LTE Planning and dimensioning

ITU PITA Workshop on
Mobile network planning and security

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Introduction

I. Radio Planning

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I. Radio planning
1. Necessity of network planning
NECESSITY OF NETWORK PLANNING

Necessity of network planning

 Construct a radio network
 Spectrum allocation limitations
 New data services, and new technologies
 Extension in the future of existing network
 Optimization of the cost and guaranteeing the network service quality
 Efficient utilization of resources
2. Purpose
NECESSITY OF NETWORK PLANNING

Purpose

- Reach good quality
- Required radio coverage
- Maximum use of resources
- Maintaining high level of system quality
- Provide both increased capacity and the improvement in required network quality
NECESSITY OF NETWORK PLANNING

- Input to network planning

Diagram:
- Spectrum Available
- Traffic Distribution
- Cost/Money

- GoS
- QoS
- Quality
- Coverage
- Speech Quality
- System Choice - C/I
3. Main features of radio planning
The basic decisions that must be taken during the radio planning phase are:

- Where to install base stations
- How to configure base stations (antenna type, height, sectors orientation, tilt, maximum power, device capacity, etc.)
FDMA/TDMA/OFDMA cellular systems adopt a two phases radio planning

- Coverage planning

- Capacity planning *(frequency assignment)*
MAIN FEATURES OF RADIO PLANNING

- **Coverage planning:**
  - Percentage of the geographical area covered by the cellular service where mobile telephony is available
    - Select where to install base stations
    - Select antenna configurations
    - Constraints on signal level in the area
  - Guarantee the signal strength in the service area
MAIN FEATURES OF RADIO PLANNING

- **Depending on the following factors**
  - *Natural*: geographical aspect/propagation conditions
  - *Human*: landscape (urban, suburban, rural)

- **Methods**
  - Theoretically through link budget calculation and computer
  - Simulation and optimization through the drive test and other measurements
MAIN FEATURES OF RADIO PLANNING

- **Capacity planning:**
  
  - Number of calls that can be handled in a certain area within a certain period of time
  
  - Probability that users will be denied access to a system due to unavailability of radio channels

  ➢ Define which radio resources can be used by each cell
MAIN FEATURES OF RADIO PLANNING

Three essential parameters

• Estimated traffic
• Antenna parameters (height, tilt, azimuth, aperture, gain, ...)
• Frequency reuse factor
II. Planning Procedures
I. Planning Procedures

1. Process overview
2. Link budget
3. Planning Input
4. Planning phases
5. Tools
1. Process overview
PROCESS OVERVIEW

«Traffic» oriented area

1. Dimensioning
2. Coverage and C/I validation
3. Optimization + frequency plan
4. Fixed network planning

«Coverage» oriented area

1. Coverage planning
2. Dimensioning: Capacity validation
3. Optimization + frequency plan
4. Fixed network planning

In FDMA/TDMA cellular systems
**PROCESS OVERVIEW**

- **Definition**
  - Strategy:
    - Coverage, Quality, Capacity
    - Dimensioning.

- **Network planning and rollout**
  - Coverage planning
  - Site selection
  - Propagation measurements
  - Coverage calculation
  - Site acquisition
  - Coverage optimization

- **Optimization and measurements**
  - Network optimization
  - Quality measurements
  - Performance analysis
  - Quality, efficiency, ...
PROCESS OVERVIEW

1. Preliminary work

- Propagation tool setup
- Terrain, clutter, vector data acquisition and setup
- Load master lease site location in data base
- Marketing Analysis
- Set initial Link Budget
- Initial cell radius calculation
- Initial cell number estimate
General approach

Pre-Planning
Define network services, basic network configuration parameters...

Main planning
Site survey, digital map, link budget, coverage plan, capacity plan

Adjustment
Drive tests, measurements, change of parameter settings...

Determine height, tilts and azimuths of the antennas, power ... to meet the QoS constraints
2. Link Budget
LINK BUDGET

- Link budget calculation
  - Signal strength loss on the path between base station and mobile phone

- Define the cell ranges along with the coverage thresholds

- Important components
  - Sensitivity, Fade margin, Connector and cable losses, Antenna gain
LINK BUDGET

- **Antenna**
  - Directional antenna
    - Sectorized antenna
  - Omni directional antenna
    - Radiates in all direction
LINK BUDGET

- **Hierarchical Cells**

  - **Macro Cell**
    - Antenna above average rooftop height

  - **Micro Cell**
    - Antenna below average rooftop height

  - **Pico Cell**
    - Indoors
3. Planning Input
PLANNING INPUT

Input data and process

Digital map → Validation of the digital maps
Radio measurements and Surveys → Propagation model
Subscribers demand → Hypothesis

Radio design
PLANNING INPUT

- Capacity related
  - Spectrum available
  - Subscriber Growth
  - Traffic density Map (traffic per subscriber)

- Clutter related
  - Dense urban
  - Urban
  - Sub urban
  - Rural
3. Planning phases
Site choice

1) Determine the power level at the cell border (sensitivity, propagation, antennas, ...),
2) Choose an available site,
3) Compute its coverage,
4) Choose other sites and draw their coverage so that they overlap.

→ In a cellular network, all the sites must be considered together.
PLANNING PHASES

Radio sites choice criteria

- Examine users needs, service area, frequencies, power constraints, …
- Survey of the service area to identify the preferred sites,
- Search existing sites in the considered areas,
- Validate the sites and determine the possibility of site sharing.
PLANNING PHASES

Radio sites location determination

Radio design

Theoretical radio sites determination

Site survey and search

Validation of the sites identified on the field

Coverage calculation
PLANNING PHASES

A. Radio design

1st constraint: link budget

→ System tuning should allow uplink and downlink balancing.
PLANNING PHASES

A. Radio design

2nd constraint: Minimum cell overlapping required for the handover

- Common area between adjacent cells: power difference between the signals received from each cells should be within a margin of a few dBs (e.g., HO_Margin)
PLANNING PHASES

A. Radio design

3rd constraint: Network coverage continuity

Network coverage should be continuous, at least in dense areas or for the main transportation axes (roads, highways, railways, ...).
A. Radio design

**4th constraint: Homogeneity**

Sites and antennas parameters should respect, as much as possible, the homogeneity constraint:

- Hexagonal cluster,
- Antennas heights,
- Antennas azimuths,
- Antennas tilts.
PLANNING PHASES

**Constraints**
- Traffic
- Available sites
- Coverage
- Economic evaluation
- Existing network

**Problem knowledge**
- Heuristics
- Engineering rules

**Data**
- Traffic
- Implementation cost
- Propagation models
- Network description

**Objectives**
- Minimize interferences
- Maximize the traffic
- Minimize the network cost
- Minimize the network evolution

Radio Site Positioning function
PLANNING PHASES

B. Site survey

- Practical sites research for BSs positioning
  - Information about the environment

  ➢ General information (morphology, structure, ...) in digital maps,
  ➢ Specific and detailed information.
PLANNING PHASES

B. Site survey

✓ Identify the highest sites,
✓ Take pictures of the sites and environment,
✓ Identify the towers and their height,
✓ Estimate the cables length (feeder, ...),
✓ Identify the existing infrastructure (buildings, energy, access, ...),
✓ Collect sites coordinates,
✓ ....
Steps and process

Environment survey

Validation of the digital maps

Radio measurements

Propagation model
PLANNING PHASES

*Survey outputs*

- ✓ List of available sites.
- ✓ Antennas constraints (type, height, aperture, ...).
- ✓ EIRP limitations.
- ✓ Forbidden areas.
C. Coverage simulation tools

Radio engineering tools

- To benefit from all network deployment required features (coverage calculation, data display, network optimization, …)

- Very important gains in time and costs.
PLANNING PHASES

Propagation prediction tools

prediction: coverage, interference, performance, etc.

databases:
  • geographical: topography, morphology, buildings, highways, etc.
  • statistics: marketing, traffic density, …
  • antenna systems,
  • propagation prediction models,
  • frequency allocation algorithms,
  • sites (to be positioned),

determine the position of the sites,
distribute the frequencies to the sites,
determine the technical characteristics of the base stations
PLANNING PHASES

Software modules

- Graphical user interface,
- Coverage prediction models,
- Frequency allocation algorithms,
- Network dimensioning methods (in BSs and BSCs number),
- Interfaces with data transmission networks (to collect measurements and counters from the OSS),
- Interfaces with radio signal measurements tools,
- Integration of advanced features (diversity, ...),
- Handovers simulation modules, ...
**PLANNING PHASES**

*Radio penetration thresholds*

- Based on statistical techniques,
- Modeled by an additional loss (in-building),
- Model predicted loss = outdoor loss + indoor loss.

<table>
<thead>
<tr>
<th>Type of penetration</th>
<th>Loss</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense urban</td>
<td>20 dB</td>
<td>8 dB</td>
</tr>
<tr>
<td>Urban</td>
<td>15 dB</td>
<td>8 dB</td>
</tr>
<tr>
<td>Suburban</td>
<td>10 dB</td>
<td>8 dB</td>
</tr>
<tr>
<td>Rural</td>
<td>8 dB</td>
<td>8 dB</td>
</tr>
<tr>
<td>In-car</td>
<td>6 dB</td>
<td>6 dB</td>
</tr>
</tbody>
</table>
PLANNING PHASES

*Tuned parameters*

- When coverage or quality criteria are not fulfilled, sites characteristics are modified:
  - Transmission power,
  - Antennas azimuths,
  - Antennas tilts,
  - Sites sectorisation,
  - Sites position changing,
  - Sites addition,
  - ...
PLANNING PHASES

*Optimized and considered data*

**Transmitted data**
- antenna,
- technical parameters (power and frequency margins, sensitivity, ...).

**Data network**
- Sites,
- Cells, sectors, links,
- Neighbors,
- Frequency plan, reuse clusters.

**Interfering networks data**
- Other operators offering the same service,
- Other services,
- Other countries.
PLANNING PHASES

Coverage by transmitter:
Display the best server coverage

Coverage by signal level:
Display the signal level across the studied area

Overlapping zones:
Display the signal level across the studied area
8. Tools
TOOLS USED FOR RADIO PLANNING

Main Planning Tools:
- Aircom Asset
- Mentum Planet
- Atoll FORSK
- ATDI
- WinProp
- EDX Signal Pro
- CelPlan
- Siradel
- Pathloss

Main Optimization Engines
- Actix
- Capesso
TOOLS USED FOR RADIO PLANNING

- Used to assets designing an optimizing Wireless network by:
  - Prediction of coverage
  - Frequency planning automatically
  - Creating neighboring list

- With a data base takes into account:
  - Clutter
  - Antenna radiation
  - Terrain
  - Number of users
  - Services supported
TOOLS USED FOR RADIO PLANNING

- **Geographical databases**
  - Digital terrain map (DTM).
  - Clutter.
  - 3D databases.
  - Indoor architecture.
TOOLS USED FOR RADIO PLANNING

1 map
TOOLS USED FOR RADIO PLANNING

MNT + Clutter
TOOLS USED FOR RADIO PLANNING

Geographical databases
TOOLS USED FOR RADIO PLANNING

- **DTM** – Digital Terrain Model
- **DEM** – Digital Elevation Model

Sources
- paper maps
- satellite images
- ...

Typical resolution:
- 20m – 1000m per pixel
TOOLS USED FOR RADIO PLANNING

- **Parameters used for coverage prediction**
  - Coordinates of the transmitter
  - Radiated power
  - Frequency
  - Antenna diagram

<table>
<thead>
<tr>
<th>TX No.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freq.: 98.0000 MHz</td>
</tr>
<tr>
<td>EPP: 1.0000 kV</td>
</tr>
<tr>
<td>Ant.H.: 40.00 m</td>
</tr>
<tr>
<td>AZM: ND</td>
</tr>
<tr>
<td>Long.: 005E23 33.394</td>
</tr>
<tr>
<td>Lat.: 50N26 53.552</td>
</tr>
</tbody>
</table>
TOOLS USED FOR RADIO PLANNING

- **Coverage simulation**
  - Static/Dynamic simulation
  - Distributions (snapshots)
  - By iteration,

  ➔ UL/DL cell load, connection status and rejected reason for each mobile
II. Dimensioning
# CIRCUIT SWITCHED VERSUS PACKET SWITCHED DIMENSIONING

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Circuits</th>
<th>Packets</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum bitrate / connection</td>
<td>Fixed (limited)</td>
<td>Variable (≤ maximum)</td>
</tr>
<tr>
<td>QoS (GoS, throughput, data loss ...)</td>
<td>Deterministic</td>
<td>Unpredictable</td>
</tr>
<tr>
<td>Traffic models</td>
<td>Simples</td>
<td>Complexes</td>
</tr>
<tr>
<td>Simultaneous connections number</td>
<td>Limited</td>
<td>Adaptable and flexible</td>
</tr>
<tr>
<td>Network resources</td>
<td>No optimization, possible waste</td>
<td>Optimization with complex resource allocation algorithms</td>
</tr>
<tr>
<td>Resource management</td>
<td>Simple</td>
<td>Complex</td>
</tr>
</tbody>
</table>
EXAMPLES OF TRAFFIC TRACES

http service traffic is more bursty than video streaming and ftp services traffic
Dimensioning objective: determine the total required bandwidth to carry the aggregated traffic with related QoS targets
WEB SERVICE

session arrival process at base station

resulting process at base station of WWW traffic

WWW-activity phase

WWW-idle

web request arrival process

HTTP on/off process

object loading process

TCP connection process
DIFFERENT BURSTINESS LEVELS EXAMPLE AT SAME PACKET RATE
DATA SERVICES DIMENSIONING PROCESS

Classification of the traffic for priority handling

Applications

Traffic classes

Traffic classes considered for the dimensioning

Class 1 traffic

Class 2 traffic

Class 3 traffic

Streaming traffic

Elastic traffic
• Models integrated into a **simulator** which generates, for different scenarios (e.g., service usage, subscriber types, codecs, ...) an aggregated traffic volume used to dimension the capacity of the nodes and/or the interfaces.

• **Drawback**: complex, time consuming and requires accurate hypothesis.
## QOS ASPECTS: EXAMPLE OF LTE QCI VALUES

<table>
<thead>
<tr>
<th>QCI</th>
<th>RESOURCE TYPE</th>
<th>PRIORITY</th>
<th>PACKET DELAY BUDGET (MS)</th>
<th>PACKET ERROR LOSS RATE</th>
<th>EXAMPLE SERVICES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>GBR</td>
<td>2</td>
<td>100</td>
<td>$10^{-2}$</td>
<td>Conversational voice</td>
</tr>
<tr>
<td>2</td>
<td>GBR</td>
<td>4</td>
<td>150</td>
<td>$10^{-3}$</td>
<td>Conversational video (live streaming)</td>
</tr>
<tr>
<td>3</td>
<td>GBR</td>
<td>5</td>
<td>300</td>
<td>$10^{-6}$</td>
<td>Non-conversational video (buffered streaming)</td>
</tr>
<tr>
<td>4</td>
<td>GBR</td>
<td>3</td>
<td>50</td>
<td>$10^{-3}$</td>
<td>Real-time gaming</td>
</tr>
<tr>
<td>5</td>
<td>Non-GBR</td>
<td>1</td>
<td>100</td>
<td>$10^{-6}$</td>
<td>IMS signaling</td>
</tr>
<tr>
<td>6</td>
<td>Non-GBR</td>
<td>7</td>
<td>100</td>
<td>$10^{-3}$</td>
<td>Voice, video (live streaming), interactive gaming</td>
</tr>
<tr>
<td>7</td>
<td>Non-GBR</td>
<td>6</td>
<td>300</td>
<td>$10^{-6}$</td>
<td>Video (buffered streaming)</td>
</tr>
<tr>
<td>8</td>
<td>Non-GBR</td>
<td>8</td>
<td>300</td>
<td>$10^{-6}$</td>
<td>TCP-based (for example, WWW, e-mail), chat, FTP, p2p file sharing, progressive video and others</td>
</tr>
<tr>
<td>9</td>
<td>Non-GBR</td>
<td>9</td>
<td>300</td>
<td>$10^{-6}$</td>
<td></td>
</tr>
</tbody>
</table>
Bandwidth based dimensioning
GENERAL APPROACH DESCRIPTION

- Dimensioning (UL or DL): based on the services required bandwidth estimation.
- **Contention ratios**: to reflect the bursty nature of the *traffic* and of the *service activity* as well as the *priorities* of the users and services.
- **Aggregation of the traffic** flows bitrates: to estimate the *total link* or *node capacity*.
- If overload (unpredicted users and services behavior): *scheduling* and *queuing* mechanisms maintain the QoS of high priority traffic. QoS parameters of some services will be degraded (e.g., bitrate, jitter, delay, BLER, ...).
ELASTIC APPLICATIONS

- **Elastic**
  - **Interactive**
    - e.g. Telnet, X-windows
  - **Interactive bulk**
    - e.g. FTP, HTTP
  - **Asynchronous**
    - e.g. E-mail, voice-mail
EXAMPLES OF ELASTIC APPLICATIONS

• E-mail:
  • asynchronous
  • message is not real-time
  • delivery in several minutes is acceptable

• File transfer:
  • interactive service
  • require “quick” transfer
  • “slow” transfer acceptable

• Network file service:
  • interactive service
  • similar to file transfer
  • fast response required
  • (usually over LAN)

• WWW:
  • interactive
  • file access mechanism(!)
  • fast response required
  • QoS sensitive content on WWW pages
INELASTIC APPLICATIONS

Inelastic (real-time)

- Tolerant
  - Adaptive
    - Delay adaptive
    - Rate Adaptive
  - Non-adaptive
- In-tolerant
  - Rate Adaptive
  - Non-adaptive

newer real-time applications

traditional real-time applications
BURTSINESS, ACTIVITY RATE, CONTENTION RATIO

**Voice**
- **Busy Hour**
- **Call Duration**
- **Activity rate (e.g., 40%)**
  - **Bitrate = 12.2 kb/s (ex.)**
  - **Burstiness = 0**

**Web**
- **Busy Hour**
- **Session Duration**
- **Activity rate (100%)**
  - **Peak bitrate**
  - **Burstiness**
  - **Contention ratio**
  - **Provisioned bandwidth**
SERVICES CLASSIFICATION AND QUEUING EXAMPLE

Voice, visiophony RT

User 1 (voice)  e.g., 20 ms, 12,2 kb/s
User 2 (visio)  e.g., 384 kb/s
User i (voice) . . .

Round Robin / WRR

Email, FTP, ... NRT

User 1 (email) . . .
User 2 (email) . . .
User i (FTP) . . .

PFS → Max(C/I)

Max(C/I)
SERVICES CLASSIFICATION AND QUEUING EXAMPLE

**Video streaming NRT**

- User 1
- User 2
- User i

**Web browsing NRT**

- User 1
- User 2
- User i

**Round Robin / WRR**

**PFS**
SERVICES TRAFFIC AGGREGATION AND PRIORITIZATION EXAMPLE

Scheduler → Priorities

Signaling

Round Robin / WRR

Non elastic traffic (jitter and delay)

Low elastic traffic (delay)

Elastic traffic

Very elastic traffic (BER)

Bearer

0

1

2

3

4

PFS → Max(C/I)
Aggregated bearers

**Dimensioning purpose**: determine the bearer bitrate $D$
### THEORETICAL CELL AVAILABLE BANDWIDTH

<table>
<thead>
<tr>
<th>Cell load</th>
<th>Inter site distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>500 m.</td>
</tr>
<tr>
<td>0%</td>
<td>2.17384</td>
</tr>
<tr>
<td>5%</td>
<td>2.16822</td>
</tr>
<tr>
<td>10%</td>
<td>2.07655</td>
</tr>
<tr>
<td>15%</td>
<td>1.96951</td>
</tr>
<tr>
<td>20%</td>
<td>1.86613</td>
</tr>
<tr>
<td>25%</td>
<td>1.77003</td>
</tr>
<tr>
<td>30%</td>
<td>1.67839</td>
</tr>
<tr>
<td>35%</td>
<td>1.59381</td>
</tr>
<tr>
<td>40%</td>
<td>1.51367</td>
</tr>
<tr>
<td>45%</td>
<td>1.44084</td>
</tr>
<tr>
<td>50%</td>
<td>1.37164</td>
</tr>
<tr>
<td>55%</td>
<td>1.30975</td>
</tr>
<tr>
<td>60%</td>
<td>1.25242</td>
</tr>
<tr>
<td>65%</td>
<td>1.20192</td>
</tr>
<tr>
<td>70%</td>
<td>1.15599</td>
</tr>
<tr>
<td>75%</td>
<td>1.11735</td>
</tr>
<tr>
<td>80%</td>
<td>1.08236</td>
</tr>
<tr>
<td>85%</td>
<td>1.05467</td>
</tr>
<tr>
<td>90%</td>
<td>1.03153</td>
</tr>
<tr>
<td>95%</td>
<td>1.01523</td>
</tr>
<tr>
<td>100%</td>
<td>1.00000</td>
</tr>
</tbody>
</table>

**Capacity =** $C_{\text{total}} \times \text{Loading Factor} \times \text{Scaling Factor}$

<table>
<thead>
<tr>
<th>3GPP Release</th>
<th>User Equipment Category</th>
<th>Maximum L1 datarate (Downlink)</th>
<th>Maximum number of DL MIMO layers</th>
<th>Maximum L1 datarate (Uplink)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Release 8</td>
<td>Category 1</td>
<td>10.3 Mbit/s</td>
<td>1</td>
<td>5.2 Mbit/s</td>
</tr>
<tr>
<td>Release 8</td>
<td>Category 2</td>
<td>51.0 Mbit/s</td>
<td>2</td>
<td>25.5 Mbit/s</td>
</tr>
<tr>
<td>Release 8</td>
<td>Category 3</td>
<td>102.0 Mbit/s</td>
<td>2</td>
<td>51.0 Mbit/s</td>
</tr>
<tr>
<td>Release 8</td>
<td>Category 4</td>
<td>150.8 Mbit/s</td>
<td>2</td>
<td>51.0 Mbit/s</td>
</tr>
<tr>
<td>Release 8</td>
<td>Category 5</td>
<td>299.6 Mbit/s</td>
<td>4</td>
<td>75.4 Mbit/s</td>
</tr>
<tr>
<td>Release 10</td>
<td>Category 6</td>
<td>301.5 Mbit/s</td>
<td>2 or 4</td>
<td>51.0 Mbit/s</td>
</tr>
<tr>
<td>Release 10</td>
<td>Category 7</td>
<td>301.5 Mbit/s</td>
<td>2 or 4</td>
<td>102.0 Mbit/s</td>
</tr>
<tr>
<td>Release 10</td>
<td>Category 8</td>
<td>2998.6 Mbit/s</td>
<td>8</td>
<td>1497.8 Mbit/s</td>
</tr>
</tbody>
</table>

**Theoretical capacity:** $C_{\text{total}}$

**Example:** $C_{\text{total}} = 150.8 \text{ Mb/s}$, **Loading Factor** = 60% and **Scaling Factor** = 1.25242 (for cell radius = 500m.)

**Capacity =** $150.8 \times 0.60 \times 1.25242 = 113.319 \text{ Mb/s}$
DIMENSIONING PROCESS

Step 1: initial configuration (dimensioning and planning)

Traffic and mobility model
Subscribers classes
Services QoS characteristics
Services and subscribers contention ratios
Transmission and protocols overheads

Aggregate required capacity (Mb/s)

Theoretical cell available bandwidth

Initial number of required cells

Radio planning
Radio interface characteristics
Coverage and interference requirements
Subscribers geographic distribution
Allocated spectrum

Cell available bandwidth (Mb/s)
DIMENSIONING PROCESS

Step 2: final configuration

Cell available bandwidth (Mb/s)
Aggregate required capacity (Mb/s)
Coverage and interference characteristics
Radio interface characteristics
New radio planning: optimization

Final number of required cells and sites configuration
Inputs

- Subscribers classes,
- Service usage/subs. class,
- Contention ratios/subs. class,
- Subscribers geographic distribution,
- Services bitrates,
- Services and protocols overheads.
## MCS Description and Required Receiver Sensibility

<table>
<thead>
<tr>
<th>Modulation Type</th>
<th>Coding Rate</th>
<th>SNR</th>
<th>5 MHz</th>
<th>10 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK</td>
<td>1/2</td>
<td>5</td>
<td>-92.30</td>
<td>-89.29</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>8</td>
<td>-89.30</td>
<td>-86.29</td>
</tr>
<tr>
<td>16-QAM</td>
<td>1/2</td>
<td>10.5</td>
<td>-86.80</td>
<td>-83.79</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>14</td>
<td>-83.30</td>
<td>-80.29</td>
</tr>
<tr>
<td>64-QAM</td>
<td>1/2</td>
<td>16</td>
<td>-81.30</td>
<td>-78.29</td>
</tr>
<tr>
<td></td>
<td>2/3</td>
<td>18</td>
<td>-79.30</td>
<td>-76.29</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>20</td>
<td>-77.30</td>
<td>-74.29</td>
</tr>
</tbody>
</table>
### MSC DISTRIBUTION AMONG USERS IN THE CELL EXAMPLE

<table>
<thead>
<tr>
<th>Modulation Type</th>
<th>Coding Rate</th>
<th>Weight</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>BPSK</strong></td>
<td>1/2</td>
<td>5.0%</td>
<td>1</td>
</tr>
<tr>
<td><strong>QPSK</strong></td>
<td>1/2</td>
<td>2.5%</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>2.5%</td>
<td>2</td>
</tr>
<tr>
<td><strong>16-QAM</strong></td>
<td>1/2</td>
<td>5.0%</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>5.0%</td>
<td>4</td>
</tr>
<tr>
<td><strong>64-QAM</strong></td>
<td>2/3</td>
<td>40.0%</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>3/4</td>
<td>40.0%</td>
<td>6</td>
</tr>
</tbody>
</table>
DISTRIBUTION OF THE CAPACITY PER QOS TYPE

CBR

VBR_{MR}

VBR_{MS}

BE

Class of Service

Realtime (voice)

Business Critical

Video

Priority Queue

Best Effort

bulk
CONTESTION RATIO

• Measures the simultaneity of users requesting bit rate from the BS because most users won’t demand data at the same time. The absolute peak demand on shared resources rarely occurs. User simultaneity is defined by the contention ratio.

• If many of the connected subscribers demand data, their packets will be delivered assuming some latency or jitter (less priority).

• Example: if 2 contention ratios are defined for the non-guaranteed partition of the bandwidth (e.g., 30 for residential users (less priority) up to 10 for business users (higher priority and throughput)), we have:

<table>
<thead>
<tr>
<th>Subscriber class</th>
<th>DL BE service</th>
<th>Offered data rates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential Class</td>
<td>X = 512 kbps</td>
<td>X’ = 512/30=17 kbps</td>
</tr>
<tr>
<td>Business Class</td>
<td>Y = 1 Mbps</td>
<td>Y’ = 1000/10=100 kbps</td>
</tr>
</tbody>
</table>

Actual data-rates considered in the system capacity calculations.
OVER SUBSCRIPTION RATIO (1)

• OSR = ratio of the total subscriber’s demand over the reference capacity of the base station when taking into account the adaptive modulation.

• The reference capacity of the base station corresponds to the available bit rate of the lowest modulation scheme served with that BS (here BPSK1/2).

\[ C_{\text{ref}} = \frac{\text{FFT}_{\text{used}}}{2T_s} \]

• \( \text{FFT}_{\text{used}} \) and \( T_s \) (symbol duration) values depend on the channel bandwidth (in LTE: from 72 to 1200) and the Cyclic Prefix factor respectively (=CP/Symbol duration).
OVER SUBSCRIPTION RATIO (2)

- **Residential class** = \( A\% \) of the users in the cell,
- **Business class** = \( B\% \) of the users in the cell.
- Total capacity for OSR calculation:
  \[
  C_{\text{tot}} = N \times (A\% \times X + B\% \times Y)
  \]
  \[
  \text{OSR} = \frac{C_{\text{tot}}}{C_{\text{ref}}}
  \]

Worldwide distribution of service classes
DL CHANNEL RAW BANDWIDTH

\[ BW_{\text{raw}} = \frac{FFT_{\text{used}} \times \sum (%P \cdot k \cdot OCR)}{T_s} \]

- \( FFT_{\text{used}} \) = number of data subcarriers dependent on the channel bandwidth (from 72 to 1200 in LTE).
- \( %P \) = percentage (weight),
- \( k \) = number of bits per symbol,
- \( OCR \) = overall coding rate.
<table>
<thead>
<tr>
<th>Application</th>
<th>Data rate (kbps)</th>
<th>Weight (average usage during a session)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multiplayer interactive gaming</td>
<td>D1 = 50</td>
<td>W1 = 25.0 %</td>
</tr>
<tr>
<td>VoIP and Video Conference</td>
<td>D2 = 32</td>
<td>W2 = 10.0 %</td>
</tr>
<tr>
<td>Streaming Media</td>
<td>D3 = 64</td>
<td>W3 = 12.5 %</td>
</tr>
<tr>
<td>Web browsing and instant messaging</td>
<td>Nominal</td>
<td>W4 = 32.5 %</td>
</tr>
<tr>
<td>Media content downloading</td>
<td>BE</td>
<td>W5 = 20.0 %</td>
</tr>
</tbody>
</table>
Dimensioning Method
DIMENSIONING METHOD

Planning Design: Application to LTE
LTE dimensioning requires three steps:

- Subs Number / Class
- Traffic Model

Traffic Evaluation

Bandwidth

S1 U - S1 C - X2

A GW – P GW

- C/I Distribution
- Subscribers Distribution
- Radio Planning and Link budget

- Cell Average Capacity
Traffic Estimation

1. Subscribers population
2. Mobility and Traffic Model
3. Cell Characteristics and Planning assumptions
TRAFFIC ESTIMATION

1. Subscribers population
SUBSCRIBERS POPULATION

- Inputs - Outputs

<table>
<thead>
<tr>
<th>Input Subscribers</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Population (in Thousands)</td>
</tr>
<tr>
<td>(2) Market Share Estimation (%)</td>
</tr>
<tr>
<td>(3) Subscribers Classes (VIP, SME,...)</td>
</tr>
<tr>
<td>(4) BH Session Number</td>
</tr>
<tr>
<td>(5) Area (in Km2)</td>
</tr>
<tr>
<td>(6) Subscriber Growth Rate (%)</td>
</tr>
<tr>
<td>(7) Planning Period (in years)</td>
</tr>
</tbody>
</table>

(A) Subs. Number/Class

(B) Subs. Density

(C) Growing Evolution
Subscribers Population Formulas

1. (A) Subs. Number/Class = (1) \times (2) \times (3)
2. (B) Density / Subs. Class = (A) ÷ (5)
3. (C) Subs. Growth for n year(s) = (B)[1 + (6)]^{(7)}
2. Traffic Model
### TRAFFIC MODEL

#### Inputs – Outputs

**Mobility & Traffic Model**

- (8) Service Average Bitrate (kb/s)
- (9) Service Activation Number at BH per Subs Class
- (10) Service Activity Rate
- (11) Burstiness Margin / Service
- (12) Service or Signaling Procedure Average Duration
- (13) Average BLER (for NRT services)
- (14) Contention Ratio / Service / Subs. Class
- (15) TAUs number / Subscriber at BH
- (16) HO number / Subscriber at BH
- (17) Mobility Margin (for the area)
- (18) Security Margin (for total traffic volume). Here taken instead of OSR
- (19) Signaling bitrate / Procedure
- (20) Low layers overhead
- (21) Carrier Bandwidth (MHz)

- (D) Throughput/Service
- (E) Throughput/Subs
- (F) Throughput/Subs Class
- (G) Bandwidth/Area
- (H) Bandwidth / Evolution
- (I) Traffic /Area
- (J) Traffic /Area Growing
TRAFFIC MODEL

Formulas

• (D) Service bandwidth = (8) x (10) x [(1 + (11)) x [(1 + (13)) x (1 + (20))]
• (E) Throughput / Subscriber class = (D) x [(9) x (12) x (14) / 3600] + (19) x [((4), (15), (16)) x (12) / 3 600]
• (F) Bandwidth/ area = [\(\sum\) (A) x (E)] x [(1 + (17)) x (1 + (18))]
• (G) Bandwidth Evolution = \(\sum\) (C) x (F)
• (H) Bandwidth / km\(^2\) = (F) / (5)
TRAFFIC MODEL

Assumptions

- (K) Initial Cell Capacity value (Starting Assumption) = Peak Rate (100 Mb/s for LTE) \times (21) / 20 MHz (for LTE) \times 70%

- (M) Number of Cells (First estimation) = (F)/(K)
3. Cell Characteristics and Planning assumptions
CELL CHARACTERISTICS AND PLANNING ASSUMPTIONS

- Link Budget principle
Radio Planning Overview

Radio configuration table

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downlink transmission power</td>
<td></td>
</tr>
<tr>
<td>Downlink reference</td>
<td>Signal power</td>
</tr>
<tr>
<td></td>
<td>offset</td>
</tr>
<tr>
<td>Antenna tilt</td>
<td></td>
</tr>
<tr>
<td>Antenna azimuth</td>
<td></td>
</tr>
<tr>
<td>Antenna height</td>
<td></td>
</tr>
</tbody>
</table>

Planning tool
- Capacity and coverage problems
- Radio configuration tuning

Coverage and capacity optimization
- Measurement request
- Measurement report

Capacity problem detection
- Capacity problems
- Coverage problem detection
- Capacity problems

Radio configuration control
- Radio configuration update

Internal measurements
- Radio configuration control

eNB

RRC
**CELL CHARACTERISTICS AND PLANNING ASSUMPTIONS**

- **Planning Process**

  1. Model Tuning
  2. User density and distribution
  3. Site Selection
  4. eNB number (M)
  5. Configuration Planning (Tilt, Azimuth, Height, ...)

  **Initial Planning**

  **Planning**

  **Coverage Planning**

  - 1. Coverage Rate
  - 2. Parameters Tuning
  - 3. Interference Rate

  **Optimization**
CELL CHARACTERISTICS AND PLANNING ASSUMPTIONS

- Inputs - Outputs

(M) Number of eNB before planning (dimensioning output)

(Q) subs/ MCS type area distribution

(P) Throughput UL - DL

(O) Cell Capacity

(M') Number of cells

- Radio Planning
- Link Budget

Step 1

Step 2

Cell Characteristics and Planning Assumptions

(22) MCS Types
(23) MIMO Configuration
(24) Distribution of the subs in the area (%)
(25) Coverage Rate
## Coverage estimation

<table>
<thead>
<tr>
<th>(21) MCS</th>
<th>(22) Bandwidth (MHz)</th>
<th>(23) MIMO Configuration</th>
<th>(24) Distribution of the subscribers</th>
<th>f{(21), (22), (23)}</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK 1/8</td>
<td>1,4</td>
<td>SISO</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>QPSK 1/5</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>QPSK 1/4</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>QPSK 1/3</td>
<td>3</td>
<td>SIMO</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>QPSK 1/2</td>
<td>5</td>
<td>MISO</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>QPSK 2/3</td>
<td>10</td>
<td>MIMO</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>QPSK 4/5</td>
<td>15</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>16 QAM 1/2</td>
<td>20</td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>16 QAM 2/3</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>16 QAM 4/5</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>64 QAM 2/3</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>64 QAM 3/4</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>64 QAM 4/5</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

\[(O) \text{Cell Capacity} = \sum (24) \times f{(21), (22), (23)}\]
## PEAK DATA RATES DL AND UL (IN LTE)

<table>
<thead>
<tr>
<th>Modulation coding</th>
<th>1.4 MHz</th>
<th>3.0 MHz</th>
<th>5.0 MHz</th>
<th>10 MHz</th>
<th>15 MHz</th>
<th>20 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK 1/2 Single stream</td>
<td>0.7</td>
<td>2.1</td>
<td>3.5</td>
<td>7.0</td>
<td>10.6</td>
<td>14.1</td>
</tr>
<tr>
<td>16QAM 1/2 Single stream</td>
<td>1.4</td>
<td>4.1</td>
<td>7.0</td>
<td>14.1</td>
<td>21.2</td>
<td>28.3</td>
</tr>
<tr>
<td>16QAM 3/4 Single stream</td>
<td>2.2</td>
<td>6.2</td>
<td>10.5</td>
<td>21.1</td>
<td>31.8</td>
<td>42.4</td>
</tr>
<tr>
<td>64QAM 3/4 Single stream</td>
<td>3.3</td>
<td>9.3</td>
<td>15.7</td>
<td>31.7</td>
<td>47.7</td>
<td>63.6</td>
</tr>
<tr>
<td>64QAM 4/4 Single stream</td>
<td>4.3</td>
<td>12.4</td>
<td>21.0</td>
<td>42.3</td>
<td>63.6</td>
<td>84.9</td>
</tr>
<tr>
<td>64QAM 3/4 2x2 MIMO</td>
<td>6.6</td>
<td>18.9</td>
<td>31.9</td>
<td>64.3</td>
<td>96.7</td>
<td>129.1</td>
</tr>
<tr>
<td>64QAM 1/1 2x2 MIMO</td>
<td>8.8</td>
<td>25.3</td>
<td>42.5</td>
<td>85.7</td>
<td>128.9</td>
<td>172.1</td>
</tr>
<tr>
<td>64QAM 1/1 4x4 MIMO</td>
<td>16.6</td>
<td>47.7</td>
<td>80.3</td>
<td>161.9</td>
<td>243.5</td>
<td>325.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Modulation coding</th>
<th>1.4 MHz</th>
<th>3.0 MHz</th>
<th>5.0 MHz</th>
<th>10 MHz</th>
<th>15 MHz</th>
<th>20 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>QPSK 1/2 Single stream</td>
<td>0.7</td>
<td>2.0</td>
<td>3.5</td>
<td>7.1</td>
<td>10.8</td>
<td>14.3</td>
</tr>
<tr>
<td>16QAM 1/2 Single stream</td>
<td>1.4</td>
<td>4.0</td>
<td>6.9</td>
<td>14.1</td>
<td>21.6</td>
<td>28.5</td>
</tr>
<tr>
<td>16QAM 3/4 Single stream</td>
<td>2.2</td>
<td>6.0</td>
<td>10.4</td>
<td>21.2</td>
<td>32.4</td>
<td>42.8</td>
</tr>
<tr>
<td>16QAM 1/1 Single stream</td>
<td>2.9</td>
<td>8.1</td>
<td>13.8</td>
<td>28.2</td>
<td>43.2</td>
<td>57.0</td>
</tr>
<tr>
<td>64QAM 3/4 Single stream</td>
<td>3.2</td>
<td>9.1</td>
<td>15.6</td>
<td>31.8</td>
<td>48.6</td>
<td>64.2</td>
</tr>
<tr>
<td>64QAM 1/1 Single stream</td>
<td>4.3</td>
<td>12.1</td>
<td>20.7</td>
<td>42.3</td>
<td>64.8</td>
<td>85.5</td>
</tr>
<tr>
<td>64QAM 1/1 V-MIMO (cell)</td>
<td>8.6</td>
<td>24.2</td>
<td>41.5</td>
<td>84.7</td>
<td>129.6</td>
<td>171.1</td>
</tr>
</tbody>
</table>
CELL CHARACTERISTICS AND PLANNING ASSUMPTIONS

- Numbers of sites

(F) Traffic / Area
(O) Cell Capacity
(25) Sectorisation Type

Sites Evaluation

(R) Number of cells
(P) Number of sites

(R) Number of cells = (F) / (O)

(P) Number of sites = (R) / (25)

If (R) ≠ (M′) new radio planning process is required. (O) may change and the new (R) may also change.
Iterative process is then required until (R) = (M′).
S1 U, S1 C and X2 Dimensioning

1. Bandwidth Inputs-Outputs
2. Traffic Model
3. Formulas
1. Bandwidth Inputs-Outputs
S1 U, S1 C AND X2 DIMENSIONING

- Inputs - Outputs

- S1 U Link
  - (22) Service (i) Use
  - (23) Service Overhead
  - (24) % of subs
  - (T) S1 U BW

- S1 C Link
  - (25) Number of TAUss
  - (26) Number of HO
  - (27) Mobility Margin
  - (U) S1 C BW

- 3% (S)
  - (V) X2

- Link Criteria
  - (28) Link bandwidth
  - (29) Support Bandwidth
  - (30) Usage Rate
  - (W) Link Number
2. Traffic model
### Codecs Model

<table>
<thead>
<tr>
<th>Traffic Model</th>
<th>Codecs</th>
<th>Radio Interface with HO compression</th>
<th>Compression Ratio</th>
<th>Radio Interface without HO compression</th>
</tr>
</thead>
<tbody>
<tr>
<td>VoIP</td>
<td>AMR</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Video Conference</td>
<td>MPEG4</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>HTTP</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Web Browning</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>FTP</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Video Streaming</td>
<td>MPEG4</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>email</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Interactive Gaming</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
VoIP dimensioning for G.711 and G.729a

• The amount of bandwidth required to carry voice over an IP network depend on:
  ➢ Codec (coder/decoder) and sample period
  ➢ IP header (includes IP, UDP and RTP protocol layers)
  ➢ Transmission medium
  ➢ Silence suppression

RTP adds 12 octets, UDP adds 8 octets, IP adds 20 (v4) or 40 (v6) octets. Sample period of 20 ms and 40 octets headers ➞ 16 kbps additional bitrate

➢ G.711 codec and 20 ms sample period ➞ payload = 160 octets
With 40 octets of IP header, total is 200 octets ➞ 80 kbps for VoIP
Ethernet adds 38 octets ➞ 95.2 kbps for VoIP over Ethernet

➢ With G.729a, the bitrate would be 39.200 kbps for VoIP over Ethernet

Silence suppression reduces the demand for BW by 50%. 
## Codec Throughputs

<table>
<thead>
<tr>
<th>Codec</th>
<th>Bandwidth</th>
<th>Sample period</th>
<th>Frame size</th>
<th>Frame/packet</th>
<th>Ethernet bandwidth</th>
</tr>
</thead>
<tbody>
<tr>
<td>G.711 (PCM)</td>
<td>64 kbps</td>
<td>20 ms</td>
<td>160</td>
<td>1</td>
<td>95.2 kbps</td>
</tr>
<tr>
<td>G.723.1A (ACELP)</td>
<td>5.3 kbps</td>
<td>30 ms</td>
<td>20</td>
<td>1</td>
<td>26.1 kbps</td>
</tr>
<tr>
<td>G.7231A (MP-MLQ)</td>
<td>6.4 kbps</td>
<td>30 ms</td>
<td>24</td>
<td>1</td>
<td>27.2 kbps</td>
</tr>
<tr>
<td>G.726 (ADPCM)</td>
<td>32 kbps</td>
<td>20 ms</td>
<td>80</td>
<td>1</td>
<td>63.2 kbps</td>
</tr>
<tr>
<td>G.728 (LD-CELP)</td>
<td>16 kbps</td>
<td>2.5 ms</td>
<td>5</td>
<td>4</td>
<td>78.4 kbps</td>
</tr>
<tr>
<td>G.729A (CS-CELP)</td>
<td>8 kbps</td>
<td>10 ms</td>
<td>10</td>
<td>2</td>
<td>39.2 kbps</td>
</tr>
<tr>
<td>AMR (ACELP)</td>
<td>4.75 kbps</td>
<td>20 ms</td>
<td>12</td>
<td>1</td>
<td>36.0 kbps</td>
</tr>
<tr>
<td>AMR (ACELP)</td>
<td>7.4 kbps</td>
<td>20 ms</td>
<td>19</td>
<td>1</td>
<td>38.8 kbps</td>
</tr>
<tr>
<td>AMR (CELP)</td>
<td>12.2 kbps</td>
<td>20 ms</td>
<td>31</td>
<td>1</td>
<td>43.6 kbps</td>
</tr>
<tr>
<td>AMR-WB/G.722.2 (ACELP)</td>
<td>6.6 kbps</td>
<td>20 ms</td>
<td>17</td>
<td>1</td>
<td>38.0 kbps</td>
</tr>
</tbody>
</table>
### Traffic Model on S1 U link

<table>
<thead>
<tr>
<th>(22) Traffic Model</th>
<th>Codecs</th>
<th>Bit Rates (Kbps)</th>
<th>(23) IP Overhead (byte)</th>
<th>(24) % of use</th>
</tr>
</thead>
<tbody>
<tr>
<td>VoIP</td>
<td>AMR</td>
<td>12.2</td>
<td>40</td>
<td>50 %</td>
</tr>
<tr>
<td>Video Conference</td>
<td>MPEG4</td>
<td>64</td>
<td>1 000</td>
<td>30 %</td>
</tr>
<tr>
<td>HTTP</td>
<td>x</td>
<td>0.576</td>
<td>1071</td>
<td>60 %</td>
</tr>
<tr>
<td>Web Browning</td>
<td>x</td>
<td>1.209</td>
<td>600</td>
<td>20 %</td>
</tr>
<tr>
<td>FTP</td>
<td>x</td>
<td>2 000</td>
<td>2 000</td>
<td>10 %</td>
</tr>
<tr>
<td>Video Streaming</td>
<td>MPEG4</td>
<td>64</td>
<td>400</td>
<td>10 %</td>
</tr>
<tr>
<td>email</td>
<td>x</td>
<td>80</td>
<td>22.7</td>
<td>10 %</td>
</tr>
<tr>
<td>Interactive Gaming</td>
<td>x</td>
<td>128</td>
<td>300</td>
<td>5 %</td>
</tr>
<tr>
<td>P2P</td>
<td></td>
<td>500</td>
<td>500</td>
<td>20 %</td>
</tr>
</tbody>
</table>
S1 U, S1 C AND X2 DIMENSIONING

- Link Mobility Model on S1 C link

<table>
<thead>
<tr>
<th>(25) Number of TAUss</th>
<th>500</th>
</tr>
</thead>
<tbody>
<tr>
<td>(26) Number of HO</td>
<td>475</td>
</tr>
</tbody>
</table>
3. Formulas
S1 U, S1 C AND X2 DIMENSIONING

Formulas

- (T) S1 U BW = \( \sum 8\text{kb/s} \times (23) \times (24) \)
- (U) S1 C BW = 8 \text{ kb/s} \ [(25) + (26)]
- (V) "X" _"2" = 3\% S1 BW
- (W) Number of Links = \( (28) / [(29)/(30)] \)
Thank You