Dimensioning and planning process

Introduction

Radio team is the responsible of handling the Air Interface network in terms coverage, capacity & quality.

Planning team is the responsible of dimensioning and designing the new sites that need to be added to the network.
The final site annual plan, resulted from combining coverage, capacity and quality dimensioning, taking into accounts the practical limitation.

Visiting the nominated location to assess the real environment to determine whether it is a suitable site location.

Interacting with the rollout team to choose a suitable location, and finalize the site design (height, orientation, tilt...etc) and determine the needed equipment.

Installing the site according to its RF design.

Interacting between planning performance and optimization teams to tune the parameters of the site to achieve its optimum performance.
Cell Planning Process
Why Do We Add More And More Sites To Our Network?

<table>
<thead>
<tr>
<th>Capacity</th>
<th>Coverage</th>
<th>Quality</th>
</tr>
</thead>
</table>
| • To absorb new traffic added to the network.  
  • Resulted from a capacity dimensioning analysis.  
| • To provide coverage for the new areas.  
  • To enhance coverage for the old areas according to a new threshold.  
  • Resulted from a coverage dimensioning analysis | • To solve quality problems (lack of dominance, fading….etc. )  
  • Resulted as last action from the tuning process, with no separate dimensioning analysis. |

Dimensioning isn’t an isolated process !!

Capacity Dimensioning

• Traffic Unit:
  \[ \text{Erlang} = \text{One resource is busy for 1 hour per hour.} \]

\[ \text{Traffic in Erlang} = \frac{\text{Number of calls/hr} \times \text{Average call holding time (Sec)}}{3600} \]

• Required resources:
  • Define the blocking rate (GOS).
  • Differentiate between offered traffic and carried traffic.

  \[ \text{carried traffic} = (1 - \text{GOS}) \times \text{offered traffic} \]

  \[ \text{GOS} = \frac{T^n \times e^{-T}}{N!} \]

  \[ T: \text{Traffic in Erlang} \]

  \[ N: \text{Resources (Time slots)} \]

• Using \textbf{Erlang B table}
Capacity Dimensioning

Table is designed assuming arrival rate as a Poisson distribution function

<table>
<thead>
<tr>
<th>Resources</th>
<th>GOS 1%</th>
<th>GOS 2%</th>
<th>GOS 3%</th>
<th>GOS 5%</th>
<th>GOS 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.01</td>
<td>0.02</td>
<td>0.03</td>
<td>0.052</td>
<td>0.1111</td>
</tr>
<tr>
<td>2</td>
<td>0.15</td>
<td>0.223</td>
<td>0.2815</td>
<td>0.381</td>
<td>0.5954</td>
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<tr>
<td>3</td>
<td>0.455</td>
<td>0.6</td>
<td>0.715</td>
<td>0.8994</td>
<td>1.27</td>
</tr>
<tr>
<td>4</td>
<td>0.869</td>
<td>1.09</td>
<td>1.25</td>
<td>1.5249</td>
<td>2.0454</td>
</tr>
<tr>
<td>5</td>
<td>1.36</td>
<td>1.657</td>
<td>1.8752</td>
<td>2.218</td>
<td>2.8811</td>
</tr>
<tr>
<td>6</td>
<td>1.9</td>
<td>2.2795</td>
<td>2.543</td>
<td>2.9603</td>
<td>3.7584</td>
</tr>
<tr>
<td>7</td>
<td>2.5</td>
<td>2.935</td>
<td>3.249</td>
<td>3.737</td>
<td>4.6662</td>
</tr>
<tr>
<td>8</td>
<td>3.12</td>
<td>3.627</td>
<td>3.966</td>
<td>4.542</td>
<td>5.5971</td>
</tr>
<tr>
<td>9</td>
<td>3.78</td>
<td>4.345</td>
<td>4.747</td>
<td>5.3702</td>
<td>6.5464</td>
</tr>
<tr>
<td>10</td>
<td>4.48</td>
<td>5.084</td>
<td>5.529</td>
<td>6.2157</td>
<td>7.5106</td>
</tr>
<tr>
<td>11</td>
<td>5.15</td>
<td>5.8445</td>
<td>5.298</td>
<td>6.9784</td>
<td>8.4871</td>
</tr>
</tbody>
</table>

- **Trunking efficiency ($\mu_T$):**
  - A very important factor to be taken into consideration while dimensioning.
  - Measure the utilization of traffic resources: $\mu_T = \frac{\text{Traffic in Erlang}}{N \text{ of resources}} \times 100$
Capacity Dimensioning (for new network)

- **Assumption to be made/obtained for excepting capacity**

- **1-Traffic map calculation:**
  - Area is to be divided to smaller areas with homebound traffic profile.
  - Total number of subscribers per sub area.
    - (Total number of people X mobile penetration ratio X operator share).
  - Peak hour percentage
    - How many user will use their mobiles in the peak hour.
  - Traffic user profile.
    - Normally to be assumed between (20mE→40mE).
  - Get the traffic estimated for each sub area

- **2-Determine the resources needed**
  - Assuming site design criteria.
    - Omni/ securitized size.
    - Freq reuse pattern. (3/9, 4/12….etc).
  - Erlang B (GOS) table to get the traffic that can be handled by each cell.
  - Determine the space that can be covered be each cell.
  - Get the number of cells.

- **3-Verifications**
  - Check utilization for each cell (GOS% or reuse pattern).
  - Check C/I.
  - Check coverage thresholds.
*Capacity Dimensioning (for existing network)*

**Cell Traffic Dimensioning**

- Done on cell basis
- Answer the question
  - What will be the traffic of the cell?
  - Is an extra site needed to offload traffic, what type (*macro, micro, etc.*)?

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**Coverage dimensioning**

- **Wave propagation (Air Interface loss)**
  - **Free space propagation.**
    \[ L_{fs} = 32.44 + 20 \log(F) + 20 \log(D) \]
  - **2 rays model.**
    \[ L_{2r} = 20 \log(h_{bs}) + 20 \log(F) + 40 \log(D) \]
  - **Multi path model (*Hata model*).**
    - Based on practical measurements.
    \[ L_{h} = C_1 + C_2 \log(f) - 13.82 h_{bs} - a (h_{ms}) + (44.9 - 6.55 \log h_{ms}) \log d. \]
Coverage dimensioning

- Fading

2 main type of fading...

- Normal Fading (slow fading): Shadowing effect (10-20M)
  Due to obstruction

- Rayleigh fading (fast fading): Multi path fading (17 cm). (3 dB)
  Due to multi-path.
Coverage dimensioning overview

- **Power Budget Equation:**

  \[ P_{re} = P_{cab} - L_{feeder} + G_{bant} - L_{coupling} - L_{air interface} - L_{fading} - L_{margin} + G_{mant} \]

  - Output power of the cabinet, determined according to the cabinet type
  - Base station antenna gain
  - Losses due to the air propagation (2 rays model, multipath model...etc)
    - Function in Distance.
  - Margins due to any exception obstacles (Cars, Buildings, Body lose...etc)

- **Power received from mobile... determined according to:**
  1. Coverage threshold.
  2. Required C/I.

- **Output power of the cabinet:**
  - Feeder loses.
  - Coupling losses that represent the ratio of the obtained power from the mobile to the total power of the antenna (30→50 db)

- **Losses due to the air fading (slow fading & fast fading).**
  - Function in Distance.

- **Margins due to any excepted obstacles (Cars, Buildings, Body lose...etc)**

Coverage dimensioning detailed power budget equation

- **1-Required Signal Strength:**

  \[ SS_{req} = MS_{sens} + RF_{marg} + IF_{marg} + BL \]

  where

  - \( MS_{sens} \) = MS sensitivity \( \Rightarrow -104 \) dB
  - \( RF_{marg} \) = Rayleigh fading margin \( \Rightarrow 3 \) dB
  - \( IF_{marg} \) = Interference margin \( \Rightarrow 3 \) dB
  - \( BL \) = Body loss \( \Rightarrow 3-5 \) dB

  \( SS_{req} = -94 \) dBm
• 2-Design Signal Strength.
  - Depending on the target coverage area (coverage strategy)

The design level can be calculated from:

$$SS_{design} = SS_{req} + LNF_{marg(o)} \quad MS \text{ outdoor} \quad (2)$$

$$SS_{design} = SS_{req} + LNF_{marg(o)} + CPL \quad MS \text{ in-car} \quad (3)$$

$$SS_{design} = SS_{req} + LNF_{marg(o+i)} + BPL_{mean} \quad MS \text{ indoor} \quad (4)$$

where

$$LNF_{marg(o)} = \text{Outdoor log-normal fading margin.}$$

$$LNF_{marg(o+i)} = \text{Outdoor + indoor log-normal fading margin,}$$

$$CPL = \text{Car penetration loss} \quad \Rightarrow 6 \text{ dB}$$

$$BPL_{mean} = \text{Mean building penetration loss}$$

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### Coverage dimensioning detailed power budget equation

• Log normal fading values (outdoor and in-car).

<table>
<thead>
<tr>
<th>Area type</th>
<th>Coverage [°]</th>
<th>SS$_{req}$ [dBm]</th>
<th>LNF$_{marg(o)}$ [dB]</th>
<th>SS$_{design}$ outdoor [dBm]</th>
<th>SS$_{design}$ in-car [dBm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense urban</td>
<td>75</td>
<td>-94</td>
<td>-3.1</td>
<td>-97.1</td>
<td>-91.1</td>
</tr>
<tr>
<td></td>
<td>85</td>
<td>-94</td>
<td>0.7</td>
<td>-93.3</td>
<td>-87.3</td>
</tr>
<tr>
<td></td>
<td>90</td>
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<td>-90.8</td>
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<td>98</td>
<td>-94</td>
<td>10.7</td>
<td>-83.3</td>
<td>-77.3</td>
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<tr>
<td>σ$_{LNF(o)} = 10$</td>
<td>75</td>
<td>-94</td>
<td>-3.4</td>
<td>-97.4</td>
<td>-91.4</td>
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<tr>
<td>Urban</td>
<td>85</td>
<td>-94</td>
<td>-0.2</td>
<td>-94.2</td>
<td>-88.2</td>
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<td>90</td>
<td>-94</td>
<td>1.8</td>
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<td>-86.2</td>
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<td>95</td>
<td>-94</td>
<td>4.9</td>
<td>-89.1</td>
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<td>σ$_{LNF(o)} = 8$</td>
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<td>Urban</td>
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<td>-0.2</td>
<td>-94.2</td>
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<td>4.9</td>
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<td>98</td>
<td>-94</td>
<td>8.1</td>
<td>-85.9</td>
<td>-79.9</td>
</tr>
</tbody>
</table>
Coverage dimensioning detailed power budget equation

- Log normal fading values (indoor).

<table>
<thead>
<tr>
<th>Area Type</th>
<th>Coverage [%]</th>
<th>$SS_{req}$ [dBm]</th>
<th>$LNF_{marg(ρ=τ)}$</th>
<th>BPL-mean [dB]</th>
<th>$SS_{design}$ in door [dBm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense urban</td>
<td>75</td>
<td>-94</td>
<td>-3.2</td>
<td>18</td>
<td>-79.2</td>
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<tr>
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<td>85</td>
<td>-94</td>
<td>1.8</td>
<td>18</td>
<td>-74.2</td>
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<tr>
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<td>90</td>
<td>-94</td>
<td>5.1</td>
<td>18</td>
<td>-70.9</td>
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<td>95</td>
<td>-94</td>
<td>9.9</td>
<td>18</td>
<td>-66.1</td>
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<td>98</td>
<td>-94</td>
<td>15.3</td>
<td>18</td>
<td>-60.7</td>
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<tr>
<td>Urban</td>
<td>75</td>
<td>-94</td>
<td>-3.1</td>
<td>18</td>
<td>-79.1</td>
</tr>
<tr>
<td></td>
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<td>4.2</td>
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<td>95</td>
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<td>8.4</td>
<td>18</td>
<td>-67.6</td>
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<tr>
<td></td>
<td>98</td>
<td>-94</td>
<td>13.1</td>
<td>18</td>
<td>-62.9</td>
</tr>
</tbody>
</table>

Coverage dimensioning detailed power budget equation

- Max path loss

$$PL_{(max)} = P_{tx} (Cab power) – feeder loss + Gant + G mob - SS (design) + diversity gain...etc$$

$$L_p = A - 13.82\log h_b + (4.49 - 0.53\log h_p)\log d - a(h_m) \text{ (dB)}$$

where

- $A = 146.2$ (800) 146.8 (900) 153.8 (1800) 154.3 (1900) urban area
- $A = 136.4$ (800) 136.9 (900) 146.2 (1800) 146.9 (1900) suburban and semi open areas
- $A = 127.1$ (800) 127.5 (900) 134.1 (1800) 134.6 (1900) rural areas
- $A = 117.9$ (800) 118.3 (900) 124.3 (1800) 124.8 (1900) open areas
- $h_p = \text{base station antenna height [m]}$
- $d = \text{distance from transmitter [km]}$
- $h_m = \text{mobile station antenna height [m]}$
- $a(h_m) = 3.2(\log(1.75h_m))^2 - 4.97$
Coverage dimensioning detailed power budget equation

- Max path loss
  \[ P_{l\text{ (max)}} = P_{tx} (\text{Cab power}) - \text{feeder loss} + G_{ant} + G_{mob} - SS (\text{design}) + \text{diversity gain} \ldots \text{etc} \]

- For dense areas (less than 1 Km cell radius) use a modified propagation loss equation.

  \[ L_b = K + 38 \log d - 18 \log (h_B - 17) \]

  \[
  \begin{array}{l}
  \text{142.4 for 850 MHz} \\
  \text{143.2 for 900 MHz} \\
  \text{153.2 for 1800 MHz} \\
  \text{154.1 for 1900 MHz}
  \end{array}
  \]

  Where \( K \) :

  According to Walfish-Ikegami, the cell range then becomes:

  \[ d = 10^\alpha, \text{ where } \alpha = \frac{[L_{\text{path max}} - K + 18 \log (h_B - 17)]}{38} \]

Coverage dimensioning detailed power budget equation

- Verification

  - Link budget equation should be calculated in the uplink and the downlink the weaker output should be strict to.
  - Use a traffic map to calculate the needed resources for the each cell (non homogenous freq planning)
Site component; site types & site design
1- Site component

GSM site equipment

• Radio cabinets
• Transmission cabinets
• Radiating element
• Feeders
• Accessories
GSM site equipment

Radio equipment

Shelter

TX equipment

Accessories

2206 Cab Blocks
Macro Radio Cabinets

• 1-TRUs
  • Transmitter and receiver unit responsible of transmitting the downlink freqs and receive the uplink carrier.
  • Max output power determine the coverage limitation of the site.
  • Typical values
    • Macro site (47 dbm)
    • Micro site (33 dbm)
  • Max output power is limited by the balance between uplink and downlink link budget.
  • Support diversity for the uplink.
  • Number of trus per cabinet determine its capacity
  • Typical Values
    • Macro cabs (6-12 TRUs)
    • Micro cabs (2-4 TRUs)

Macro Radio Cabinets

• 2-CDU (1/3)
  • Combiner and distributed unit use to combine more than one TRU for one antenna (Downlink); and distribute the received signal between the TRUs (Uplink).
  • Consists of
    • Combiner (direction coupler use to combine signal in downlink).
    • Duplexer (Circulator used to transmit and receive signal at the same antenna).
  • Number of CDUs determine numbers of cells supported per cab.
  • Capabilities of TRU determine the possible configuration of each cell.
  • The losses introduced by the combiner define the output power to the antenna.
  • The transmitted signal in the downlink is the downlink freqs only while the received signal in the uplink is the total RF band received by the antenna.
Macro Radio Cabinets

- 2-CDU (2/3)
  - Two type of combiner.
  - Hybrid combiner
  - Filter combiner

Radio Cabinets

- 2-CDU (3/3)
  - Two type of combiner.
  - Hybrid combiner
  - Filter combiner
Macro Radio Cabinets

• **3-CXU**
  - Configuration switching unit distrusting signal from TRU to the CDU and vice versa.
  - Programmable controlled switches; make it possible to expand and reconfigure a
    without moving or replacing any RX cables.

![Diagram of 3-CXU](image1)

Macro Radio Cabinets

• **4-DXU**
  - Distribution switching unit which act as a transmission interface.
  - Convert between Abis interface and Air interface (Um).
  - Processing number of E1s related to the cabs capacity.
    - 1E1 → 12 GSM TRUs
    - 1E1 → 3 GPRS/EDGE TRUs.

![Diagram of 4-DXU](image2)

Macro Radio Cabinets

• **5-PSU**
  - Power supply unit which act as regulator for the cab devices.
  - Cab devices works of a voltage ranges (-48 → +24V).

![Diagram of 5-PSU](image3)

Macro Radio Cabinets

• **6-DF**
  - Distribution frame that provide the alarm system for the cabs.
  - Can support up to 16 external alarms.

![Diagram of 6-DF](image4)
Radiating Element (Antenna)

What is the Antenna?

The antenna is the device responsible of converting the electric signal confined “guided” in the cables to a radiating waves.

Isotropic Antenna

• An isotropic antenna is a completely non-directional antenna that radiates equally in all directions. Since all practical antennas exhibit some degree of directivity, the isotropic antenna exists only as a mathematical concept.
• All the antenna specs will be measured relative to the isotropic antenna (Reference antenna)
Radiating Element (Antenna)

**Antenna specs**

**1-Gain**

- Defined as the ratio between the power of the max direction of the antenna to the power obtained by an isotropic antenna in the same direction.
- Virtual gain (antenna is a passive element).
- Define for both vertical and horizontal plans.

**2-BeamWidth**

- Defined as the angel between the max direction to the direction where the power is reduced to the half in the max direction.
- Represent the directivity of the antenna.
- Define for both vertical and horizontal plans.

**3-Tilt**

- Defined as the angle between the direction of the maximum radiation to the direction of the horizontal axes.
- Define for the horizontal plane only.
- Can be achieved electrically or mechanically.

![Antenna Top View](image-url)
Radiating Element (Antenna)

**Antenna specs**

**4-Diversity**
- Defined as the redundancy in receiving and/or transmitting the signal.
- The purpose is to overcome fading/attenuation that may be experienced in the signal path.
- Typical gain value is (3→6)db.
- Three types of diversity
  - Freq
  - Space
  - Polarization.

**X not used in GSM**

**✓ Used in GSM**

**Radiating Element (Antenna)**

**Antenna specs**

**5-Side loops**
- First side loops suppression ratio
- Front to back loop ratio.
- Side loops is important for GSM to achieve near field coverage; while the effect for the back loop is bad as it's adding an interference.

**design hint**
- The mechanical tilt affecting both the main loop only; while the electrical tilt affecting the front and back loops.
Antenna Specs (Summary)

- Gain
  - Horizontal Gain
  - Vertical Gain
- Beam-width
  - Horizontal Beam
  - Vertical Beam width
- Tilting
  - Electrical Tilt
  - Mechanical Tilt
- Diversity
  - Space
  - Freq
  - Polarization
- Side loops suppression ratio

Radiating Element (Antenna)

**How could we reform the antenna pattern?**

- Input current amplitude.
- Input current phase.
- Geographical shape of the radiating element.
- GSM antenna pattern (N-array dipole)
Radiating Element (Antenna)

**Half-Wave Dipole (Omni) Antenna**

A half-wave dipole antenna may also be used as a gain reference for practical antennas. The half-wave dipole is a straight conductor cut to one-half of the electrical wavelength with the radio frequency.

**Practical directional Antenna**

**GSM antenna types**

**Omni-Directional Antennas**

Omni-directional antennas have a uniform radiation pattern with respect to horizontal directions. However, concerning vertical directions, the radiation pattern is concentrated, what makes gain possible. Typical gain values are 2.15 dB.

**Uni-Directional Antennas**

A uni-directional antenna has a non-uniform horizontal and vertical radiation pattern and is often used in sectored cells. The radiated power is concentrated, more or less, in one direction.

**Manufacturing type**

N array dipole.
2-Site Types

Sites Types

Site's Types

- Micro Site
  - Indoor
  - Street Level
- Macro Site
  - Outdoor
  - Indoor
  - Roof Top
  - COW
  - Green Field
    - Stuptower
    - Poles
    - Tower
    - Monopole
- Repeater Site
  - Indoor
Macro Site

• **Green filed:**

Used to provide coverage for wide indoor/outdoor rural areas (all Roads)

Macro Site

• **Roof top:**

Used to provide coverage and capacity for wide indoor/outdoor urban areas (all cities)
Macro Site

• **COW (Cell on Wheels):**
  
  Used as a temporary solution to provide Coverage or Capacity for certain duration (Events).

Micro Site

• **Street level:**
  
  Used to provide street level coverage for high capacity areas
Micro Site

- **Indoor:**

  Used to provide In-building coverage with high capacity demands (Big hotels).