Syllabus

• Mobile Communication Technology
• 3G RNP Overview
• RNP Concept
  – Step Radio Network Planning
  – GSM, 3G, and LTE Planning Differences
• Radio Network Dimensioning
  – Link Budget Calculation
• Simulation
• Analysis
Mobile Communication Technology

- Mobile Cellular Concept
- Mobile Cellular Evolution
- System Architecture
- 3G WCDMA Concept
- Radio Aspect/Physical Layer
Mobile Cellular Concept

Cell Ideal

Cell Real

Cell Model
Cell Configuration

1) Omnidirectional

2) Sectoring 120°

3) Sectoring 60°

Example:

- 3-sector cell tower
  - 120° per sector
- 3 sectors
  - 1 channel per sector
Mobile Cellular Evolution

- **1G - TACS**
- **2G - GSM/GPRS/EDGE**
  - Research & Std
  - **3G - WCDMA/HSPA/HSPA+**
    - Research & Std
  - **4G - LTE/LTE-Advanced**
    - Research & Std
  - **5G - Infinite Capacity**
    - Next generation Global standard around 2020
    - Peak “5G” volume around 2040

- Systems tend to co-exist rather than replacing previous generations
Data Transmission Evolution

- **HSCSD, GPRS & EDGE**: combining 1-8 TS
- **HSCSD**: Circuit Switched
- **GPRS**: Packet Switched; new Infrastructure
- **EDGE**: 8PSK instead of GMSK
- **UMTS**: UTRA (WCDMA) optimised for PS

**GSM**
- **Phase 1/2**: 9.6 kbit/s
- **New network elements & protocol architecture**: prerequisite for UMTS!!

**HSCSD**
- 115 kbit/s
- No new network elements; SW-changes
- 4 \( \times \) (8) x 14.4 kbit/s

**GPRS**
- 171 kbit/s
- No new network elements; only changes in modulation principle
- 8 \( \times \) 21.4 kbit/s

**EDGE**
- 553 kbit/s
- New transmission principles (WCDMA)
- Network elements
- Protocols
- 8 \( \times \) 69.2 kbit/s

**UTRA**
- 1920 kbit/s

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**HSCSD**: High Speed Circuit Switched Data  
**GPRS**: General Packet Radio Services  
**EDGE**: Enhanced Data rates for the GSM Evolution  
**8PSK**: Phase Shift Keying  
**GMSK**: Gaussian Minimum Shift Keying  
**UMTRA**: UMTS Terrestrial Radio Access
GSM & UMTS Evolution

GSM Limits:
- narrow-band radio access
- resource efficiency
- additional frequency bands required

GSM & UMTS Evolution

GSM
- Phase 1: TeleServices TS, BS max. 9.6 Kbit/s
- Phase 2: Supplementary Services SS (= ISDN)
- Phase 2+: new SS, flexible Service Concept (CAMEL, MExE, ...), higher data rates (HSCSD, GPRS, EDGE), new network elements
- Release '96
- Release '97
- Release '98
- Release '99

UMTS
- Release 3
- Release 4
- Release 5

close to original 3G plans

Ph1: TeleServices TS, BS max. 9.6 Kbit/s
Ph2: Supplementary Services SS (= ISDN)
new SS, flexible Service Concept (CAMEL, MExE, ...), higher data rates (HSCSD, GPRS, EDGE), new network elements
new WCDMA Radio Interface (large bandwidth, Flexible data rates; optimized for PS); new RAN
new CN solutions (R'4: CS domain modification R'5: IMS); new RTT options (LCR-TDD)

IMS: IP Multimedia Subsystem
LCR: Low Chip Rate
RTT: Radio Transmission Technology
GSM and 3G Architectures
3G WCDMA - Wideband CDMA

Radio access technology for one of the UMTS access modes (UTRA FDD) using 5 MHz duplex channels.

- Frame length is of 10 msec, Chip rate is 3.84 Mcps
- All users share the same frequency and time domain
- Users separated by the codes
UMTS Radio Frequency Ranges

- FDD (Frequency Division Duplex)
- TDD (Time Division Duplex)

**FDD bands:**
- 1920 – 1980 MHz UL
- 2110 – 2170 MHz DL
- 1850 – 1910 MHz UL
- 1930 – 1990 MHz DL

**TDD bands:**
- 1900 – 1910 MHz
- 2010 – 2025 MHz
Channelization in UMTS

- Logical Channel between RLC and MAC
  - Specific for information types
  - What type of data to be transferred
- Transport channel between MAC and PHY
  - Specific for “how to transfer information?” (quality guarantee)
  - How and with which type of characteristic the data is transferred by the Physical Layer
- Physical Channel
  - Exact Physical characteristics of the radio channel
WCDMA Channel (Cont.'s)

- Spreading means increasing the signal bandwidth
- Spreading includes two operations
  - Channelization (increases signal bandwidth)
    - Orthogonal Spreading
  - Scrambling (does not affect the signal bandwidth)
    - Use pseudo-noise codes

channelization codes (SF)  scrambling codes

Data → bit rate → chip rate → chip rate

Scrambling code:
- separates different sources
- UL: separates different UE in 1 cell

Channelization code:
- separates channels from the source
- UL: channels of the same UE
  - e.g. different applications (max. 6 SF variable)
Handover Concept

Site B

Posisi 3

BSC

Handover Req Acknowledge
Handover Req Acknowledge
Handover Complete

Posisi 2

Handover Request
Handover Req Acknowledge
Handover command
Handover Request

Posisi 1

Site A
Radio Network Planning

- RNP Overview
- Objective
- GSM and 3G Planning Differences
- Radio Network Dimensioning
- Power Link Budget
Radio Network Planning Overview

Radio Network Planning?
According to deployment and evolution requirements, as well as cost-effectiveness consideration, generate the amount of **Network Elements (NE)**, **NE configuration**, and **Transmission design** between different NE.

Network Planning Scope:
- **Core network**: focus on CN element dimension and configuration.
- **Radio network**: focus on RAN element dimension and configuration.
- **Transmission network**: focus on link dimension and configuration between network elements.
Radio Network Planning Solution

- 3G Radio network planning (NodeB/RNC)
- 3G Transmission network planning (Iu/Iur/Iub)
- 3G Core network planning (CS/PS domain)
- 3G RNP tools development

- Network KPI
- Soft-handover ratio and probability
- Best Server Distribution
- Pilot pollution
- Access probability of different services
- Estimation result
- CE dimension
The RF Design of wireless system revolves around four main principles. These principles are **Coverage, Capacity, Quality and Cost**. And further, adapt to the future network development and expansion.

Realization of excellent balance of all aspect via networks planning
GSM and 3G Planning Differences

- Realize 1 x 1 frequency reuse
- The capacity per WCDMA cell is “soft” for it is related to environment and neighbor cell interference.
- Supports multiple services with different speed rate and QoS, and each service has different coverage range.

3G

- Adopts cellular network structure and frequency planning to guarantee intra/inter-frequency interference
- Users supported can be calculated from carriers and timeslots if the interference meets the requirements.
- Provides voice service

GSM
3G RNP Procedure Overview

- Capacity
- Interference
- Coverage
- Quality

Dimensioning
Nominal Planning
Site survey
Detailed planning & pre-optimization
Deployment
Final design
Preliminary design
Preparation
Radio Network Dimensioning

**Input**
- Coverage related
  - Coverage area
  - Coverage probability
- Capacity related
  - Traffic model
  - Service model
  - User density
- Quality related
  - QoS requirements
  - GoS requirements
  - Demodulation threshold

**Output**
- System dimensioning
  - Number of sites
- System configuration
  - Sector structure
  - Number of carriers
- Cost on network construction
  - Site cost
  - Equipment cost
Power Link Budget

1. Receiver Sensitivity
2. $P_{DCH_{Max}}$
3. Minimum Required Signal Strength
4. EiRP
5. $P_{UE_{Max}}$

- Slow Fading Margin
- Penetration Loss
- Body Loss
- Interference Margin
- Fast Fading Margin
- Margin for Background Noise

Antenna

Soft Handover Area

Duplexer

TX RX

UE

Node B

Cable

PL_DL

PL_UL
Example Calculation

Coverage

### Link budget of AMR 12.2 kbps voice service (120 km/h, in-car users, Vehicular A type channel, with soft handover)

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmitter (mobile)</td>
<td></td>
</tr>
<tr>
<td>Max. mobile transmission power [W]</td>
<td>0.125</td>
</tr>
<tr>
<td>As above in [dBm]</td>
<td>21.0 a</td>
</tr>
<tr>
<td>Mobile antenna gain [dB]</td>
<td>0.0 b</td>
</tr>
<tr>
<td>Body loss [dB]</td>
<td>3.0 c</td>
</tr>
<tr>
<td>Equivalent Isotropic Radiated Power (EIRP) [dBm]</td>
<td>18.0 d = a + b - c</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Receiver (base station)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal noise density [dBm/Hz]</td>
<td>-174.0 e</td>
</tr>
<tr>
<td>Base station receiver noise figure [dB]</td>
<td>5.0 f</td>
</tr>
<tr>
<td>Receiver noise density [dBm/Hz]</td>
<td>-169.0 g = e + f</td>
</tr>
<tr>
<td>Receiver noise power [dBm]</td>
<td>-103.2 h = g + 10^ log (3480000)</td>
</tr>
<tr>
<td>Interference margin [dB]</td>
<td>3.0 i</td>
</tr>
<tr>
<td>Total effective noise + interference [dBm]</td>
<td>-100.2 j = h + i</td>
</tr>
<tr>
<td>Processing gain [dB]</td>
<td>25.0 k</td>
</tr>
<tr>
<td>Required $E_b/N_0$ [dB]</td>
<td>5.0 l</td>
</tr>
<tr>
<td>Receiver sensitivity [dBm]</td>
<td>-120.2 m = 1 - k + j</td>
</tr>
<tr>
<td>Base station antenna gain [dB]</td>
<td>18.0 n</td>
</tr>
<tr>
<td>Cable loss in the base station [dB]</td>
<td>2.0 o</td>
</tr>
<tr>
<td>Fast fading margin [dB]</td>
<td>0.0 p</td>
</tr>
<tr>
<td>Max. path loss [dB]</td>
<td>154.2 r</td>
</tr>
<tr>
<td>Log-normal fading margin [dB]</td>
<td>7.3 s</td>
</tr>
<tr>
<td>Soft handover gain [dB], multicell</td>
<td>3.0 t</td>
</tr>
<tr>
<td>In-car loss [dB]</td>
<td>8.0 u = q - r + s - t</td>
</tr>
<tr>
<td>Allowed propagation loss for cell range [dB]</td>
<td>141.9</td>
</tr>
</tbody>
</table>
From the RLB above, the cell range $R$ can be calculated. e.g. with the *Okumura–Hata* propagation model for an urban macro cell with base station antenna height of 30 m, mobile antenna height of 1.5 m and carrier frequency of 1950 MHz:

$$L = 137.4 + 35.2 \log_{10} (R_{km}) \quad \text{.....Urban}$$

$$L = 129.4 + 35.2 \log_{10} (R_{km}) \quad \text{.....Sub-Urban}$$

From RLB above, MAPL for 12.2 kbps voice service is 141.9 dB:

- Urban: $R_{cell} = 1.34$ km
- Sub-urban: $R_{cell} = 2.27$ km
Example Calculation

Capacity

\[ M = \eta \left[ 1 + \frac{Rc \times Gs}{\frac{Eb}{No} \times Ri \times Vi \times (1+f)} \right] \]

- \( Eb/No \) = 8.5 dB
- Chip Rate, \( Rc \) = 3.84 Mcps
- Bit Rate, \( Ri \) = 12.2 kbps (voice)
- Activity factor, \( Vi \) = 0.4
- \( Gs \) (Antenna Sector Gain) = 1
- \( f \) (other-cell relative interference factor) = 0.6
- \( \eta \) (load factor) = 0.5

\[ M = 0.5 \left[ 1 + \frac{1}{69.46} \right] = 35.23 \approx 35 \]

Blocking Probability 2%

Erlang Table

\( A(35; 2\%) = 26.435 \text{ Erlang} \)

\[ \sum \text{user} = \frac{A_{\text{carried trafik}}}{A_{\text{subs}}} \]

\[ \frac{26.435}{0.025} = 1057.4 \approx 1058 \text{ user} \]
Network Dimension flow chart

Applicable Propagation Model
COST231-HATA, ...

UL cell range with specific UL loading

Cell Range

Service-specific Information
Service Type, Proportion
Service Density
Service Forecast

Geographical information
DU km²
U km²
SU km²
RA km²
HW km²

Number of Site

Cell Range

Cell Loading vs. Maximum Allowable Value

SiteConfiguration

If the upper limit of configuration be reached

Add the amount of configuration (sectorization, carriers,...)

Equal to

Shrink the Cell

UL loading

Downwards

If the upper limit of configuration be reached

Large than (Capacity-limited)

Less than (Coverage-limited)

SiteConfiguration

Cell Range

Adjust UL loading Downwards
Nominal Planning

Based on the result of network dimension, preliminary design present Information of theoretical sites including following:

- Site coordinates.
- Engineering parameters such as Antenna height, azimuths and tilts.
- Radio parameters such as scrambling code, transmit power of different channels, etc.
Software Simulation

- Simulation Flow Chart
- Simulation Output
- Step by Step
- Verification by System Simulation
Preliminary design flow chart

1. Bidding Document
2. Radio Network Dimensioning
3. Dimensioning Report
4. Contract
5. Available sites information
6. Initial sites choosing
7. System simulation
8. Propagation model
9. Site adjustment
10. Nominal planning report (Including: search ring and Theoretical site specification)
Simulation Output

Simulation Parameter

- Pilot coverage (Ec, Ec/lo) in the target areas
- Best server plot
- Coverage probability distribution of each service
- Access failure distribution and statistic of each service
- Continuous coverage areas of each service
- Cell load distribution of downlink and uplink
- Pilot pollution distribution
- Soft handover areas statistic of each service
Task and Exercise

- Find map of Yogyakarta City
- Find number of users in Yogyakarta City
- Plot Cells
  - Based on Calculation of Coverage Cell
  - Based on Capacity Calculation
Simulation flow-chart

Setup network Design → Run Pilot Field Strength Prediction → Pilot Level OK? → YES

Traffic model

Traffic Forecast Avail? → YES

Run UMTS Traffic simulation

Setup fixed Load values

NO

Run UMTS Traffic simulation

Setup fixed Load values

NO

YES

Make predictions (Services)

NO

NO

NO

Scrambling code allocation criteria

Neighborhood planning criteria

NO

Output parameters

YES

Neighbors planning & Scrambling code allocation

Performance Requirements Fulfilled?

YES

NO

Neighborhood planning criteria

Scrambling code allocation criteria
Atoll Simulation Step

1. Preparation
2. Start Project
3. Configure Coordinate
4. Import Digital Maps
5. Set Propagation Model
6. Draw Zone
7. Make Prediction based on Coverage
8. Simulation
9. Make Prediction based on Simulation
10. Check Planning Results
Preparation

• Data Planning (Import Information)
• Map
  – Vector
  – Clutter
  – Height
Start Project

UMTS HSDPA
Interface

Map

Propagation Model
Configure Coordinate
Import Digital Maps

MAP: Vector Clutter Height
Set Propagation Model

[Image of software interface showing propagation models and parameters]

Duplicate
Cell Planning
Draw Zone
Make Prediction based on Coverage
Check Planning Result
Verification by System Simulation

It is an iterative process to verify the final design until all the requirements are fulfilled.

Coverage prediction

Are Requirements Fulfilled?

Traffic distribution

System simulation

RNP Planning results
References

- Atoll Manual
- U-Net Planning Tools
- Huawei, WCDMA RNP & RNO Conspectus
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감사합니다