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Radio Network Planning Tools
Basics, Practical Examples & Demonstration on NGN Network Planning
Part II

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Regional Seminar on evolving network infrastructures to NGN and related Planning Strategies and Tools, for the CEE, CIS and Baltic States

Belgrade, Serbia and Montenegro, 20-24 June 2005

Case Study

Wireless Local Loop / WiMAX Network

Case Study: WLL / WiMAX Network

Project Description

- WLL Network to provide fast Internet
- 3,5 GHz band
- Two Scenarios
  - Scenario 1: Rural Area
  - Scenario 2: Urban Area
- Basic Business Model and Coverage Criteria

Project Steps

- Comparison of available Hardware
- Definition of the Planning Guideline
- Tool-based Network Design

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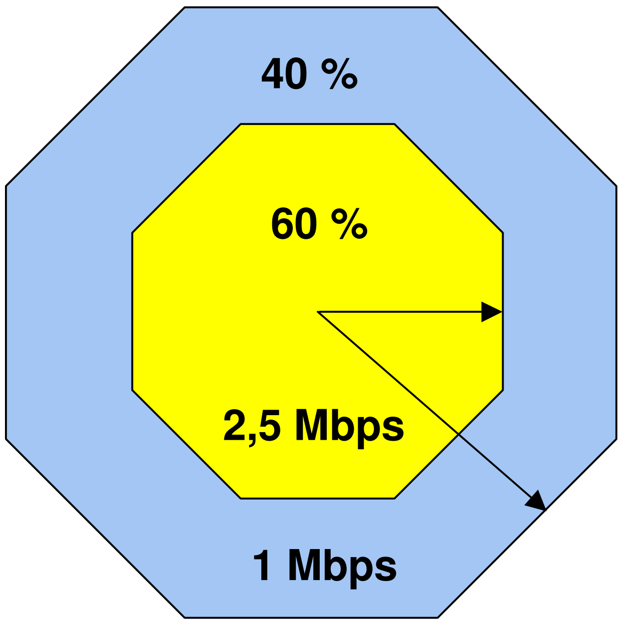
Basic Requirements

Scenario 1: Rural Area

- Location: valley, rural area
- Outdoor coverage
- Data Rate
  - >1 Mbit/s

Scenario 2: Urban Area

- Location: Top City
- Indoor coverage
- Data Rate
  - 2,5 Mbit/s (60%)
  - 1,0 Mbit/s (40%)



Hardware Comparison & Selection

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- Technical Data Base Stations

Vendor	Vendor 1	Vendor 2	Vendor 3
Multiple access scheme	CDMA (MC-SCDMA)	PPMA	256 FFT OFDM / TDMA
Duplex Mode	TDD	TDD/FDD	HD- FDD/TDD
Ausgangsleistung	max. 47 dBm (EIRP)	max. 27 dBm	max. 33 dBm
Bandbreite	5 Mhz, 10 x 500 kHz sub-channels	1 MHz sub-channel spacing	3,5 / 7 / 14 MHz channel spacing
Antennengewinn	max. 17 dBi	max. 18 dBi (15°-Antenne)	max. 12 dBi (60°-Antenne)
Modulationsarten	QPSK / 8BPSK / 16 QAM	2 / 4 / 8 CPFSK	BPSK, QPSK, 6QAM, 64QAM
max. Kapazität pro Sektor (5 MHz)	4.2 Mbit/s (16 QAM)	4 Mbit/s	35 Mbit/s (64QAM)
max. Sektoranzahl pro BS	3	24 BSRs	12

...

- Technical Data User Terminals

Vendor	Vendor 1	Vendor 2	Vendor 3
Output Power	31 dBm (EIRP)	27 dBm	20 dBm
Antenna Gain	6 dBi	max. 18 dBi /externe Antenne	max. 6 dBi (internal; integrated)
Bandwidth	5Mhz, 10x500 kHz sub-channels	1 MHz sub-channel spacing	3,5 MHz channel spacing
Modulation	QPSK	2 / 4 / 8 CPFSK	BPSK, QPSK, 16QAM, 64QAM
Capaity (max.)	2,2 Mbit/s (QPSK)	4 Mbit/s (8CPFSK)	13,1 Mbit/s (3,5 MHz,FDD)

...

Hardware Comparison & Selection

	Vendor valuation ratios		
			Sum
4	**Analysis of the Technical Data (Data Sheet) for vendor: _______**		**1500**
4.1	Base-Station and Terminal Output-Power	200	
4.2	Antenna Pattern , Gain, F/B Ratio	200	
4.3	Link Budget	100	
4.4	Carrier to Interference Ratio (C/I)	100	
4.5	Carrier to Noise Ratio (C/N)	100	
4.6	Base-Station, Receiver Sensitivity	100	
4.7	Throughput, Terminal per cell	200	
4.8	Type of Terminal	100	
4.9	Transmitting / Modulation System	100	
4.10	Availability	100	
4.11	Power Consumption	100	
4.12	Mechanical Size Base – Station / Terminal	100	
5	**Coverage calculation for vendor: ______**		**1500**
5.2	Coverage plot for 2.5 m receiver height	500	
5.3	Coverage plot for 5 m receiver height	500	
5.4	Coverage plot for 9 m receiver height	500	
6	**Analysis of Measurements field test for vendor: _____________**		**7000**
6.3	Fieldstrength depending of the Distance and max. link distance	1500	
6.4	Throughput	2000	
6.5	Influence of Load	1500	
6.6	System Performance	1000	
6.7	System - Stability	1000	
			10000

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Hardware Comparison & Selection

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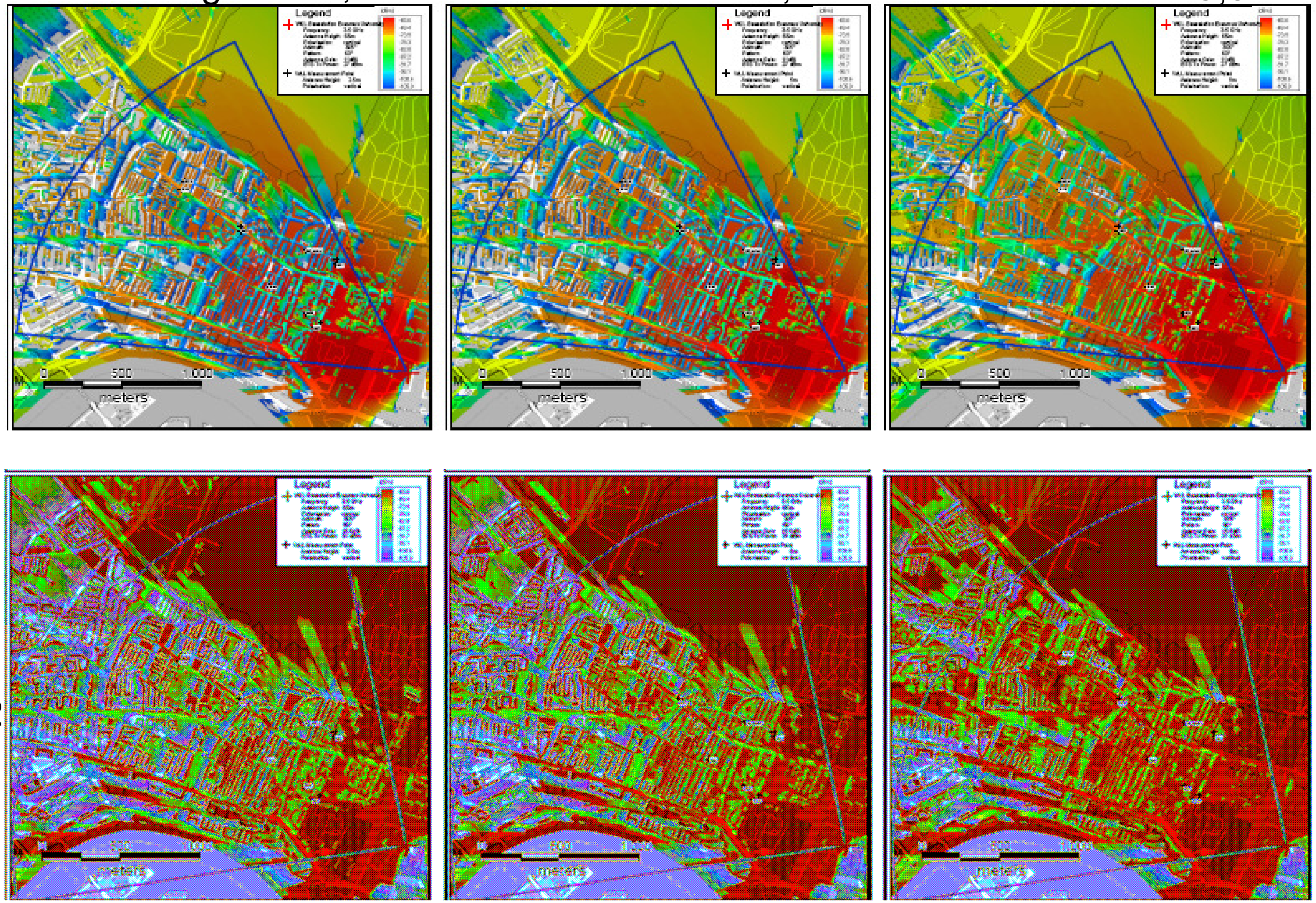
receiver height 2,5 m 5,0 m 9,0 m

vendor 1

vendor 2



Hardware Comparison & Selection

Results (for scenario 1 and scenario 2):

	9. Vendor valuation matrix					
			Vendor			
		Sum (max)	1	2	3	4
4	**Analysis of the Technical Data**					
4.X.1	Base-Station and Terminal Output-Power	200	150,00	130,00	80,00	180,00
4.X.2	Antenna Pattern , Gain, F/B Ratio	200	70,00	100,00	150,00	190,00
4.X.3	Link Budget	100	60,00	80,00	60,00	80,00
4.X.4	Carrier to Interference Ratio (C/I)	100	50,00	70,00	50,00	70,00
4.X.5	Carrier to Noise Ratio (C/N)	100	60,00	70,00	60,00	70,00
4.X.6	Base-Station, Receiver Sensitivity	100	50,00	90,00	50,00	90,00
4.X.7	Throughput, Terminal per cell	200	150,00	80,00	130,00	130,00
4.X.8	Type of Terminal	100	60,00	80,00	60,00	80,00
4.X.9	Transmitting / Modulation System	100	50,00	80,00	40,00	80,00
4.X.10	Availability	100	-	-	-	-
4.X.11	Power Consumption	100	60,00	60,00	60,00	40,00
4.X.12	Mechanical Size Base – Station / Terminal	100	60,00	60,00	60,00	60,00
5	**Coverage calculation**					
5.X.2	Coverage plot for 2.5 m receiver height	500	200,00	420,00	200,00	420,00
5.X.3	Coverage plot for 5 m receiver height	500	250,00	440,00	250,00	440,00
5.X.4	Coverage plot for 9 m receiver height	500	300,00	450,00	300,00	450,00
6	**Analysis of Measurements**					
6.X.3	Fieldstrength depending of the Distance and max. link	1500	800,00	1000,00	700,00	1500,00
6.X.4	Throughput	2000	1400,00	1400,00	1600,00	1500,00
6.X.5	Influence of Load	1500	1300,00	100,00	1300,00	1300,00
6.X.6	System Performance	1000	600,00	600,00	500,00	950,00
6.X.7	System - Stability	1000	800,00	100,00	800,00	990,00
	Sum:	**10000**	**6470**	**5410**	**6450**	**8620**

System Crash with increasing cell load

Measurement Points probably not in the main beam of the antenna elevation pattern. (MP to close to the BS)

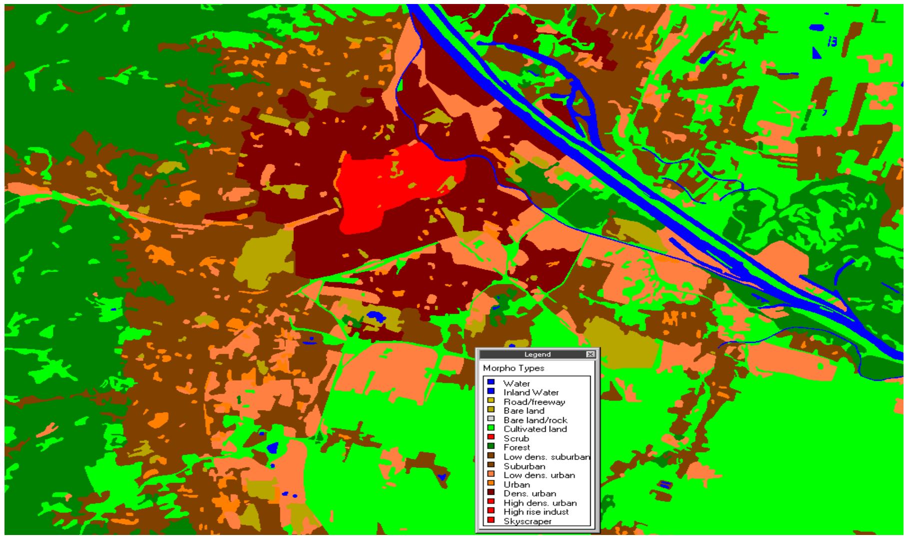
System became instable when the number of connections in the cell has been increased

Planning Guideline

Planning Parameters

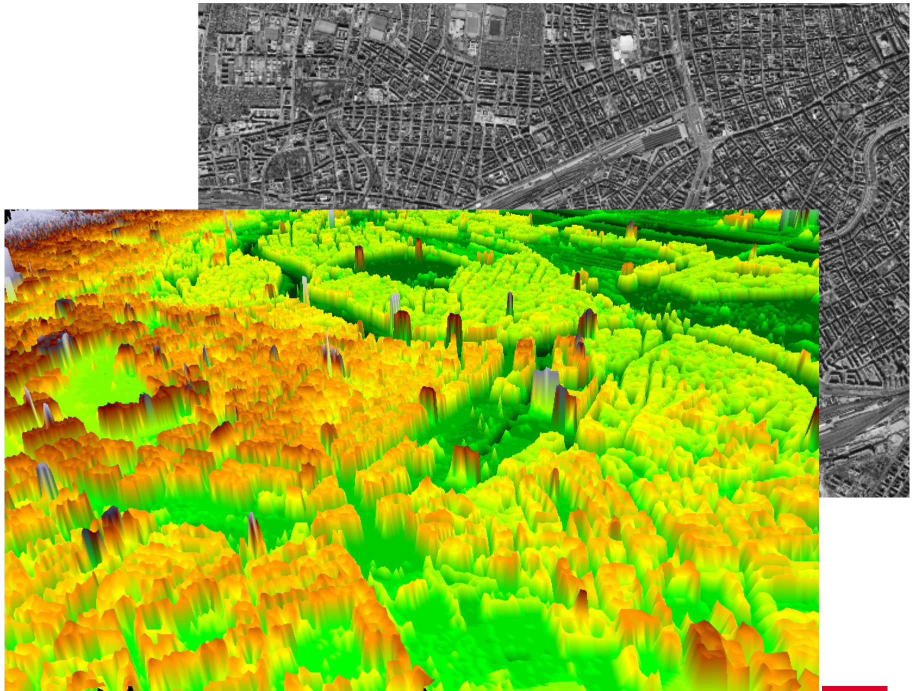
Rural Area

- Based on existing sites
- Antenna height: 20m above ground
- Receiver height: 2.5 / 5.0 / 9.0 m
- Digital Terrain Model, 50m resolution
- Digital Clutter Model, 50m resolution



Urban Area - Vienna

- “greenfield” planning, fictive sites
- Antenna height: 3m above rooftop
- Receiver height: 2.5 / 5.0 / 9.0 m
- Digital Elevation Model, 5m resolution
- Sat-Image, 1m resolution



Planning Guideline

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Based on the system data of the selected hardware, the link budgets for the different scenarios

- rural, outdoor
- urban, indoor

have been generated

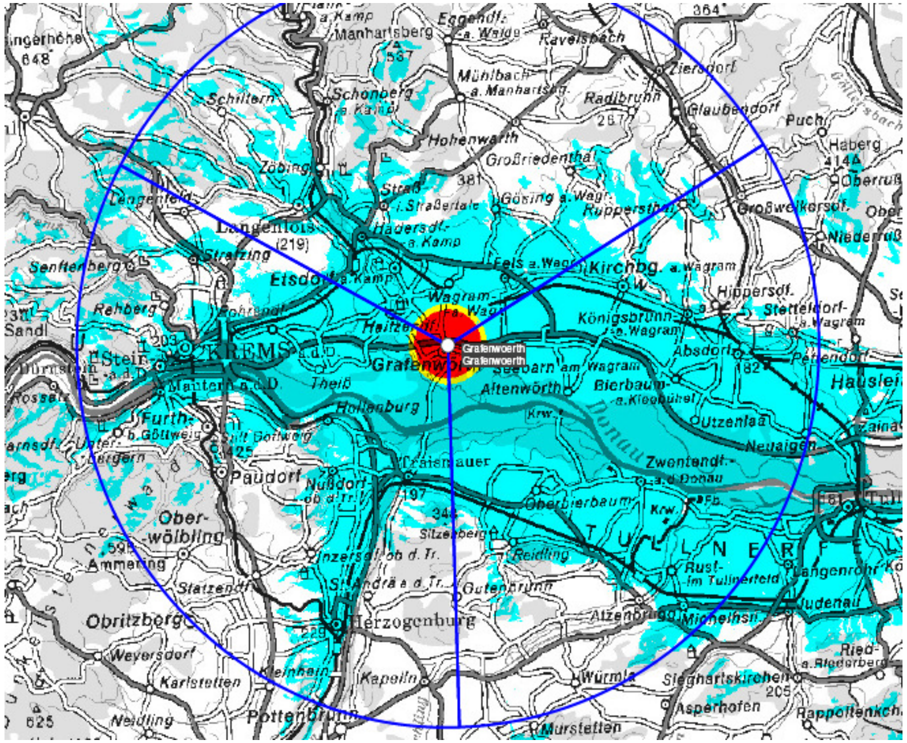
Linkbilanz		3.5 GHz / 2.5 Mbit/s / Indoor	
Downlink		**Uplink**	
Sender (WLL Basisstation)		**Sender (WLL Terminal)**	
Max. Sendeleistung	1600,0 mW	Max. Sendeleistung	316,0 mW
Anzahl parallel genutzter Codes	200,0	Anzahl parallel genutzter Codes	30,0
Max Sendeleistung pro Code	8,0 mW	Max Sendeleistung pro Code	10,5 mW
Max. Sendeleistung pro Code in dBm	9,0 dBm	Max. Sendeleistung pro Code in dBm	10,2 dBm
Kabelverluste	2,0 dB	Kabelverluste	0,0 dB
Antenna Gain	17,0 dBi	Antenna Gain	6,0 dBi
EIRP pro Code	24,0 dBm	EIRP pro Code	16,2 dBm
Empfänger (WLL Terminal)		**Empfänger (WLL Basisstation)**	
Rauschdichte Thermisches Rauschen	-174,0 dBm/Hz	Rauschdichte Thermisches Rauschen	-174,0 dBm/Hz
Rauschzahl Empfänger	5,0 dB	Rauschzahl Empfänger	5,0 dB
Rauschdichte Empfänger	-169,0 dB/Hz	Rauschdichte Empfänger	-169,0 dB/Hz
Effektive Bandbreite pro Subcarrier	400,0 kHz	Effektive Bandbreite pro Subcarrier	400,0 kHz
Rauschleistung am Empfänger	-113,0 dBm	Rauschleistung am Empfänger	-113,0 dBm
Noise Rise (50% Zelllast)	3,0 dB	Noise Rise (50% Zelllast)	3,0 dB
Interferenzleistung am Empfänger	-113,0 dBm	Interferenzleistung am Empfänger	-113,0 dBm
Rauschen + Interferenz Empfänger	-110,0 dBm	Rauschen + Interferenz am Empfänger	-110,0 dBm
Spreizfaktor	32	Spreizfaktor	32
Processing Gain	15,1 dB	Processing Gain	15,1 dB
benötigtes Eb/N0	6,0 dB	benötigtes Eb/N0	6,0 dB
Min. Empfangspegel	-119,0 dBm	Min. Empfangspegel	-119,0 dBm
Antennengewinn	6,0 dBi	Antennengewinn	17,0 dBi
Kabelverluste	0,0 dB	Kabelverluste	2,0 dB
Max. Funkfelddämpfung (50%)	**149,1 dB**	**Max. Funkfelddämpfung (50%)**	**150,3 dB**
Zuschlag Versorgungswahrsch. 95 %	12,0 dB	Zuschlag Versorgungswahrsch. 95 %	12,0 dB
Reflektionsdämpfung	9,0 dB	Reflektionsdämpfung	9,0 dB
Gebäudedämpfung	20,0 dB	Gebäudedämpfung	20,0 dB
Designwert Funkfelddämfpung (95 %)	**108,1 dB**	**Designwert Funkfelddämfpung (95 %)**	**109,3 dB**
Maximale Linklänge	**1,733 km**	**Maximale Linklänge**	**1,990 km**

Vendor	Vendor 1	Vendor 2	Vendor 3
Indoor 2,5 Mbit/s	1480 m	140 m	1120 m
Indoor 1,0 Mbit/s	1890 m	170 m	1360 m
Outdoor 2,5 Mbit/s	18400 m	2600 m	19600 m

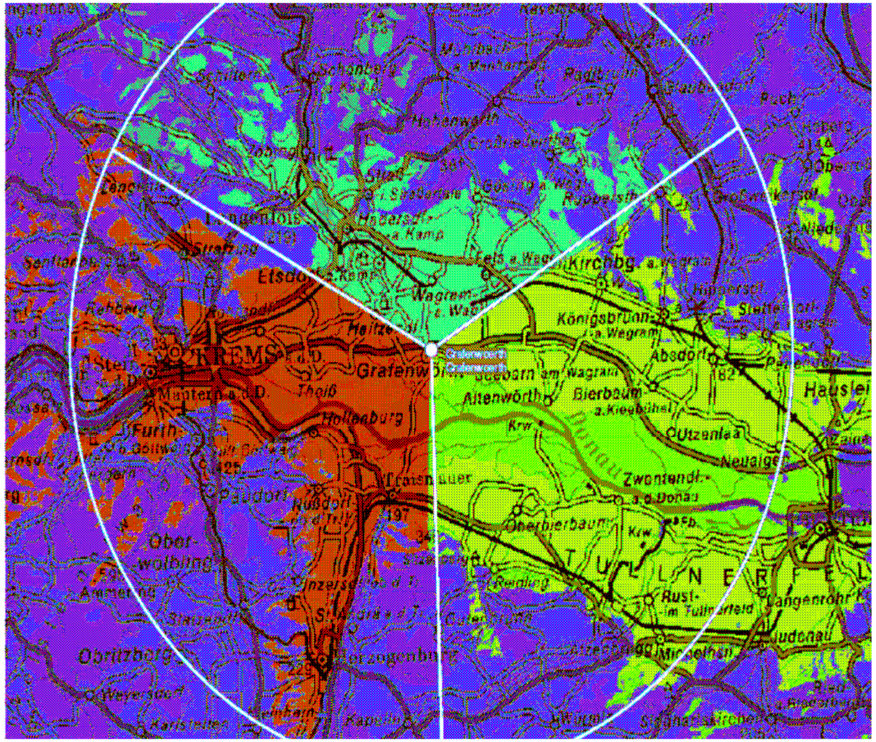
Network Design

- Rural Area

Coverage Plot



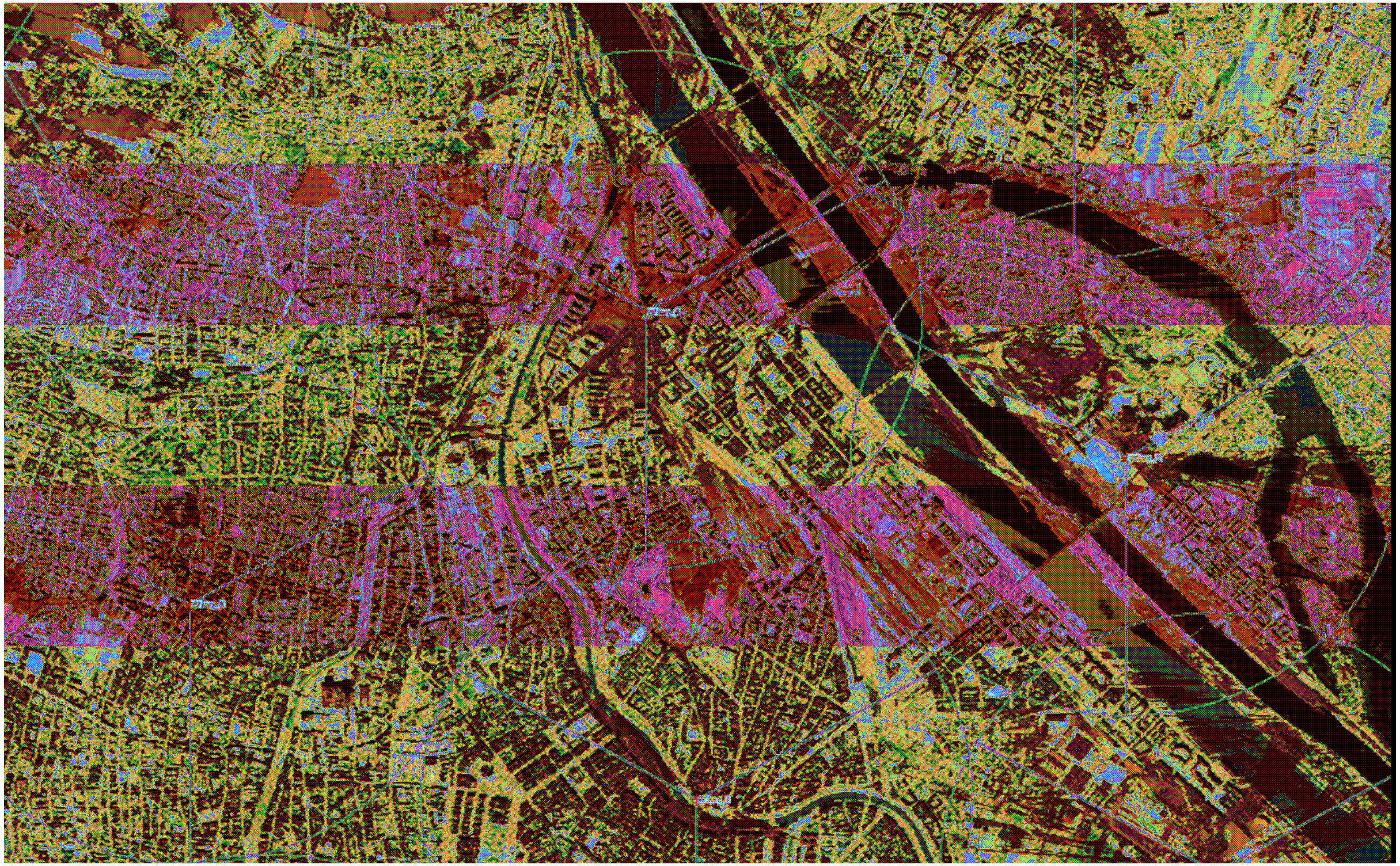
Best Server



blue: outdoor 1Mbit/s
yellow: indoor 1Mbit/s
red: indoor 2,5 Mbit/s

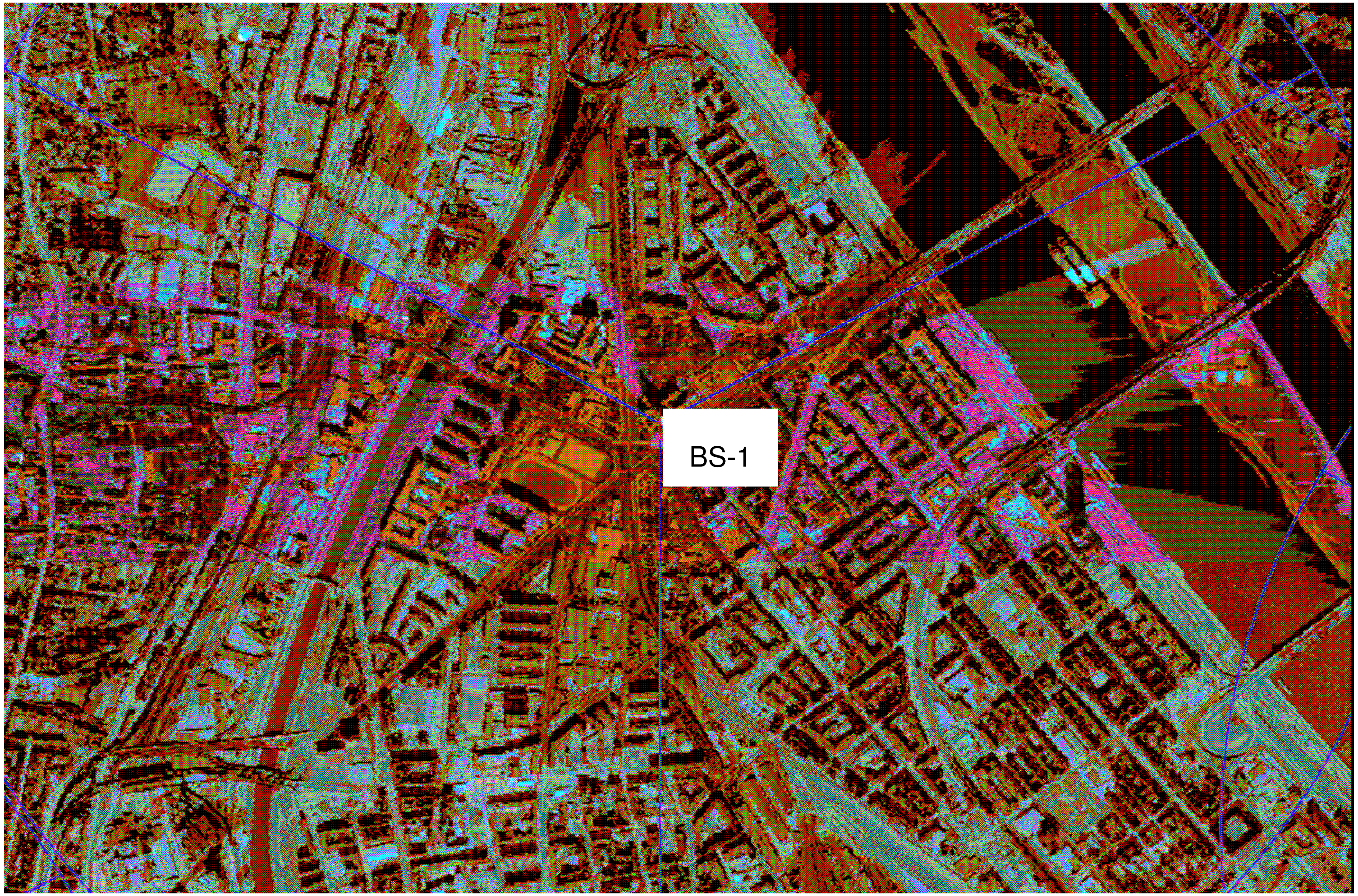
Network Design

- Urban Area – Top City



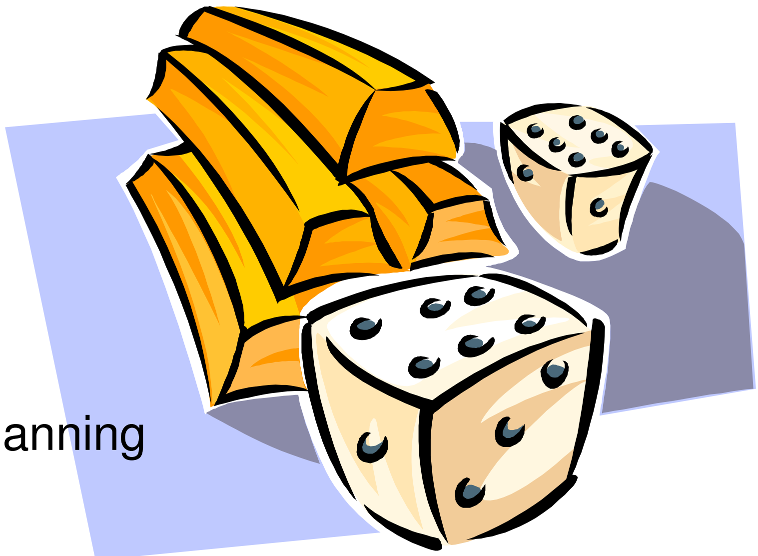
Network Design

- Zoom In



Results

- 2 scenarios have been defined
- For each scenario the following tasks have been done:
  - Definition of the planning guideline
    - Link budgets
    - Terrain data sets
    - Calculations algorithms
    - Planning procedure
  - Selection of the hardware
  - Network design
  - Creation of input data for business case planning
    - Number of base stations
    - Covered area
    - Necessary bandwidth
    - Services to be offered



Case Study

3G Mobile Network Planning

3G Mobile Network Planning

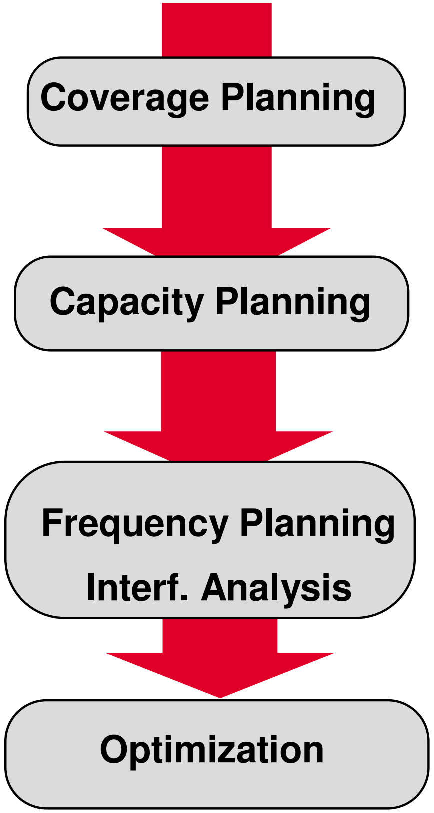
Goal is to explain:

- **What are the network design challenges coming up with the next generation networks?**
- **Differences between 2G and 3G network planning**
- **Impact on network design**
- **Impact on 3G Roll-Out Philosophie**

Let´s have a closer look to tasks and methods of 3G cellular networked planning compared to the well-understood procedures for recent 2G networks

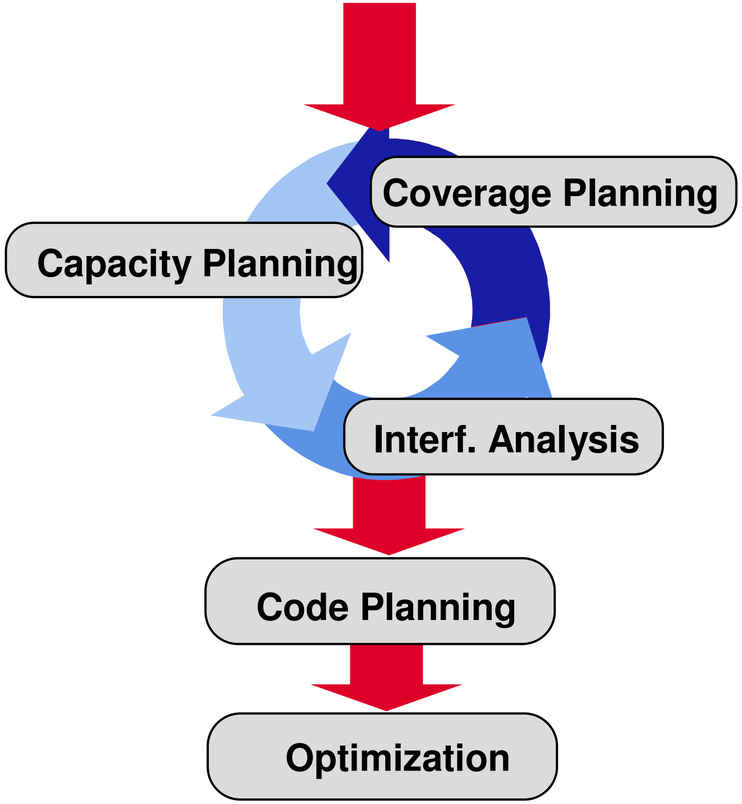
3G Mobile Network Planning

2G Network Planning



Steps are **independent** from each other.
If the traffic load exceeds a cell's capacity, an other transceiver can be added to the cell.

3G Network Planning



Coverage -, capacity planning and interference analysis are **not independent**.
-> Dynamic Cell Areas

3G Mobile Network Planning

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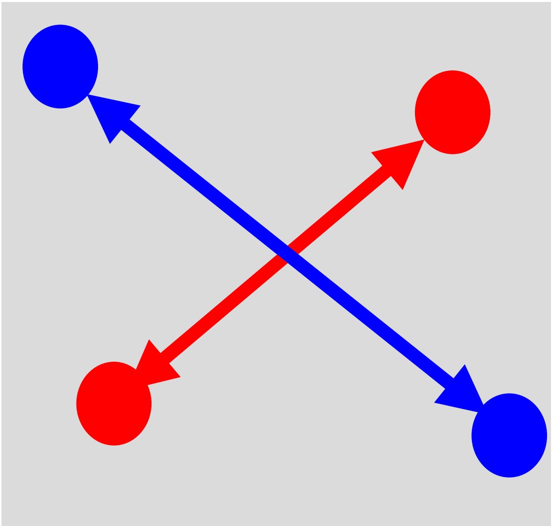
- Especially for GSM-dominant countries 3G/UMTS is a completely new technology
- There are major differences like
  - cell breathing effects (compared to GSM networks)
  - mixed traffic scenarios (packet and circuit switched)
  - mix of services (bit rates, etc.)

- There is a dependency between load and coverage area of a cell
- The separation of coverage planning, capacity planning and interference analysis will no longer work in 3G systems

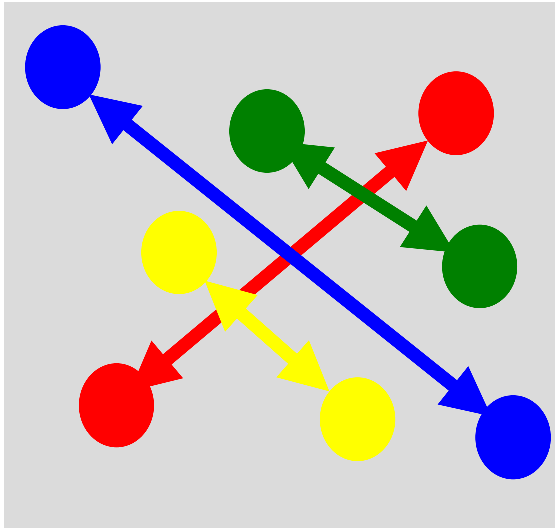
New Challenges for Radio Network Planning Engineers

Cell Breathing

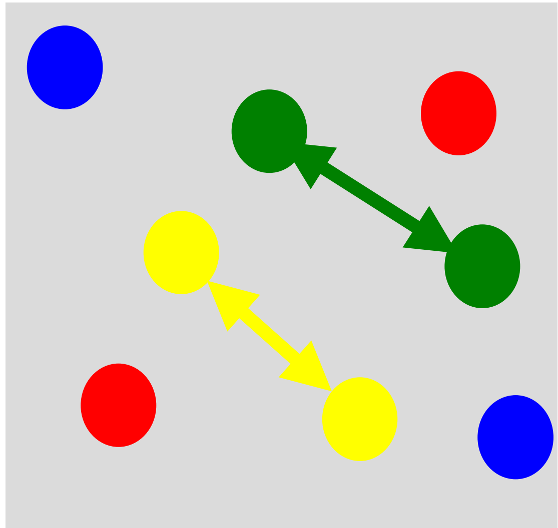
Party Scenario



- 2 couples in one room
- Noise level low
- Interference level low
- conversation possible



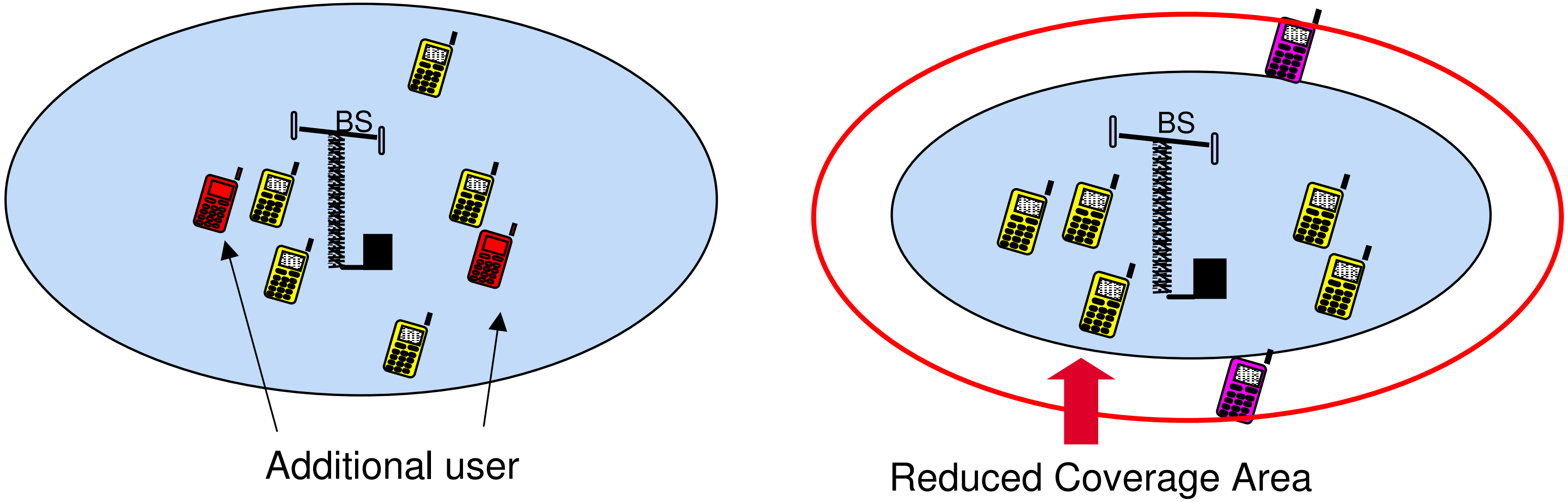
- 2 additional couples enter the room
- Noise level goes up
- Interference level goes up



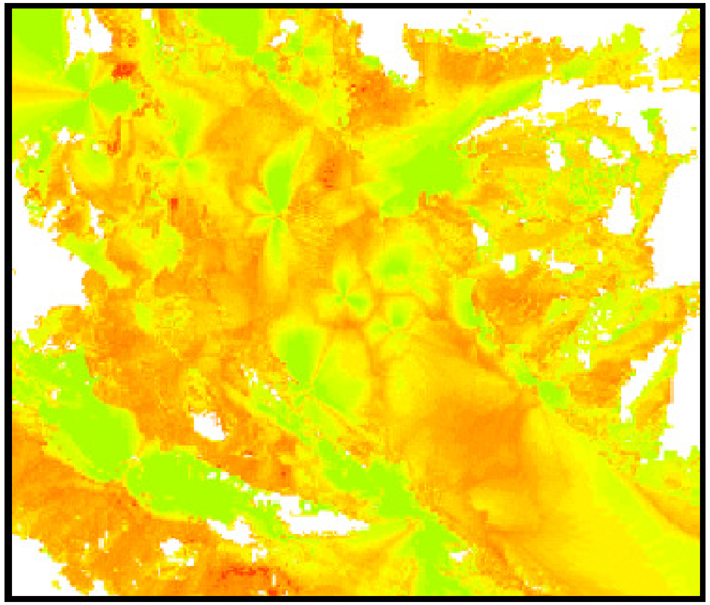
- Noise level too high for red and blue couples
- Distance to far
- Conversation no longer possible

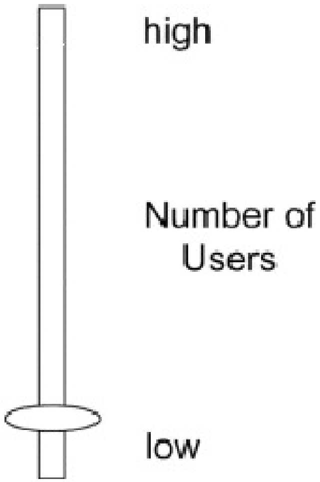
Cell Breathing

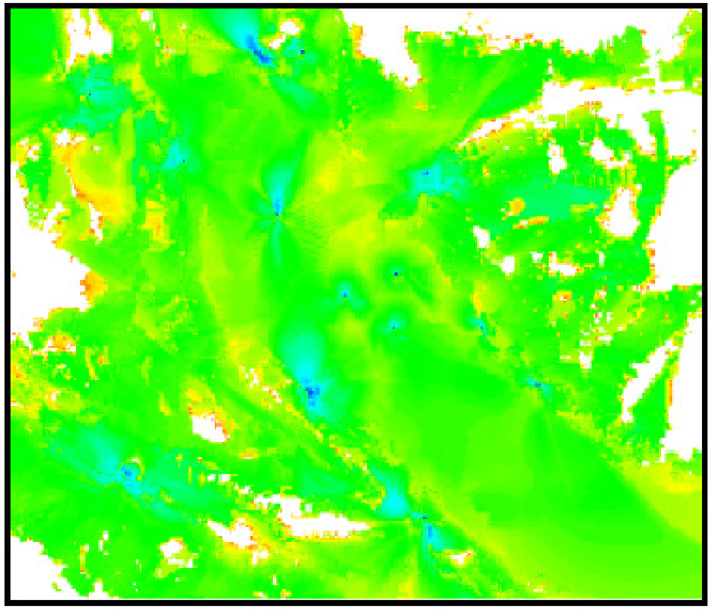
- More users inside a cell increase interference signal (noise)
- Power control has to increase the transmit power to fulfill the E_b/N_0 requirements
- Users far apart from the BS who cannot increase their power anymore
- Their connection will be lost
- When the cell load increases the coverage area shrinks and vice versa
- The cell is breathing



Coverage for the 144kbps service





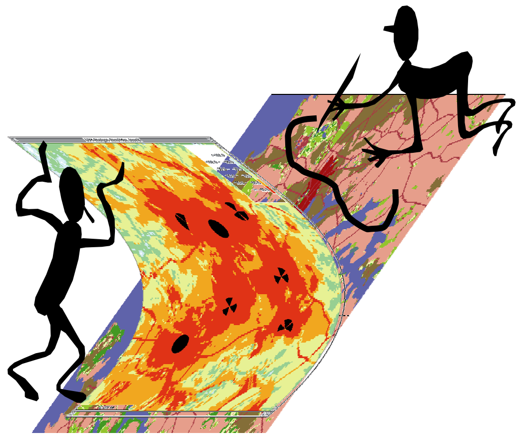


Downlink coverage

Uplink coverage

Cell Breathing

- Capacity enhancements have to be considered from the beginning
- It won’t be possible to add another frequency /TRX
- That means at the beginning:
  - smaller cell sizes than necessary
  - More base stations than necessary
  - Higher invest



- If the traffic estimation was too low
  - Cell areas will shrink
  - Coverage holes in the network will appear

This could only be solved by adding additional base stations

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The Impact of Service Mixes

- One of the key features of 3G Systems is its inherent flexibility regarding data rates and service types
- there exist lots of services and they are very different from each other
  - in their data rates
  - in their traffic types
  - in their and QoS demands
- In 2G there was only one service, therefore **co-interference** caused by other services simply did not exist.
- 3G networks cannot be optimized per service but only per service mix as a 3G base station serve all users and their specific services within its cell simultaneously

A cell will no longer have one coverage area,

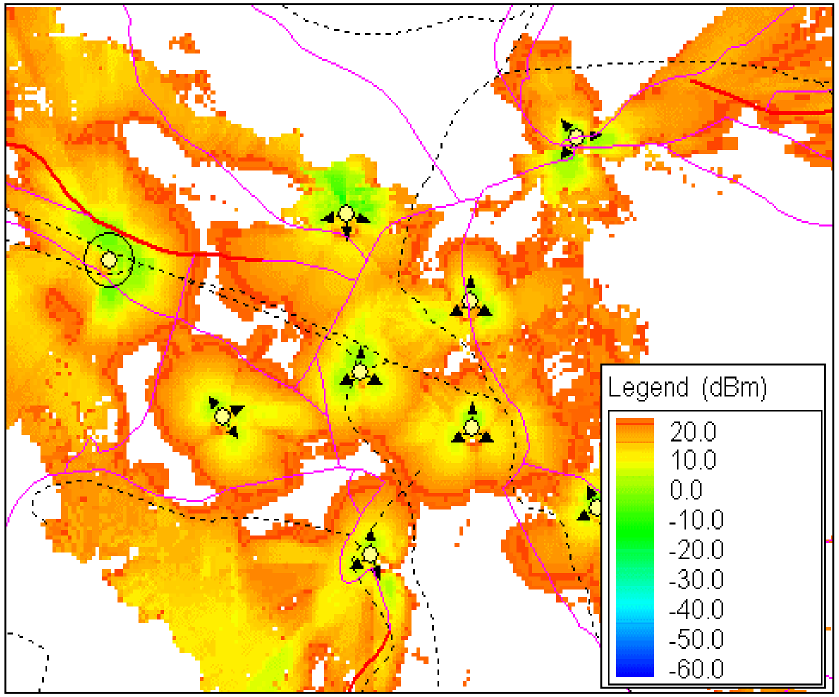
a cell will have one coverage area for each service

Based on which service/coverage area should the network be dimensioned?

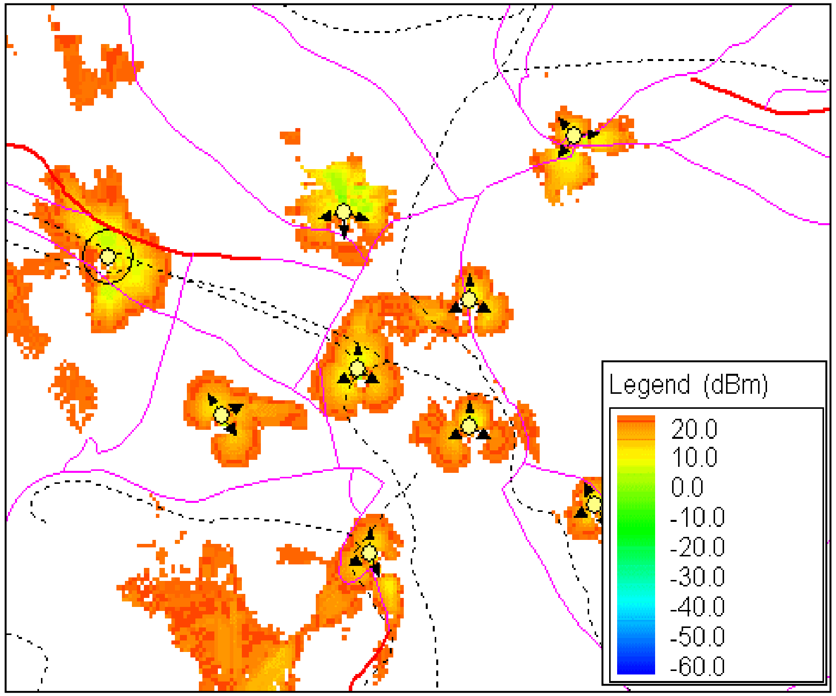
Coverage Areas for Different Services

Comparison Uplink Coverage Speech / 64 kBit/s

Needed transmit power in Uplink
for **speech service**



Needed transmit power in Uplink
for **64 kBit/s data**

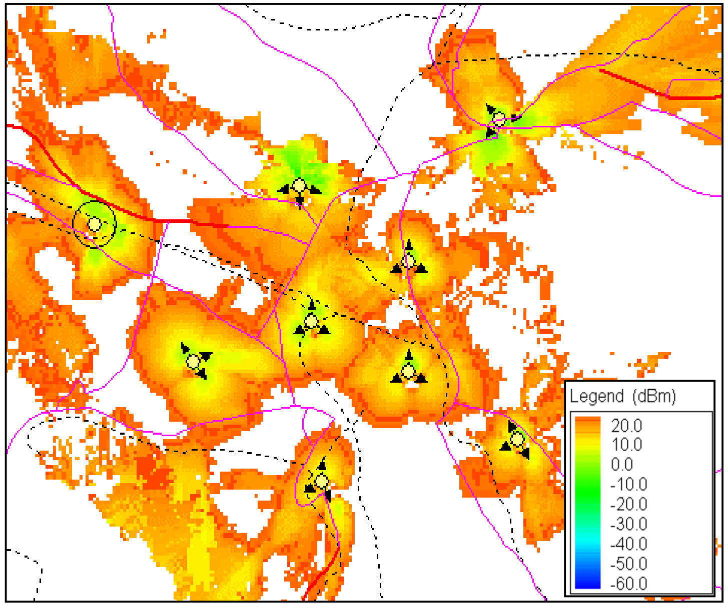


Services with a high data rate use a lower spreading factor. Therefore they operate with a small processing gain, and need in general a higher transmit power to achieve the required Eb/No. This will lead to smaller service areas compared to speech service

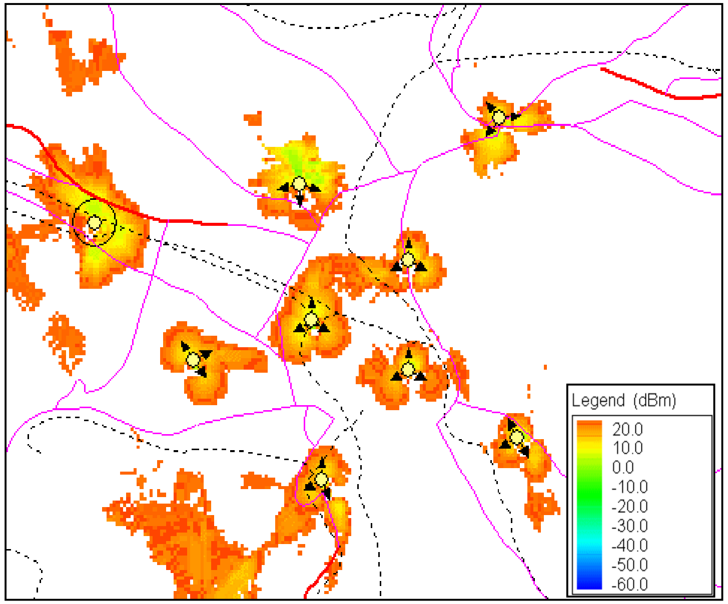
Coverage Area for one Service

- Coverage area for a specific service is not constant
- Even then, when the load on this specific service is constant
- The coverage area is also dependant on the traffic of other services in the cell

Comparison Coverage 64 kBit with and without speech subscribers



Needed transmit power for data service 64 kBit/s
No additional speech users are in the network



Needed transmit power for data service 64 kBit/s
Additional speech users are in the network

Design of 3G Mobile Networks:
What needs to be considered with 3G?

Many planning jobs from 2G networks re-appear in 3G networks also, but often more complicated (e.g. neighbor planning) or simultaneously (e.g. coverage and capacity analysis)

New problems (like service mix or re-use of existing 2G sites) add to this, rendering the network design a very challenging process.

Consequences:

- forecasting of traffic and user behaviour is more important
- reaction times from operations to planning need to be optimised

"Operative Planning"

Thank you for your attention !

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