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Cellular Network Planning and Optimization
Part X: WCDMA planning challenges

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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

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

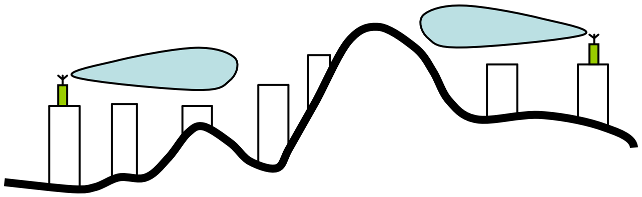
Planning – antenna height

- 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

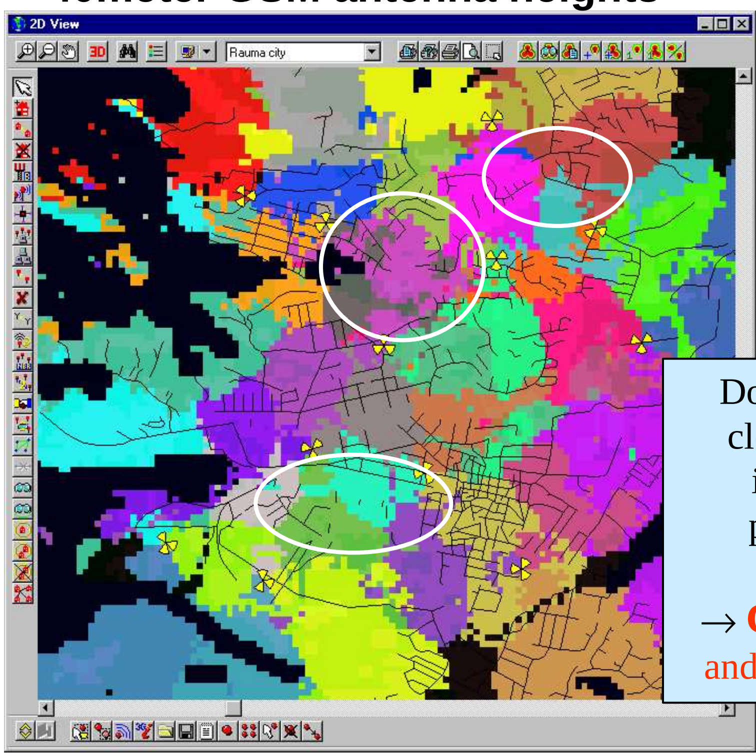
- Example of a UMTS cell, that is naturally bordered (wall effect) by buildings



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

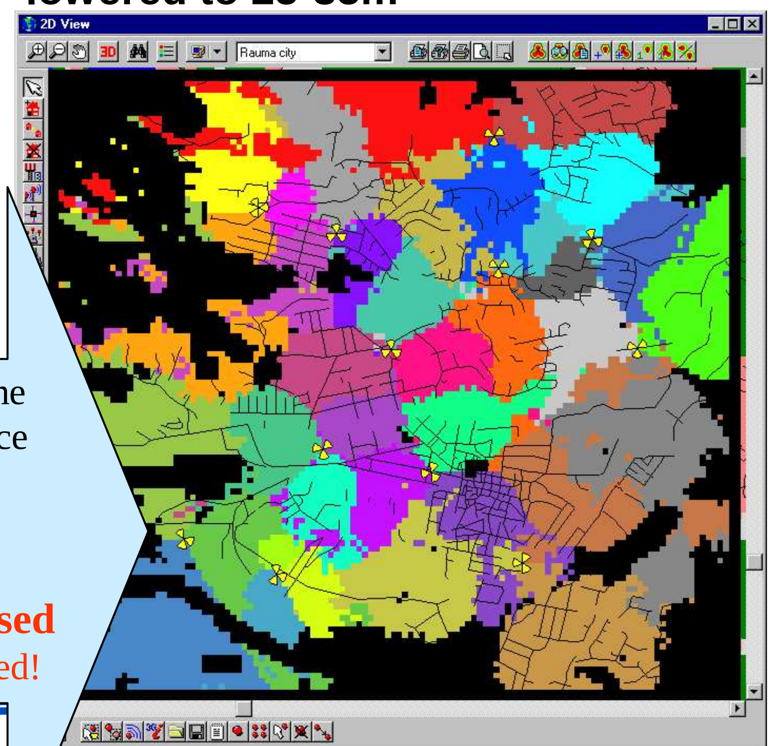
Part of network with re-used few +40meter GSM antenna heights



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

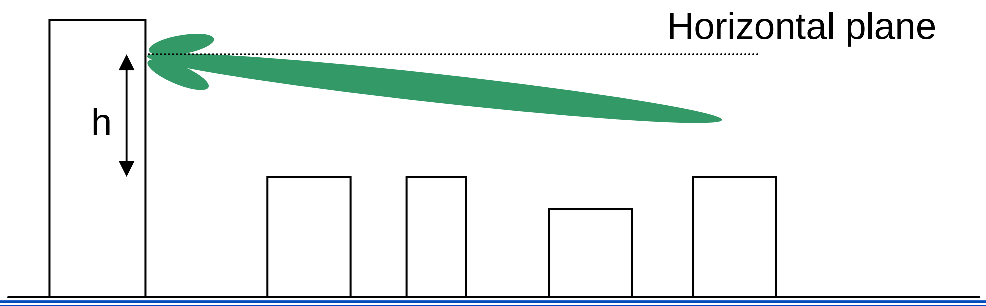
→ **Capacity is increased** and performance enhanced!

High UMTS antenna positions lowered to 25-35m



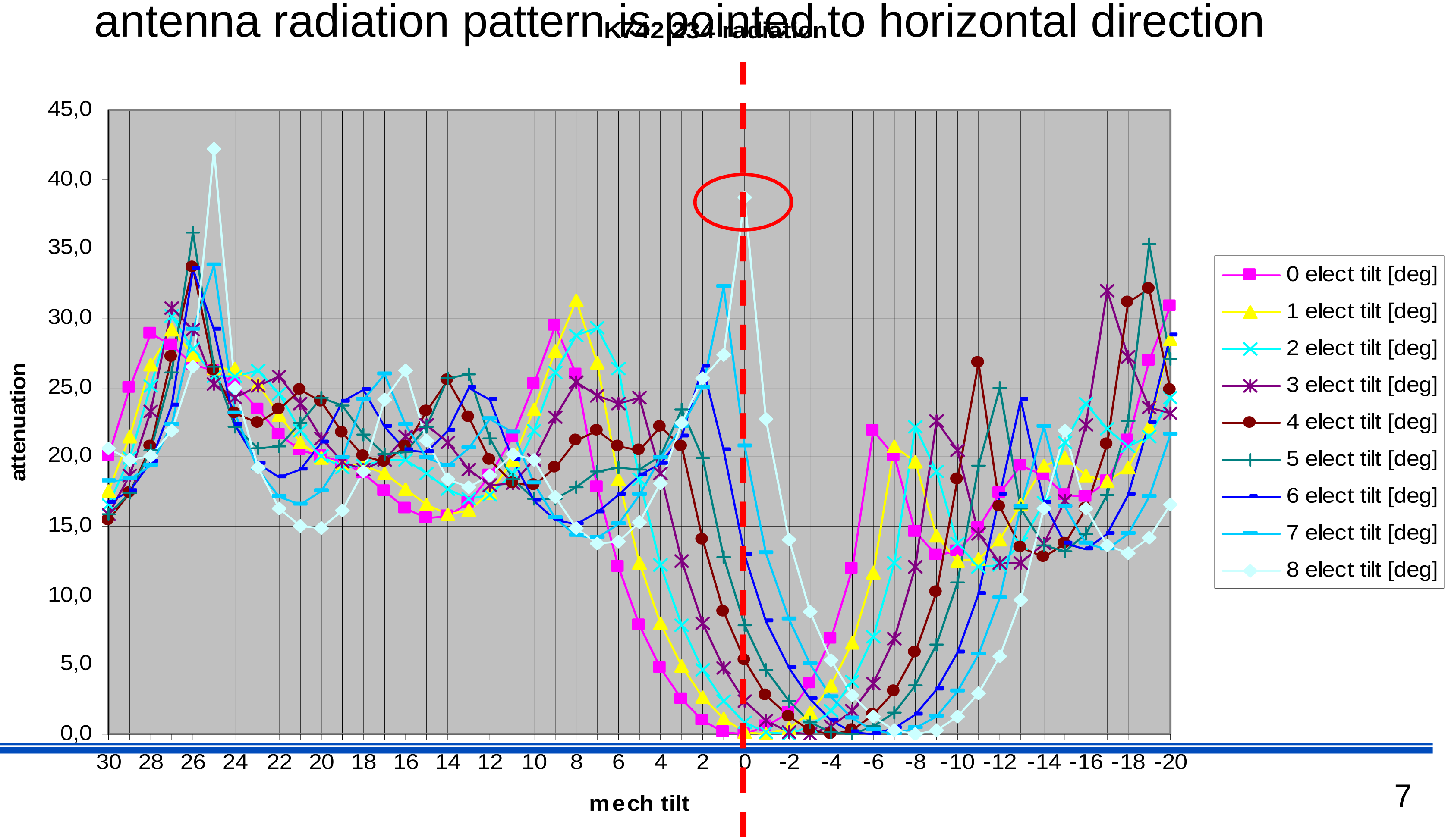
Planning – antenna tilt

- In addition to antenna height, downtilting is very important physical means for interference minimising in WCDMA
- Basic rule of designing 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 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

- Most important is plan the tilting according to antenna characteristics
- The correct amount is the one with which the first zero of the antenna radiation pattern is pointed to horizontal direction



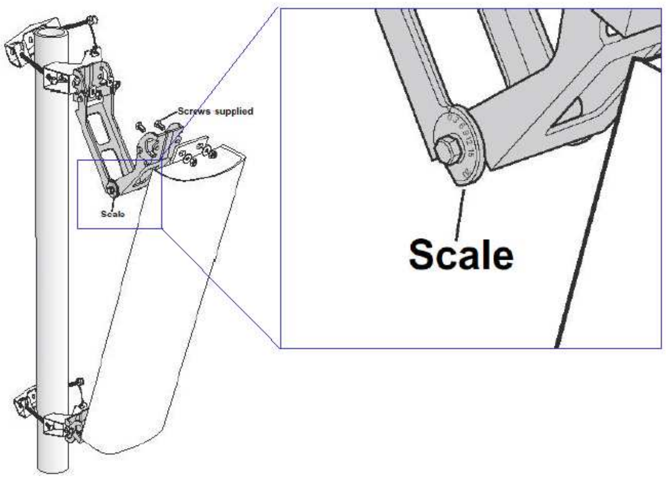
Planning – antenna tilt

- 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, 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 horizont since interference from the antenna increases with larger tilt.

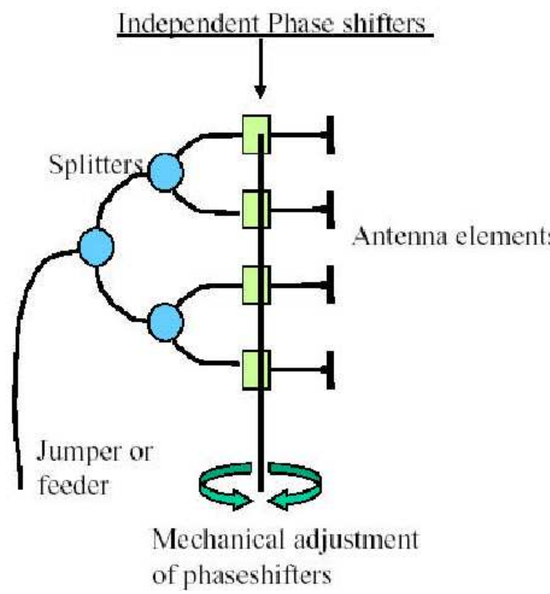
Planning – antenna tilt

Mechanical or electrical tilting?

Mechanical Tilt



Electrical Tilt



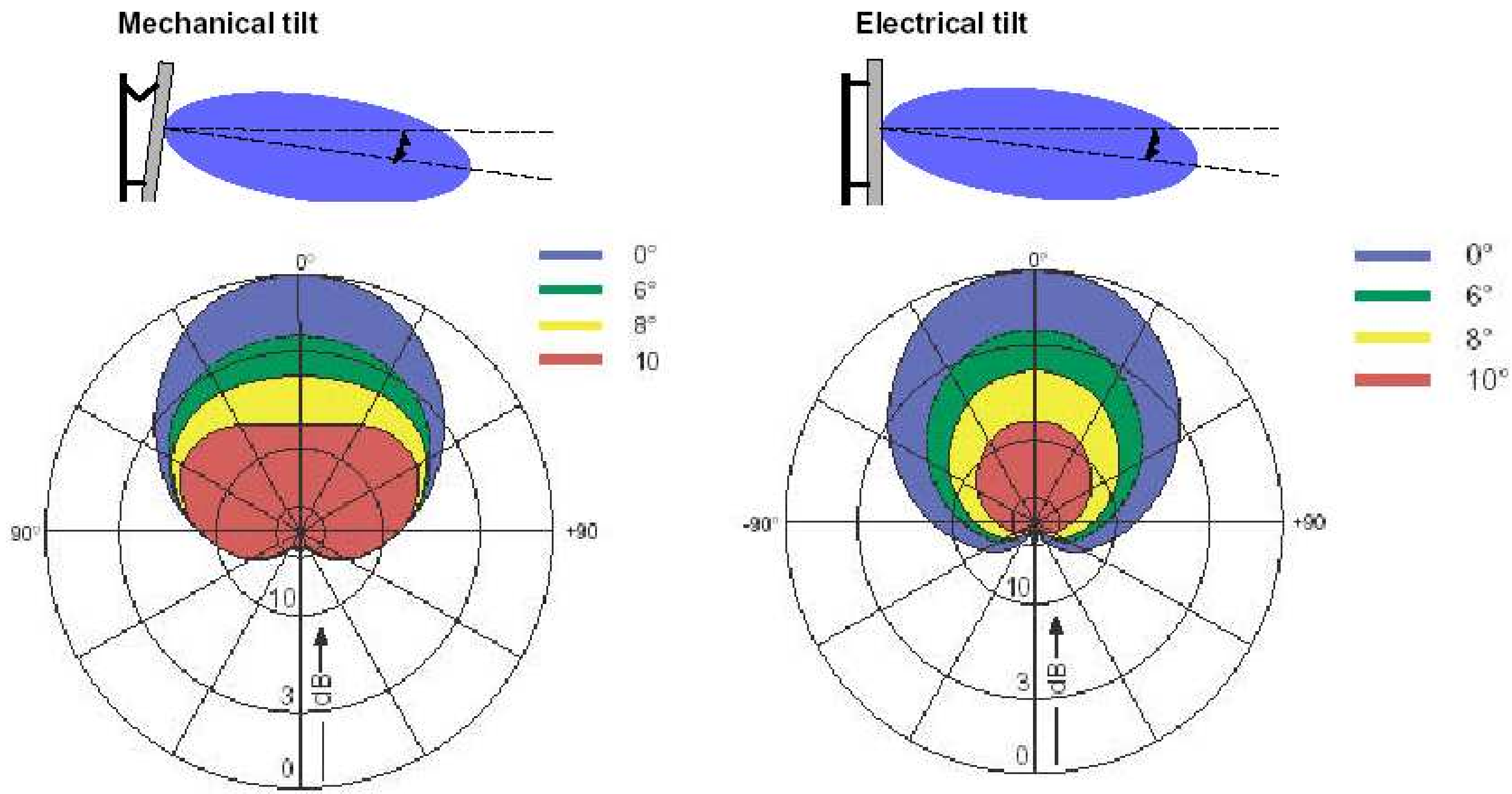
Remote tilt

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 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 sideways horizontally is there is a need for it
- When a high site is to be implemented, the antennas should be wall-mounted, because then the needed level of attenuation to the wanted directions is easier to achieve.

Planning – antenna tilt



Planning – antenna tilt

- According to experience even 15 degrees of downtilting is not impossible (if the radiation pattern of the antenna supports it), although in practise not very often needed.

- There has also been lot of discussion of a potential need to change the tilts often during the network lifecycle (even regurarly)
- However practise have not shown such need if the tilts are design well from the start with help from simulations
- But once WCDMA gets congested this might be given another look (Remote tilts).

Sectorisation

- According to simulations and analysis, sectorisation of WCDMA site helps to improve capacity of the network
- However, as permissions for additional antennas are quite hard to come by, e.g. 6-sector sites might be very rare

- sectorisation can increase the capacity if correct beamwidth antennas are selected and SHO properly controlled

Antenna 3 dB beam width	Other to own cell interference ratio, i	Served users	Soft handover overhead	UL coverage probability (outdoor to indoor) for 8/64/144 kbps
OMNI CASE				
omni	0.79	240	28%	70 / 32 / 40%
THREE SECTOR CASE				
120°	1.33	441	39%	85 / 50 / 59%
90°	1.19	461	35%	87 / 55 / 62%
65°	0.88	575	34%	86 / 59 / 62%
FOUR SECTOR CASE				
120°	1.72	489	54%	90 / 62 / 68%
90°	1.49	510	51%	92 / 67 / 72%
65°	1.09	604	41%	92 / 70 / 71%
33°	0.92	691	40%	88 / 65 / 64%
SIX SECTOR CASE				
120°	2.18	593	64%	95 / 75 / 79%
90°	1.97	627	59%	96 / 80 / 82%
65°	1.43	758	55%	96 / 80 / 81%
33°	1.15	880	48%	93 / 76 / 76%

Mast head amplifiers

- The MHA can be used in WCDMA in the uplink direction to compensate for the cable losses and thus reducing the required mobile stations' transmit powers.
- Using MHA the performance in uplink can be improved also in WCDMA systems.
- However in practise if the network turns to downlink limited then the MHA won't help

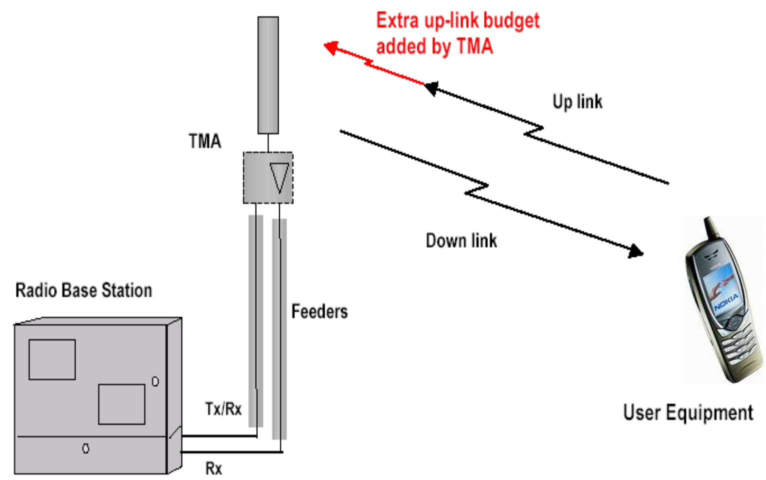
Simulations by Nokia

	Other to own cell interference ratio, i	Served users in UL	Served users in DL	UL coverage probability (outdoor to indoor) for 8/64/144 kbps
THREE SECTORED CASE, 65° antenna				
no MHA	0.60	1038	807	93 / 78 / 78%
with MHA	0.61	1064	746	95 / 82 / 82%
FOUR SECTORED CASE, 65° antenna				
no MHA	0.73	1089	884	96 / 86 / 85%
with MHA	0.73	1107	846	98 / 89 / 89%
SIX SECTORED CASE, 33° antenna				
no MHA	0.88	1124	1052	97 / 87 / 86%
with MHA	0.90	1132	1021	98 / 90 / 90%
no MHA, 4 dB cable losses	0.88	1109	1057	95 / 83 / 82%
with MHA, 4 dB cable losses	0.90	1132	1016	98 / 90 / 90%

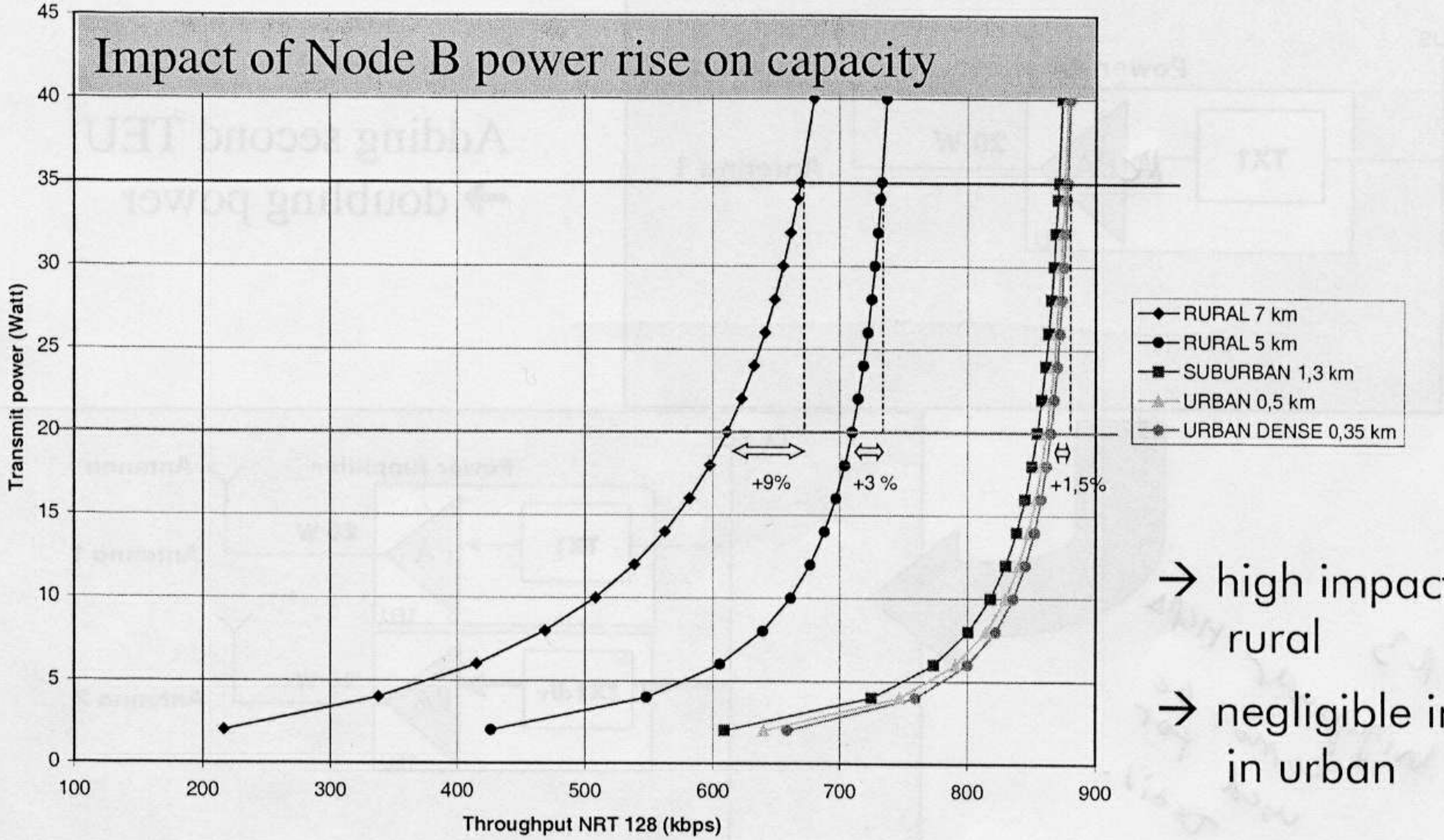
Mast head amplifiers

- Increases uplink coverage/capacity in low loaded network
- Compensates for feeder and combiner losses in the uplink direction, increasing coverage for suburban, rural and road sites where antennas are in very high positions and the feeder lines are long
- Allows UEs to reduce transmission power level
- With heavily loaded network (i.e. high interference) the benefit of the mast head amplifier is negligible
- Also in downlink limited 3G networks (DL oriented traffic, users in cell edge, DL tx-power per user low e.g. in for high bit rate indoor users) the usage of mast head amplifier is not justified
- Needs extra space in the masts and increase the wind load

MHA is sometimes called as Tower Mounted Amplifier (TMA)



Transmit power increase



→ high impact in rural

→ negligible impact in urban

Transmit power increase

- The achievable capacity increase from doubling the transmit power is far from double.
  - Recall DL load equation and related example
- Due to downlink character, higher transmit power will be more efficient in rural than in urban environments.
- Capacity gain is higher when increasing the power e.g. from 5W to 10W than it is for increase 20W => 40W.
- The capacity gain depends on the cell range.

Carrier addition

- Adding a carrier leads to less transmit power per carrier, if no additional PA is installed.
- Additional carrier can also be used for e.g. optimisation of indoor coverage with clever network planning and parametrisation (not with power reduction).
- Even with less transmit power, there is a capacity gain possible especially for high traffic areas (low cell range)
  - Actual gain produced is heavily dependent on traffic mix

Carrier configuration	DL Capacity gain 1 PA			
	Dense Urban 350m	Urban 550m	Suburban 1700m	Rural 7km
1C>2C	92%	87%	77%	60%
2C>3C	41%	37%	27%	15%

Transmission powers

- Default powers are determined by the vendors
- In initial phase of the RNP must DL TCHs & CCHs tx-powers and UL MS max tx-power be defined

- 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

- Mobile max tx-power should be set to 21-24 dBm (network operation and battery life of mobile support this, but also 27dBm terminals are seen...)
- Most important tunable tx-power is the pilot (CPICH)

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
  - Maximum UE transmission power is to be defined
- 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
- Maximum UE transmission power should be set to 21-24 dBm (network operation and battery life)
- Most important control channel is the common pilot channel (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 practise
  - 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 power increase signalling 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.

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 and interference minimisation
- 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 maximum UE TX-power and 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 planned 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 is the key.

Transmission powers

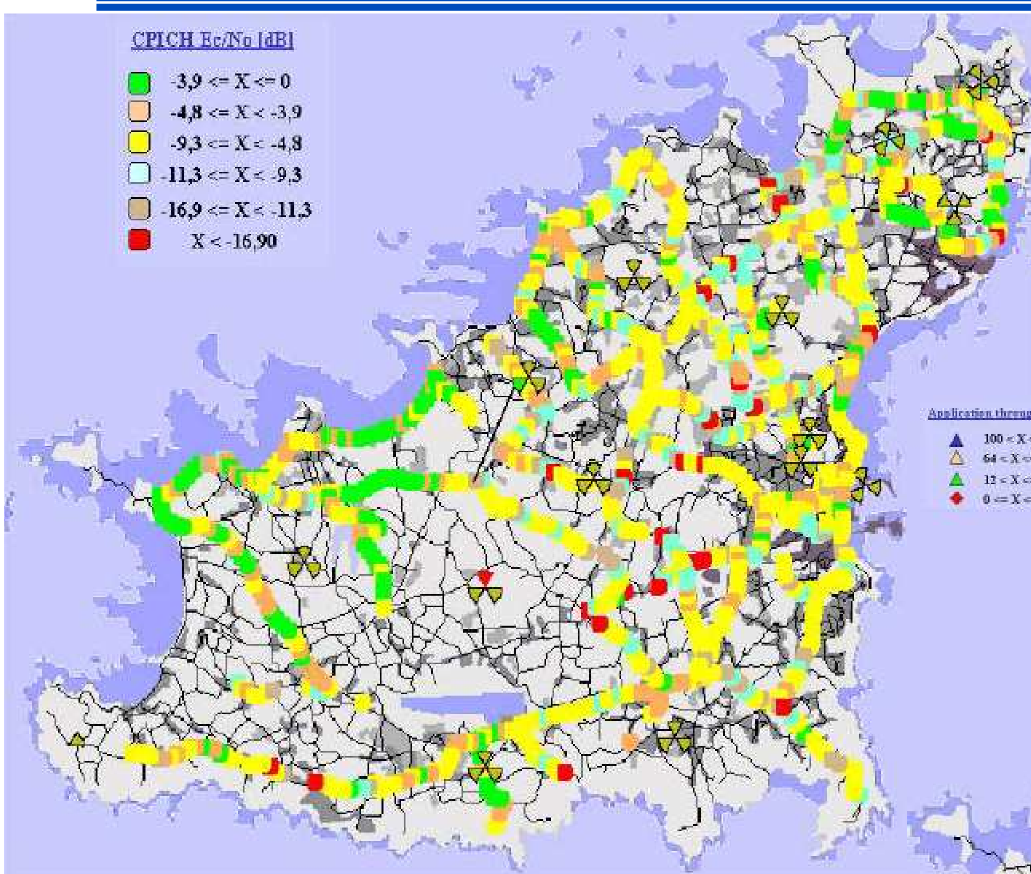
- Antenna and transmission power design lead to certain achievable Ec/Io over the network, which in turn depict a certain service level

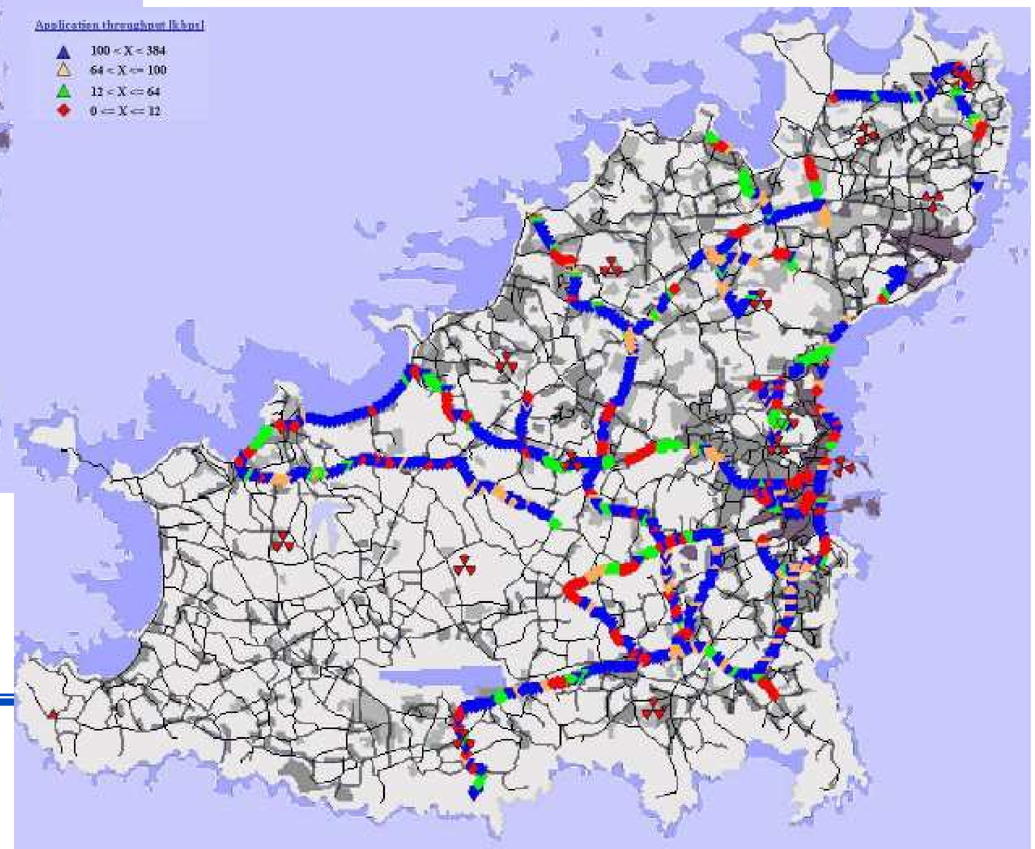
DCH Ec/Io determines the service coverage!

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

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.

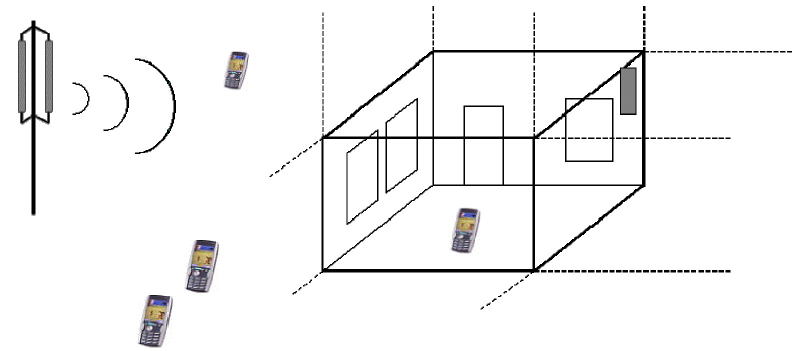
Transmission powers





Indoor coverage aspects

- Most of the UMTS users will probably be indoors. Therefore good indoor coverage is vital for UMTS success
- In GSM indoor coverage is pretty straightforward to plan. However this is not the case with WCDMA
- **Indoor coverage provided from outdoor base stations is highly sensitive to cell load increase in WCDMA**
- If outdoor user is given a high-data rate bearer this can result in loss of coverage to users indoors



INDOOR COVERAGE ANALYSIS:

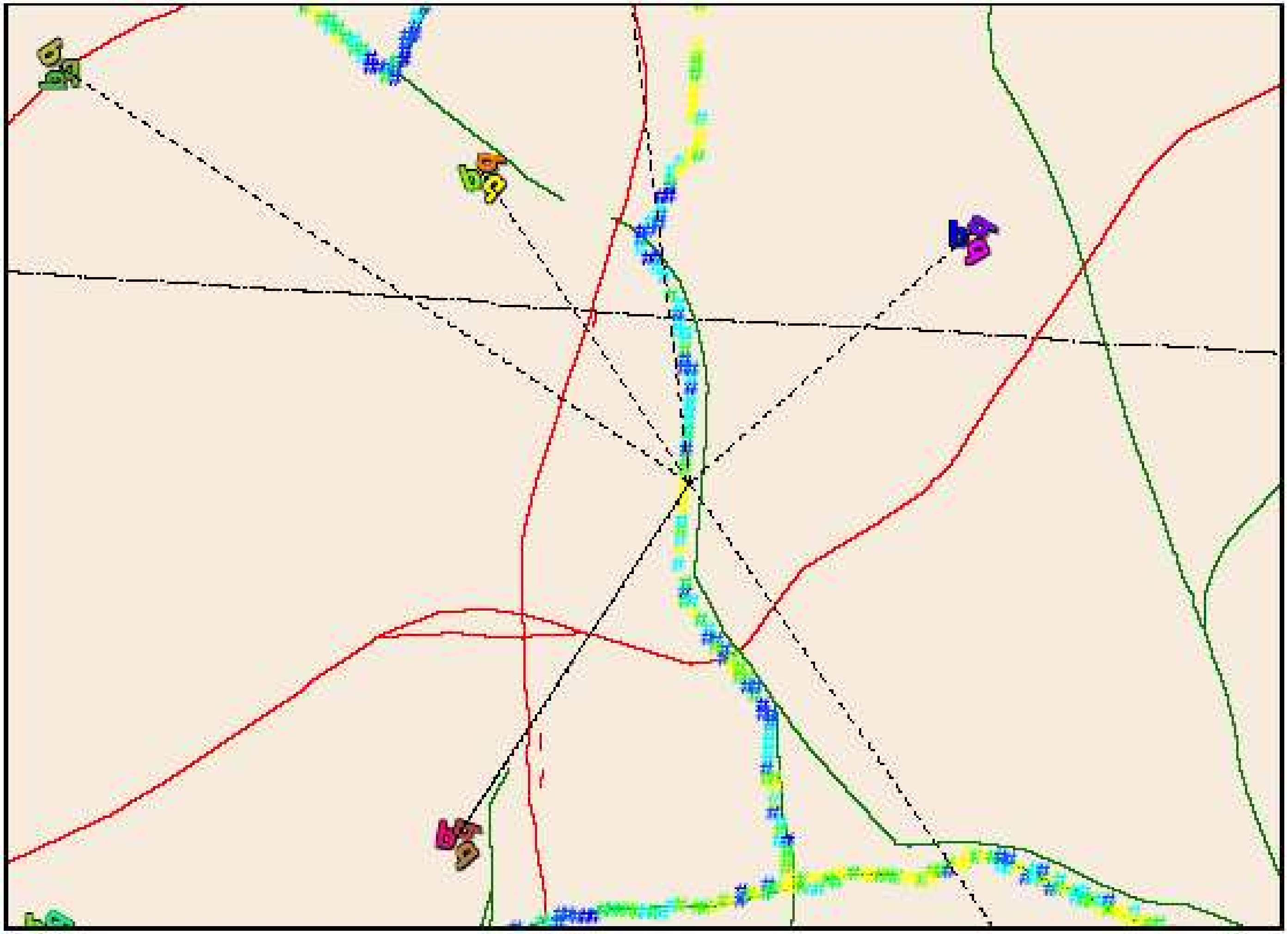
- **Consider different RAB / coverage scenarios**
- **Carefully estimate the effect of cell loading to the coverage**
- **Use repeaters if possible**
- **Assess the need for indoor sites**
- **Carry out real-life verification of planning**

Pilot pollution

- Pilot pollution is faced on a certain area when there is no clearly dominant 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.
  - Higher non-controllable load

Pilot pollution

- The yellow dots represent points where 4-5 CPICHs were received within 6dB window
- As Active Set size is typically 3, in this situation the rest of the Pilots left outside the AS produce unnecessary interference



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
- Balanced UL & DL
- SCH/DCH power adjustments

Neighbour cell relations

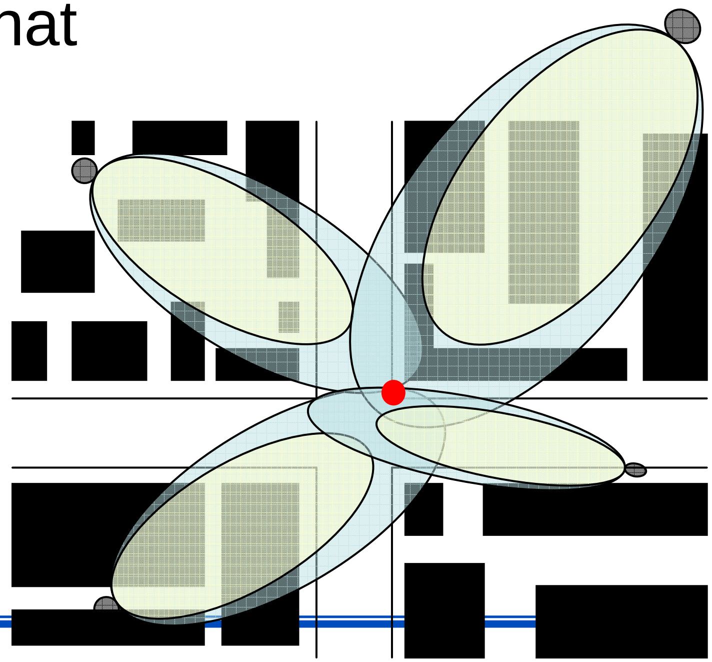
- The Monitored Set is also called as a Neighbour List. This list can be defined in network planning and it can be later changed in network optimization.
- The list of neighbours play an important role since WCDMA is interference limited. Insufficient planning of neighbour relations will lead to unnecessary high interference
  - E.g. if suitable SHO candinate is not in the monitore 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 neighbour relations and the algorithms how system evaluates neighbours for cell lists depend on vendor
  - minimum CPICH RSCP or Ec/Io
  - Ec/Io margin
  - maximum number of neighbours
- A neighboring set (or monitored set) is defined for each cell
  - Utilise planning tools automatised functions and check with drive tests
  - Optimise according to 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 neighbour can be detected during drive tests
  - If the best cell shown in the 3G scanner does not enter the active set missing neighbour
  - Include the missing cell to neighbour list if it's wanted to active set or change cell plan if not

SHO optimisation

- Soft/Softer HO planning and correct operation is one of the most important means of optimising WCDMA networks
- The importance is high because of the high biterate (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 optimisation

- SHOs have effect to the network performance

PROS

❑ Required to avoid near-far effects

❑ Coverage increases when more distant users can connect

❑ Capacity can be "increased" if more users can be connected

❑ Alongside with PC, SHO is the main interference migitation means in WCDMA

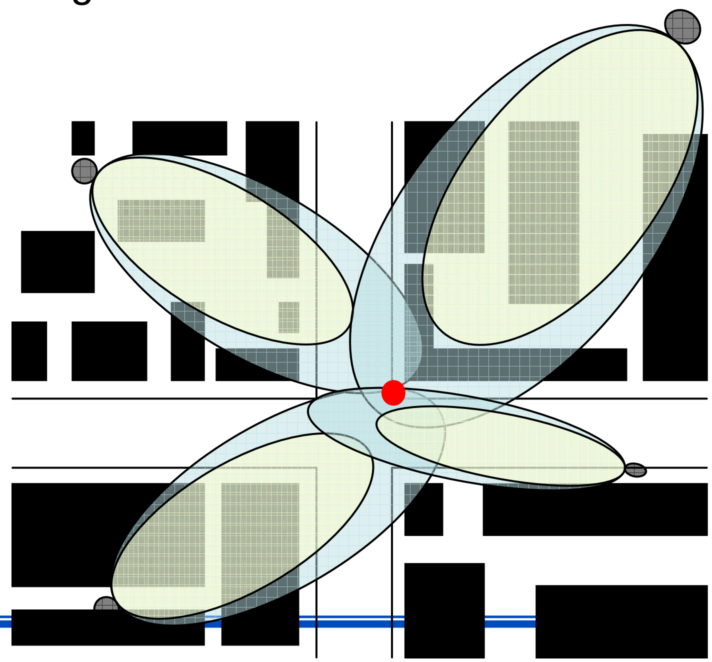
CONS

❑ Requires more connections, thus eats DL transmission power and decreases capacity

❑ Introduces more interference to DL

❑ Increases the traffic in Iub

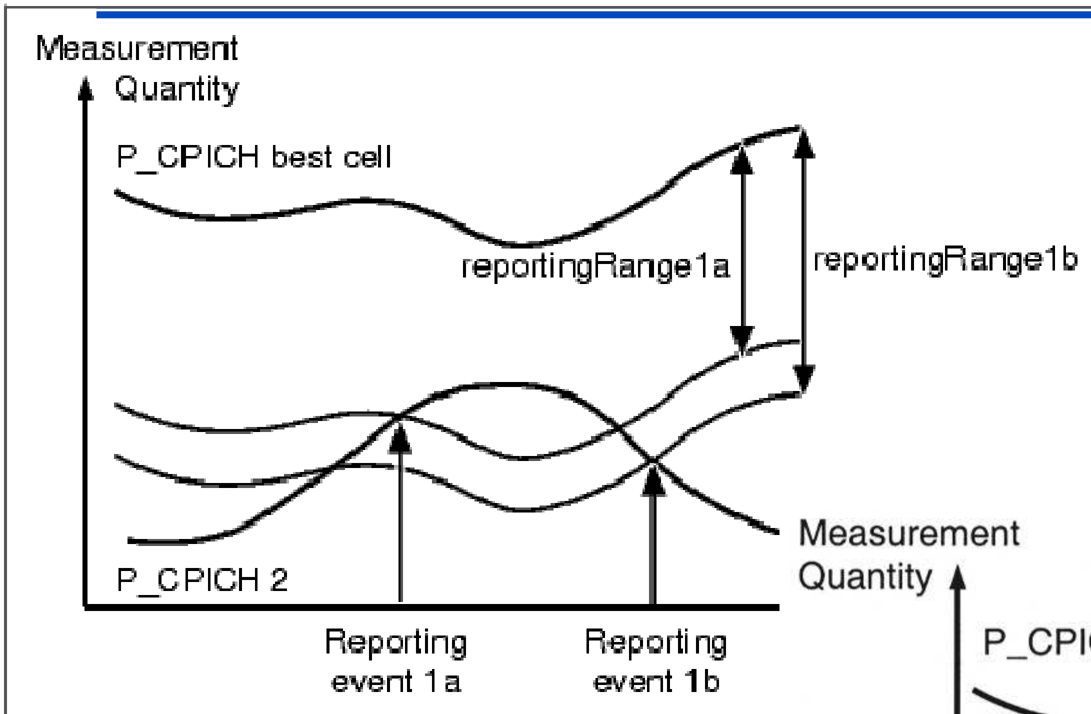
40% SHO probability → 1.4 times the traffic!



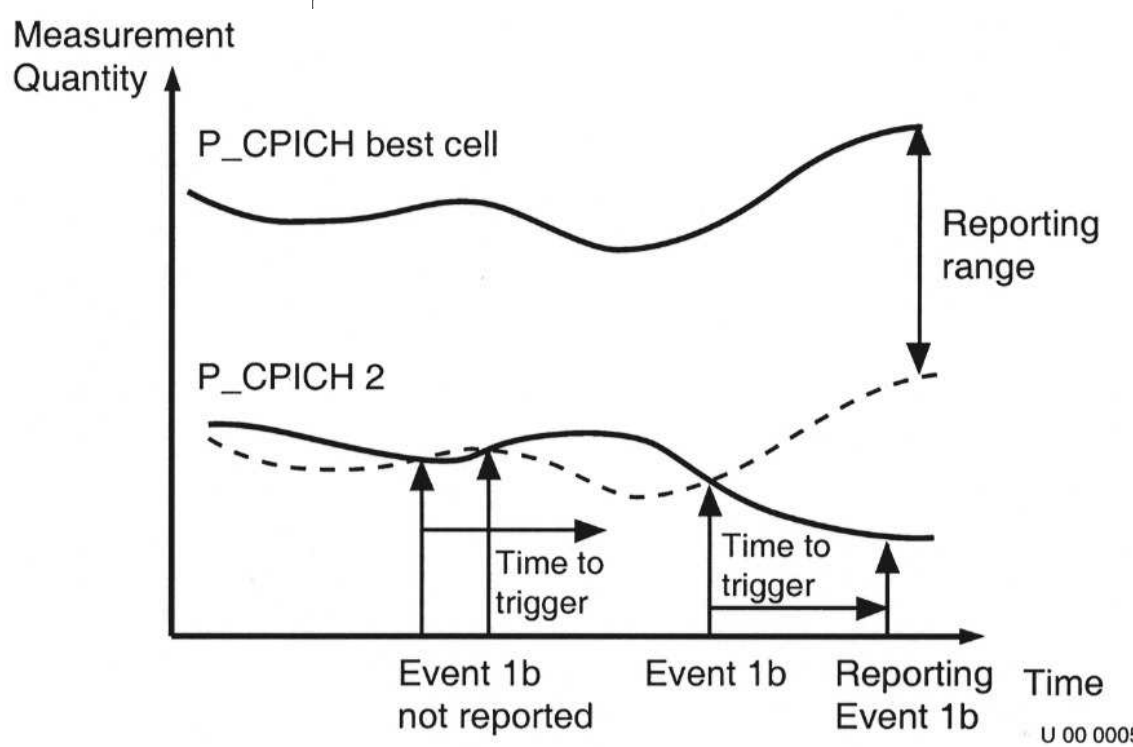
SHO optimisation

- 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
- SHO most important in urban areas due to serious shadowing

SHO optimisation



Recall some parameters



SHO optimisation