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

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LS telcom AG

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
**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

### Technical Data Base Stations

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

### Technical Data User Terminals

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

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## Vendor valuation ratios

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

**Total:** 10000
Hardware Comparison & Selection

vendor 1

receiver height 2,5 m

vendor 2

receiver height 5,0 m

receiver height 9,0 m
## Results (for scenario 1 and scenario 2):  

<table>
<thead>
<tr>
<th>Vendor valuation matrix</th>
<th>Vendor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 Analysis of the Technical Data</td>
<td>Sum (max)</td>
<td>200</td>
<td>150.00</td>
<td>130.00</td>
<td>80.00</td>
</tr>
<tr>
<td>4.X.1 Base-Station and Terminal Output-Power</td>
<td></td>
<td>200</td>
<td>70.00</td>
<td>100.00</td>
<td>150.00</td>
</tr>
<tr>
<td>4.X.2 Antenna Pattern, Gain, F/B Ratio</td>
<td></td>
<td>100</td>
<td>60.00</td>
<td>60.00</td>
<td>80.00</td>
</tr>
<tr>
<td>4.X.3 Link Budget</td>
<td></td>
<td>100</td>
<td>60.00</td>
<td>70.00</td>
<td>50.00</td>
</tr>
<tr>
<td>4.X.4 Carrier to Interference Ratio (C/I)</td>
<td></td>
<td>100</td>
<td>60.00</td>
<td>70.00</td>
<td>60.00</td>
</tr>
<tr>
<td>4.X.5 Carrier to Noise Ratio (C/N)</td>
<td></td>
<td>100</td>
<td>50.00</td>
<td>90.00</td>
<td>50.00</td>
</tr>
<tr>
<td>4.X.6 Base-Station, Receiver Sensitivity</td>
<td></td>
<td>100</td>
<td>150.00</td>
<td>80.00</td>
<td>130.00</td>
</tr>
<tr>
<td>4.X.7 Throughput, Terminal per cell</td>
<td></td>
<td>100</td>
<td>60.00</td>
<td>80.00</td>
<td>60.00</td>
</tr>
<tr>
<td>4.X.8 Type of Terminal</td>
<td></td>
<td>100</td>
<td>50.00</td>
<td>80.00</td>
<td>40.00</td>
</tr>
<tr>
<td>4.X.9 Transmitting / Modulation System</td>
<td></td>
<td>100</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
</tr>
<tr>
<td>4.X.10 Availability</td>
<td></td>
<td>100</td>
<td>60.00</td>
<td>60.00</td>
<td>60.00</td>
</tr>
<tr>
<td>5 Coverage calculation</td>
<td></td>
<td>500</td>
<td>200.00</td>
<td>420.00</td>
<td>420.00</td>
</tr>
<tr>
<td>5.X.2 Coverage plot for 2.5 m receiver height</td>
<td></td>
<td>500</td>
<td>250.00</td>
<td>440.00</td>
<td>440.00</td>
</tr>
<tr>
<td>5.X.3 Coverage plot for 5 m receiver height</td>
<td></td>
<td>500</td>
<td>300.00</td>
<td>450.00</td>
<td>450.00</td>
</tr>
<tr>
<td>5.X.4 Coverage plot for 9 m receiver height</td>
<td></td>
<td>500</td>
<td>800.00</td>
<td>100.00</td>
<td>800.00</td>
</tr>
<tr>
<td>System Crash with increasing cell load</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Analysis of Measurements</th>
<th>Vendor</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.X.3 Fieldstrength depending of the Distance and max. Link</td>
<td>1500</td>
<td>800.00</td>
<td>1000.00</td>
<td>700.00</td>
<td>1500.00</td>
</tr>
<tr>
<td>6.X.4 Throughput</td>
<td>2000</td>
<td>1400.00</td>
<td>1400.00</td>
<td>1600.00</td>
<td>1500.00</td>
</tr>
<tr>
<td>6.X.5 Influence of Load</td>
<td>1500</td>
<td>1300.00</td>
<td>100.00</td>
<td>1300.00</td>
<td>1300.00</td>
</tr>
<tr>
<td>Measurement Points probably not in the main beam of the antenna - evaluation pattern. (MP close to the BS)</td>
<td>1000</td>
<td>500.00</td>
<td>600.00</td>
<td>500.00</td>
<td>950.00</td>
</tr>
<tr>
<td>6.X.6 System Performance</td>
<td>1000</td>
<td>800.00</td>
<td>100.00</td>
<td>800.00</td>
<td>890.00</td>
</tr>
<tr>
<td>System became unstable when the number of connections in the cell has been increased</td>
<td></td>
<td>10000</td>
<td>6470</td>
<td>5410</td>
<td>6450</td>
</tr>
</tbody>
</table>

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

- rural, outdoor
- urban, indoor

have been generated
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

BS-1
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.
Steps are **independent** from each other. If the traffic load exceeds a cell’s capacity, an other transceiver can be added to the cell.

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

![Diagram showing cell 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
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 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**

Comparison Uplink Coverage Speech / 64 kBit/s

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 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
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!

For more information:

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