Highlighting the Specific Design and Measurement Challenges Faced when Developing WCDMA Indoor Networks

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Outline

• Identifying and overcoming the particular design challenges of indoor WCDMA networks considering the service requirements of subscribers in offices and public buildings

• Simulating WCDMA in-building applications / solutions

• Optimising onsite measurements
In-building coverage solutions with emphasis on speech

• In offices and public building dedicated indoor systems are normally mainly for increasing the capacity
  – However, in general 9 out of 10 calls are still over fixed lines
• For speech capacity design we know:
  – # of users with mobiles in the building
  – 50 to 100 mErlang
  – Blocking requirement 1% (Erlang B)
• In WCDMA we have soft-degradation as “normally” we are interference limited
  – From simulation we know: 60 to 120 Erlang per WCDMA carrier per sector, depending on the interference. E.g. 60 Erlang/100 mErlang/user = 600 speech users (see previous IIR talks).
  – Consider also if GSM indoor system exists less speech capacity is needed for the indoor WCDMA system

Future considerations:

• Migrating the fixed users to mobile users
• Fixed-mobile convergence (VoIP e.g. over WLAN)
## How “much” should we plan for data?

<table>
<thead>
<tr>
<th>Locations</th>
<th>Main choice for data/internet connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Offices (corporate customers)</td>
<td>1) LAN</td>
</tr>
<tr>
<td></td>
<td>2) WLAN (IEEE 802.11)</td>
</tr>
<tr>
<td></td>
<td>3) Cellular indoor (GPRS/EDGE/WCDMA)</td>
</tr>
<tr>
<td>Larger public buildings (airport, train station, supermarket)</td>
<td>1) WLAN</td>
</tr>
<tr>
<td>Public transport (train, airplanes)</td>
<td>1) WLAN</td>
</tr>
<tr>
<td></td>
<td>2) Cellular outdoor (GPRS/EDGE/WCDMA)</td>
</tr>
<tr>
<td>Smaller public buildings (Hotels, coffee shops, petrol stations)</td>
<td>1) WLAN</td>
</tr>
</tbody>
</table>

### Open questions:
- How large is the data piece for indoor cellular systems in the future?
- Is there a “special” indoor cellular/WCDMA data service which the LAN or WLAN can not offer?
Speaking about time scales and interworking

• Macro/micro/pico GSM/GPRS/EDGE/WCDMA BSs
  – Passive/active distributed antenna system for larger buildings mainly designed to increase capacity (for speech service).
  – Current WCDMA radio network based on 3GPP R99. We have data rates of 384/64 kbps, mobiles with uplink data rates of 128 kbps are available e.g. the Nokia 6630.
  – 3GPP Rel-5 includes HSDPA. IPv6 is a mandatory protocol in Rel-5 which will simplify roaming between 2G/3G and WLAN. Rel-5 content functionally was frozen mid 2002 and vendors availability will be early 2006.
  – 3GPP Rel-6 includes UMA (Unlicensed Mobile Access) technical specification which supports tight interworking and HSUPA. Rel-6 content functionally was frozen Dec 2004.

• WLAN/Bluetooth access points for data and VoIP
  – Bluetooth in nearly every mobile but short range (~10 meter Class 3)
  – Private WLAN access points in many homes.
  – Only a few WLAN enabled mobiles (GSM & WLAN) on the market so far. However, promising forecasts about GSM/WCDMA/WLAN enabled mobiles.
Speaking about time scales and interworking

• Tight and loose interworking for speech and data service between cellular and WLAN networks
  – Loose interworking (IP interworking): Standardisation at 3GPP, IEEE802.11u/IEEE802.21.
    – Works today with RADIUS roaming, mainly about authentication and billing.
    – Mobility are not solved in standard, no handover.
    – Telia HomeRun WLAN service offers “Connect Pro” which allows automatic in-logging to the “best” available connection GPRS/WCDMA, WLAN or LAN, VPN tunnel to the companies intranet and allowing seamless data sessions for the user, see www.homerun.telia.com.
  – Tight interworking (WLAN integrated in UTRAN): Standardisation at 3GPP (see Rel-6, UMA). Indoor mobile calls are routed over the fixed network using e.g. WLAN/Bluetooth.
    – Works today with proprietary solutions (for speech),
    – For UMA it needs IPsec in the mobile and in the network we need a Generic Access Network Controller (GANC) for the WLAN.
    – UMA speech over GSM/WLAN/Bluetooth trials:
      – TeliaSonera Denmark trial in Denmark
      – BTs Bluephone project in England.

In “large” offices and public buildings we have existing DASs for GSM and WCDMA and it is difficult to foresee a large penetration of WLAN enabled mobile terminals in the next two years.
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• Identifying and overcoming the particular design challenges of indoor WCDMA networks considering the service requirements of subscribers in offices and public buildings

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• Optimising onsite measurements
Simulation: Outdoor-to-indoor and dedicated indoor coverage
Interference sources
LOS/NLOS probability

We studied the LOS probability from outdoor antennas above the rooftop to buildings within a radius of 300 meter (from the digital maps of 3 European cities):

• 50 to 90% to the rooftop of these buildings (high interference)

• 8 to 31% to the middle of the buildings

• 5 to 31% to 2 meter above the ground
Simulation results

• Input parameters outdoor/indoor:
  – Cell radius 300/25 metre
  – Feeder loss 3/35 dB
  – Path loss model Walfish-Ikegami/COST 231 multiple wall model
  – Orthogonality factor 0.5/0.2

<table>
<thead>
<tr>
<th>Indoor</th>
<th>LOS</th>
<th>NLOS</th>
</tr>
</thead>
<tbody>
<tr>
<td>i-factor</td>
<td>0.5 to 0.8</td>
<td>0.1 to 0.2</td>
</tr>
<tr>
<td>SHO area (indoor-to-outdoor)</td>
<td>20 to 23%</td>
<td>2 to 4%</td>
</tr>
<tr>
<td>Indoor-to-outdoor connections</td>
<td>33 to 36%</td>
<td>1 to 4%</td>
</tr>
<tr>
<td>Capacity speech Erlang with activity factor 0.5 per carrier per sector</td>
<td>60</td>
<td>120</td>
</tr>
</tbody>
</table>
Limiting interference

• **Metalised windows** give some extra attenuation. Essential for modern buildings with large window areas.

• **Tune the outdoor network** to avoid strong radiation to the building with dedicated indoor system. Micro cells with antennas below roof top.

• **Use separate indoor carriers and hierarchical cell architecture.** The problem is that many operators have only 2 to 3 WCDMA carriers. However:
  
  – In some countries like Sweden and Germany UMTS frequency spectrum in the core band at around 2 GHz was returned and could be used.
  
  – Future UMTS extension band (2.5 GHz) should be around 2008 available

• Keep the **indoor feeder loss low** (20 to 30 dB), but consider also the cost factor.

• Don’t increase the pilot power in order to “force” the indoor users to the indoor system as this would pollute also the outdoor network.
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Dedicated indoor GSM/WCDMA solution at the Ericsson building in Lindholmpiren, Gothenburg

- Office building complex with 1600 employees, 52 400 m² 10 floors (8 above ground)
- GSM 1800 (1 x RBS 2206 plus 3 x RBS 2202), two GSM operators
- WCDMA (1 x RBS 3202 with 3 TRXs)
- 3 cells (3 x Combining Boxes)
- 124 antennas
- 400 of the employees have a 3G phone as the only phone (SonyEricsson Z1010) while the rest have GSM phones
Dedicated indoor GSM/WCDMA solution at the Ericsson building in Lindholmspiren, Gothenburg

- Indoor Macro Node B: $P_{\text{max}} = 43$ dBm, CPICH = 32 dBm
- Passive DAS losses range from 23 to 33 dB at UMTS frequencies
- CPICH EIRP ranges from 1 dBm to 11 dBm (mainly omni-antennas)
- Cell radius per antenna ~14 to 18 meter
- Optimized RANOS settings for the indoor
- Three E1 lines
- Distance to closest outdoor Node Bs are about 500 to 800 meter
Test and measurement tools

• Software: TEMS and Agilent Nitro Chariot from NetIQ
• Mobiles: Qualcomm TM6200, SonyEricsson Z1010, Motorola A835, Nokia 6650
• Agilent scanner
• Various laptops
• Tektronix YBT250 BTS Transmitter and Interference Analyzer
Coverage measurement

![Graph showing coverage measurement with lines for different floors and signal conditions.](image-url)
Coverage measurement

- Low interference
- SHO area:
  - to outdoor negligible
  - indoor-to-indoor floor 3 about 8%
  - indoor-to-indoor floor 8 < 1%
Load test

• With up to 11 mobiles located in different meeting rooms.
• We used FTP download
• **Room A**: Signal only from one sector (low interference from the other cells), ~15 metre from the antenna.
  – **We achieved average user throughput of ~2400 kbps.** This meant six 384 kbps connections, two 128 kbps packet switched connection and two video calls *(New record!)*.
  – The Node B transmit power per data channel was ~ 28 dBm. We were code limited
• **Room B**: Strong SHO to the various indoor cells
  – We achieved average user throughput of ~1900 kbps. This meant five 384 kbps connections and two 128 kbps packet switched connection.
  – We were interference limited
Summary

• Current indoor GSM and WCDMA systems are mainly designed and used for speech service.

• Indoor simulation and measurement results showed: (i) very good code orthogonality, (ii) small soft-handover area and (iii) low interference from the outdoor cells

• Load test with record downlink total average user throughputs of up to ~2400 kbps within one sector using one WCDMA carrier are achieved in TeliaSonera’s live 3G network in Göteborg, Sweden, in the Ericsson building at Lindholmspiren

• Minimize interference from the outdoor network. In the future for some building separate indoor carrier using hierarchical cell architecture may be necessary in order to limit the number of SHOs.
TeliaSonera