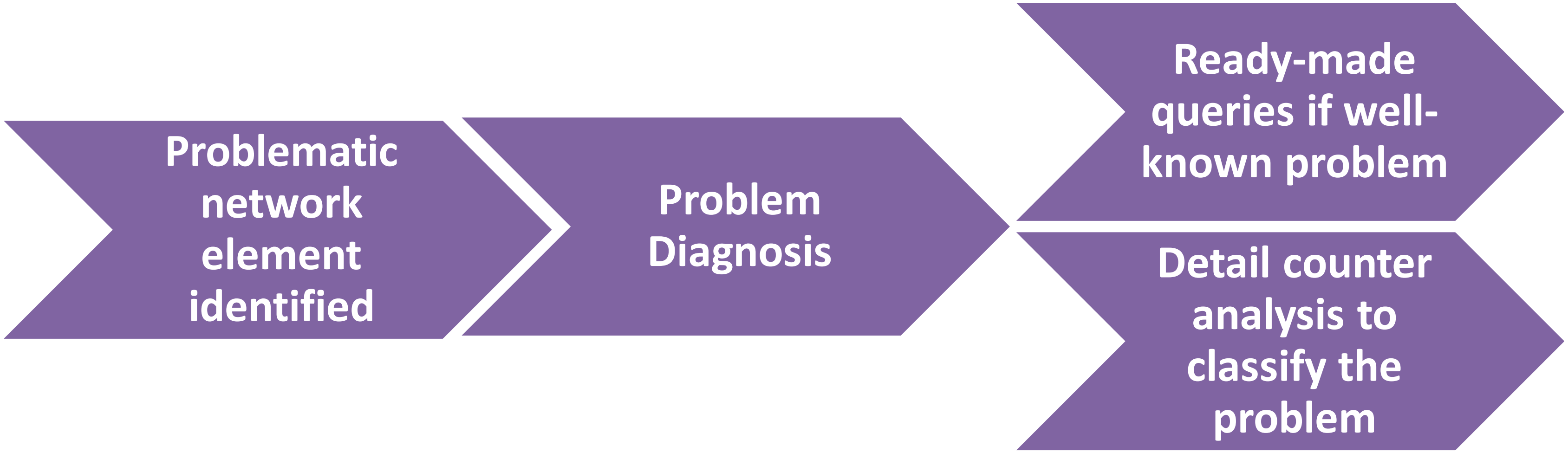
Example important indicators

- traffic
- traffic deviation
- traffic mix
- soft handover percentage
- average TX power
- average RX power
- drop calls
- handovers per call
- handovers per cell
- inter-system handovers
- Throughput
- BER, BLER, FER

QoS monitoring and spotting problems

- Analyzing statistics is a top-down process.
  - **High level (network or RNC level) performance indicators** are monitored to find out if there is a problem in the network
  - High level performance problems, anomalies and regular patterns of performance variation are triggers that indicate a need for further investigation
  - Typical granularity of high level performance data is one day and the monitored period lasts for two months.
  - Examples of high level performance indicators are: cell availability, call setup success rate, drop call rate
  - After identifying a problem in **high level performance indicators** in order to find out what is causing the problem, low level performance indicators need to be analyzed based on large numbers of statistical counters
    - It can be started from cell-level KPI calculation or counter based problem identification leading to problematic cell
- Analyzing the geographical proximity of cells having problems might indicate something wrong with a whole cluster of cells, e.g. the HW/SW problem related to the transmission network, etc.

QoS monitoring and spotting problem



Problematic network element identified

Problem Diagnosis

Ready-made queries if well-known problem

Detail counter analysis to classify the problem

The field measurements analysis is usually started after looking at (statistical) performance data (counters) to evaluate how much the analyzed area had problems from end user perspective.

Details on counters and drive test parameters

NMS/OMS/OSS and drive and test product specific

Example counters: RAB active failures

Example drive and test parameters: RSCP, Ec/Io

TASK: Identify and examine some counters and drive and test parameters for WCDMA NMS and drive and test products available on the market, say those applied by Ethio Telecom

AAiT

WCDMA optimization

Based on identified network problems seen using indicators, appropriate optimization tasks including those approaches applied during planning phase need to be applied so that the network continuously deliver quality services for subscribers!