LTE Radio Access, Rel. RL70, Operating Documentation, Issue 01

LTE Radio Dimensioning Guideline

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Table of Contents

This document has 156 pages

List of Figures

List of Tables

1 Summary of changes

Changes between document issues are cumulative. Therefore, the latest document issue contains all changes made to previous issues.

Changes between issues 05A (2014-04-15, RL50) and 06 (2014-11-30, RL70)

- New section 11 *Flexi Zone Micro Radio interface dimensioning* added

Changes between issues 05 (2013-09-25, RL50) and 05A (2014-04-15, RL50)

- Section 8 *Baseband dimensioning*: editorial changes

Changes between issues 04B (2013-01-25, RL40) and 05 (2013-09-25, RL50)

This is the first issue for release RL50.

- section 3.1 *General parameters*: RF modules for RL50 added and update of all tables
- new section 4.2.4 *LTE907: TTI Bundling* added
- new section 5.4.3 *LTE568: DL adaptive closed loop MIMO 4x2* added
- new section 5.5.4 *LTE1089: Downlink carrier aggregation - 20 MHz added*
- section 8.2: tables *RL50 System capability* added

Changes between issues 04 A (2012-10-11, RL40) and issue 04B (2013-01-25, RL40)

- Section 4.1.2.1 *NSN LTE radio units* updated
- Editorial changes in section 9 *Baseband dimensioning*

Changes between issues 04 DRAFT (2012-07-13, RL40) and issue 04A (2012-10-11, RL40)

- Editorial changes in sections .3.4.5 ; 6.4.7; 6.5.1; 6.5.2
- New section 10 *Dimensioning parameter overview*

2 Introduction

This document provides guidelines for Long Term Evolution (**LTE**) air interface dimensioning campaigns. Air interface dimensioning is the first step performed in order to provide the first estimation of the sites volumes that need to be taken into account when deploying an LTE radio network. A dimensioning campaign is to calculate the number of sites, for a defined geographical network area. A defined minimum quality of service to be guaranteed at the cell edge. The density of the sites, their cell ranges and areas in correspondence with the pre-defined site layouts, clutter types and simulation cases must be considered. The results of radio dimensioning are also used by radio network planners as the first step in the radio planning process.

The following document focuses on all aspects that need to be considered when creating the detailed link budget and capacity estimation for Evolved Universal Terrestrial Radio Access Network (**E-UTRAN**) air interface.

The first part of the document covers typical dimensioning aspects that apply for all cells, Macro and Micro. Further, the information presented provides examples that are based on the Flexi Macro. Section 11 addresses various dimensioning aspects that are modified to address the Flexi Zone Micro small cell.

3 Air interface dimensioning process

An air interface dimensioning campaign consists of numerous successive steps in the link budget calculation, which in turn is based on a set of input parameters that can be categorized/grouped as follows:

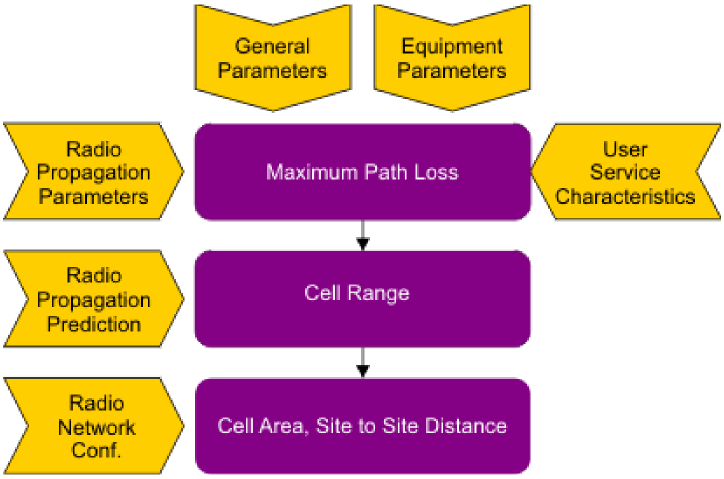
- **General parameters** - define possible center frequencies (operating bands), channel bandwidths, clutter types, simulation cases, etc.
- **Equipment parameters** - provide equipment specifications, antenna configurations, gains and losses etc.
- **Radio propagation parameters** - consist of parameters which describe wave propagation in a specific radio environment, for example channel models, mobility, etc.
- **Capacity dimensioning** - parameters of this group are necessary in E-UTRAN for a correct definition of power and resource sharing among users.
- **Interferences** - represents the group of parameters related to interference calculation for example cell loads, G-factor, etc.
- **Radio propagation prediction** - represents the group of parameters related to propagation models, for example intercept points, propagation model slopes, eNodeB antenna and UE heights
- **Radio Network Configuration** - represents the group of parameters that specify cell layout and sectorization

The output of an air interface dimensioning campaign is the following:

- **Maximum Allowable Path Loss**
- **Cell ranges** based on propagation models' formulas
- **Site-to-Site distance and site areas** for different site layouts, which finally yields an estimation of the number of sites and site density required to cover the given area.

Figure 1: Inputs and course of dimensioning process presents the parameter groups which need to be taken into account for a dimensioning process and shows the sequence of the steps within a dimensioning campaign.

Figure 1 Inputs and course of dimensioning process



4 Dimensioning Concept Details - Link Budget

The link budget calculation presented in this document is based on a minimum throughput requirement at the cell edge. This approach was chosen to provide cell range calculation in a very easy and efficient way for the planner. By defining the service throughput value prior to the link budget calculation, it is possible to roughly estimate bandwidth and power allocation per one user; this allows for an appropriate estimation of the scheduling behavior in a real system.

4.1 General parameters

This section describes general parameters that are mandatory inputs for the dimensioning campaign as they define, among others, the physical basis for the radio resources that can be used for the transmission of user data and control information via the LTE radio interface. Moreover, the environment related and coding scheme related parameters are shortly described in this section.

4.1.1 E-UTRAN operating bands

Although Technical Report [3GPP TR 36.104], see *References* 2, defines a wide range of operating bands, not all of them must be considered here. From the link budget point of view and its accuracy it is allowed to perform uplink and downlink related calculations using the same frequency being the operating band center frequency for example 2600MHz for Band 7.

Table 1 E-UTRAN FDD frequency bands

E-UTRAN Band	UL frequencies		DL frequencies		Band separation	Duplex mode
	Lowest	Highest	Lowest	Highest		
1	1920	1980	2110	2170	130	FDD
2	1850	1910	1930	1990	20	
3	1710	1785	1805	1880	20	
4	1710	1755	2110	2155	355	
5	824	849	869	894	20	
6	830	840	875	885	35	
7	2500	2570	2620	2690	50	
8	880	915	925	960	10	
9	1749.9	1784.9	1844.9	1879.9	60	
10	1710	1770	2110	2170	340	
11	1427.9	1452.9	1475.9	1500.9	23	
12	698	716	728	746	12	
13	777	787	746	756	41	
14	788	798	758	768	40	
...						
17	704	716	734	746	18	
...						
20	832	862	791	821	11	

Operating bands

For the link budget calculation there is no need to perform calculations for the exact frequency ranges listed above. For the sake of simplicity, it is legitimate to assume that only the main center frequencies are considered. This means that only center frequencies are considered for link budget calculation.

In case of Band 4 or 10 (1700/2100; AWS), where band separation is considered, it is recommended to set two separate link budget scenarios, one for downlink and the other one for uplink and then take the MAPL values that limit the cell range.

It is recommended to check with the BTS product management, to ensure the BTS supports the desired operating band.

4.1.2 E-UTRAN channel bandwidth configurations

Scalable channel bandwidth is one of the biggest advantages of the LTE air interface. E-UTRAN can operate in a channel bandwidth range from 1.4 MHz up to 20 MHz as presented in [3GPP TR 36.104], see *References* 2

Thus the operators will be able to implement the new technology all over the world exploiting the bandwidth scalability in case of very limited frequency resources. It also allows migration from the lower generation systems (for example GSM/EDGE Radio Access Network (**GERAN**), Universal Terrestrial Radio Access Network (**UTRAN**)) or assignment of small bandwidths in the initial deployment phases.

As can be seen in Table 2: E-UTRAN channel bandwidth configurations every bandwidth configuration features a defined number of so-called Physical Resource Blocks (PRB).

Table 2 E-UTRAN channel bandwidth configurations

Bandwidth [MHz]	1.4	3	5	10	15	20
No. of PRBs	6	15	25	50	75	100
Subcarrier spacing	15 kHz					

A Physical Resource Block is an allocation unit of Orthogonal Frequency Division Multiple Access (**OFDMA**)/Single Carrier Frequency Division Multiple Access (**SC-FDMA**) resources in time and frequency domain. Its size depends on the cyclic prefix length and the subcarrier spacing used in the system. Subcarrier spacing represents the frequency offset between two consecutive subcarriers; it is one of the factors ensuring the carrier orthogonality within a single OFDM symbol. This parameter is constant for all bandwidth configurations; this has been achieved by using different sampling frequencies and Fast Fourier Transform (**FFT**) sizes.

Subcarrier spacing can be obtained from the following equation:

$$\Delta f = \frac{f_{sampling}}{N} = 15 \text{ kHz}$$

where:

$f_{samplling}$ - sampling frequency

N - FFT size

Performance depending on channel bandwidth

The bandwidth configuration impacts factors such as overhead ratio and total cell throughput. The best network performance (regarding maximum peak data rates and cell throughputs) is achieved by the deployment of 20 MHz bandwidth. One should expect certain performance degradation especially for 1.4 MHz and 3 MHz bandwidth because of worse scheduling gain as well.

4.1.2.1 NSN LTE radio units

NSN LTE Release: RL10

Supported channel bandwidth (please note that this does not correspond to actual HW capabilities but to SW release functionality):

- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

Table 3 Supported RF units (RL10;LTBTS1.0)

RF unit	**Operating band**	**max. output power per sector**
FRMA (Triple RFM)	800EU [Band 20]	60 W
FRMB (2Tx RRH)	800EU [Band 20]	40 W
FRIE (Triple RFM)	1.7/2.1 [Band 4/10]	60 W
FRGP (Triple RFM)	2100 [Band 1]	60 W
FRHA (Triple RFM)	2600 [Band 7]	60 W

NSN LTE Release: RL20

Supported channel bandwidth (please note that this does not correspond to actual HW capabilities but to SW release functionality):

- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

Table 4 Supported RF units (RL20; LTBTS2.0)

RF unit	**Operating band**	**max. output power per sector**
FRLB (2Tx RRH)	730 [Band 12/17]	30W + 30W
FXCA (Triple RFM)	850 [Band 5/6/18/19]	60 W
FRNA (Triple RFM)	1600 [Band 24]	40W + 40W
FXEA (Triple RFM)	1800 [Band 3/9]	60 W

Table 4 Supported RF units (RL20; LTBTS2.0) (Cont.)

RF unit	Operating band	max. output power per sector
FHEA (2Tx RRH)	1800 [Band 3/9]	40 W

NSN LTE Release: RL30

Supported channel bandwidth (please note that this does not correspond to actual HW capabilities but to SW release functionality):

- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

Table 5 Supported RF units (RL30; LTBTS3.0)

RF unit	Operating band	max. output power per sector
FRBB (Triple RFM)	760 [Band 14]	40 W
FHCA (2Tx RRH)	850 [Band 5]	40W + 40W
FRGQ (2Tx RRH)	2100 [Band 1]	40W + 40W
FRHB (2Tx RRH)	2600 [Band 8]	40W + 40W

NSN LTE Release: RL40

Supported channel bandwidth (please note that this does not correspond to actual HW capabilities but to SW release functionality):

- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

Table 6 Supported RF units (RL40; LTBTS4.0)

RF unit	Operating band	max. output power per sector
FEXB (Triple RFM)	1800 [Band 3/9]	80 W
FXFA (Triple RFM)	1900 [Band2]	60 W

Table 6 Supported RF units (RL40; LTBTS4.0) (Cont.)

RF unit	**Operating band**	**max. output power per sector**
FHDB (2TX RRH)	900 [Band]	2x60 W
FRIG (4TX RRH)	1.7/2.1 [Band 4]	4x30 W
FRMD (Triple RFM)	800EU [Band 20]	3x60 W
FRGV 2TX RRH)	2100 [Band1]	2x40 W

NSN LTE Release: RL50

Supported channel bandwidth (please note that this does not correspond to actual HW capabilities but to SW release functionality):

- 1,4 MHz
- 3 MHz
- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

Table 7 Supported RF units (RL50; LTBTS5.0)

RF unit	**Operating band**	**max. output power per sector**
FRHC (6TX RFM)	2600 MHz [Band 7]	6x40 W
FRHF (6TX RFM)	2600 [Band 7]	6x40 W
FXDA (Triple RFM)	900 MHz [Band 8]	3x60 W
FRPA (6TX RFM)	APT700 [Band 28]	6x40 W
FRPB (6TX RFM)	APT700 [Band 28]	6x40 W
FHEB (2TX RRH)	1800 MHz [Band 3/9]	2x60 W
FRGT (Triple RFM)	2100 MHz [Band 1]	3x80 W
FRGS (Triple RFM)	2100 MHz [Band 1]	3x80 W
FXDB (Triple RFM)	900 MHz [Band 8]	3x80 W
FRHD (4TX RRH)	2600 MHz [Band 7]	4x30 W

Table 7 Supported RF units (RL50; LTBTS5.0) (Cont.)

RF unit	Operating band	max. output power per sector
FRHE (4TX RRH)	2600 MHz [Band 7]	4x30 W
FRMC (6TX RFM)	800 MHz [Band 20]	6x40 W

NSN LTE Release: RL50FZ

Supported channel bandwidth (please note that this does not correspond to actual HW capabilities but to SW release functionality):

- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

Table 8 Supported RF units (RL50FZ; Flexi Zone LBTSFZ5.0)

RF unit	Operating band	max. output power per sector
FWGB	2100 [Band 1]	5W per branch
FWHA	2600 [Band 7]	5W per branch
FWIB	1.7/2.1 [Band 4]	5W per branch

NSN LTE Release: RL60

Supported channel bandwidth (please note that this does not correspond to actual HW capabilities but to SW release functionality):

- 1,4 MHz
- 3 MHz
- 5 MHz
- 10 MHz
- 15 MHz
- 20 MHz

Table 9 Supported RF units (RL60; LTBTS6.0)

RF unit	Operating band	max. output power per sector
FXFC	2100 MHz [Band 2/25]	80 W

Table 9 Supported RF units (RL60; LTBTS6.0) (Cont.)

RF unit	Operating band	max. output power per sector
FXFB	2100 [Band 2/25]	60 W
FXCB	900 MHz [Band 5]	80 W
FRPK	APT700 [Band 28]	20 W

4.2 Tx/Rx path parameters

4.2.1 eNB Tx power

The eNodeB transmission power has to be set with respect to known hardware restrictions (see section 4.1.2.1 *NSN LTE radio units*).

FD-LTE:

One and the same Flexi Triple RF Module can support 8, 20, 40 or 60 W RF power modes with software licenses. From the point of hardware complexity, one module (Flexi Triple RF Module) is able to support up to 3 sectors. It allows for a 3-sector site 60 W / 60 W / 60 W. The default power license provides 20 W output power. Any change requires additional power licenses. The wide variety of power options in the one Flexi RF Module allows to use the one and the same hardware for many different deployment scenarios (e.g. the same RF part is useful for small micro cells with 8 W output power but also for extended rural coverage with 60 W Tx power). Moreover, the Flexi RF Module can be adjusted for use with various channel bandwidth configurations if one wants to keep the Power Spectral Density on a similar level (see Table 10: Tx Power per PRB (example to keep same PSD)).

Table 10 Tx Power per PRB (example to keep same PSD)

Bandwidth [MHz]	No. of PRBs	eNB power [W]	Power per PRB [dBm]
1.4	6	8	31
3	15	20	31
5	25	40	32
10	50	60	31
15	75	60+60	32
20	100	60+60	31

There are also Remote Radio Heads offered for FD-LTE typically equipped with two PAs providing 2Tx MIMO coverage for a single cell.

4.2.2 UE Tx powers

The nominal UE power is specified by 3GPP (see *References* 3). It is the broadband transmit power of the UE. The available power classes are listed below.

Table 11 LTE capable UE power classes

Class	Power [dBm]	Tolerance [dB]
1	30	n/a
2	27	n/a
3	23	+/- 2
4	21	n/a

eNB and UE transmission power

Transmission power per eNB antenna should take into consideration the deployment-specific requirements and law/regulations in the given country (for example power spectral density limitations). A general rule could be: low Tx power for small bandwidth, high Tx power for large bandwidth.

UE Power Class 3 shall be assumed for dimensioning. It means 23 dBm mobile Tx power in the link budget calculation.

4.2.3 Power allocation

The eNB allocates constant power per subcarrier in downlink transmission, which is configurable by the operator as an O&M parameter. The total eNB power is shared among all subcarriers, no matter how many of them are used for data allocation. The lower the number of subcarriers assigned to the user, the less power is received at the UE.

UE output power is shared between subcarriers assigned to transmission. This means that, when the UE operates with smaller amounts of subcarriers, it distributes the available power only over the used subcarriers. This scenario results in an increased TX power per subcarrier and, consequently, improves the uplink coverage. Although the uplink direction is controlled by the Power Control algorithm (Open Loop Power Control or Closed Loop Power Control with additional correction factors), it is not relevant for the link budget because the focus is on estimate the maximum possible coverage with the UE located at the cell border, and for this reason the maximum output power of 23 dBm can be assumed.

Power allocation

Downlink

Power sharing among subcarriers means that if the coverage is limited by Tx power, the planner should increase the output power or decrease the channel bandwidth.

Uplink

The smaller amount of scheduled resources means higher Tx power per subcarrier. On the other hand, it requires higher MCS with better SINR. Additionally, spreading info bits over smaller amount of resources leads to worse frequency diversity.

4.2.4 Antenna gain

The antenna gain value depends on the antenna type and is usually indicated in the technical data sheets of the antenna manufacturer. For the link budget calculation, it is assumed that the transmitting antenna is correctly oriented towards the reception antenna. Thus, the maximum gain value is used.

Typical antenna gains which can be assumed for link budget calculation are given below.

Table 12 Typical antenna gains (dBi) for dimensioning

	Omni	2-sector (road)	3-sector		6-sector	
			typical	high gain	typical	high gain
Low band (for example 730, 750, 760, 800, 850,900 MHz)	12.1	16.8	18.0	---	18.1	---
Mid band (for example 1.5, 1.6, 1.7,1.8, 1.9 GHz)	13.0	21.0	18.0	20.7	21.0	22.0
Mid band (for example 2.1, 2.3 GHz)	13.0	21.0	18.5	21.0	21.5	22.5
High band (that is 2.5, 2.6 GHz)	14.0	22.0	19.5	22.0	22.5	23.5

Antenna gain

Unless manufacturer data sheets state otherwise, one can assume

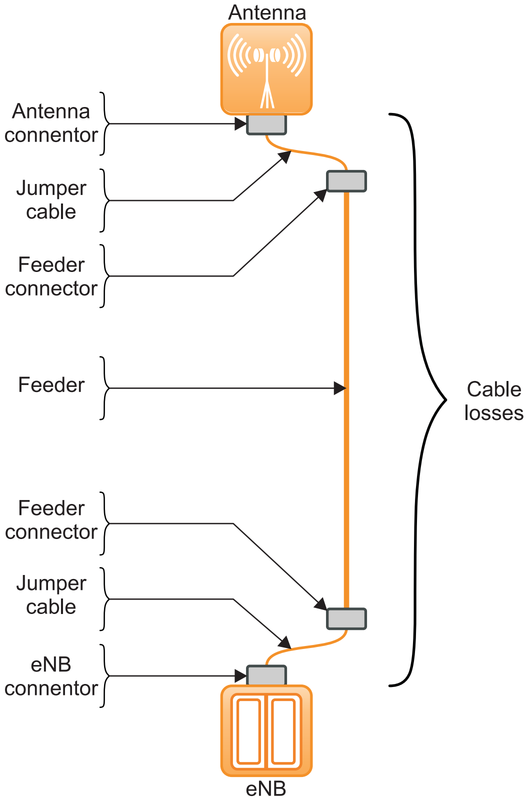
- gain values stated above
- 18 dBi for 2x2 MIMO
- 0 dBi for UE antenna (it can differ for some specific deployment scenarios, such as the Customer Premise Equipment with yagi antenna mounted on the roof or laptop data card with an external antenna; one can use the gain values known from some WiMax deployment cases.)
- 3 dBi - PCMCIA

From the point of link budget evaluation, it makes sense to (re-) use 3G antennas (provided that the operating band is the same for both technologies).

4.2.5 Cable loss

The received signal experiences the additional attenuation introduced by the cable connection between an antenna and eNB, here considered as an end device (see Figure 2: Antenna system elements). The attenuation of each antenna system element depends on its physical properties and can differ for the various dimensioning scenarios (the impact of operating band, cable length, etc.)

Figure 2 Antenna system elements



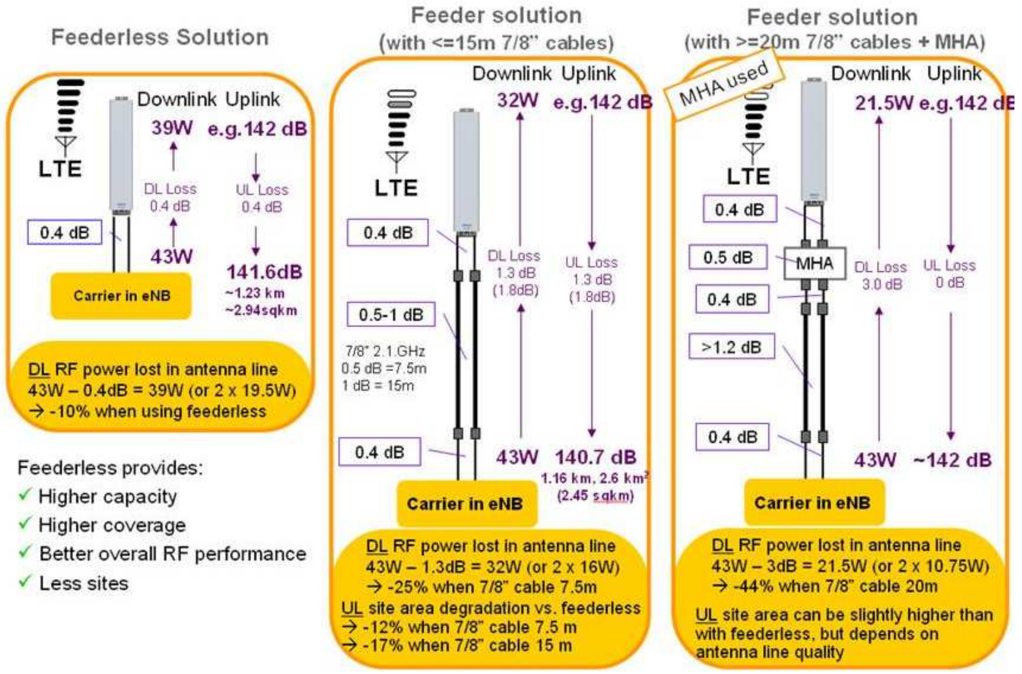
The latter attenuation can be subdivided into cable loss and connector loss.

There are generally three different deployment scenarios regarding the site configuration Flexi Triple RF Module (see Figure 3: LTE site solutions).

4.2.5.1 Feeder-less solution

This is the most beneficial site construction enabling very good overall RF performance and leading to the reduced number of sites. Such a site can be deployed with the Remote Radio Head mounted close to the antenna system. There are only jumper cables between the Remote Radio Head and antenna connectors. This is the best performing solution from the coverage and capacity, because of the small loss of about 0.4 dB.

Figure 3 LTE site solutions



4.2.5.2 Feeder solution

This is a standard construction with a long cable between the Flexi RF Module and the antenna connector, the attenuation of which depends on its length and the configured operating band. Assuming 15 m cable and jumpers to the antenna/RFM connectors, there is almost a 2 dB cable loss in both directions.

4.2.5.3 Feeder solution with TMA/MHA

If the cable length starts to be the limiting factor for the cell coverage, there might be a need for Tower Mounted Amplifier (sometimes called the Mast Head Amplifier). It is possible to compensate UL cable loss with the introduction of TMA. An additional loss must be taken into account for DL direction though. The TMA is one more element at the antenna line and causes ~0.5 dB loss in DL.

It is recommended to assume 0.4 dB feeder loss at eNB in both directions when considering the feeder-less site (no matter if the Flexi Triple RF Module or the Flexi Remote Radio Head is considered). In this case, there is no need for TMA. Feeder solution is typically characterized by 2 dB feeder loss, compensated in UL to 0 dB if the TMA is introduced (the TMA reduces eNB noise figure by 0.2 dB; related to Friis formula). Due to the great flexibility of LTE RF parts, it is highly recommended to assume the feeder-less solution sites for dimensioning unless stated otherwise by general deployment assumptions. It is recommended to assume 0 dB feeder loss at UE for a typical dimensioning case.

4.2.5.4 LTE614: Distributed sites (up to 20km)

Typical feeder-less solution offers an optical connection between System Module and RF unit up to 200m. With the introduction of *LTE614: Distributed sites* feature, it is possible to connect an RF unit located 20km away from the System Module. This is possible with single mode optical transceivers (SFP) installed within Tx/Rx path. Additionally, it is required to provide 48V power supply to remotely located RF units. HW capabilities of the System Module do not change; FSME can support up to three 15MHz (or 20MHz) cells with 2Tx MIMO and 2Rx diversity (or up to six 10MHz MIMO cells).

Distributed sites

Distributed sites feature has no explicit impact on coverage dimensioning. Since an optical connection is applied, cable loss shall be considered the same as for the feeder-less solution

4.2.5.5 LTE977: RF chaining with FSME

RF chaining is possible only with FSME. The following limitations refer to LTE RF chaining:

- Single FSME is capable of serving up to six LTE cells each with 10MHz carrier
- Single 3Gb/s optical link can support two 10MHz cells with 2Tx MIMO and 2Rx diversity
- Up to three chains each with maximum two RF units can be connected to FSME,
- An RF unit in a chain can be either RRH or RFM with 2Tx MIMO and 2Rx diversity (supporting one cell only)
- In feeder-less solution, the maximum distance between System Module and two RF units in a chain is limited to 200m
- In distributed solution, maximum distance between System Module and the last RF unit in a chain is limited to 20km

RF chaining

RF chaining has no explicit impact on coverage dimensioning. The planner shall keep in mind the above mentioned restrictions concerning maximum carrier bandwidth; distance limitations will be compared against calculated cell ranges. Since an optical connection is applied, cable loss shall be considered as for feeder-less solution.

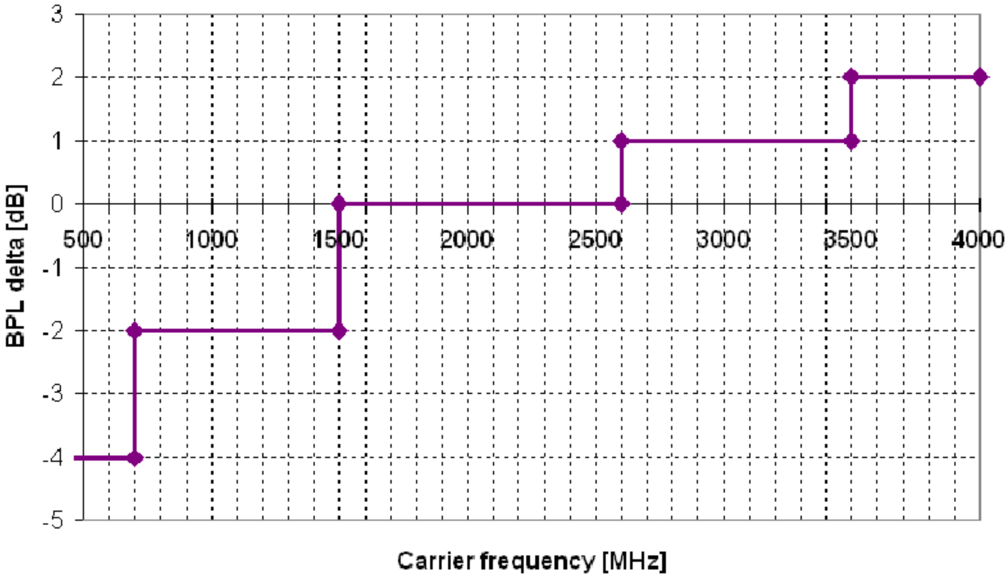
4.2.6 Other losses

Other losses depend on scenario specific assumptions.

For indoor coverage calculation it is required to assume a certain penetration loss depending on the environment (that is glass surface, concrete walls, room dividers, etc.)

It is clear that the attenuation behavior of signals that penetrate walls depends on the frequency band of the signal as well as on the consistence of penetrated obstacles (building types and materials). Obviously, this has impact on the results of the coverage (that is link budget) calculation. There is a lot of available literature investigating the mentioned effect, however, due to the variety of possible deployment scenarios it is required to propose one generalized model with respect to frequency-dependent building penetration loss for dimensioning. Compiling recommendations from “COST231” and other papers, it seems that the following rule can be applied for the majority of dimensioning cases.

Figure 4 Frequency-dependent penetration loss delta



The figure above presents a relative difference in building penetration loss between the reference case (1500/2600MHz) and other operating bands. For example, if one assumes 20dB penetration loss at Band 7 (2.6GHz), it is recommended to assume the following:

- 20dB - 2 = 18dB at Digital Divident band (700MHz in US, 800MHz in Europe)

Building penetration loss

It is recommended to modify the building penetration loss accordingly when dimensioning for lower bands (700/800/900MHz).

Dimensioning for two-sector sites located along highways/tracks should be done with additional in-car/in-train loss.

In-car and body losses

Body loss can be assumed to be 3 dB. In-car loss can be assumed to be 6 dB. Indoor penetration loss can be assumed to be 10...20 dB.

4.2.7 Receiver noise figure

The receiver noise figure depends on the receiver equipment design and it represents the additive noise generated by various hardware components. That is why the value should be parameterized in the particular receiver's vendor specification.

Receiver noise figure

The Flexi FD-LTE base station (RFM) can be assumed with 2 dB noise figure (with TMA) and 2.2 dB (w/o TMA).

UE noise figure can be assumed to be 7 dB.

4.3 Frame structure

In E-UTRAN, the DL/UL transmission is organized into radio frames. The duration of each radio frame is 10 ms.

- Type 1 valid for FDD
- Type 2 valid for TDD

4.3.1 Frame structure for FD-LTE

The frame structure consists of 10 sub-frames, each sub-frame consists of two timeslots, and thus the duration of single timeslot is 0.5 ms.

Figure 5 Radio frame Type 1

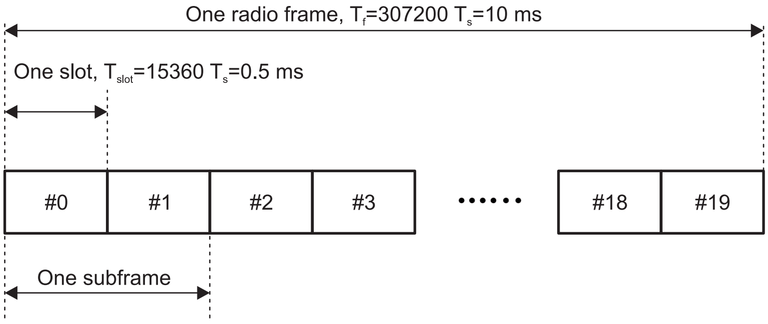


Table 13 Sampling rate versus FFT size

Subcarrier spacing [Hz]	FFT size	Sampling frequency [Hz]	Sampling period[μs]
15000	128	1920000	0.520833
	256	3840000	0.260417
	512	7680000	0.130208
	1024	15360000	0.065104
	1536	23040000	0.043403
	2048	30720000	0.032552

The highest sampling frequency (see Table 13: Sampling rate versus FFT size; last row) corresponds to the smallest time period of the elementary signal representation part in the time-domain which is noted as the smallest time-domain unit Ts. By multiplying this value by an additional factor, we can obtain lengths of many time structures, the examples of which are listed in Table 14: Time structures lengths.

Table 14 Time structures lengths

Time structure name	Size
Radio frame	10 ms = 307200 x T_s
Timeslot	0.5 ms = 15360 x T_s
Half-frame (TDD)	5 ms = 153600 x T_s

Signal transmission in each slot can be described by a resource grid of:

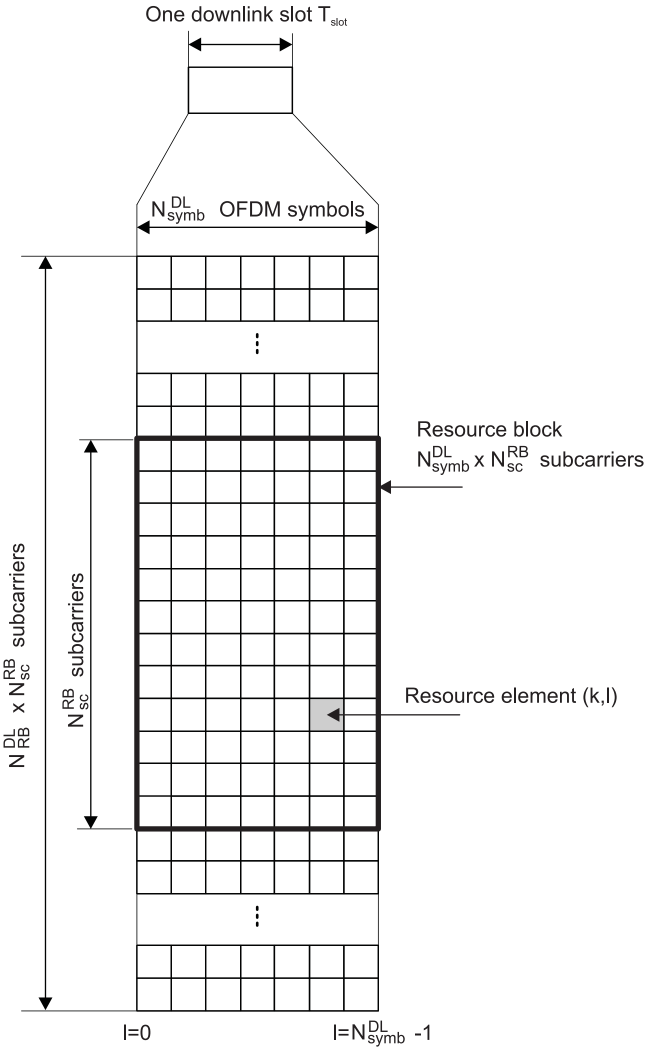
$$N_{BW}^{DL} \cdot N_{SC}^{RB}$$

subcarriers and:

$$N_{symb}^{DL}$$

OFDM symbols. The minimum resource allocation unit, which is allowed to be assigned to user, is a Physical Resource Block (PRB).

Figure 6 Resource grid



Depending on the chosen Cyclic Prefix (**CP**) option and a type of frame structure used for data transmission the number of subcarriers:

$$N^{RB}_{SC}$$

in the frequency domain and the number of:

$$N^{DL}_{symb}$$

OFDM symbols in the time domain can differ as presented in [3GPP TS 36.211], see *References* 1

Table 15 Frame Type 1 resource block frequency/time dimensions [1]

Domain	Number of OFDM symbols	Number of subcarriers

Table 15 Frame Type 1 resource block frequency/time dimensions [1] (Cont.)

Frequency	N/A	12
Time	7 (normal CP) 6 (extended CP)	N/A

A single Physical Resource Block corresponds to 180 kHz in frequency domain and 0.5 ms in time domain. The maximum number or PRBs which can be allocated to a user depends on the channel bandwidth (). It must be noted that the scheduler works on subframe basis (1 ms) so that the smallest time allocation unit corresponds to a single TTI (1 ms).

4.4 Overhead factors

For the link budget calculation, the resources allocated to the given user must be estimated. This can be done correctly only if the whole amount of system overhead and BLER (Block Erasure Rate) target are taken into account. In order to determine the amount of radio resources that are really available for user data transmission, it is necessary to subtract, the system overhead portion that is consumed by signaling messages and control fields from the overall amount of physical resources provided by the channel bandwidth configuration.

Note: System overhead described in the following subsection corresponds to LTE PHY layer only.

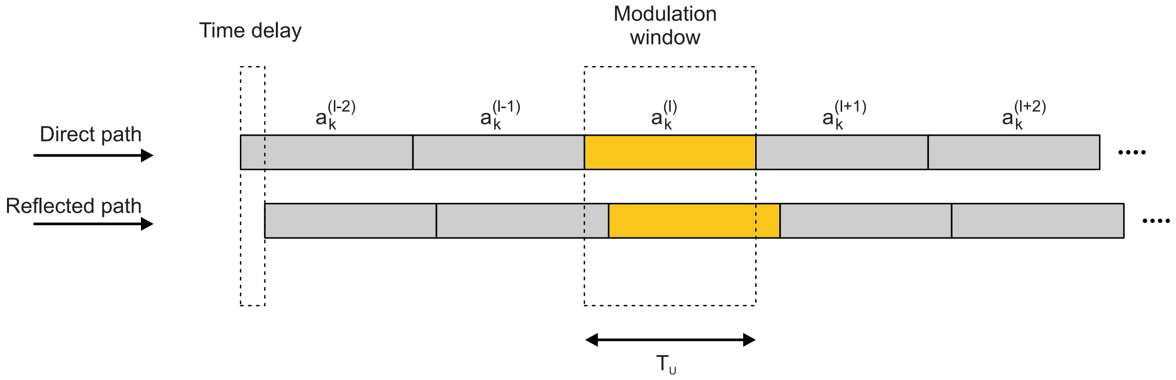
4.4.1 Cyclic Prefix (CP)

The Cyclic Prefix (**CP**) is a mechanism implemented on Layer 1 of the LTE radio interface to avoid inter-symbol interference.

Multipath propagation results in radio rays coming to the receiver at different time moments. The larger the distance between transmitter and receiver antennas, the bigger the time differences between incoming radio waves of the same signal. This effect can be even more significant in the environment with a high number of obstacles (for example hilly environment).

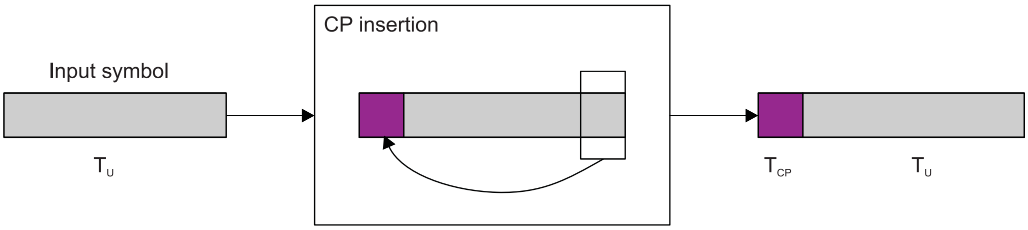
This effect can cause inter-symbol interference. The greater the ratio between average time shifts of incoming radio rays and average symbol duration, the greater the interference level. This rule has a huge impact on transmission speed in single carrier systems. In OFDMA systems, the delay spread is much less destructive due to a relatively long symbol duration. For better understanding of the delay spread impact on signal quality, see Figure 7: Inter-symbol interference in the multipath environment and the explanations below.

Figure 7 Inter-symbol interference in the multipath environment



Two independent paths come to the receiver. The reflected path reaches the receiver after the direct signal because of a longer propagation distance. Both rays are delivered to the demodulator input and, although the demodulation window is aligned with the direct transmission path, it also covers some part of the previous symbol $a_k^{(l-1)}$. The *k* index denotes the subcarrier belonging to the *l*-th OFDM symbol. If a part of another symbol arrives at the demodulation window, orthogonality is out of question (there is no orthogonality between subcarriers originating from different OFDM symbols). This leads to degradation of the original signal (the *l*-th symbol) because of inter-symbol interference. The solution is a cyclic prefix insertion, which is depicted in Figure 8: Cyclic prefix insertion against multipath effect.

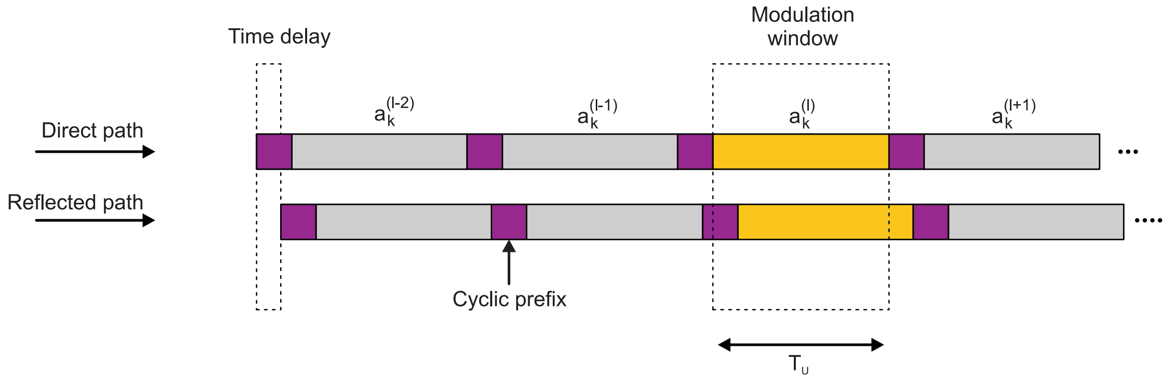
Figure 8 Cyclic prefix insertion against multipath effect



The CP length is a system dependent parameter, and its insertion is a simple copy/paste operation: the “tail” of the original symbol is copied to the front part of the symbol. The FFT anyway assumes a periodical signal and thus this copy/past operation has no negative effect because the signal inside the modulation window remains periodic.

If the time delay of the reflected path is equal or shorter than the CP length, the demodulator proceeds with the part of one symbol, preserving full orthogonality (see Figure 9: No inter-symbol interference due to CP insertion).

Figure 9 No inter-symbol interference due to CP insertion



The disadvantage of CP usage is the reduced effective amount of user data which can be sent during the given time period (a cyclic prefix carries the information which is part of original OFDM symbol).

Cyclic prefix

There is only support for a normal cyclic prefix type. The extended cyclic prefix planned for further releases is designed for very large cells or **MBMS** transmission when an UE receives signals from many base stations (the delay profile is much more restrictive).

For pico-, micro- and macrocell planning it is recommended to consider normal CP only; its length is sufficient to compensate the multipath effects.

As mentioned above, there are two types of supported cyclic prefix length for LTE. Depending on the chosen option, normal CP or extended CP, there are

- 6 OFDM symbols (for extended prefix) or
- 7 OFDM symbols (for normal prefix)

available in each timeslot.

Therefore, it is obvious that the overall amount of physical resources is correspondingly reduced when an extended prefix is applied.

4.4.2 Control data overhead

All resources assigned to the following channels are further discussed as control data overhead:

- PDCCH - Physical Downlink Control Channel, carries Downlink Control Information (**DCI**) that can have different formats depending on the type of control information to be transmitted, for example ACK/NACKs in response for uplink transmission, uplink scheduling grant
- PHICH - Physical HARQ Indicator Channel, is that part of the PDCCH which carries HARQ-related information only
- PCFICH - Physical Control Format Indicator Channel, carries the information about the number of OFDM symbols assigned for PDCCH transmission in a sub-frame. This number varies from 0 to 3 per sub-frame (it may also be 4 in case of 1.4 MHz system bandwidth to boost the PDCCH performance)
- PBCH - Physical Broadcast Channel, carries the system broadcast information,

- PUCCH - Physical Uplink Control Channel, carries Uplink Control Information (**UCI**) for example ACK/NACKs in response for downlink transmission, CQI reports.

The overhead of control channels is introduced as a percentage of frequency resources assigned to these channels.

Table 16 Physical channels/signals for FDD LTE

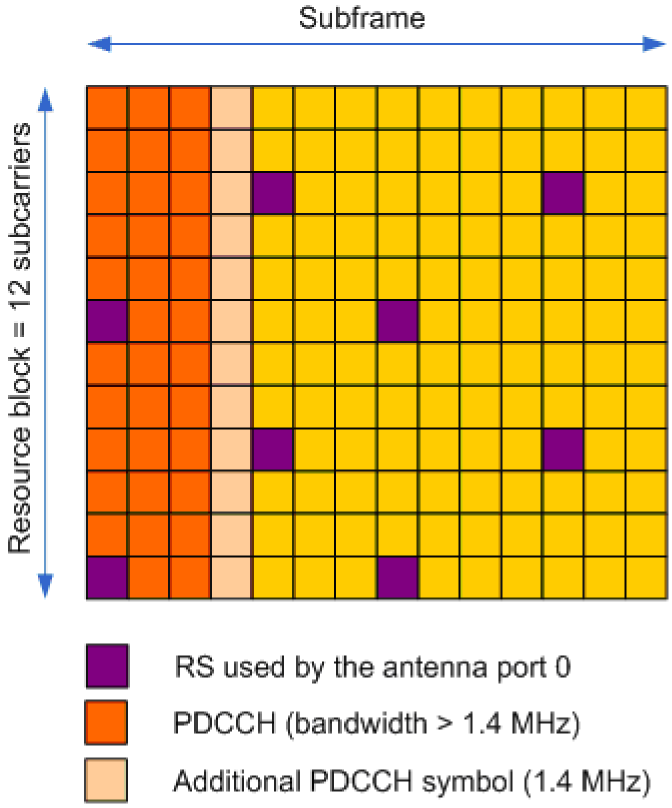
	Physical channel/signal	**Mapping details**	**Reference**
DL	Synchronization signal	• Two last OFDM symbols in timeslot 0 and 10 in every radio frame. 72 subcarriers (1.08 MHz) occupied in every symbol dedicated for synchronization channel	3GPP 36.211, *References* 1; Section 6.11
	Reference signal	• Four resource elements per PRB in case of one antenna port • Eight resource elements per PRB in case of two antenna ports • Twelve resource elements per PRB in case of four antenna ports	3GPP 36.211, *References* 1; Section 6.10
	PBCH(SI-M - System Information Master)	• Four OFDM symbols in timeslot 1 (the second timeslot of subframe 0) in every fourth radio frame (40 ms periodicity). 72 centre subcarriers in an OFDM symbol dedicated for PBCH	3GPP 36.211, *References* 1; Section 6.6
	PDCCH (including PCFICH and PHICH)	• One, two or three first OFDM symbols per subframe (four symbols possible only in 1.4 MHz bandwidth case to make PDCCH more robust)	3GPP 36.211, *References* 1; Section 6.8
UL	Reference signal for PUSCH	• Fourth OFDM symbol in every resource block dedicated for PUSCH transmission in case of normal CP • Third OFDM symbol in every resource block dedicated for PUSCH transmission in case of extended CP	3GPP 36.211, *References* 1; Section 5.5.2.1.2
	Reference signal for PUCCH	• OFDM symbols located in PRBs dedicated for PUCCH (if PUCCH overhead is considered as the number of PRBs occupied by uplink control information, it already takes into account the reference signal overhead)	3GPP 36.211, *References* 1; Section 5.5.2.2.2
	PRACH	• Six resource blocks are always consumed by PRACH, the overhead of which depends on the Random Access frequency	3GPP 36.211, *References* 1; Section 5.7
	PUCCH	• Single PUCCH always occupies two resource blocks in two consecutive timeslots	3GPP 36.211, *References* 1; Section 5.4.3

Not all Physical Layer (**PHY**) channels and signals are crucial for dimensioning. Some of them occupy a negligible amount of resources. For this reason, only a part of controlling/system information allocation is described in the following section.

4.4.2.1 PDCCH

It is recommended to assume three OFDM symbols statically configured in every TTI (four symbols in 1.4 MHz bandwidth). It makes the link budget calculation more conservative but also safer from the controlling capacity point of view. The resource mapping for PDCCH is depicted in Figure 10: PDCCH resource mapping (normal CP; 15 kHz spacing). Note that part of the cell-specific Reference Signal is spread over the controlling region; thus, it should not be counted twice.

Figure 10 PDCCH resource mapping

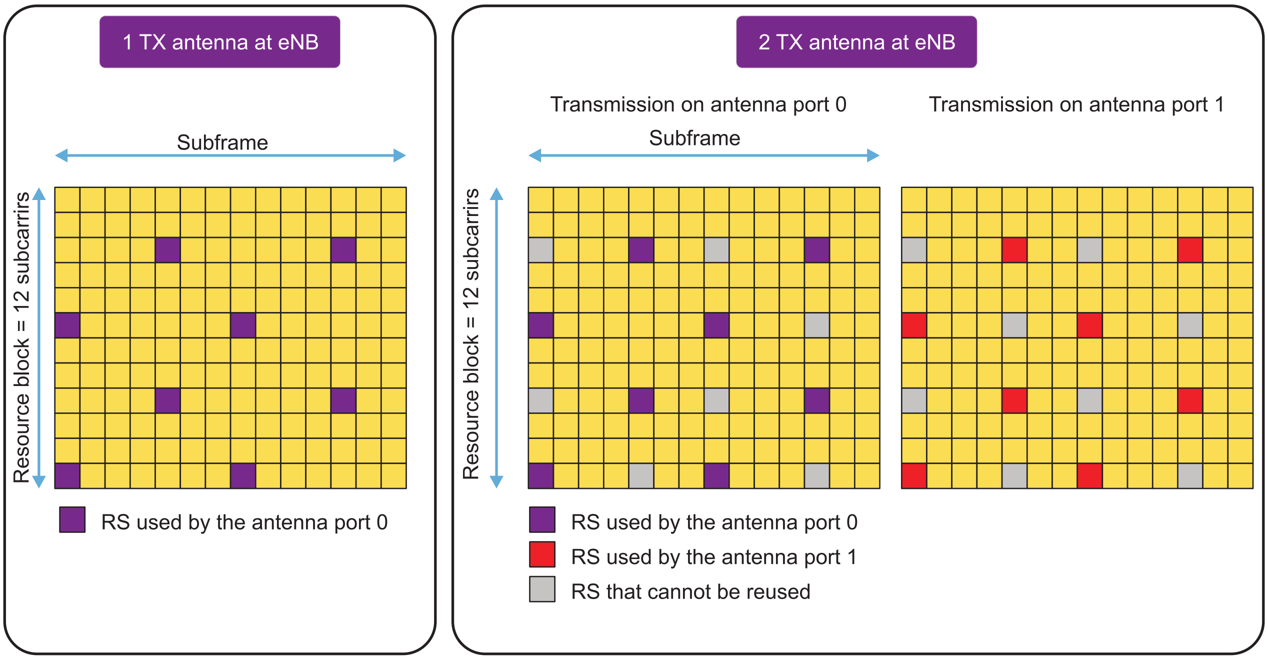


Note that with introduction of *LTE616: Usage based PDCCH adaption*, one can claim a various varying number of PDCCH symbols depending on the load conditions. For example, small PDCCH resources (1…2 symbols) in low loaded scenario or full control region (3 {or 4 in 1.4MHz} symbols) in medium/high load scenario. Although the difference in absolute overhead factor will be clearly visible, the impact on MAPL will be negligible in most of the cases.

4.4.2.2 Cell-specific reference signal

The amount of cell-specific Reference Signal in downlink depends on the number of active antenna ports. Support of single antenna transmission as well as 2x2MIMO is available starting from RL10. The resource mapping for the cell-specific Reference Signal is depicted in Figure 11: Cell-specific Reference Signal resource mapping (normal CP; 15 kHz spacing).

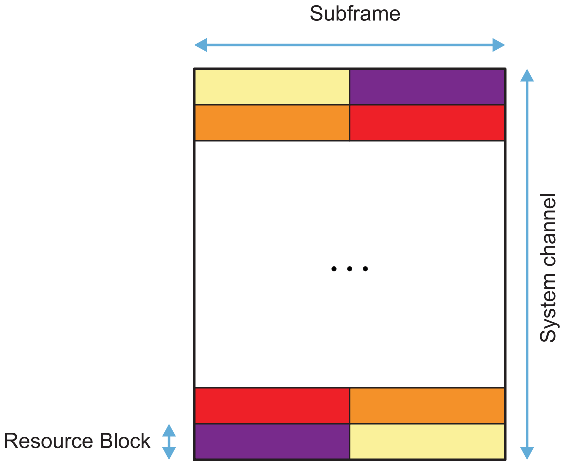
Figure 11 Cell-specific Reference Signal resource mapping



4.4.2.3 PUCCH

Dedicated uplink control resources are always located at the band edges of the available spectrum to exploit the frequency diversity effect. Figure 12: PUCCH resource mapping shows the allocation of four PUCCH channels (different colors denote multiple channels within a subframe). Note that PRBs belonging to the same PUCCH are used in different spectrum parts between two consecutive timeslots (0.5 ms).

Figure 12 PUCCH resource mapping



4.4.2.4 PRACH

Physical Random Access Channel (PRACH) is used by the UE for initial access to the cell and scheduling requests. Within one radio frame (10ms) there can be one or few subframes with a reservation for PRACH. This is controlled by higher layers. Single

PRACH resource occupies always six PRBs. As mentioned before, the total overhead introduced by PRACH strongly depends on the used configuration determining the density of PRACH resources per radio frame.

In RL20, RL30, RL40, RL50 , PRACH configurations are limited to the set of [3…8] and [19...24]]. The default configuration is 3 meaning one single PRACH resource per each radio frame.

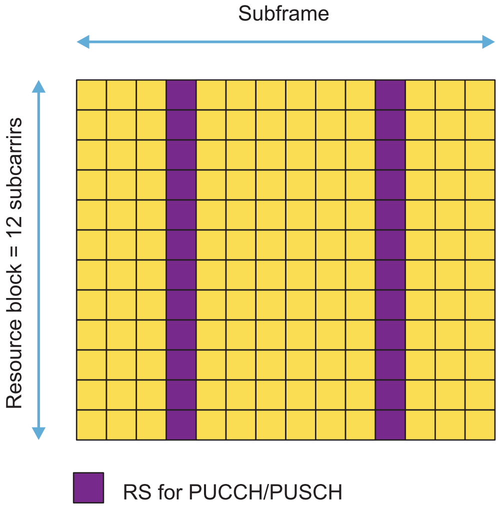
Table 17 PRACH configuration index

PRACH configuration Index	**Preamble Format**	**DensityPer 10 ms**	**PRACH configuration Index**	**Preamble Format**	**Density Per 10 ms**
0	0	0.5	15	0	5
1	0	0.5	16	0	5
2	0	0.5	17	0	5
3	0	1	18	0	6
4	0	1	19	0	6
5	0	1	20	1	0.5
6	0	2	21	1	0.5
7	0	2	22	1	0.5
8	0	2	23	1	1
9	0	3	24	1	1
10	0	3	25	1	2
11	0	3	26	1	3
12	0	4	27	1	4
13	0	4	...		
14	0	4	29	4	5

4.4.2.5 Reference signal for PUSCH demodulation

Reference Signal for demodulation must be always present in PRBs belonging to PUSCH/PUCCH transmission. Since PUCCH is already counted as overhead, it is necessary to consider the Reference Signal for PUSCH. Figure 13: Reference Signal for PUSCH resource mapping shows the allocation of the Reference Signal for PUSCH demodulation within a scheduled PRB (normal CP; 15 kHz spacing).

Figure 13 Reference Signal for PUSCH resource mapping



4.4.2.6 PUSCH UCI

The system is able to use Physical Uplink Shared Data Channel (PUSCH) for Uplink Control Information (UCI) sending. Hence, PUSCH UCI issue has to be investigated separately. The decision whether the UE needs to transmit UCI on PUSCH is up to the eNB. Moreover, the eNB configures the mode in which the UE should report. Although 3GPP defines several reporting modes for PUCCH and PUSCH, see *References* 4, only some of them are supported in the first release RL10. The UE must perform the aperiodic CQI reporting using PUSCH upon receiving an indication sent in the scheduling grant. Thus it is clear that the eNB is in charge of the aperiodic CQI reporting. The minimum reporting interval is one subframe. Various reporting modes, see *References* 4, determine the granularity of reporting in frequency domain (that is per Resource Block Group, wideband reports, etc.). In other words, the UE subdivides the overall bandwidth into subbands (the subband size is defined by k), measures and reports the channel quality separately for each subband. Starting from release RL10 there is support for Mode 2-0 and Mode 3-0. Note that UE capabilities have to be taken into account, that is support of Mode 2-x. PUSCH UCI is not supported in 1.4 MHz bandwidth due to very limited spectrum resources availability. RL20 also supports Modes 3-1 and 2-2 which are designed for closed loop MIMO.

Mode 2-0 (UE selected subband feedback)

This mode is relevant only for transmission modes 1, 2, 3, 7, denoting respectively single antenna transmission, transmit diversity, open loop spatial multiplexing and beamforming. The reports do not include PMI (Precoding Matrix Indicator); therefore the mode cannot be applied when operating with closed loop MIMO schemes. The CQI payload is given by the following formula (which does not include CRC overhead, that is 8 bits should be added in addition):

$$P = R(RI) + 2 + L + 4 + (2 + T) \cdot C$$

where:

P - Payload for CQI

R(RI) - R=2 for 4-layer SM; R=1 for 2-layer SM; R=0 otherwise

T - T=0 for Mode 2-0

C - C=0 for Mode 2-0

$$L = \left[\log_2 \binom{N}{M}\right]$$

where:

N - number of k-sized subbands in the channel

M - number of preferred subbands

Table 18 CQI Mode 2-0 parameters

No. of PRBs	**Subband size k [PRB]**	***M***
6 - 7	(wideband CQI only)	(wideband CQI only)
8 - 10	2	1
11 - 26	2	3
27 - 63	3	5
64 - 110	4	6

The bandwidth-dependent parameters determining the subband size and the number of measured/reported subbands are listed in Table 18: CQI Mode 2-0 parameters.

Mode 3-0 (Higher layer configured subband feedback)

This mode, similarly to Mode 2-0, is valid for the single antenna transmission, transmit diversity or open loop spatial multiplexing modes because it does not include PMI. The CQI payload is given as follows:

$$P = R(RI) + 2 \cdot \ N + 4) + (2 + T) \cdot \ C$$

where:

P - Payload for CQI

R(RI) - R=2 for 4-layer SM; R=1 for 2-layer SM; R=0 otherwise

T - T=0 for Mode 3-0

C - C=0 for Mode 3-0

N number of k-sized subbands in the channel

$$N = \left[\frac{N_{RB}^{DL}}{k} \right]$$

Table 19 CQI Mode 3-0 parameters

No. of PRBs	Subband size k [PRB]
6 - 7	(wideband CQI only)
8 - 10	4
11 - 26	4
27 - 63	6
64 - 110	8

The bandwidth-dependent parameters determining the subband size and the number of measured/reported subbands are listed in Table 19: CQI Mode 3-0 parameters.

Mode 2-2 (UE selected subband CQI report)

This mode is used in combination with close loop spatial multiplexing mode. The system bandwidth is divided into multiple subbands, selects a set of preferred subbands ,then reports one CQI value for the wideband and one differential CQI value for the set (assume transmission only over the selected M subbands).

Mode 3-1 (The higher layer configured subband report)

This mode is also used for close loop spatial multiplexing mode. It provides the highest granularity than mode 2-2. Here the entire system bandwidth is divided into multiple subbands. One wideband CQI value is reported and multiple differential CQI values, one for each subband.

Table 20 CQI and PMI Feedback Types for PUSCH reporting Modes

		No PMI	Single PMI	Multiple PMI
PUSCH CQI Feedback Type	Wideband (wideband CQI)			Mode 1-2
	UE Selected (subband CQI)	Mode 2-0		Mode 2-2
	Higher Layer-configured (subband CQI)	Mode 3-0	Mode 3-1	

Coding rate offset for PUSCH UCI

When transmitting control information multiplexed with data on PUSCH, the appropriate coding offsets are applied to CQI (and PMI), ACK/NACK and Rank Indicator (RI). 3 dB offset is used for CQI reports whereas 7 dB offset is used for ACK/NACK and RI. These values ensure enough robustness for control data. The payload of ACK/NACK message is 1 bit for single stream transmission and 3 bits (including 1 bit for parity check) for dual stream spatial multiplexing.

4.4.3 Estimated overhead

Table 21: Downlink signaling overhead and Table 22: Uplink signaling overhead (64 kb/s user traffic demand) present an example of system overhead estimation for downlink and uplink.

Table 21 Downlink signaling overhead

Physical channel/signal	Channel bandwidth[MHz]					
	1.4	3	5	10	15	20
Reference signal	9.52%	9.52%	9.52%	9.52%	9.52%	9.52%
Synchronization signals	2.86%	1.14%	0.69%	0.34%	0.23%	0.17%
PBCH	2.62%	1.05%	0.63%	0.31%	0.21%	0.16%
PDCCH	19.05%	19.05%	19.05%	19.05%	19.05%	19.05%
Total	34.05%	30.76%	29.89%	29.23%	29.01%	28.90%

Table 22 Uplink signaling overhead (64 kb/s user traffic demand)

Physical channel/signal	**Channel bandwidth[MHz]**					
	1.4	**3**	**5**	**10**	**15**	**20**
Reference signal	11.90%	12.38%	13.14%	13.14%	13.14%	13.14%
PRACH	10.00%	4.00%	2.40%	1.20%	0.80%	0.60%
PUCCH	16.67%	13.33%	8.00%	8.00%	8.00%	8.00%
PUSCH UCI	n/a	2.29%	1.71%	1.20%	0.73%	0.61%
Total	38.57%	32.01%	25.26%	23.37%	22.67%	22.35%

Figure 14: Downlink and uplink overhead comparison shows a visual comparison between the DL and UL overhead. One can notice that the small bandwidth of 1.4 MHz is significantly impacted by controlling resources, whereas the effect is much smaller for bandwidth higher than 5 MHz. Note that PUSCH UCI for 1.4 MHz is not available due to limited resources.

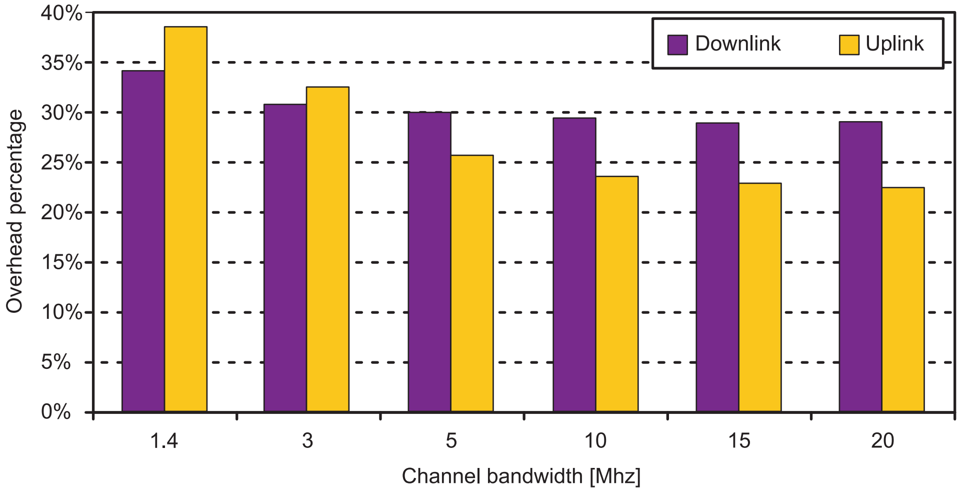
System overhead

It is recommended to assume 3 OFDM symbols per TTI for PDCCH to account for maximized controlling region capacity. The cell-specific Reference Signal overhead depends on the number of active antenna ports (it is two times higher for dimensioning with transmit diversity at the cell-edge). These are the two most important factors impacting dimensioning and capacity results. The rest of DL PHY channels and signals can be neglected.

For uplink control channel (PUCCH), it is recommended to assume 1 PRB (1.4 MHz), 2 (3 and 5 MHz), 4 (10 MHz), 6 (15 MHz), 8 (20 MHz).

PRACH density (number of PRACH resources per radio frame) can be set to 1, which means that one PRACH resource (consisting of 6 PRBs) is reserved per every radio frame. It obviously depends on the subscriber profile (that is service usage, mobility, etc.).

Figure 14 Downlink and uplink overhead comparison



4.4.4 LTE495: OTDOA

<u>NSN LTE Release: RL40, RL35TD</u>

Observed time difference of arrival (OTDOA) is one of the techniques to support location based services (LBS) defined within the LTE positioning protocol (LPP). Other means are A-GNSS (Assisted Global Navigation Satellite System) and E-CID (Enhanced Cell ID).

To support LBS the network should be able to localize a UE usually within the 2D grid (x and y dimension). For this reason LTE Rel-9 introduced special signals in the DL, the so-called positioning reference signals (PRS). Those allow for the needed hearability in the UE even from non-serving cells located quite far away. The UE is informed about the PRS configuration via the LPP (LTE positioning protocol). OTDOA requires an accurately synchronized air interface for the cells transmitting PRS signals. The assumption is that GPS is available at each site to serve as a common absolute timing reference.

The additional overhead introduced by the PRS signaling depends strongly on the PRS bandwidth (number of PRBs used for PRS), PRS repetition period (time between consecutive PRS signal transmissions) and number of DL subframes dedicated for PRS. Table 3-25 presents the influence of the PRS bandwidth settings on the overall PRS signaling overhead assuming that the channel bandwidth is 20 MHz (maximum number of PRBs used for PRS can be up to 100), PRS repetition time is 160 ms and there is one DL frame dedicated for PRS.

Please note that decreasing the number of PRBs utilised for PRS signaling causes reduction of the additional overhead. From the table below, it can be seen that when the PRS bandwidth equals the channel bandwidth (that are all available PRBs within the channel bandwidth are utilized for PRS signaling), the PRS signaling overhead will be equal to 0.625% for FDD. In this case, the table is based on a 20MHz channel bandwidth with a maximum of 100 PRBs. However, this relationship holds true for other channel bandwidths as well. For example, in the case of a 10 MHz channel bandwidth, if all 50 PRBs are utilized for PRS signaling, then the PRS signaling overhead will be equal to 0.625%, since the PRS bandwidth equals the channel bandwidth.

Table 23 Influence of the PRS bandwidth on the overall PRS signaling overhead

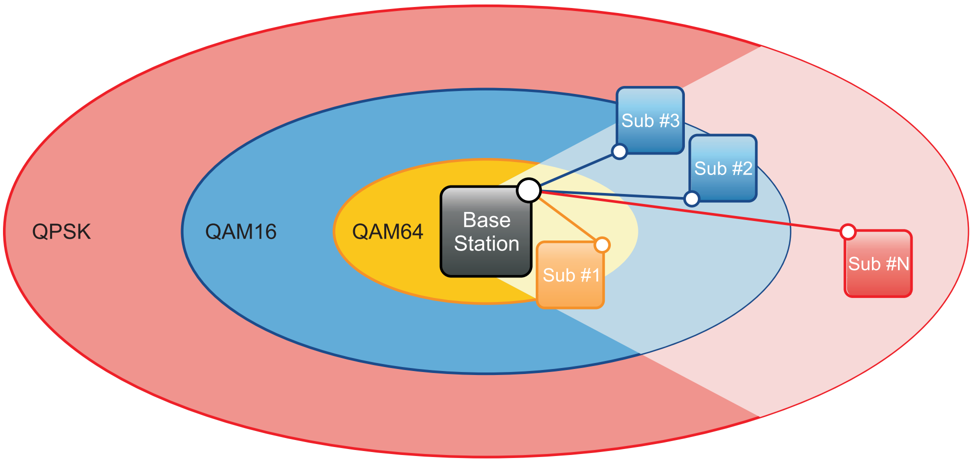
PRS Bandwidth [PRB]	**PRS signaling overhead**		
	FDD	**TDD (DL-to-UL Configuration 1)**	**TDD (DL-to-UL Configuration 2**
6	0,038%	0,094%	0,063%
15	0,094%	0,234%	0,156%
25	0,156%	0,391%	0,260%
50	0,313%	0,781%	0,521%
75	0,469%	1,172%	0,781%
100	0,625%	1,563%	1,042%

Effect of the overhead reduction can be also obtained by extending the PRS repetition period (PRS signals appears in longer time intervals). On the other hand, PRS signaling overhead can be increased by increasing the number of the DL subframes that are used for PRS signals (it consumes more resources in time domain within one PRS signal repetition).

4.5 Link adaptation

For LTE, the 3GPP standard has defined numerous Modulation and Coding Schemes (**MCS**) that provide, besides differences in the modulation patterns (QPSK, 16QAM, 64QAM) additional differences in the coding rate (that is ratio of coding portion to the total radio packet length). The more complex symbols are supported (4 for QPSK, 64 for 64 QAM etc.) and the smaller the ratio of the coding portion, the higher the throughput per symbol but the lower the robustness of the MCS against bad SINR conditions. Several Link Adaptation methods are performed according to the channel conditions in order to provide the guaranteed transmission performance such as data rate, packet error rate or latency. One of these methods is called Adaptive Modulation and Coding (**AMC**) that allows the application of various modulation schemes and channel coding rates based on the channel conditions. Figure 15: Link Adaptation presents the general idea of a basic Link Adaptation (**LA**) mechanism. Generally speaking, the closer to the serving base station, the higher MCS may be used. Conversely, when the UE moves further away from the base station, the SINR decreases due to increased signal attenuation and increased interference coming from neighboring cells.

Figure 15 Link Adaptation



As a general rule, the 3GPP standard has specified that the same MCS has to be applied to all groups of resource blocks belonging to the same Layer 2 (L2) Protocol Data Unit (**PDU**) scheduled to one user within one TTI by a single antenna stream. The same rule applies to multiple streams transmission. The MCS index is stated in the Transport Format together with information about the Transport Block Size, resource allocation and transmission rank (that is one or two code-words). The Transport Format is provided by the Medium Access Control (**MAC**) layer.

For each E-UTRAN physical channel there is a defined list of modulation schemes which are available / allowed for use (see Table 24: Available modulation schemes for various physical channels).

Table 24 Available modulation schemes for various physical channels

Physical channel	**Modulation**
PDSCH	QPSK, 16QAM, 64QAM
PBCH	QPSK
PDCCH (and PCFICH)	QPSK
PHICH	BPSK
PUSCH	QPSK, 16QAM
PUCCH	BPSK and QPSK (for ACK/NACK and CQI messages) On/off keying (for scheduling request)

The highest modulation (64QAM) ,which offers 6 data bits carried by a modulated symbol can be applied only for downlink or uplink shared data channels. The most robust schemes are chosen for signaling channels that are vital for the basic system operation (for example paging, synchronization, controlling, etc.).

4.5.1 MCS selection in the link budget

Although, the Radio Resource Management includes several Link Adaptation entities (fast PDSCH AMC, slow periodic PUSCH AMC and event-triggered aperiodic PUSCH AMC), the MCS selection for the link budget is quite simple. Due to the fact the goal of coverage dimensioning focuses on estimating the maximum possible cell range, the planner should choose the most robust MCS providing the best coverage and fulfilling a certain cell-edge throughput requirement. Slightly different principles apply to MCS selection in DL and UL mainly because of different power allocation rules (see).

A set of 29 different MCS indexes is available in [3GPP TS 36.213], see *References* 4 They are listed in Table 25: Available downlink modulation and coding schemes and Table 26: Available uplink modulation and coding schemes. As one can see, every MCS is unambiguously mapped to a certain modulation order (there are three groups: QPSK, 16QAM, 64QAM; according to what has been stated in Table 24: Available modulation schemes for various physical channels). Moreover, every MCS index is assigned a TBS index. The Transport Block Size (TBS) reflects the amount of user data bits sent during one TTI (1 ms) the TBS depends on the number of scheduled PRBs. Table 27: Transport Block Size table shows the available configurations. The maximum number of scheduled PRBs in Table 27: Transport Block Size table is 110, and that this is more commonly available in the 20 MHz bandwidth (see). However, this is only true for the exceptional case with reduced guard band.

Table 25 Available downlink modulation and coding schemes

MCS index	Modulation order	TBS index
0	2	0
1	2	1
2	2	2
3	2	3
4	2	4
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	4	9
11	4	10
12	4	11

Table 25 Available downlink modulation and coding schemes (Cont.)

MCS index	**Modulation order**	**TBS index**
13	4	12
14	4	13
15	4	14
16	4	15
17	6	15
18	6	16
19	6	17
20	6	18
21	6	19
22	6	20
23	6	21
24	6	22
25	6	23
26	6	24
27	6	25
28	6	26

Table 26 Available uplink modulation and coding schemes

MCS index	**Modulation order**	**TBS index**
0	2	0
1	2	1
2	2	2
3	2	3
4	2	4

Table 26 Available uplink modulation and coding schemes (Cont.)

MCS index	**Modulation order**	**TBS index**
5	2	5
6	2	6
7	2	7
8	2	8
9	2	9
10	2	10
11	4	10
12	4	11
13	4	12
14	4	13
15	4	14
16	4	15
17	4	16
18	4	17
19	4	18
20	4	19
21	6	19
22	6	20
23	6	21
24	6	22
25	6	23
26	6	24
27	6	25
28	6	26

Table 26 Available uplink modulation and coding schemes (Cont.)

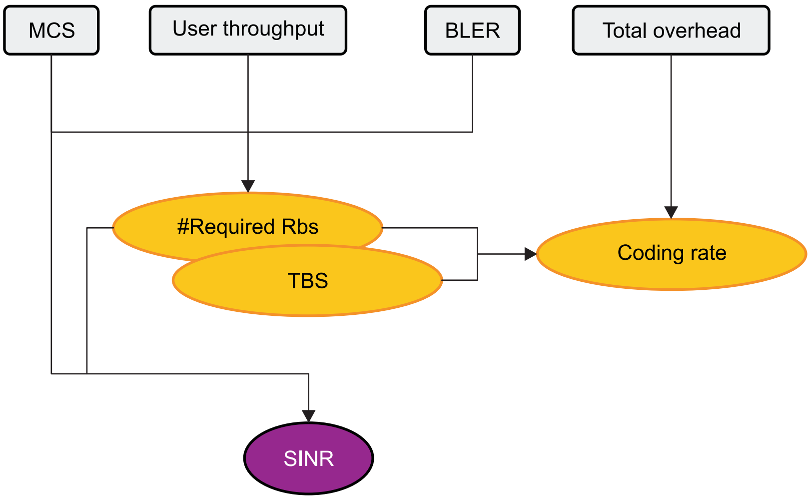
MCS index	Modulation order	TBS index
29, 30, 31	reserved	

Table 27 Transport Block Size table

	Number of scheduled PRBs									
TBS index	**1**	2	3	**4**	**5**	6	...	100	...	110
0	16	32	56	88	120	152	...	2792	...	3112
1	24	56	88	144	176	208	...	3624	...	4008
2	32	72	144	176	208	256	...	4584	...	4968
3	40	104	176	208	256	328	...	5736	...	6456
4	56	120	208	256	328	408	...	7224	...	7992
5	72	144	224	328	424	504	...	8760	...	9528
...	...	...	...	...	...	...	...	...	...	...
26	712	1480	2216	2984	3752	4392	...	75376	...	75376

The target user throughput is one of the most important input values for the link budget calculation. It is the minimum acceptable net throughput for one single user to be experienced at the cell edge. In addition to the cell edge user throughput and MCS, also the BLER (Block Error Ratio) target must be taken into account as any retransmission of failed blocks requires resources that are no longer available for user data. The BLER target represents a requirement for the radio interface quality that is to be interpreted as the retransmission ratio, in other words, the probability that a transmitted block is not correctly received and cannot be correctly decoded at the receiving end (for example 10% BLER after initial transmission indicates that, on the average, the transmission of one Transport Block out of ten attempts fails after the initial transmission and requires a re-transmission). At the end, the coding rate can be considered to account for overhead differences between the original link budget scenario and assumptions made for required SINRs (see Control data overhead). A very general view on this procedure is depicted below in Figure 16: User throughput related calculation.

Figure 16 User throughput related calculation



The required user throughput $UserThr_{input}$ must be increased due to the given BLER target as follows (assuming this is the BLER after 1st transmission):

$$\mathrm{UserThr} = \frac{\mathrm{UserThr_{input}}}{1 - \mathrm{BLER}}$$

Knowing the value of user throughput *UserThr*, one can select among different TBS configurations in Table 27: Transport Block Size table.

Example:

Assuming the cell edge user throughput of 256 kbps and 10% BLER (10% = 0.1), the chosen transmission scheme (the configured Transport Block) should be capable of serving

[256 kbps / (1 - 0.1)] = [256 kbps / 0.9] = **284.5 kbps**

This data rate already includes the additional throughput requirement caused by one successful retransmission. Transport Block Sizes in Table 27: Transport Block Size table are defined in terms of user data bits sent during the time period of one TTI. This means, that the 284.5 kbps requirement forces the usage of the Transport Block Size of at least 285 bits. For example, with four scheduled PRBs, the system would establish a 328 bits Transport Block and use QPSK modulation (TBS index = 5 → MCS index = 5 → QPSK). This is, however, not the optimum configuration from the coverage point of view. The question is how to select the optimum MCS/#PRBs (resulting in the suitable TBS). It can be done in combination with the required SINRs values (see Optimum MCS selection).

If the TBS is already known, one can easily obtain the maximum throughput achievable in the total channel assuming that all users are homogeneous (meaning all users are using the same TBS configuration), and that the cell works with 100% resource use. This leads to the following formula:

$$\mathrm{MaxMCSThr} = \mathrm{TBS} \cdot \frac{N_{RB}^{total}}{N_{RB}^{used}} [\mathrm{kbps}]$$

MaxMCSThr	- overall channel throughput that can be achieved if all resources are used
TBS	- Transport Block Size
N_{RB}^{total}	- total number of PRBs within the available bandwidth
N_{RB}^{used}	- number of PRBs used by a single user

The reciprocal value of the expression:

$$N_{RB}^{total} / N_{RB}^{used}$$

indicates the percentage of resources R_u used by a single user:

$$R_u = \frac{N_{RB}^{used}}{N_{RB}^{total}}$$

When the MCS/#PRBs combination is known and the TBS is derived, one can compute the Effective Coding Rate (ECR) by assuming a certain system overhead:

$$ECR = \frac{TBS}{N_{RB}^{used} \cdot (1-0) \cdot 2 \cdot N_{symb} \cdot N_{SC}^{RB} \cdot M}\left[\frac{bits}{RE}\right]$$

O - overhead

N_{symb} - number of symbols per timeslot

N_{SC}^{RB} - number of subcarriers per resource block

M - number of PRBs used by a single user

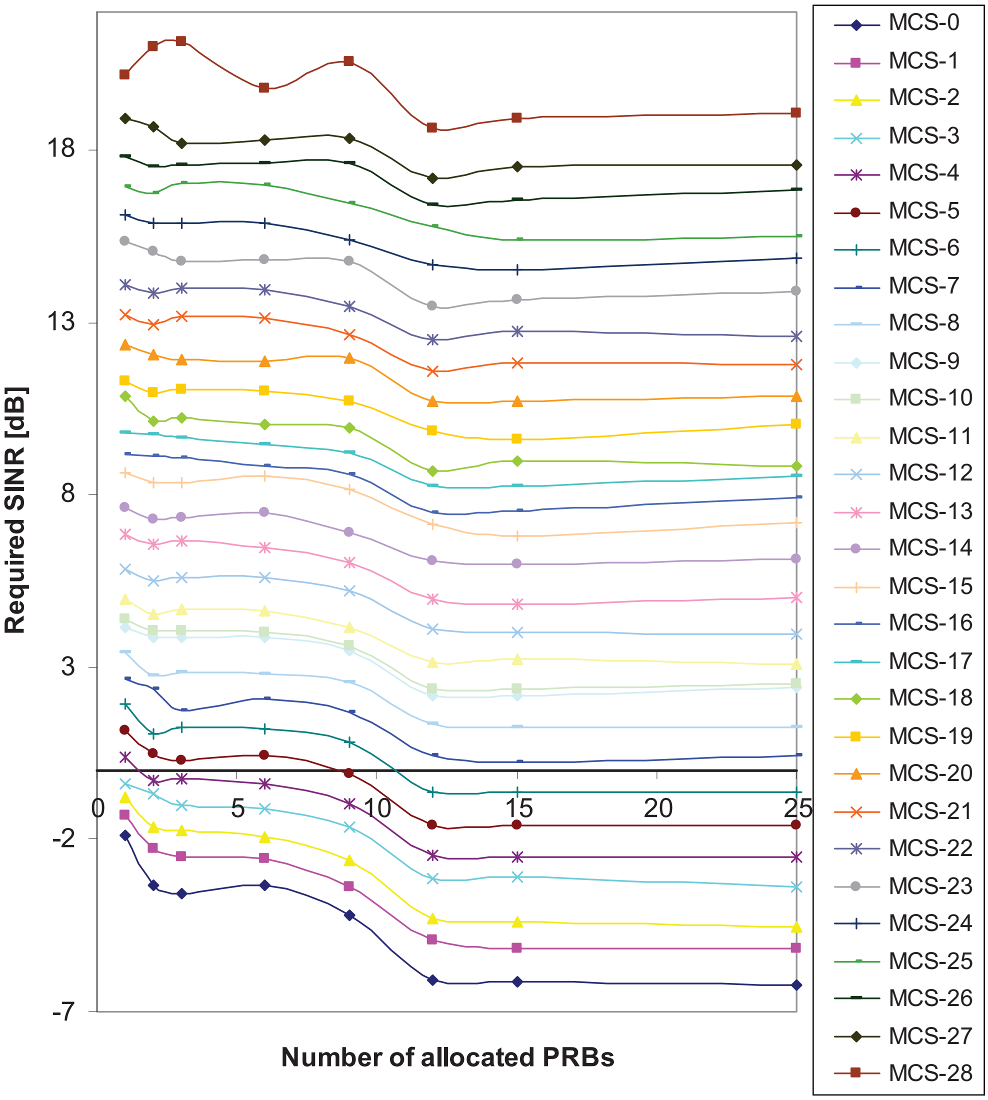
4.5.1.1 Optimum MCS selection

Generally, a more robust MCS needs a lower SINR. A lower required SINR value leads to better receiver sensitivity and thus provides better coverage results. For this reason, it is usually enough to select the lowest possible MCS index for downlink. The same rule cannot be applied for uplink. Additionally, the planner needs to understand the trade-off between the required SINR and the power per PRB.

Turbo coding degradation

On the other hand, especially for low bit rate services (requiring small amount of PHY resources), the link may experience a turbo coding degradation effect. It is clearly visible in Figure 17: DL SINR requirements (DL 2Tx-2Rx; Tx diversity; EPA05; BLER=10%), which shows the SINR requirements for the EPA05 channel model assuming 2Tx diversity at eNodeB at 2Rx Maximum Ratio Combining at the UE. The reason why SINR deteriorates for a low number of PRBs is related to the efficiency of turbo coder implementation, which is not sufficient for a very small amount of input data. As one can see, it is especially strong for the number of PRBs lower than 10. If the planner fixes the MCS for low throughput requirement, it is likely that a slight increase of the throughput requirement will lead to a better cell range. This leads to a situation when scenarios with a higher traffic demand are characterized by better coverage performance (larger maximum allowable path loss) because the turbo coder degradation effect has been eliminated.

Figure 17 DL SINR requirements (DL 2Tx-2Rx; Tx diversity; EPA05; BLER=10%)



Power allocation impact

As stated in the section Power allocation , the UE transmission power is accumulated on the allocated subcarriers. Therefore switching to a higher MCS increases the power per subcarrier. Due to the fact that turbo coding degradation is slightly smaller for higher modulation indexes it is sometimes possible that switching to higher MCS will improve the maximum allowable path loss. In other words, the increase of required SINR value will not be as high as the increase of the power per PRB. This effect is not relevant for downlink direction, because in this case, the power per PRB is constant and does not depend on the amount of allocated resources.

4.6 Channel model

Any radio dimensioning calculation must be based on validated link level and system level data in order to get reliable results. Both types of input (that is required SINR look-up tables and spectral efficiency values) are defined for a certain channel model. Thus, the channel model is also implicitly considered in the link budget and capacity evaluation.

Specifications, see *References* 2 and 3, suggest using the channel models specially designed for OFDM-based air interfaces, these are listed below:

- Enhanced Pedestrian A (EPA)
- Enhanced Vehicular A (EVA)
- Enhanced Typical Urban (ETU)

These channel models account for:

- delay profile characterized by a sufficient number of taps
- Doppler frequency
- correlation between UE and eNB antennas in case of multi-antenna systems
- large channel bandwidth sizes

It is possible to use the maximum Doppler frequency just after the EPA/EVA/ETU term, thus EPA 5 Hz would stand for Enhanced Pedestrian A with the maximum Doppler frequency of 5 Hz. The Doppler frequency determines the rate of frequency response variations and can be obtained with the following equation:

$$f_D = \frac{v}{c} \cdot f_c$$

where:

f_D - Doppler frequency

v - UE speed

f_c - carrier frequency

c - speed of light

Example:

Doppler frequency of 5 Hz can be met in case of 2.3 km/h velocity and 2300 MHz carrier frequency. Thus, EPA 5 Hz for 2300 MHz is especially valid if the velocity of mobiles is about 3 km/h. Example relations between Doppler frequency and mobile velocity are shown in Table 28: Operating band vs. Doppler frequency.

Table 28 Operating band vs. Doppler frequency

Carrier frequency[MHz]	**Effective speed for EPA05 [km/h]**	**Effective speed for EPA70 [km/h]**
730	7.4	103.6
750	7.2	100.8
900	6.0	84.0
1500	3.6	50.4
1700	3.2	44.5
1800	3.0	42.0
2100	2.6	36.0
2600	2.1	29.1

Channel model

In the presented link budget approach, the impact of fading profile is covered by the appropriate selection of SINR values coming from link level simulations. Any additional margins such as indoor/in-car/etc. losses could be considered separately.

Since the initial LTE deployments will rather focus on stationary subscribers (that is wireless DSL customer), it is recommended to use the SINR requirements defined for EPA05 channel model. ETU70 introduces more restrictive SINRs due to a higher delay spread (impact on inter symbol interference) compared to EPA05.

4.7 Multi-antenna systems

LTE PHY layer supports multi-antenna transmission at both eNB and UE. There are several kinds of operating modes regarding multi-antenna solutions. The principles are described below:

- **Receive diversity** - used for fading suppression, which improves the experienced SINR. The solution can employ the Maximum Ratio Combining (**MRC**) or Interference Rejection Combining (**IRC**). In general, both methods allow an increase of the weights of branches, for which the mean signal level is higher and the noise level lower. Therefore, adding the signals with the appropriate gain weights leads to obtaining the optimal output signal. Flexi RF Modules and RRH available for RL20, support MRC scheme only.
- **Transmit diversity** - the idea of transmitting the same data stream using multiple antennas. Similar to the receive diversity, transmit diversity will not increase the peak data rates, but it is the method against signal degradation due to propagation losses. Tx diversity induces an improvement of the experienced SINR especially for cell-

edge users, who typically suffer from the inter-cell interference. 3GPP Release 8 specifies the Tx diversity in downlink only. This means that the technique is relevant only for the eNB antenna system (the UE cannot transmit in such a mode).

- **Multiple Input Multiple Output** (MIMO) - the term MIMO can comprises many antenna configurations between two radio peers, and its exact meaning should be fully understood prior to any analysis. Generally speaking, MIMO is a specific solution of using multiple antennas for both receiving and transmitting purposes in downlink or uplink. For example, the term MIMO 2Tx-2Rx used for DL denotes two Tx antennas at eNB along with two RX antennas at the UE. The same can be denoted as 2x2MIMO. It is impossible to assume that the same scheme is also valid in UL direction since the uplink could be characterized by 1Tx-2Rx (that is one transmit antenna at UE along with two antennas at eNB). One cannot assume, that for the following dimensioning proposal, the term:
  - “nRx” always refers to the MRC receive diversity with n antennas, whereas
  - “mTx-” stands for m transmit antennas in one of two following modes:
- **Spatial Multiplexing** (SM) - transmitting different data streams over separate antennas. The solution can be applied only to those UEs operating under very good SINR conditions which are able to combine such highly rated streams. In other words, the SM improves the peak data rates - the gain depends on the number of applied transmission layers. There are two modes SM kinds for E-UTRAN air interface. Open loop SM is a two-layer transmission mode without additional precoding, where as closed loop SM requires the Precoding Matrix Indicator (PMI) to be reported by UE to build a proper precoding vector.
- **Space Frequency Block Code** (SFBC) - transmitting signal using one code-word and multiple antennas. SFBC is a specific kind of already introduced Tx diversity. The main goal is to improve the SINR.

In a real-world system, the multiple antenna schemes are under control of eNB. The E-UTRAN release provides the mechanism of dynamic MIMO control. Depending on the channel condition, the eNB decides which technique should be used for a given transmission:

- Tx diversity in case of poor achievable SINR
- SM if there is no need for a further improvement of signal quality; the UE can handle high peak data rates

RL10, offers a support for Dynamic Open Loop MIMO Mode Control (MIMO-MC), which enables dynamic switching between single stream and dual stream transmission (Mode 3). Additionally, RL20, supports Mode 4 which is closed loop MIMO scheme (precoding based on the reported PMI).

There are several antenna modes which can be activated for PDSCH:

- **DL MIMO Mode 1** - Single stream (1Tx antenna; single antenna port),
- **DL MIMO Mode 2** - Single stream transmit diversity (2Tx antennas; SFBC)
- **DL MIMO Mode 3** - Dual stream open loop MIMO spatial multiplexing (2Tx antennas; LD-CDD) or single stream transmit diversity (2Tx antenna; SFBC)

When transmitting over multiple antennas, the UE must be able to estimate the channel response corresponding to each antenna. That is why every antenna or, more specifically, each antenna port has to transmit its own reference signal. The time/frequency resources carrying the reference signal symbols cannot be reused at the other antenna ports. In other words, the resource elements occupied by the first antenna's reference signal cannot be used by any of physical channels/signals by another antenna. In addition to that, in case of four antennas, the density of reference signal on the third and fourth port is two times lower than the density of signal on the first and second one. The aim of this solution is to prevent overly high reference signal overhead.

As the reference signal is used for coherent demodulation at the receiver's side, it determines on which antenna port the transmission will be possible. For the purpose of procedures such as broadcasting, synchronization, and initial cell search, the antenna port 1 is dedicated. This is because a UE does not have full information about the number of eNB antennas at the beginning of the transmission.

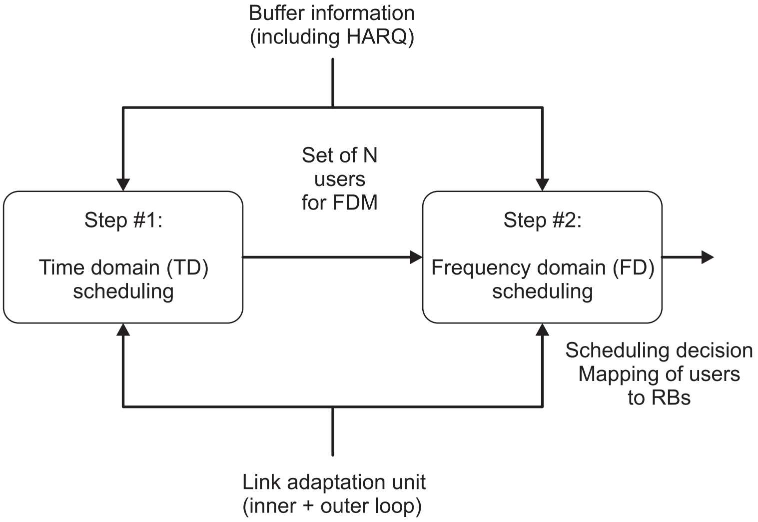
4.8 Frequency scheduling gain

One of the biggest advantages of LTE is the possibility of resource allocation in a two-dimensional domain: frequency and time. This makes it possible to use of so-called channel dependent schedulers. These are schedulers which exploit the knowledge about the frequency domain by means of subband Channel Quality Indicator (**CQI**) reports. This method provides high gain compared to channel unaware resource allocation (for example used in WiMax). On the other hand, it requires additional implementation complexity. Note that the frequency domain scheduling is especially beneficial for UEs that are stationary or moving at low speeds, as the mechanism only makes sense as long as the channel conditions remain more or less stable within the measurement/reporting period. If the UE moves fast, the measured, filtered and reported CQI may be out-of-date when taken into account by the scheduler. Fortunately, the length of TTI in LTE is very short (1 ms), and a typical configuration setup provides CQI measurements on the subframe basis. The scheduler evaluates the resources on TTI basis as well.

There are separate Radio Resource Management (**RRM**) entities for scheduling algorithms in UL and DL. Although 3GPP Release 8 allows the allocation of resources in a localized or distributed manner, RL20 supports the localized allocation only. It means that the resources assigned to one single UE must be contiguous in the frequency domain. This obviously affects the scheduling performance because it limits the variety of possible allocations.

The scheduler implementation is depicted in Figure 18: Frequency Dependent Packet Scheduling. It represents the idea of Frequency Dependent Packet Scheduling (FDPS).

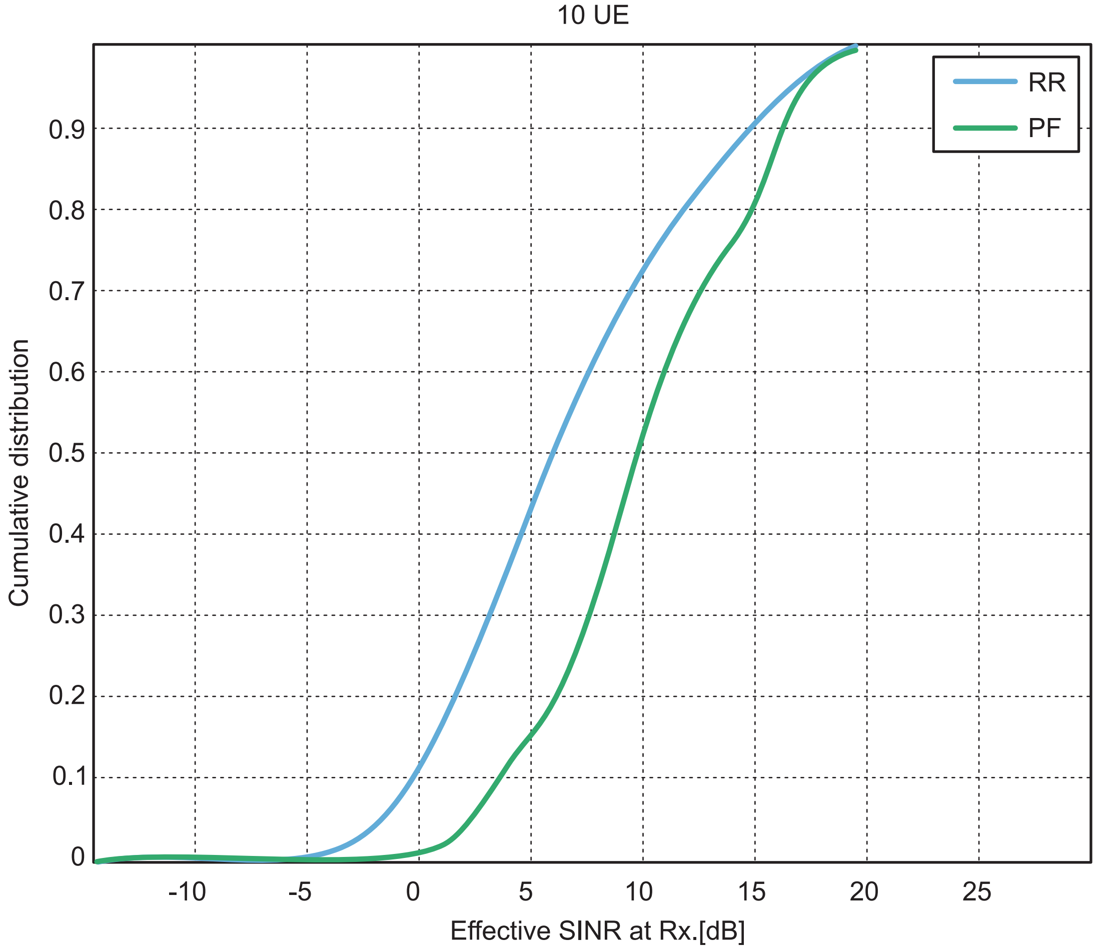
Figure 18 Frequency Dependent Packet Scheduling



The time domain (TD) -related entity determines the set of users to which the resources will be assigned to (the time assignment depends mainly on the pending retransmissions, buffer status of other users, signaling, etc.). The frequency domain (FD) -related operation is the next step applied to the previously defined set of users. The FD block analyzes the channel condition for every user and makes the best possible assignment with respect to the certain optimization criterion. It is possible to configure the mentioned criteria by O&M parameters; thus every operator is able to set up their own scheduling strategy (for example maximize C/I, Round Robin, Proportional Fair (PF), maximize cell throughput). A basic configuration provides PF-like strategy for downlink, which is a slight variation from a typical PF (Proportional Fair). In RL20 Round Robin is applied for uplink direction which means that the frequency resources are assigned randomly without the channel knowledge.

In the introduced dimensioning procedure, the FDPS gain is considered as SINR improvement at the receiver side. System level simulations for full-buffer UEs show the dependency between the number of scheduled users and the channel aware scheduling gain (full buffer approach for a single user does not show any gain since the user occupies all available resources and there is no possibility of using another set of PRBs). From the dimensioning point of view, the number of scheduled users in a full buffer simulation campaign can be translated into the resource use by a single user (the number of allocated PRBs is known for every dimensioning case; see). The larger amount of resources is available for scheduling of a single user, the higher the chance of avoiding channel quality gaps is. As a result, it impacts the coverage performance.

Figure 19 SINR distribution for RR and PF scheduling



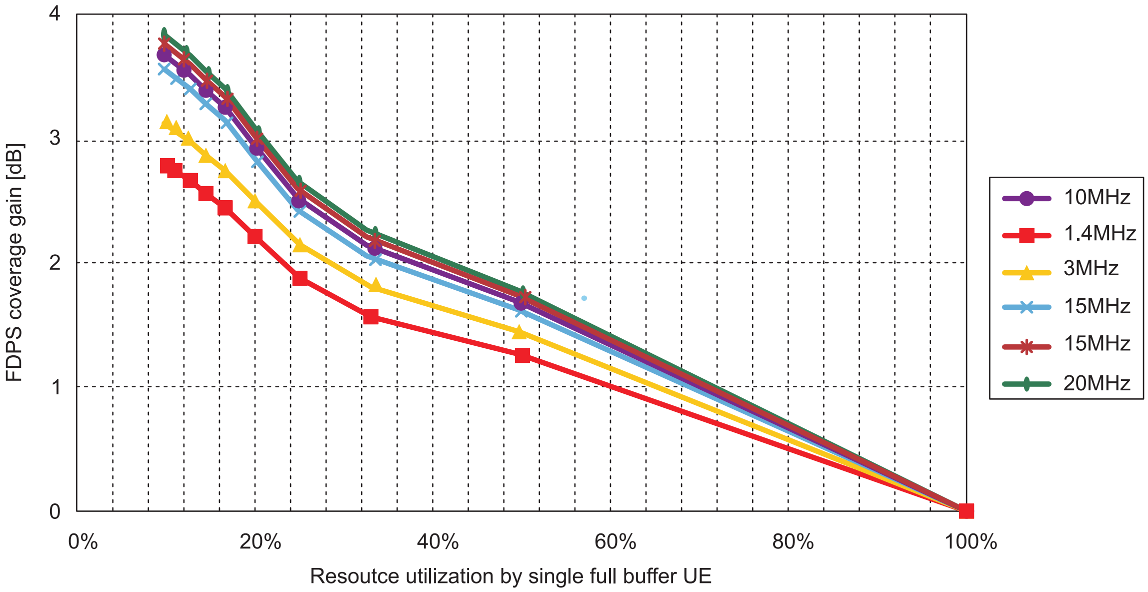
Two example simulation results for 10 UEs scheduled in 10 MHz TTI are shown in Figure 19: SINR distribution for RR and PF scheduling. There are two cases:

- RR - Round Robin in time and frequency domain - random allocation without the channel knowledge. The scheduler does not take into account historical knowledge about experienced user data rates. The resource allocation is random and uses the frequency hopping pattern.
- PF - Proportional Fair in time and frequency domain - allocation based on metrics assigned to UEs (those metrics also consider historical measurements, radio conditions, etc.). Simply expressed, a PF scheduler monitors, for every connection, the achievable rate as well as the experienced rate, and tries to allocate the resources to those connections first, that have the biggest deviation between achievable and experienced data rate. Thus those connections that have been previously neglected to the highest extent are served first. Moreover, the PF strategy in the frequency domain means that the scheduler is channel aware when it estimates scheduling metrics for PRB assignment. In other words, the channel aware entity operates with its own metrics (for example subcarrier priority, subcarrier condition for the given UE) in the PF manner.

Figure 19: SINR distribution for RR and PF scheduling clearly shows the gain by means of improved SINR when the scheduler operates with the PF channel aware strategy. The difference for 10th percentile of SINR distribution is about 3.7 dB. Obviously, the

presented case does not correspond to all dimensioning cases. On the other hand, when the terminal uses fewer PRBs, its chances to be properly allocated increase. In other words, a better set of PRBs can be chosen, ensuring better SINR. For this reason, all the results obtained from full buffer system level simulations can be translated to the case with the bandwidth usage of a single UE. The scheduling gain strictly depends on the channel bandwidth. The wider the bandwidth, the higher gain can be expected. This is reflected in gain correction factors defined for each channel. Post-processed results are shown in Figure 20: Frequency scheduling gain.

Figure 20 Frequency scheduling gain



When the number of allocated PRBs is known, it is easy to compute the fraction of the total available spectrum. The percentage is nothing else than a cell-edge user bandwidth use. This input is needed to derive the frequency scheduling gain from the above plot (see Figure 20: Frequency scheduling gain). Due to the way in which the gain values have been obtained, it can be also referred to as Multi User Diversity (MUD) gain.

4.9 Link budget margins

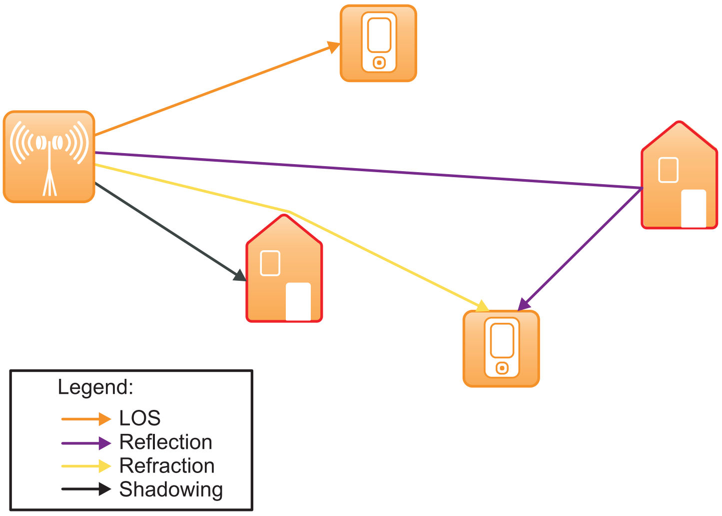
As explained before, the MAPL is calculated based on particular throughput requirements (which in turn are linked to a defined SINR requirement), technology characteristics and constraints. In addition to these, several additional margins need to be taken into account to reflect SINR degradations that arise due to known phenomena that a user can experience in real network application. These margins usually reflect [in dB] the “additional” buffer that must be taken into account to allow a compensation of these degradations. While the causes for the SINR degradations are usually known and therefore predictable, it is difficult to quantify the effects accurately. Hence, all margins described in the sections Fading margins and Interference margin, are based on estimations that assume particular base conditions (for example neighbor cell load).

4.9.1 Fading margins

In a cellular network, a propagating radio wave meets many obstacles on the radio path. For indoor environments these obstacles can be floors, walls or furniture. In outdoor environments they can be buildings, cars or just some specific terrain shape. In all cases the radio wave can be reflected, refracted or scattered as presented in Figure 21: Multipath radio wave propagation. Hence, the signal received at the receiver is a product of waves passing through paths of different lengths. Multipath propagation is related to the following effects causing signal fading and distortion:

- Shadowing also known as log-normal fading or slow fading
- Rayleigh fading also known as fast fading
- Delay spread (related to the channel model; see *Channel Model*)

Figure 21 Multipath radio wave propagation



With a mobile receiver movement, the received power changes - it rises and decreases depending on obstacles entering into the Line of Sight (**LOS**) between transmitter and receiver antennas. The radio signal is affected by slow fading (shadowing). Shadowing fades can be even 20 dB deep. For the purpose of radio network dimensioning, the received signal strength can be modeled by the Gaussian random process, thus it is possible to estimate the probability of the received signal strength exceeding a certain threshold. The log-normal fading effect is not considered in the standard propagation model; which assumes a 50% cell edge probability (means: 50% probability that an UE receives, at the cell edge, the signal in such a way that at least the ”required SINR” condition is fulfilled). To consider a probability of more than 50% that the signal strength will induce an SINR above the “required SINR” threshold, a Log Normal Fading (LNF) margin has to be calculated. The mentioned variations are log-normal distributed, so the loss is higher (or lower) than the average value. In other words, this margin is defined to maintain coverage with a certain location probability in these cases as well. The shadowing margin is the amount by which a received signal level may be reduced without causing system performance to fall below a specified threshold value.

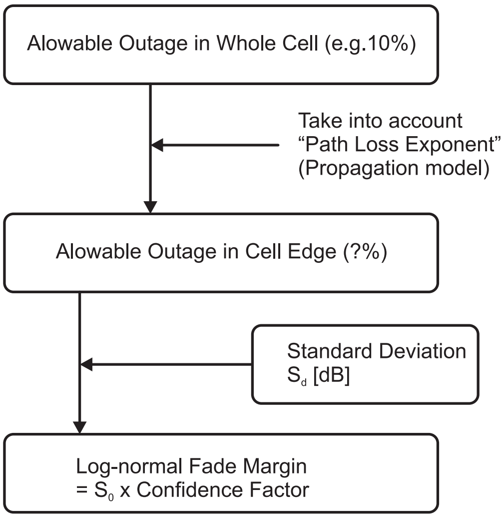
$$\mathrm{LNF} = x \times \sigma$$

where:

σ - standard deviation of the slow fading distribution

x - argument of the normal cumulative density function F(x) the values of which define the cell edge location probability

Figure 22 Calculation of the logfading (shadowing margin)



The LNF margin values in dependency of the cell edge probability are presented in Table 29: Tabularized LNF margin in a function of location probability at cell border

Table 29 Tabularized LNF margin in a function of location probability at cell border

Location probability at cell border [%]	**Log-normal fading margin [dB]**
50	σ x 0
60	σ x 0.25
70	σ x 0.52
75	σ x 0.67
80	σ x 0.84
85	σ x 1.04
90	σ x 1.28
91	σ x 1.34
92	σ x 1.4
93	σ x 1.48
94	σ x 1.55

Table 29 Tabularized LNF margin in a function of location probability at cell border (Cont.)

Location probability at cell border [%]	Log-normal fading margin [dB]
95	σ x 1.64
96	σ x 1.75
97	σ x 1.89
98	σ x 2.05
99	σ x 2.33

LNF margin is calculated as $x * \sigma$, where σ is the standard deviation of the slow fading distribution whereas x is the argument of the normal cumulative density function *F(x)*; whose values define the cell edge location probability. LNF margins are presented in Table 30: Examples of the shadowing margin

Table 30 Examples of the shadowing margin

Location probability		Standard deviation of the signal level	Log normal fading margin (LNF)
In whole cell	On cell edge		
95%	86.9%	9 dB	10.1 dB
	86.0%	8 dB	8.6 dB
	84.9%	7 dB	7.2 dB
	78.7%	4 dB	3.2 dB

There are two different ways to describe the outage probability. One is the probability related to the cell edge, and the other one is related to the cell area. The dependency between these two probability figures is a function of the propagation exponent and the standard deviation. To consider the slow fading impact for a given target cell area probability (usually provided as a design target), Jake's formula must be used. It can be applied only in the case of signal reception from one cell. The impact of multi-cell coverage is considered as the gain against shadowing. This formula gives a relation between the cell edge probability and the corresponding cell area probability. The cell area probability is the probability that a UE receives, within the entire area of the cell, the signal in such a way that at least the “required SINR” condition is fulfilled.

A standard deviation is the deviation from the mean value. This parameter is used for log-normal fading calculation. The standard deviation value is derived from measurements and depends on the clutter type or simulation case.

The following deployment classes (see Table 31: Deployment classes) have been defined to systemize different slow fading related parameters depending on the clutter type.

Table 31 Deployment classes

	Deployment class	Clutter type			
		Dense Urban	Urban	Suburban	Rural
Location probability [%]	**Basic**	82.6	81.5	81.5	69.8
	Mature	84.7	83.7	83.7	73.3
	High End	86.9	86.0	82.6	85.0
Standard deviation for LNF[dB]	**Basic**	9	8	8	7
	Mature	9	8	8	7
	High End	9	8	8	7
eNodeB height[m]	**Basic**	30	30	30	50
	Mature	30	30	30	30
	High End	30	30	30	30
Penetration loss[dB]	**Basic**	20	15	10	5
	Mature	22	17	12	10
	High End	25	20	15	15

Note that the deployment class definition also determines eNB height (for propagation model calculation) and the penetration loss (see).

Fading margin

There is no need to assume the fast fading margin in the LTE link budget mainly very short TTI (1 ms) and fast AMC/scheduling mechanisms preventing falling into the fading gaps. In the presented dimensioning approach, the impact of fast fading and user velocity is covered by the selection of an appropriate SINR value coming from link level simulation results.

For the calculation of shadowing margin, it is recommended to use the Mature deployment class. Additionally, penetration loss depends on the carrier frequency (see Annex C); above listed values refer to 2.1GHz.

4.9.2 Interference margin

The “Interference margin” is a dB value that represents, as a “summarized value”, the safety margin that needs to be taken into account in the overall MAPL in order to compensate for interference signals from neighbor cells under traffic load. As a rule, the higher the traffic load in the neighbor cell, the more subcarriers are used there and, consequently, the stronger the interfering signal, especially when frequency reuse 1 is applied (which means that the serving and the neighbor cells use the same subcarriers). The same margin is also included in 3G-specific cell range evaluations. However, the related formula cannot be explicitly applied to LTE. The reason is that the interference characteristic differs between OFDMA-based air interface and WCDMA-based system.

Intra-cell interference

Intra-cell interference refers to any interference caused by the active terminals within the same cell. The 3G systems suffer from the cell breathing effect because of working with one frequency (frequency reuse = 1) and multiplexing users based on the orthogonal codes assignment. The OFDMA-based systems outperform the CDMA systems and the mentioned phenomena should not be perceptible. In the OFDM transmission scheme the separate subcarriers are orthogonal. Obviously, it refers to the sub-carriers within one particular symbol. The unused ones have no bearing on the signal reception whereas the occupied ones cannot interfere each other because they are orthogonal. For this reason, the number of multiplexed users in the frequency domain does not influence the interference level between them. Moreover, a single Resource Element is able to carry one user's bits, which is completely different from the CDMA solution, where the multiplexed users occupy the same time and frequency resources. Assuming that there is no orthogonality loss inside a cell, no users experience intra-cell interference. A higher number of active users causes a decrease of the available resources, but it does not influence the G-factor (wideband C/I). There is no point in considering “cell breathing” phenomena, which is a well-known disadvantage of WCDMA networks. The eventual conclusion is that intra-cell interference does not exist and therefore does not require the consideration of any additional link budget safety margins during dimensioning.

Inter-cell interference

The situation becomes complicated when the neighboring cells are taken into consideration. In that case, dependencies among the cells served by different base stations must be modeled. The general deployment approach does not include any reuse schemes; thus, all sites are allowed to work in the same frequency range (reuse=1). The proper operation in a single cell is assured by the orthogonal property of FFT. Such a perfect situation is usually reflected in reality for those terminals which are not located at cell boundaries, while cell-edge users suffer from the interference from the neighbor cells.

The aspect of downlink and uplink interference is depicted in Figure 23: Downlink inter-cell interference and Figure 24: Uplink inter-cell interference. It is crucial to remember that the orthogonality between subcarriers is preserved only within one single OFDM symbol.

Figure 23 Downlink inter-cell interference

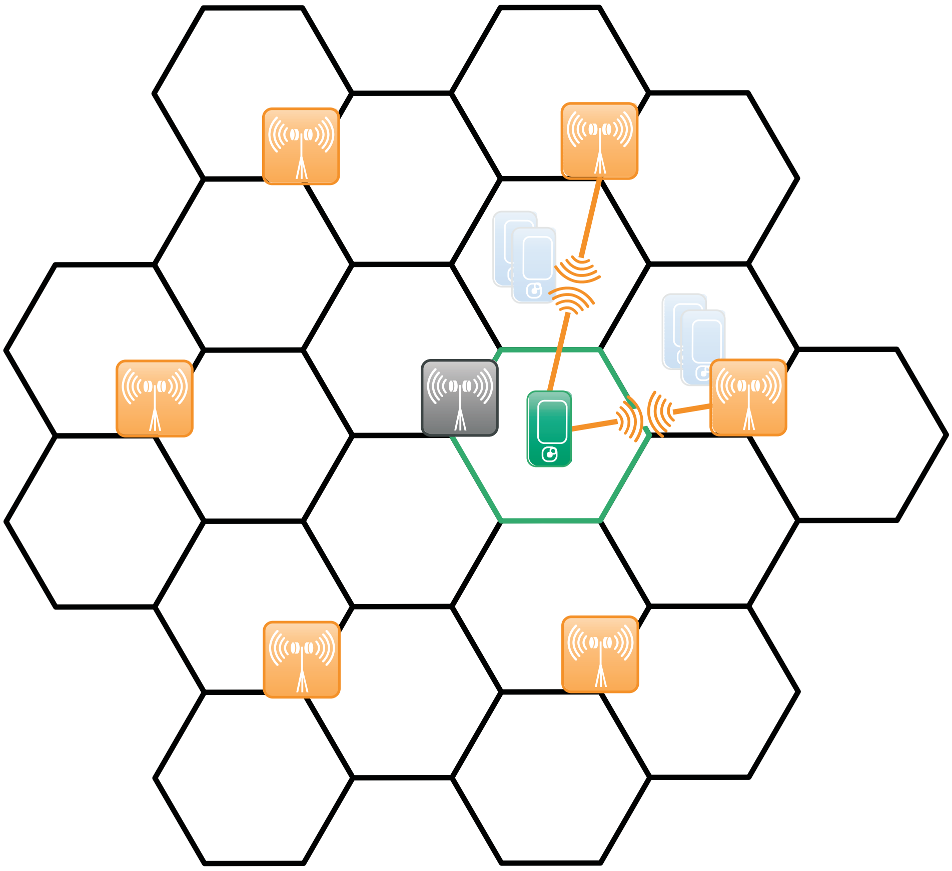
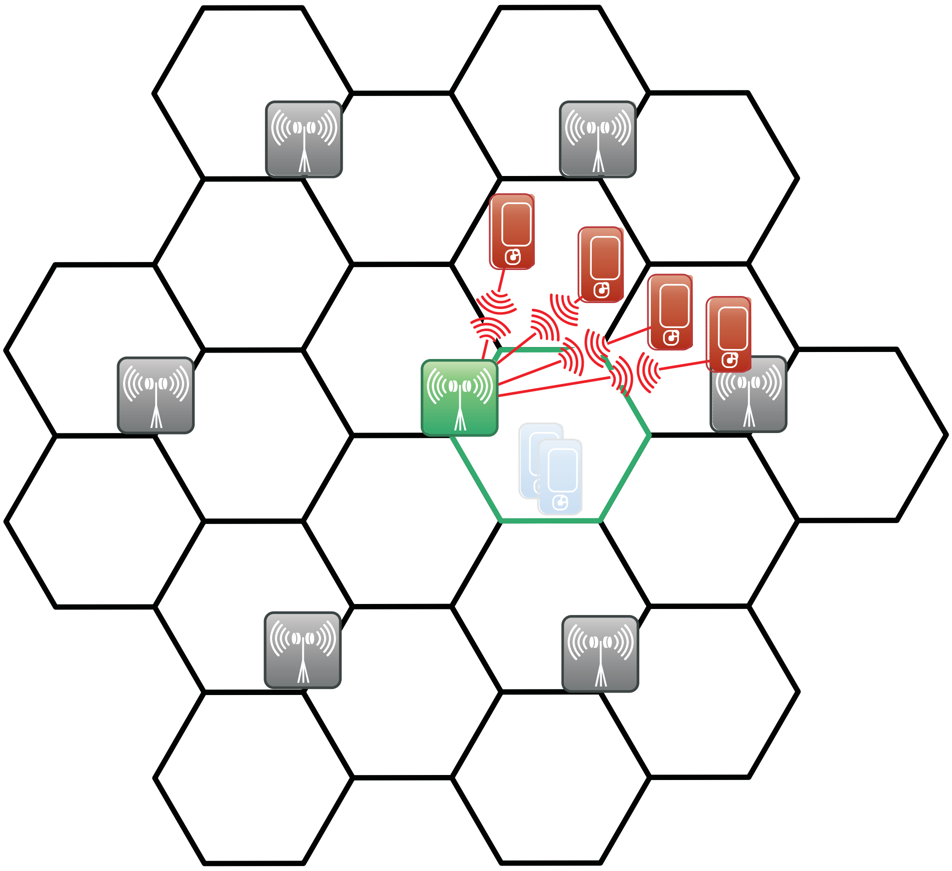


Figure 24 Uplink inter-cell interference



The downlink interference margin can be obtained using analytical methods as presented in the following section, while the uplink interference margin values are usually taken from simulations as a result of the distribution of non-deterministic users.

Frequency reuse

The higher frequency reuse schemes are possible but the study shows there is no significant gain in network performance compared to the loss of available resources (peak data rate and capacity decrease).

For the purpose of initial coverage dimensioning, one should assume frequency reuse 1, meaning that all cells operate with the same spectrum.

4.9.2.1 Calculation of downlink interference margin

For the estimation of the DL interference margin one can assume constant power per subcarrier, which actually corresponds to the current product specification. Hence, the power received by a single mobile is given by the following expression:

$$S = \frac{P_{RB} \times N_{RB}^{used}}{L}$$

where:

S - power per user / per UE

P_{RB} - power per resource block

N_{RB}^{used} - number of resource blocks assigned to user

L - signal attenuation (path loss)

Since there is no need to consider intra-cell interference, I_{own} can be set to 0.

$$I_{own} = \frac{\eta \times P_{total} - P_{RB} \times N_{RB}^{used}}{L} \times (1 - \alpha) = 0$$

where:

η - cell load (the average amount of occupied frequency resources during the time of interest)

P_{total} - maximum total transmission power from eNodeB

α - orthogonality factor (1 stands for the case when the orthogonality is perfectly preserved, 0 means there is no orthogonality)

Although the above formula is valid for a WCDMA evaluation, it is used here, but one must remember its final outcome is to always be equal to 0 - no intra-cell interference in case of the OFDM-based air interface.

Interference power coming from another cell is given as follows (the result should be aggregated over all neighbor cells assuming corresponding *L* figures):

$$I_{oth} = \frac{P_{RB} \times N_{RB}^{used}}{L} \times \eta \times \frac{1}{G}$$

where

G - G-factor, corresponds to C/I ratio (the offset between the target signal level C and any interferences I affecting the transmission).

The value can be obtained from a system level simulation for a certain percentile of C/I distribution corresponding to the given location probability.

In this situation, the only part of channel bandwidth to be considered is the one on which the user receives data. The power coming from other cells needs to be multiplied by the factor η to take into account the load of interfering cells.

The Interference margin (IM) can be defined as a relation between signals received with interferences and without interferences. See the formula below:

$$IM = \frac{\frac{S}{N}}{\frac{S}{I}}$$

The following algorithms demonstrate the way of calculation the interference margin using presented formulas and their transformations:

$$IM = \frac{\frac{S}{N}}{\frac{S}{I_{own} + I_{oth} + N}} = \frac{S}{N} \times \frac{I_{own} + I_{oth} + N}{S}$$

$$\times\ IM \times \frac{N}{S} = \frac{I_{own} + I_{oth} + N}{S}$$

$$SINR = \frac{S}{1 + N} = \frac{S}{IM + N}$$

$$SINR = \frac{S}{I_{own} + I_{oth} + N}$$

$$N = \frac{S}{SINR} - I_{own} - I_{oth}$$

$$IM = \frac{I_{own} + I_{oth} + \frac{S}{SINR} - I_{own} - I_{oth}}{\frac{S}{SINR} - I_{own} - I_{oth}}$$

$$IM = \frac{\frac{S}{SINR}}{\frac{S}{SINR} - \left(\frac{\eta \cdot P_{total} - P_{RB} \cdot N_{RB}^{used}}{L}\right) \cdot (1-\alpha) - \frac{P_{RB} \cdot N_{RB}^{used}}{L} \cdot \eta \cdot \frac{1}{G}}$$

$$IM = \frac{\frac{S}{SINR}}{\frac{S}{SINR} - \left(\frac{\eta \cdot P_{total} \cdot S - P_{RB} \cdot N_{RB}^{used} \cdot S}{P_{RB} \cdot N_{RB}^{used}}\right) \cdot (1-\alpha) - S \cdot \eta \cdot \frac{1}{G}}$$

$$IM = \frac{\frac{1}{SINR}}{\frac{1}{SINR} - \left(\frac{\eta \cdot P_{total}}{P_{RB} \cdot N_{RB}^{used}} - 1\right) \cdot (1-\alpha) - \eta \cdot \frac{1}{G}}$$

$$IM = \frac{1}{1 - SINR\left(\frac{\eta \cdot P_{total}}{P_{RB} \cdot N_{RB}^{used}} - 1\right) \cdot (1-\alpha) - SINR \cdot \eta \cdot \frac{1}{G}}$$

Assuming subcarriers are fully orthogonal (α=1), the following equation is used for the link budget purpose:

$$IM = \frac{1}{1 - SINR \times \eta \times \frac{1}{G}}$$

$$IM = -10\log\left(1 - SINR \times \eta \times \frac{1}{G}\right)$$

Downlink Interference Margin

The interference margin for LTE is not exactly the same as the 3G-specific interference margin. The presented formula expresses the offset between:

- the required SINR value (determined by the selected MCS, the number of allocated PRBs, and the scheduling gain in case of DL),
- the C/I at the cell-edge (obtained from a system level simulation for the given cell-edge definition - location probability).

In addition, since the C/I depends on the neighbor cell interference, the result must be scaled due to the neighbor cell load. Whilst the location probability remains unchanged, the interference margin effectively depends on the neighbor cell load and the selected MCS. The higher the MCS, the higher margin is assumed. Therefore, the neighbor cell load of about 70%-90% is realistic only for low MCSs. The same network load cannot be achieved for higher MCSs (16QAM / 64QAM). Moreover, this tendency is consistent with the presented cell-edge dimensioning approach. It is unlikely that the network should operate with the highest MCSs at the cell boundary.

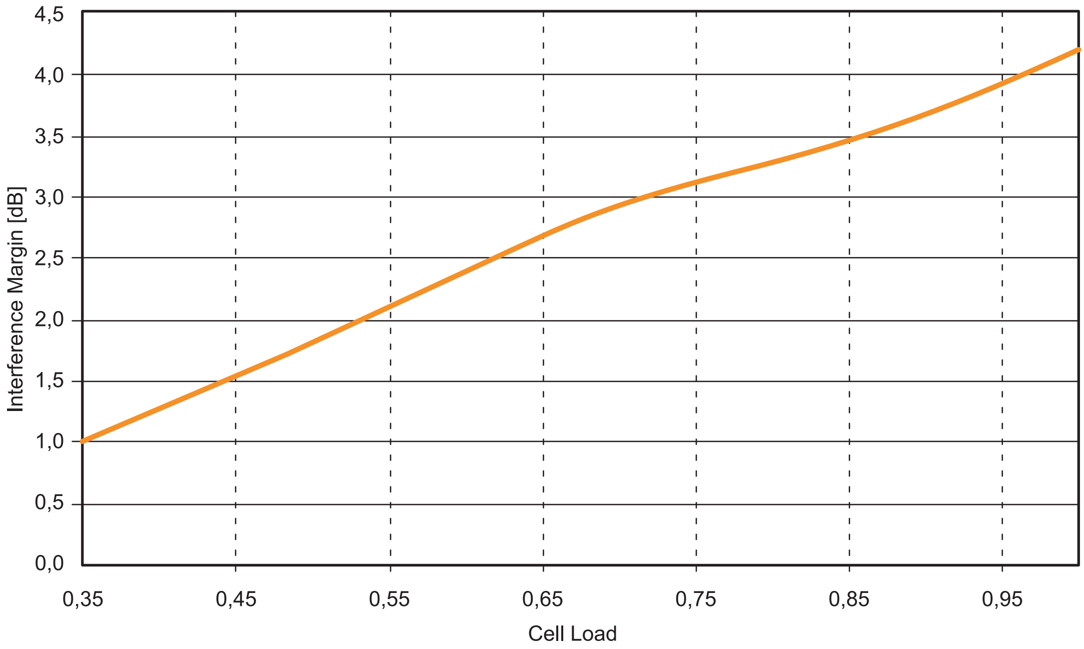
On the other hand, the cell load is used for capacity calculation. It determines the inter-cell interference impact and the average resource use in the target cell. Thus, higher interference levels and higher resource use are in direct correspondence with higher cell loads (which can improve the capacity at some point).

4.9.2.2 Uplink interference margin

According to the non-deterministic characteristic of uplink interference (in terms of interferer location) it would be very hard to make any mathematical model. Therefore, the values that are to be used in the link budget evaluation are usually obtained from the system-level simulations.

Figure 25: Interference Margin in a function of cell load presents example values simulated for an operating band of 2100 MHz and 10 MHz system channel.

Figure 25 Interference Margin in a function of cell load



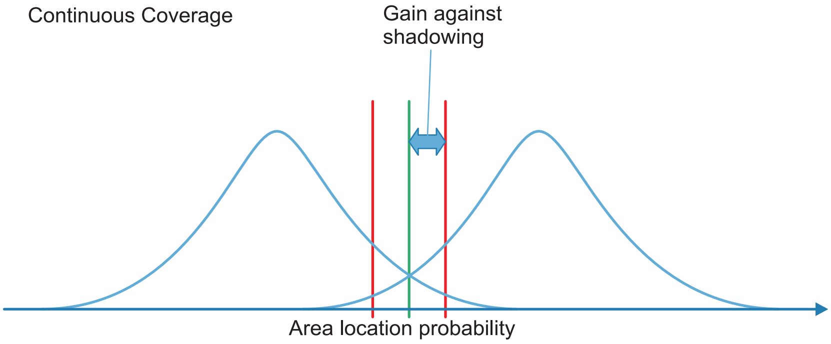
Uplink Interference Margin

The values for uplink interference margin can be obtained using the simulation results. In case of cell load lower than 35% one can use 1 dB by default.

4.9.3 Gain against shadowing

The gain is considered at the cell edge. It is sometimes called multi server gain. The traditional way of calculating the LNF assures a margin regarding single cell coverage. It is however recommended to account for multi cell coverage.

Figure 26 Multi cell coverage



The gain against shadowing reflects the possibility of switching to another cell available at a certain position. The computation is based on modified Jakes formula. The detailed explanation of the used algorithm can be found in *References* 5

4.10 Maximum allowable path loss

The Maximum Allowable Path Loss (MAPL) formula expresses the maximum allowable attenuation of the radio wave traversing the air interface. Together with the propagation model, it is used for cell range estimation. MAPL is usually presented in a logarithmic scale. The formula comprises all the gains and losses that can be experienced in the system. The formula is the same for DL and UL and is independent from the chosen operating band.

$$N = \left\lceil \frac{A}{A_{site}} \right\rceil$$

The symbol ⌈.⌉ stands for roundup operation

$$MAPL^{UL} = EIRP^{UL} - S^{eNB}_{Rx} - LNF - IM^{UL} + G^{eNB}_{antenna} + G^{UL}_{shad} - L^{eNB}_{feeder} - L_{pen}$$

where:

MAPL - maximum allowable path loss

EIRP - equivalent isotropic radiated power

S_{Rx} - receiver sensitivity

LNF - log normal fading margin

IM - interference margin

$G_{antenna}$ - antenna gain

G_{shad} - gain against shadowing

L_{pen} - penetration loss

L_{feeder} - feeder loss

L_{body} - body loss

4.10.1 Equivalent isotropic radiated power

EIRP stands for the power that would be radiated by a theoretical isotropic antenna to achieve the peak power density observed in the direction of maximum antenna gain. The power radiated by a directional antenna is transposed into radiated power of an isotropic antenna by consideration of antenna gain and power at the antenna input.

$$EIRP^{DL} = P^{eNB}_{Tx} + G^{eNB}_{antenna} - L^{eNB}_{feeder}$$

$$EIRP^{UL} = P^{UE}_{Tx} + G^{UE}_{antenna} - L_{body}$$

where:

P_{Tx} - total transmission power

$G_{antenna}$ - antenna gain

L_{feeder} - feeder loss

L_{body} - body loss

4.10.2 Receiver sensitivity

The receiver sensitivity denotes the minimum signal level which can still be successfully received. This level refers to the antenna connector and should take into account the further demodulation and the required output signal quality. Generally, it is a function of SINR, a receiver noise figure and a channel bandwidth as presented in the formula below.

$$S_{Rx} = N^{sub}_{T} + SINR + f_{noise} + N_{RB}$$

where:

N_T^{sub} - thermal noise power per subcarrier (corresponding to 15 kHz bandwidth in case of standard subcarrier spacing)

SINR - signal to interference and noise ratio

f_{noise} - receiver noise figure

N_{RB} - number of resource blocks

4.10.2.1 Thermal noise power

The calculation for the thermal noise power is given by the following equation:

$$N_T = k \cdot T \cdot B$$

where:

N_T - thermal noise power

T - Temperature [Kelvin]

k - Bolzmann constant

B - Bandwidth

The thermal noise power is calculated as the thermal noise power per subcarrier multiplied by the number of resource blocks. However, the bandwidth of a resource block is not 15 kHz as a resource block consists of 12 subcarriers. Therefore for a correct calculation of the receiver sensitivity the factor - subcarriers per resource block (which is 12(as factor) or 10.8dB) must be added.

Since the transmission channel is composed of more than only one subcarrier it is necessary to determine the number of resource blocks for the reception - N_{RB}. It is equal to the total number of resource blocks in the available system bandwidth in case of downlink OFDMA transmission, whereas for uplink SC-FDMA transmission it should be equal to the number of resource blocks used by users.

The lower sensitivity limit is the thermal noise power spectral density and it is a noise level below which it is impossible to separate the target transmission. It is based on the Boltzman constant *k* and the conductor temperature *T* as presented below.

$$N_T = k \cdot T = 1,38E-23\frac{J}{K} \cdot 293K = 4,04E-21J$$

Using the logarithmic scale in relation to 1 Hz is as follows.

$$10\log\left(\frac{N_T}{0,\ 001}\right) \cong -174\frac{dBm}{Hz}$$

If the thermal noise spectral density is known, it is easy to obtain the thermal noise power at the receiver with respect to a single subcarrier bandwidth of 15 kHz.

$$N_T^{sub} = N_T + 15kHz$$

4.10.2.2 Required SINR

Signal to Interference and Noise Ratio (SINR) is the power ratio of useful signal to total interference coming from neighboring cells plus thermal noise. From the point of link budget evaluation, SINR values are considered as the targets for which the transmission using a certain MCS can still be accomplished with a predefined quality (BLER). This target SINR value in dependency of the MCS is also called ”required SINR”.

4.11 Clutter types and simulation cases

Radio wave propagation (for example multipath effect, attenuation) varies considerably among different clutter environments. In other words, to suitably consider different propagation factors such as building density, street structure, and obstacles characteristic, it is required to use different, correspondingly adapted modeling methods. The propagation model formulas consider the differences in the radio attenuation behavior of different clutter types by clutter-type-specific correction terms, and coverage reliability related parameters (that is standard deviation, cell area probability etc.). For the link budget calculation, it is recommended to consider the following clutter types:

- Urban - this environment consists of large buildings, offices, shops, etc. It is characterized by the mean street density with no specific pattern. The major streets should be visible on satellite maps. The built-up obstacles should appear distinct from each other. Some small vegetation can be included. The average height of buildings is below 40m.
- Dense-urban - this environment represents the part of urban environment with dense building deployment. The obstacles do not appear distinct from each other. Heights of buildings can be above 40m.
- Suburban - this environment represents wide-ranging housing areas, which includes some vegetation, mostly found at the border of urban areas, spreading outwards from the city centers. The average height of buildings is below 15 m.
- Rural - this environment represents areas without buildings but with water, trees, etc.

The input parameters which depend on the chosen clutter type are listed in .

4.12 Propagation models

The propagation model should be adjusted to the environment in which the sites will be built up. This means that propagation measurements and tuning of the model are recommended for real network deployment. However, for the dimensioning phase standard models can be used by default (this section is dedicated to outdoor propagation models only - for indoor specific ones please refer to indoor dimensioning annex.

The COST 231 Hata Model with some additional modifications is used for cell range estimation in all offered frequency bands. The default propagation model for Macro cells is the so-called “one-slope” model, which is applicable to cells whose range is larger than 1 km. For small cells, the so-called “two-slope” model should be taken into account. In small cells, antenna height is slightly below or at the mean roof top level, therefore the path loss depends mainly on diffraction and scattering at the rooftops. A small cell typically has a range from 100 m up to about 2 km.

4.12.1 One-slope model

The “one-slope” model can be used for both large and small cells where the base station antenna height is above the rooftop level of buildings adjacent to the base station. The path loss *L* (given in dB) depends on the distance *d* between the base station antenna and the mobile station, the carrier frequency *f*, the heights of the base station antenna h_{eNB} and the mobile station h_{UE}, and the clutter type. The formulas below are valid for the following ranges of the parameters:

- Frequency *f*: 150-2000 MHz*
- Base station height h_{eNB}: 30-200 m
- Mobile height h_{UE}: 1-10 m
- Distance *d*: 1-20 km

* same model is used for frequency higher than 2 GHz (i.e. 2.1 and 2.6 GHz band)

The path loss formula is as follows:

$$L = A + B \cdot \log\left(\frac{f}{MHz}\right) - 13.82 \cdot \log\left(\frac{h_{eNB}}{m}\right) - a \cdot \left(\frac{h_{UE}}{m}\right) + s \cdot \log\left(\frac{d}{km}\right) + L_{clutter}$$

$$s = 44.9 - 6.55 \cdot \log\left(\frac{h_{eNB}}{m}\right)$$

Table 32 Frequency related path loss coefficients

Frequency	A	*B*
150-1500 MHz	69.55	26.16
1500-2000 MHz	46.30	33.90

Table 33 UE height correction factors

Clutter type	$a \cdot \left(\frac{h_{UE}}{m}\right)$
Dense urban	$3{,}\ 2 \cdot \log^2\left(11{,}\ 75 \cdot \frac{h_{UE}}{m}\right) - (4{,}\ 97)$
Urban	
Suburban	$\frac{h_{UE}}{m}\left(1{,}\ 1 \cdot \log\left(\frac{f}{MHz}\right) - 0{,}\ 7\right) - \left(1{,}\ 56 \cdot \log\left(\frac{f}{MHz}\right) - 0{,}\ 8\right)$
Rural	

Table 34 Clutter type correction factors

Clutter type	$L_{clutter}$
Dense urban	3
Urban	0
Suburban	$-2 \cdot \log^2\left(\frac{f}{28MHz}\right) - 5{,}\ 4$
Rural	$-4{,}\ 78 \cdot \log^2\left(\frac{f}{28MHz}\right) + 18{,}\ 33 \cdot \log\left(\frac{f}{MHz}\right) - 40{,}\ 94$

4.12.2 Two-slope model

The general “two-slope” path loss model is a straightforward extension of the “one-slope” model. The path loss formula (L) introduced in the preceding section still holds, but the slope parameter s is redefined to cover all possible distances d in the following way.

$$s = \begin{cases} 44.9 - 6.55 \cdot \log\left(\frac{h_{eNB}}{m}\right) & d \geq 1km \\ \left(47.88 + 13.9 \cdot \log\left(\frac{f}{MHz}\right) - 13.82 \cdot \log\left(\frac{h_{BS}}{m}\right)\right) \cdot \frac{1}{\log 50} & d < 1km \end{cases}$$

Note: If the calculated cell range is higher than 1 km, the “two-slope” model acts exactly in the same way as the “one-slope” model (note that there is the same slope s formula for d>=1km for both “one-slope” and “two-slope” models). It is, however, not recommended to the “one-slope” model if we expect a cell range lower than 1 km (especially in case of dense urban and urban environment).

4.12.3 Cell range estimation

Cell range *d* is calculated by solving the propagation equation for the maximum allowable path loss *MAPL*.

$$\mathrm{MAPL} = L(d)$$

4.12.4 UL and DL balancing

Several implementation and equipment aspects may cause link imbalance in an LTE system. Such a situation is very unfavorable since the network plan is made with respect to the weakest link.

Several solutions can be applied to diminish the described effect. One of the most commonly used is an insertion of a tower mounted amplifier (TMA), which allows to compensates the feeder loss in uplink. Furthermore, the deployment of a remote radio head (RRH) minimizes feeder loss in downlink.

It must be noted that there is a huge impact of the number of resource blocks assigned to users in case of uplink, for example the narrower bandwidth is, the greater coverage can be served, according to lower noise power at the receiver side.

4.13 Radio network configuration

The cell range obtained from the link budget evaluation is an input parameter to radio network configuration establishment (cell area, site-to-site distance, etc.)

Calculations depend on the selected cell layout. A traditional hexagonal cloverleaf cell model is usually applied. In general, sectorization improves the coverage performance when compared to omni-directional cells. The main reason is a significant gain of directional antennas and lower interference level in case of such a network layout.

In fact, many factors have to be considered when deciding on the cell pattern:

- Traffic density in the area to be covered
- Available frequency band and possibility to apply particular frequency reuse schemes
- Required coverage and structure of the area to be covered: urban area, road, etc.
- Costs and possibilities of sites installation
- Expected network development path

The number of sites *N* (each of area A_{site}) required to cover certain area *A* is as follows:

$$N = \left\lceil \frac{A}{A_{site}} \right\rceil$$

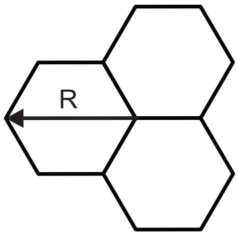
The symbol $\lceil . \rceil$ stands for roundup operation

4.13.1 Cell Area, Site Area and Site-to-Site Distance

The way the cell area is calculated depends on the chosen cell type.

For three-sector sites with a main antenna beam of less than 90°, hexagonal cells are assumed (see Figure 28: Cell Range and site to site distance for hexagonal cells).

Figure 27 Hexagonal three-sector site



In this case, the cell area A_{cell} is calculated as follows.

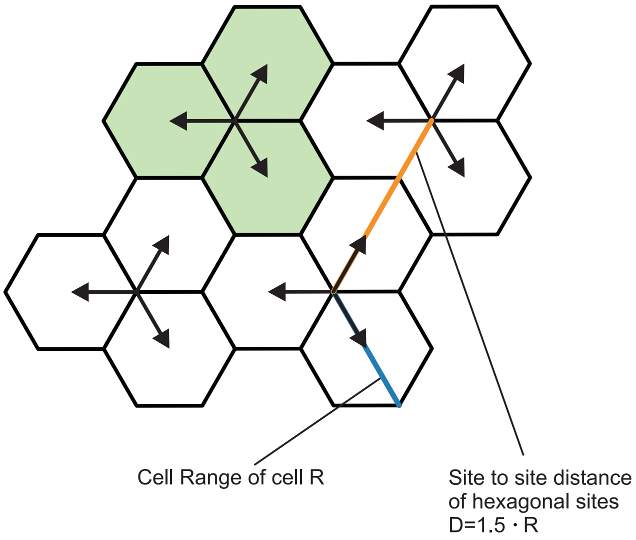
$$A_{cell} = \frac{3\sqrt{3}}{8} \cdot R^2$$

R stands for the cell range *d*. A site-to-site distance is given by the following formula.

$$D = 1,5 \cdot R$$

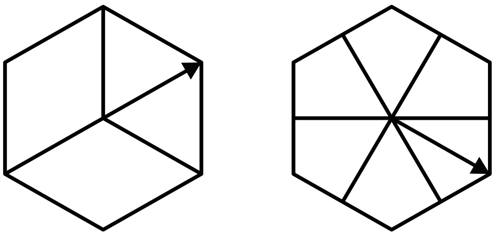
A site-to-site distance is depicted in Figure 29: Three-sector and six-sector rhomboidal cell layout.

Figure 28 Cell Range and site to site distance for hexagonal cells



This approach is used for three sector sites as well as two sector sites along the road. Another option of three sector sites is a rhomboidal cell layout for which the main antenna beam width is more than 90° (120° is usually assumed). Rhomboidal cell shape is also used for omni-directional sites and six sector sites (see Figure 29: Three-sector and six-sector rhomboidal cell layout).

Figure 29 Three-sector and six-sector rhomboidal cell layout



In this case, the cell area A_{cell} is calculated as follows:

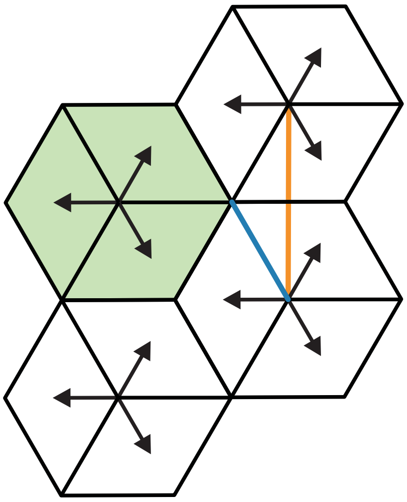
$$A_{cell} = \frac{3\sqrt{3}R^2}{S}$$

R is a cell range whereas *S* indicates the number of sectors per site.

A site-to-site distance is calculated using the following formula, illustrated below in Figure 30: Cell Range and site to site distance of rhomboidal cells.

$$D = 2R\cos(30°)$$

Figure 30 Cell Range and site to site distance of rhomboidal cells



Cell Range of cell: R

The site area is then the number of sectors (cells) per site *S* times the cell area.

$$A_{site} = A_{cell} \cdot S$$

The number of eNBs required to cover the given area can be easily calculated with the following equation:

$$N_{eNB} = \left\lceil \frac{A}{A_{cell} \cdot S} \right\rceil$$

The formulas presented in this section may be used to create general equations for site-to-site distance and site area calculation. The formulas should look as follows.

$$D = R \cdot l$$

$$A_{site} = R^2 \cdot k$$

The values of *l* and *k* coefficients depend on the used cell layout as presented in Table 35: Clutter type correction factors.

Table 35 Clutter type correction factors

Cell layout	**k**	**l**
Omni	2.6	1.73
3-sector antenna_BW<=90	1.95	1.50
3-sector antenna_BW>90	2.6	1.73
6-sector	2.6	1.73

5 Data and VoIP dimensioning

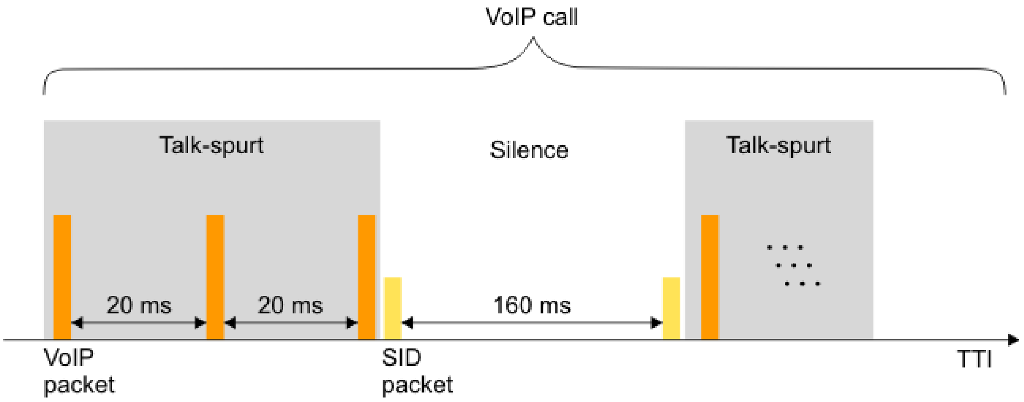
5.1 Data Dimensioning

Although even for data one could assume HARQ gain, it is not recommended since 10% BLER is a common design criterion also for UMTS networks. Besides, the default O&M setting defines the target for Link Adaptation as 10% BLER after the initial transmission.

5.2 VoIP dimensioning

Voice over Internet Protocol (VoIP) is a general term used for a family of transmission technologies of voice in IP networks. VoIP traffic is characterized by a regular traffic pattern and relatively low bitrate. It generates small packets of data which are transmitted in an almost synchronous way (see Figure below) and with strict requirements on latency, delay and jitter.

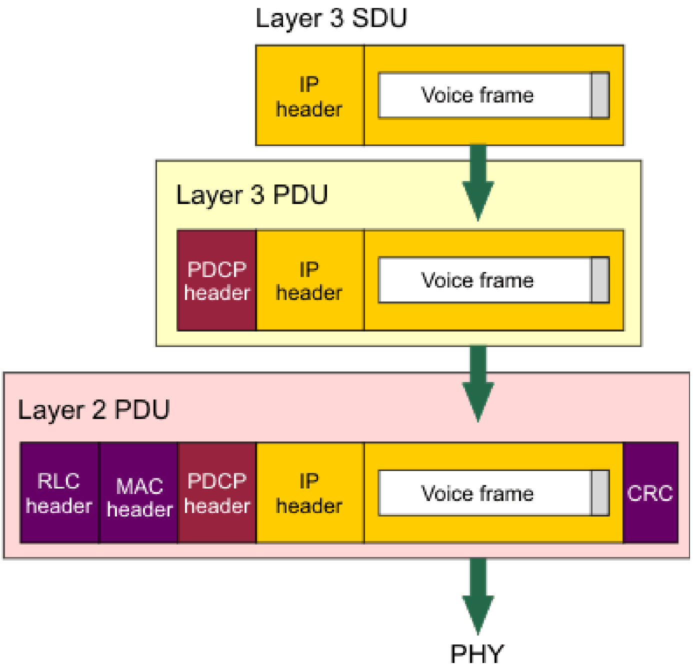
Figure 31 Example of typical VoIP traffic pattern



5.2.1 LTE10: EPS bearer for Conversational Voice

The figure below illustrates the encapsulation process of VoIP packets in LTE radio interface protocol stack. Talk spurts are separated by SID packets (Silence Insertion Descriptor), but the link budget is done only for the "real" VoIP packets (talk spurts).

Figure 32 VoIP layer 4 PDU transformations



Whenever “Service Type” is set to “AMR-NB XX” the above process is a basis for the overhead and overall packet size calculation in RNT_LTE_Dim tool (see "VoIP" sheet). The last one is automatically exported to "Link Budget" sheet to feed "Cell Edge User Throughput" requirement. The relations between different VoIP codecs and the corresponding Layer 1 SDU size is shown in the following tables.

Table 36 Various AMR-NB codecs (1)

Arrival time (ms): 20 **No. of L2 segments: 1**						
	Codec source rate (kbps)	**Frame size (bits)**	**Padding (bits)**	**PDCP header (bits)**	**L2 SDU (bits)**	**RLC header (bits)**
AMR-NB 1.8	1.8	36	4	40	80	8
AMR-NB 4.75	4.75	95	1	40	136	8
AMR-NB 5.15	5.15	103	1	40	144	8
AMR-NB 5.9	5.9	118	2	40	160	8
AMR-NB 6.7	6.75	134	2	40	176	8
AMR-NB 7.4	7.4	148	4	40	192	8
AMR-NB 7.95	7.95	159	1	40	200	8
AMR-NB 10.2	10.2	204	4	40	248	8
AMR-NB 12.2	12.2	244	4	40	288	8

Table 37 Various AMR-NB codecs (2)

Arrival time (ms): 20 **No. of L2 segments: 1**					
	MAC header (bits)	**CRC (bits)**	**Segment size (bits)**	**L1 SDU (bits)**	**Segmentation Ov.**
AMR-NB 1.8	8	24	120	120	0.00%
AMR-NB 4.75	8	24	176	176	0.00%
AMR-NB 5.15	8	24	184	184	0.00%
AMR-NB 5.9	8	24	200	200	0.00%
AMR-NB 6.7	8	24	216	216	0.00%
AMR-NB 7.4	8	24	232	232	0.00%

Table 37 Various AMR-NB codecs (2) (Cont.)

Arrival time (ms): 20

No. of L2 segments: 1

	MAC header (bits)	**CRC (bits)**	**Segment size (bits)**	**L1 SDU (bits)**	**Segmentation Ov.**
AMR-NB 7.95	8	24	240	240	0.00%
AMR-NB 10.2	8	24	288	288	0.00%
AMR-NB 12.2	8	24	328	328	0.00%

Table 38 Various AMR-WB codecs (1)

Arrival time (ms): 20 **No. of L2 segments: 1**						
	Codec source rate (kbps)	**Frame size (bits)**	**Padding (bits)**	**PDCP header (bits)**	**L2 SDU (bits)**	**RLC header (bits)**
AMR-WB 1.75	1.75	35	5	40	80	8
AMR-WB 6.6	6.6	132	4	40	176	8
AMR-WB 8.85	8.85	177	7	40	224	8
AMR-WB 12.65	12.65	253	3	40	296	8
AMR-WB 14.25	14.25	285	3	40	328	8
AMR-WB 15.85	15.85	317	3	40	360	8
AMR-WB 18.25	18.25	365	3	40	408	8
AMR-WB 19.85	19.85	397	3	40	440	8
AMR-WB 23.85	23.85	477	3	40	520	8

Table 39 Various AMR-WB codecs (2)

Arrival time (ms): 20 **No. of L2 segments: 1**					
	MAC header (bits)	**CRC (bits)**	**Segment size (bits)**	**L1 SDU (bits)**	**Segmentation Ov.**
AMR-WB 1.75	8	24	120	120	0.00%
AMR-WB 6.6	8	24	216	216	0.00%
AMR-WB 8.85	8	24	264	264	0.00%
AMR-WB 12.65	8	24	336	336	0.00%
AMR-WB 14.25	8	24	368	368	0.00%
AMR-WB 15.85	8	24	400	400	0.00%

Table 39 Various AMR-WB codecs (2) (Cont.)

Arrival time (ms): 20 **No. of L2 segments: 1**					
	MAC header (bits)	**CRC (bits)**	**Segment size (bits)**	**L1 SDU (bits)**	**Segmentation Ov.**
AMR-WB 18.25	8	24	448	448	0.00%
AMR-WB 19.85	8	24	480	480	0.00%
AMR-WB 23.85	8	24	560	560	0.00%

Once the "Cell Edge User Throughput" for VoIP has been set, the dimensioning must be performed using the same approach as for data service:

- Switching TTI bundling off
- Setting 10% BLER at first transmission as the dimensioning target

5.2.2 LTE11: Robust Header Compression

RoHC (Robust Header Compression) is the technique used to compress the RTP/UDP/IP headers. This is especially beneficial when the RTP/UDP/IP bytes occupy most of the packet size causing huge overhead. A typical example is Voice transmission which is usually characterized by small payload size (for example AMR12.2). Due to the fact that the RTP/UDP/IP structure is rather predictable in the course of transmission it is possible to compress it efficiently. Therefore, it results in a higher number of simultaneously served subscribers.

Most IPv4 headers can be compressed to 5 Byte. Comparing the RoHC header size with a standard IPv4 header of 40 Byte, it is definitely the difference which must be considered in dimensioning when calculating the required throughput of the air interface.

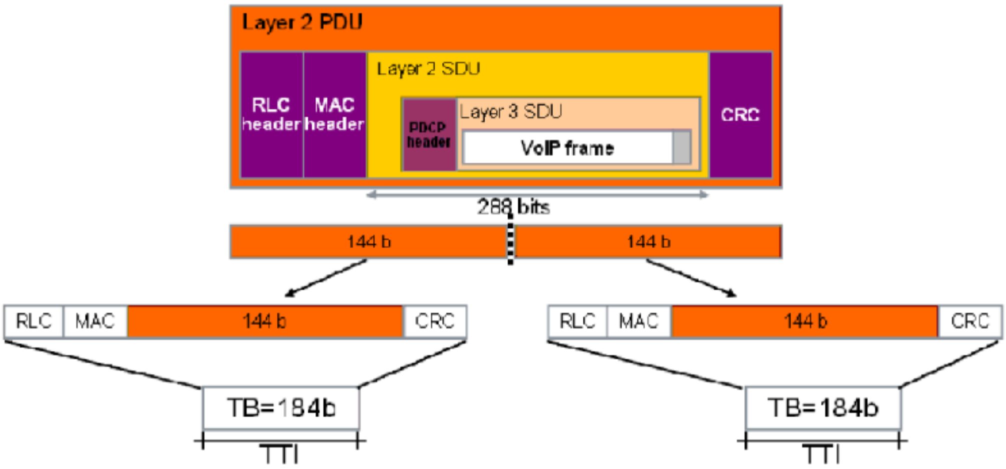
The following RoHC profiles are supported in RL20:

- 0x0000 RoHC uncompressed (RFC 4995)
- 0x0001 RoHC RTP (RFC 3095, RFC4815)
- 0x0002 RoHC UDP (RFC 3095, RFC4815)
- 0x0004 RoHC IP (RFC 3843, RFC4815)

5.2.3 LTE571: Controlled UL packet segmentation

Controlled UL packet segmentation is a technique that allows to divide single packet into segments on Layer 2. Each segment is wrapped with RLC/MAC header and CRC check sum and is transmitted in a separate Transport Block which is smaller than the original one (without segmentation). The mechanism is shown in the figure below .

Figure 33 Layer 2 packet segmentation



As a result ,more robust MCS can be used and therefore the coverage is increased. Obviously, the coverage gain is achieved at the cost of capacity. Excessive overhead coming from RLC/MAC/CRC consumes additional bandwidth and energy so less user data can be transmitted (fewer simultaneous users). Coverage-capacity trade-off by means of overhead increase in the function of number of segments for different voice codecs is shown in the following tables.

Table 40 AMR-NB: L2 segmentation for different VoIP codecs (1)

Voice Codec	**RLC/MAC/ CRC size (bits)**	**1 segment (no segmentation)**			**2 segments**		
		Segm. size (bits)	**L1 SDU (bits)**	**Segm. Over-head**	**Segm. size (bits)**	**L1 SDU (bits)**	**Segm. Over-head**
AMR-NB 1.8	40	120	120	0.00%	80	160	33.33%
AMR-NB 4.75	40	176	176	0.00%	112	224	22.73%
AMR-NB 5.15	40	184	184	0.00%	112	224	21.74%
AMR-NB 5.9	40	200	200	0.00%	120	240	20.00%
AMR-NB 6.7	40	216	216	0.00%	128	256	18.52%
AMR-NB 7.4	40	232	232	0.00%	136	272	17.24%
AMR-NB 7.95	40	240	240	0.00%	144	288	16.67%
AMR-NB 10.2	40	288	288	0.00%	168	336	13.89%
AMR-NB 12.2	40	328	328	0.00%	184	368	12.20%

Table 41 AMR-NB: L2 segmentation for different VoIP codecs (2)

Voice Codec	**RLC/MAC/CRC size (bits)**	**4 segments**			**8 segments**		
		Segm. size (bits)	**L1 SDU (bits)**	**Segm. Over-head**	**Segm. size (bits)**	**L1 SDU (bits)**	**Segm. Over-head**
AMR-NB 1.8	40	64	256	100.00%	56	448	233.33%
AMR-NB 4.75	40	80	320	68.18%	64	512	159.09%
AMR-NB 5.15	40	80	320	65.22%	64	512	152.17%
AMR-NB 5.9	40	80	320	60.00%	64	512	140.00%
AMR-NB 6.7	40	88	352	55.56%	64	512	129.63%
AMR-NB 7.4	40	88	352	51.72%	64	512	120.69%

Table 41 AMR-NB: L2 segmentation for different VoIP codecs (2) (Cont.)

Voice Codec	**RLC/MAC/CRC size (bits)**	**4 segments**			**8 segments**		
		Segm. size (bits)	**L1 SDU (bits)**	**Segm. Over-head**	**Segm. size (bits)**	**L1 SDU (bits)**	**Segm. Over-head**
AMR-NB 7.95	40	96	384	50.00%	72	576	116.67%
AMR-NB 10.2	40	104	416	41.67%	72	576	97.22%
AMR-NB 12.2	40	112	448	36.59%	80	640	85.37%

Table 42 AMR-WB: L2 segmentation for different VoIP codecs (1)

Voice Codec	**RLC/MAC/ CRC size (bits)**	**1 segment (no segmentation)**			**2 segments**		
		Segm. size (bits)	**L1 SDU (bits)**	**Segm. Over-head**	**Segm. size (bits)**	**L1 SDU (bits)**	**Segm. Over-head**
AMR-WB 1.75	40	120	120	0.00%	80	160	33.33%
AMR-WB 6.6	40	216	216	0.00%	128	256	18.52%
AMR-WB 8.85	40	264	264	0.00%	152	304	15.15%
AMR-WB 12.65	40	336	336	0.00%	192	384	11.90%
AMR-WB 14.25	40	368	368	0.00%	208	416	10.87%
AMR-WB 15.85	40	400	400	0.00%	224	448	10.00%
AMR-WB 18.25	40	448	448	0.00%	248	496	8.93%
AMR-WB 19.85	40	480	480	0.00%	264	528	8.33%
AMR-WB 23.85	40	560	560	0.00%	304	608	7.14%

Table 43 AMR-WB: L2 segmentation for different VoIP codecs (2)

Voice Codec	**RLC/MAC/CRC size (bits)**	**4 segments (no segmentation)**			**8 segments**		
		Segm. size (bits)	**L1 SDU (bits)**	**Segm. Over-head**	**Segm. size (bits)**	**L1 SDU (bits)**	**Segm. Over-head**
AMR-WB 1.75	40	64	256	100.00%	56	448	233.33%
AMR-WB 6.6	40	88	352	55.56%	64	512	129.63%
AMR-WB 8.85	40	96	384	45.45%	72	576	106.06%
AMR-WB 12.65	40	120	480	35.71%	80	640	83.33%
AMR-WB 14.25	40	128	512	32.61%	88	704	76.09%
AMR-WB 15.85	40	136	544	30.00%	88	704	70.00%

Table 43 AMR-WB: L2 segmentation for different VoIP codecs (2) (Cont.)

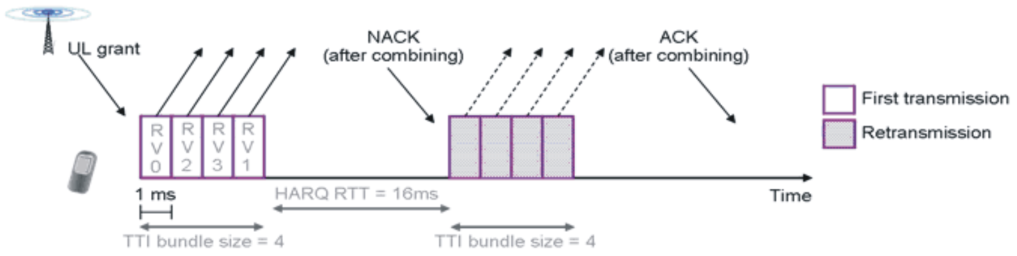
Voice Codec	**RLC/MAC/CRC size (bits)**	**4 segments (no segmentation)**			**8 segments**		
		Segm. size (bits)	**L1 SDU (bits)**	**Segm. Over-head**	**Segm. size (bits)**	**L1 SDU (bits)**	**Segm. Over-head**
AMR-WB 18.25	40	144	576	26.79%	96	768	62.50%
AMR-WB 19.85	40	152	608	25.00%	96	768	58.33%
AMR-WB 23.85	40	176	704	21.43%	112	896	50.00%

The number of segments whose packets are split is not configured configured at eNB in an explicit manner. Instead, there are two O&M parameters with which it is possible to implicitly configure packet segmentation. These are the minimum size of a Transport Block and the minimum number of PRBs per user. Simulations prove that minimal Transport Block size of 104 bits provides best results in terms of cell capacity. The Minimum number of PRBs restricts usage of high order MCSs (segmentation for good channel UEs does not introduce any gains, only losses on capacity).

5.2.4 LTE907: TTI Bundling

The purpose of TTI bundling feature is to extend uplink coverage for low data rate services such as VoIP. TTI bundling imitates 4ms TTI for a transmission of a single not segmented transport block. Consequently the energy-per-transmitted-bit is increased and eventually leads to higher decoding probability. In practice, UE spreads the transport block over four consecutive pre-scheduled TTIs (by using rate matching functionality). Each transmission occurs with a different redundancy version, allowing more effective combining at the eNB. Only after the reception of all four retransmissions does the eNB send one joint HARQ feedback for the whole bundle to the UE. In case the bundle is not received correctly, its retransmission is requested. An example of TTI bundling application has been presented in the figure below.

Figure 34 TTI bundling



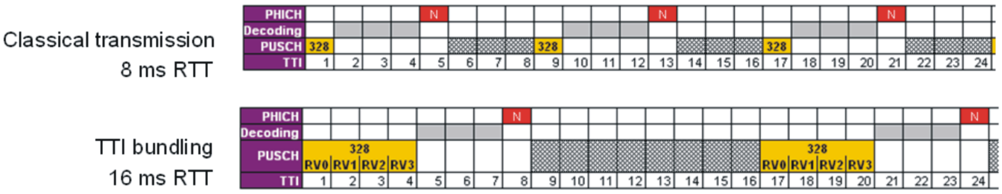
Apart from many pros of TTI bundling, there are also some disadvantages which have to be considered, for example decreased capacity in terms of the number of simultaneously supported VoIP users is a natural consequence of extending the effective transmission time of a single packet and a need to perform RRC connection reconfiguration prior to its activation/deactivation.

Before TTI bundling gain is evaluated, it is necessary to check how much energy (alternatively number of TTIs) can be collected within the assumed service delay budget ('delay budget' in this case is the maximum allowed air interface delay). One can consider 50ms delay budget for VoIP at the air interface which is an acceptable value while taking into consideration voice service requirements (less than 200-250ms end-to-end delay) and very good performance of LTE/SAE network elements/segments in this aspect.

Two cases are considered, one for a classical transmission and the second one using TTI bundling (bundle size of 4 TTIs).

- In case of classical transmission with 8 ms HARQ RTT, within 50 ms delay budget the eNB can accumulate the energy from 7 TTIs.
- With 4 TTI bundle and 16 ms HARQ RTT, within 50 ms delay budget the eNB can accumulate energy from 12 TTIs (3 bundles x 4 TTIs = 12 TTIs).

Figure 35 Classical transmissions vs. TTI bundling



The gain of TTI bundling can be expressed as a ratio of the number of TTIs used for a transmission in both of these methods.

TTI bundling gain = 10*log(12/7) = 2.34

One additional a bundle transmission (53 delay budget) would lead to 3.6 dB gain compared to classical dimensioning with 8 ms HARQ RTT.

Since bundle consists of HARQ (re)transmissions, it is not strictly required to keep the same dimensioning target BLER as for classical transmission (10% BLER at the 1st transmission). Adapting the BLER target to 1% or 2% BLER after the 4th transmission should be an acceptable move to gain even more from exploiting HARQ together with energy accumulation per packet.

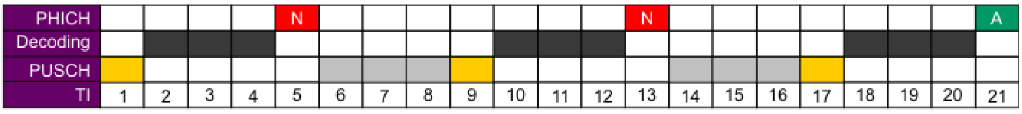
TTI bundling

TTI bundling is relevant only for UL and can be applied for every low-data rate service in order to improve its coverage. The use of TTI bundling is restricted to QPSK and #PRBs</=3 (only the transport blocks fulfilling this requirement can be transmitted using bundling technique).

5.3 HARQ- Hybrid Automatic Repeat Request

HARQ is an error detection and correction mechanism applied at Medium Access Control layer. It is based on parallel stop-and-wait processes which decide if and how erroneous data should be retransmitted. Basically there are 2 types of HARQ modes in DL: chase combining and incremental redundancy. Only the second one (IR) is supported and configured by default. In uplink, HARQ can work only in incremental redundancy mode. The use of chase combining means that the retransmissions have exactly the same rate matching parameters as the original transmission and thus exactly the same coded bits are transmitted. In the incremental redundancy mode retransmissions have different rate matching parameters and consequently they differ from the initial transmission. This diversity will be exploited to achieve higher combining gain.The first transmission of the transport block occurs at TTI #1. HARQ feedback occurs 4 ms later due to 3 ms time needed for its decoding at the base station. The retransmission comes 8 ms after the initial transmission. In this example, two retransmissions were required prior to successful packet decoding.

Figure 36 Transmission of transport block with HARQ



PHICH					N								N								A
Decoding		■	■	■						■	■	■						■	■	■	
PUSCH	🟨					▨	▨	▨	🟨					▨	▨	▨	🟨				
TI	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21

HARQ gain is achieved by combining the erroneous 1st transmission together with its forthcoming retransmissions. This gain is modeled in the RNT_LTE_Dim tool by means of the 4GMAX simulations' results which are available for every MCS, representative number of allocated PRBs and a residual BLER for a given number of retransmissions.

6 Site capacity

Cell throughput (cell capacity) figures need to be known to obtain the number of sites required to serve the expected traffic demand. In other words, during a dimensioning campaign, an estimated “cell capacity” figure needs to be calculated. This figure indicates which throughput volumes are to be typically supported in cells belonging to a certain environment type (dense urban, urban, suburban and rural). For the site count computation (capacity related), this “per cell throughput” capacity must then be compared to the overall expected traffic volume in the network (“offered traffic”). To be more precise, the expected overall traffic volume in the network is divided by the “per cell capacity” figure to calculate the number of cells required to serve the expected traffic volumes.

Overall cell throughput (average cell capacity)

Calculation of an average cell throughput is based on the method that uses Spectral Efficiency (SE) figures obtained from the dynamic system level simulator. The effects such as UE mobility, slow/fast fading, scheduling, Power Control, Admission Control, handovers, etc were taken into account during the simulation campaigns. The simulations were run for all available LTE channel bandwidths (1.4, 3, 5, 10, 15, 20 MHz). Four representative site grids (500, 1732, 3000, 9000 m) have been evaluated (both downlink and uplink directions with SIMO mode assuming 1 TX antenna and 2 RX antennas MRC). The impact of various channel bandwidth configurations (from 1.4MHz to 20MHz) has been also investigated.

Figure 37 Downlink spectral efficiency; 2.3 GHz, 3-sector hexagonal layout, 0.8W per PRB, 1TX at eNB, 2RX at UE (MRC), EPA05, NSN RRM specific scheduler, 10% BLER target, 10 UEs per sector (full buffer; 100% load), RF parameters according to [3GPP TR25.814]

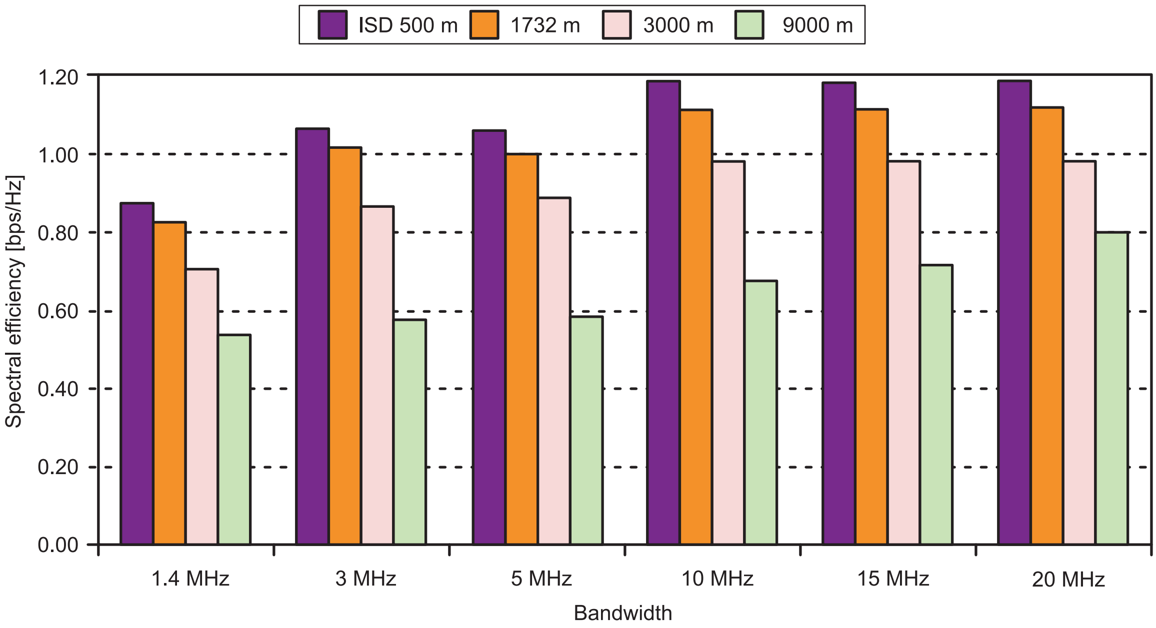
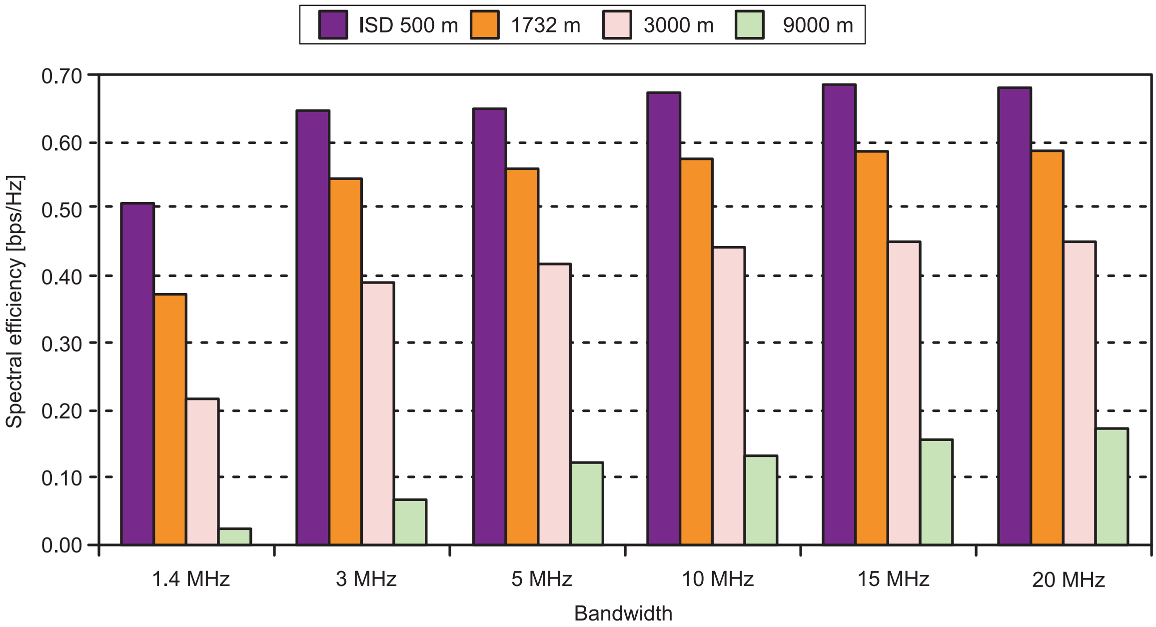


Figure 38 Uplink spectral efficiency; 2.3 GHz, 3-sector hexagonal layout, Open Loop Power Control with adjusted P0/alpha settings, 1TX at UE, 2RX at eNB (MRC), EPA05, NSN RRM specific scheduler, 10% BLER target, full buffer (100% load), RF parameters according to [3GPP TR25.814]



Note that the figures refer to SIMO mode, and the simulation setup focuses on realistic assumptions rather than on an idealized configuration. The best capacity performance can be achieved with wide channel bandwidths for which the maximum frequency diversity gain can be observed. Moreover, small bandwidth configurations (1.4 and 3 MHz) are characterized by a very high system overhead ratio. The effect of larger Inter Site Distance is clearly visible in the results; the SINR distribution is worse in large cells, which become more and more noise-limited. This impacts especially uplink performance when many UEs located at the cell edge are unable to meet the PC requirements for the transmit power.

When planning the network, one must confront the coverage against the overall cell throughput. The proposed approach is based on interpolation of spectral efficiency figures for the given ISD (the ISD is the output of link budget estimation) and the channel bandwidth. One can easily note that the approach has a certain limitation concerning the fact that the system level simulation setup is usually not fully aligned with planner's input. For this reason, additional scaling is needed to reflect the particular dimensioning case.

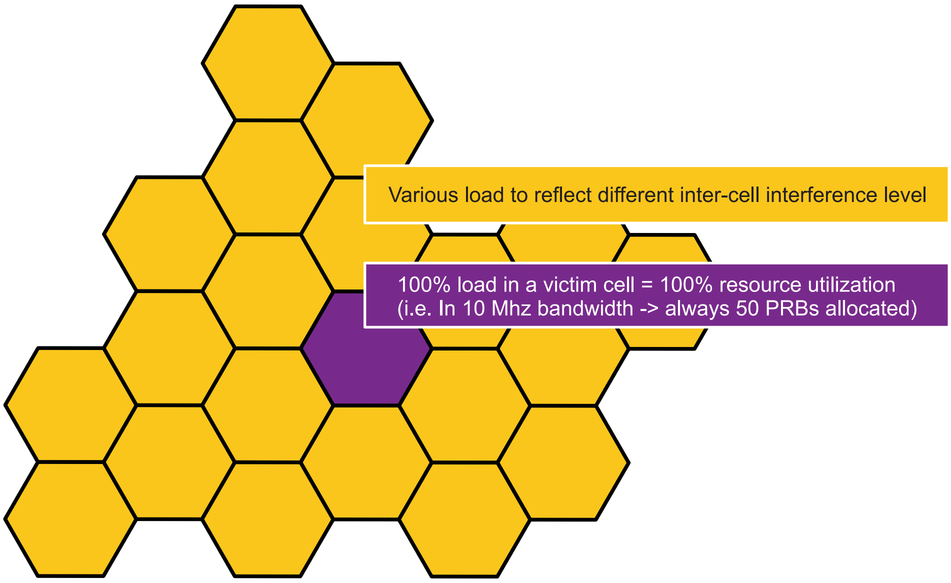
6.1 Cell load impact

An additional simulation campaign was dedicated to evaluate the cell load impact. The original values come from a 100% load scenario (see Figure 37: Downlink spectral efficiency; 2.3 GHz, 3-sector hexagonal layout, 0.8W per PRB, 1TX at eNB, 2RX at UE (MRC), EPA05, NSN RRM specific scheduler, 10% BLER target, 10 UEs per sector (full buffer; 100% load), RF parameters according to [3GPP TR25.814] and Figure 38: Uplink spectral efficiency; 2.3 GHz, 3-sector hexagonal layout, Open Loop Power Control with adjusted P0/alpha settings, 1TX at UE, 2RX at eNB (MRC), EPA05, NSN RRM specific scheduler, 10% BLER target, full buffer (100% load), RF parameters according to [3GPP

TR25.814]). It means all the cells are fully loaded with user traffic; this corresponds to 100% resource use (time/frequency domain). Since the link budget is usually performed for load<100%, the capacity method should reflect such a change.

The simulation setup is generally depicted in Figure 39: Simulation setup for load scaling factor. The center cell, which is fully loaded all the time, is the victim for which the overall cell throughput is measured. Surrounding cells impact the victim by inter-cell interference, which depends on the neighbor cell load.

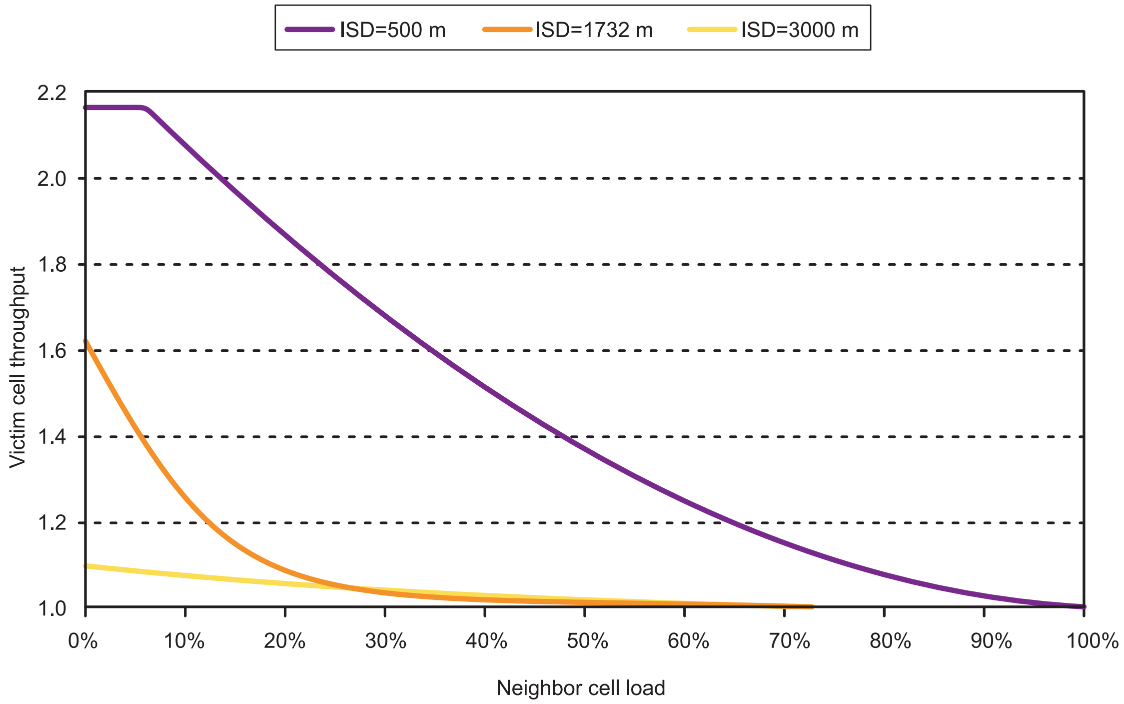
Figure 39 Simulation setup for load scaling factor



(Wrap-around layout)

Figure 40: Victim cell throughput in function of neighbor cell load shows the relation between the victim cell throughput and the neighbor cell load. The tendency proves the simulation reasonability; the most rapid impact has been observed for interference-limited scenario (ISD=500m corresponding to 3GPP Macro Case 1). Other grid configurations (ISD=1732m 3GPP Macro Case 3, ISD=3000m) are not so sensitive to other-cell interference. Note that the victim cell throughput has been normalized to 1, whereas the value of 1 means the capacity for 100% neighbor cell load. In other words, the value of 1 corresponds to spectral efficiency in Figure 37: Downlink spectral efficiency; 2.3 GHz, 3-sector hexagonal layout, 0.8W per PRB, 1TX at eNB, 2RX at UE (MRC), EPA05, NSN RRM specific scheduler, 10% BLER target, 10 UEs per sector (full buffer; 100% load), RF parameters according to [3GPP TR25.814] and Figure 38: Uplink spectral efficiency; 2.3 GHz, 3-sector hexagonal layout, Open Loop Power Control with adjusted P0/alpha settings, 1TX at UE, 2RX at eNB (MRC), EPA05, NSN RRM specific scheduler, 10% BLER target, full buffer (100% load), RF parameters according to [3GPP TR25.814].

Figure 40 Victim cell throughput in function of neighbor cell load



For the sake of simplicity, the curves for 2.1GHz are also applied for other carrier frequencies.

Capacity in dimensioning can be performed in two ways:

- Assuming victim cell always fully loaded (recommended) - the impact from neighbor cells (inter cell interference) is taken into account however the target cell throughput is not reduced according to load assumption. This means the capacity is dimensioned heterogeneously; victim (target) cell is always fully loaded using all available PRBs but the neighbors are using fewer.
- Assuming all cells with the same load - the impact from neighbor cells (inter cell interference) is taken into account and the target cell throughput is reduced according to load assumption. This means the capacity is dimensioned homogeneously; victim cell as well as all the neighbors are equally loaded (using same number of PRBs in average). This method reflects conservative dimensioning aligned with 3GPP recommendations for system level simulations, homogeneous load distribution which is not true for real networks.

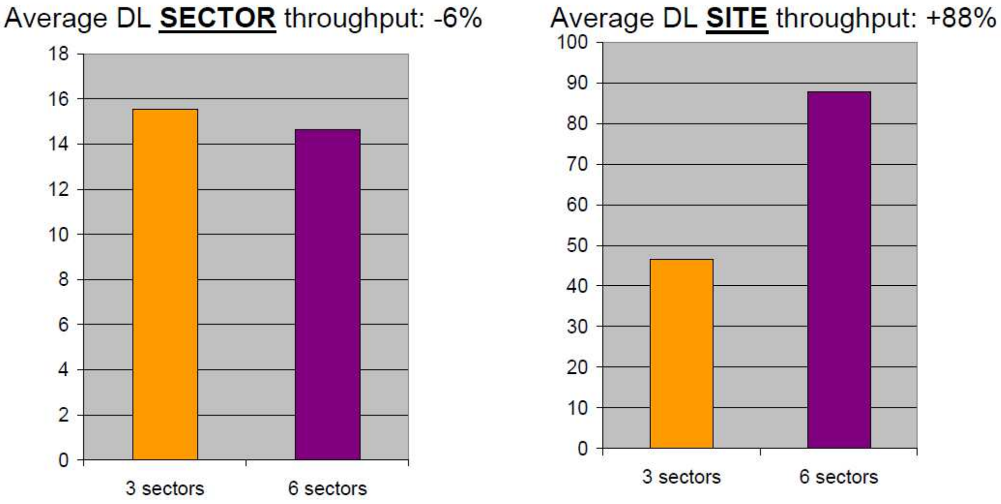
6.2 UE speed impact

System level simulations show capacity degradation when UE speed becomes higher. This is mainly caused by limited reporting accuracy; CQI reports get outdated when a mobile is moving faster and faster. When changing from 3km/h to 30km/h scenario, one can observe ~25% capacity degradation. Scenarios for speed higher than 30km/h do not differ too much from 30km/h case (~3…4% degradation; to be neglected).

6.3 6-sector impact

System level simulations show single cell throughput degradation for 6-sector deployment compared with 3-sector. This is caused by increased inter cell interference when sectors are equipped with better (more directional) antennas with higher gain. Although, there is ~6% capacity degradation for a single cell, one will see ~88% improvement in overall site capacity (twice the number of cell compared to 3-sector).

Figure 41 6-sector impact on capacity



6.4 MIMO impact and beamforming impact

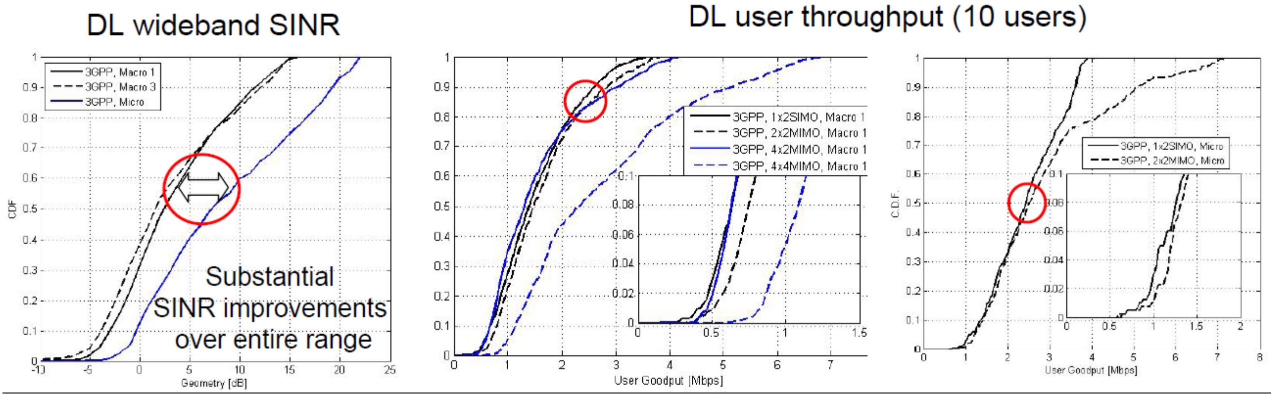
MIMO is one of the most crucial improvements of the LTE air interface, thus usually assumed in dimensioning campaigns. However, it has not been considered in the capacity simulations setup and is not reflected in the spectral efficiency depicted in Figure 37: Downlink spectral efficiency; 2.3 GHz, 3-sector hexagonal layout, 0.8W per PRB, 1TX at eNB, 2RX at UE (MRC), EPA05, NSN RRM specific scheduler, 10% BLER target, 10 UEs per sector (full buffer; 100% load), RF parameters according to [3GPP TR25.814] and Figure 38: Uplink spectral efficiency; 2.3 GHz, 3-sector hexagonal layout, Open Loop Power Control with adjusted P0/alpha settings, 1TX at UE, 2RX at eNB (MRC), EPA05, NSN RRM specific scheduler, 10% BLER target, full buffer (100% load), RF parameters according to [3GPP TR25.814].

Beamforming is foreseen for TD-LTE releases. Even up to 8-elements antenna can be used in RL15TD release. These advanced antenna systems together with transmission techniques such as beamforming or MRC can significantly improve cell capacity.

6.4.1 LTE70: DL adaptive open loop MIMO for two antennas

Whereas the transmit diversity is a typical “coverage” effect evaluated in the link budget for cell-edge UE (introducing a certain coverage gain), the dual-stream MIMO doubles the user data rate and it is very unlikely it is switched on for cell border terminals. The mechanism of adaptive MIMO Mode Control assures CQI-dependent switching between transmit diversity and dual-stream MIMO. The average capacity is then determined by the ratio of dual-stream transmissions.

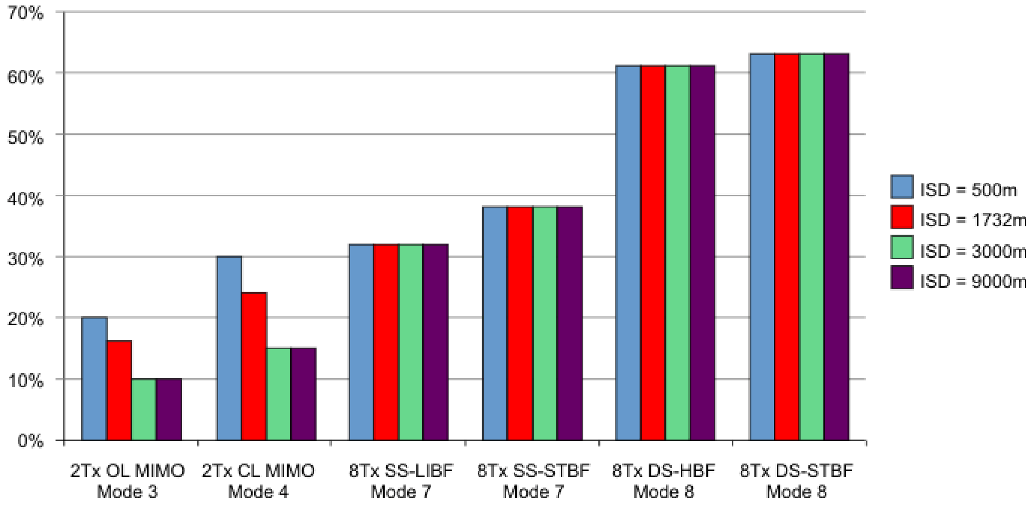
Figure 42 Dual-stream utilization



The two plots on the right depict the percentage of terminals operating with dual-stream MIMO. Typically, interference-limited 3GPP Macro Case 1 (ISD=500m) is characterized by about 20% of UEs exploiting 2x2MIMO data rates. The ratio is even higher for 3GPP Micro Case (ISD=130m) where a half of mobiles are able to receive two data streams.

Average cell throughput improvement of 2x2 OL MIMO is shown in the figure below.

Figure 43 DL capacity gain with respect to 1x2SIMO



6.4.2 LTE703: DL adaptive closed loop MIMO for two antennas

Closed loop MIMO capacity gain is shown in *Figure 47: DL capacity gain with respect to 1x2SIMO*. Although this mode needs the UE to feed back the base station with the PMI (Precoding Matrix Indicator), it is worth from the point of downlink capacity and data rate. The final decision about the precoding matrices is always up to the eNB, however the PMI clearly informs which choice is the best for maximizing the experienced SINR. The gain of closed loop MIMO transmission strictly depends on PMI computation accuracy at the UE side and the deployment environment. For small cells (characterized with many obstacles, scattering and reflection effects providing very well uncorrelated MIMO channels), the closed loop gain over the open loop scheme can be up to 10% in the overall cell throughput. Since the reported PMI gets outdated very quickly for fast moving mobiles, the closed loop gain is rather more relevant for stationary UEs (for example EPA05 channel model) however this effect is not considered in RNT_ Dim. Capacity gain of 2x2 CL MIMO is depicted in *Figure 47: DL capacity gain with respect to 1x2SIMO*.

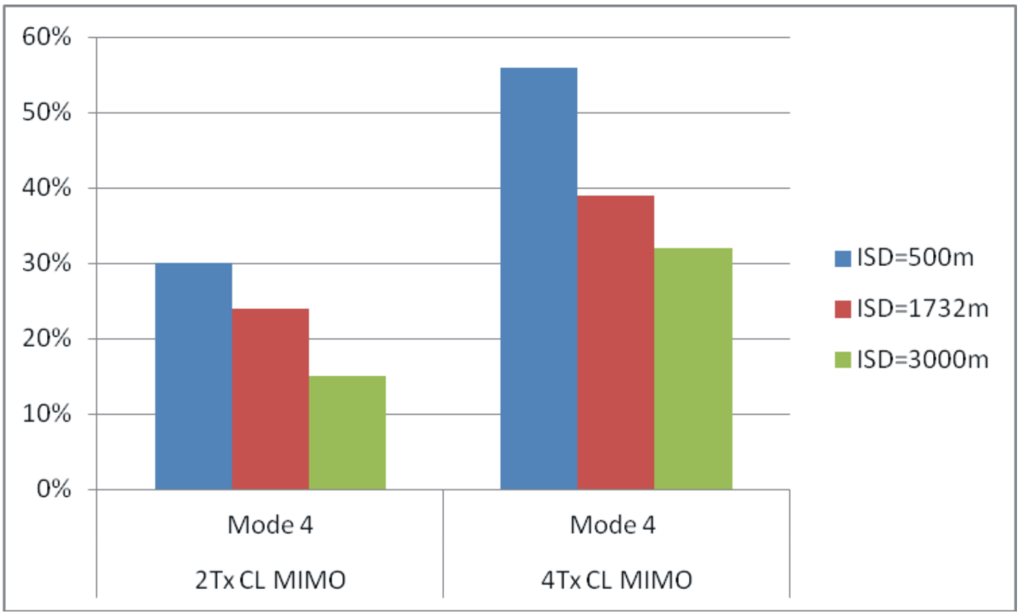
6.4.3 LTE568: DL adaptive closed loop MIMO 4x2

In essence, *LTE568: DL adaptive closed loop MIMO 4x2* is an extension of *LTE703: DL adaptive loop MIMO for two antennas* to support 4 antenna ports, so most of the descriptions from the previous chapter apply. Introduction of the 4 antenna ports has two-fold impact - the extra 2 RS (Reference Signals) in DL introduce additional overhead in the resource grid. On the other hand, the same extra 2 antennas improve the transmit diversity conditions, making it more probable for the UE to report conditions favorable to support 2 data streams. Additionally, extension of the DL antenna ports increases the codebook size to 16 positions (versus 2 in case of dual stream 2x2 MIMO), thus further improving the SINR in dual stream mode.

For cell edge calculations, 4x2 Transmit Diversity should be used, since this is the fallback transmission mode with this feature.

Capacity figures for 4x2 CL MIMO are depicted on the following figure.

Figure 44 DL capacity gain with respect to 1x2SIMO



6.4.4 LTE979: Interference Rejection Combining (IRC) FD-LTE

The feature *LTE979: Interference Rejection Combining (IRC) FD-LTE* is identical to *LTE936: Interference Rejection Combining (IRC)* except for the following aspects:

- It applies only to FD-LTE
- It applies to only 2 antennas (1Tx-2Rx antenna configuration in UL).
- It gains are lower due to fewer antennas:
  - cell average throughput - gains should be about 5%
  - cell average throughput - gains should be about 5%

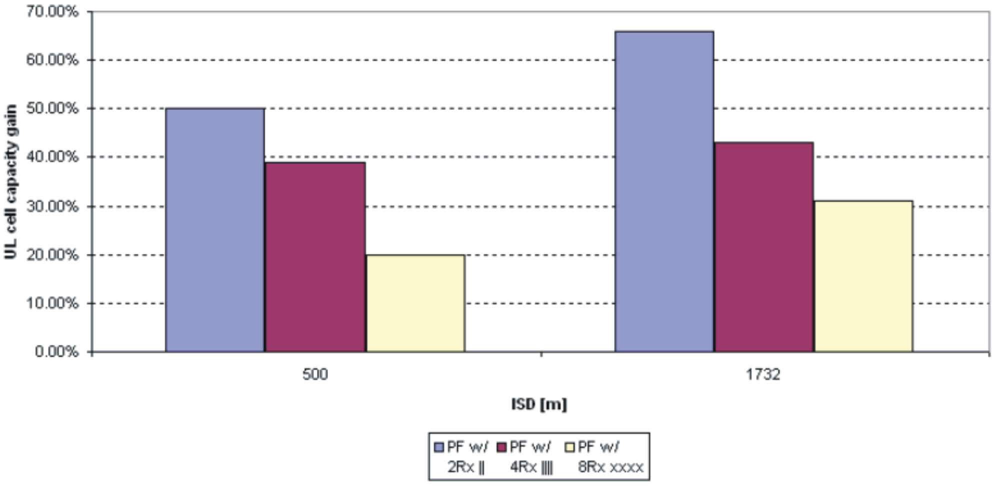
- It is assumed that the BTSs are synchronized. This ensures a constant interference power over each TTI of a victim cell which improves the performance.

6.5 Other capacity features

6.5.1 LTE46: Channel aware uplink scheduler

Scheduling gain strictly depends on the number of used Rx antennas. Gain is lower if the receiver makes the channel more stable (non frequency selective). If one decides to use PF channel-aware scheduler for uplink then following gain factors should be included in capacity estimation procedure (see Figure below).

Figure 45 Channel aware uplink scheduling gain



The main key attributes of the channel aware uplink scheduler in release RL15TD and RL40 are presented in the following table.

Table 44 Differences between UL CAS for RL40 and RL15TD

	UL CAS **(LTE46: Channel aware uplink scheduler)**	**UL CAS** **(LTE46: Channel aware uplink scheduler)**
RL	RL15 TD	RL40
duplex scheme	TDD	FDD
SRS need	yes	yes
#segments	3 PUSCH segments	n PUSCH segments
granularity in frequency domain	low	medium
resource allocation	continuous (SC-FDMA)	

Table 44 Differences between UL CAS for RL40 and RL15TD (Cont.)

	UL CAS **(LTE46: Channel aware uplink scheduler)**	**UL CAS** **(LTE46: Channel aware uplink scheduler)**
scheduling criterion	averaged relative signal strength(ranking of resources per UE)	

6.5.2 LTE619: Interference aware scheduler

The functionality of *LTE619: Interference aware scheduler* is close to the one of the channel aware scheduler *LTE46:Channel aware uplink scheduler*. Main differences are:

Table 45 Differences between *LTE46:Channel aware uplink scheduler* and *LTE619: Interference aware scheduler*

	LTE46:Channel aware uplink scheduler	**LTE619: Interference aware scheduler**
duplex scheme	TDD/FDD	FDD
scheduling criterion	received signal strength	UE Tx power density
source of scheduling criterion	SRS and Demodulation Reference Signal (PUSCH data transmission)	power headroom report
SRS need	yes	no (=> easier implementation)
# PUSCH segments	3 segments	n (=> more flexible reuse schemes)
order of UEs inside a segment	deterministic	randomized

The strategy of *LTE619: Interference aware scheduler* is:

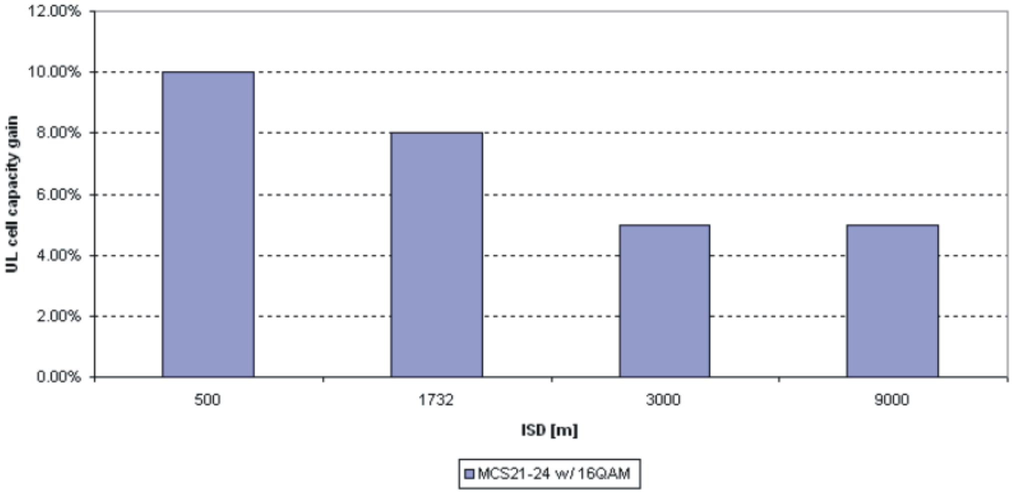
- High Tx power density denotes cell edge users creating high interference in neighbor cells,
- Cell edge users shall be scheduled in PUSCH segments with lowest measured average interference and noise power,
- As a consequence the various cells of a network will assign users with high Tx power density (mainly cell edge users) in different segments implementing a self-adaptive quasi-reuse scheme without need for information from neighbor cells via X2 interface.

Expected gain (reference: channel unaware RR scheduler, RL10) is roughly up to 20% for both cell capacity and cell edge throughput depending on the cell size. In the link budget, an interference aware scheduler is considered with additional 1 dB gain on condition that an interference margin is not lower than 1 dB.

6.5.3 LTE829: Increased uplink MCS range

The feature offers MCS indexes 21…24 signaled as 16QAM. These MCSs are specified as 64QAM however they could be signaled as 16QAM. It can increase peak data rates and depending on the environment and user distribution it also brings overall capacity gain. There is no impact on the link budget since it is about high MCS range which is not relevant for maximum coverage estimation. Gain which can be obtained from this extension could be even 10% for small ISD. For large cells gain is obviously lower because more users experience lower SINR and therefore usage of high MCS is not possible.

Figure 46 UL capacity gain for *LTE829: Increased uplink MCS range*



6.5.4 LTE1089: Downlink carrier aggregation - 20 MHz

Carrier Aggregation functionality (as introduced in RL50, *LTE1089: Downlink carrier aggregation - 20 MHz*) is the flagship RL50 feature that brings into life LTE Advanced concept. It provides means to aggregate two downlink carriers configured on two overlapped cells that operate in two separate bands. This feature will be activated for the UEs that have such CA capability on board that match with bands where CA operates in the network.

Improving the user perceived throughput (both peak and instantaneous) is the primary design target of this feature. The level of potential gains in this respect depends on many factors like: network load and resultant resource occupancy and interference level, overlapping of the sectors to be aggregated, ratio of Carrier Aggregation users and also network parametrization. It is worth to notice that there are certain means to assure some CA gains also in the highly loaded scenarios - however, at the cost of the throughput perceived by non-CA UEs.

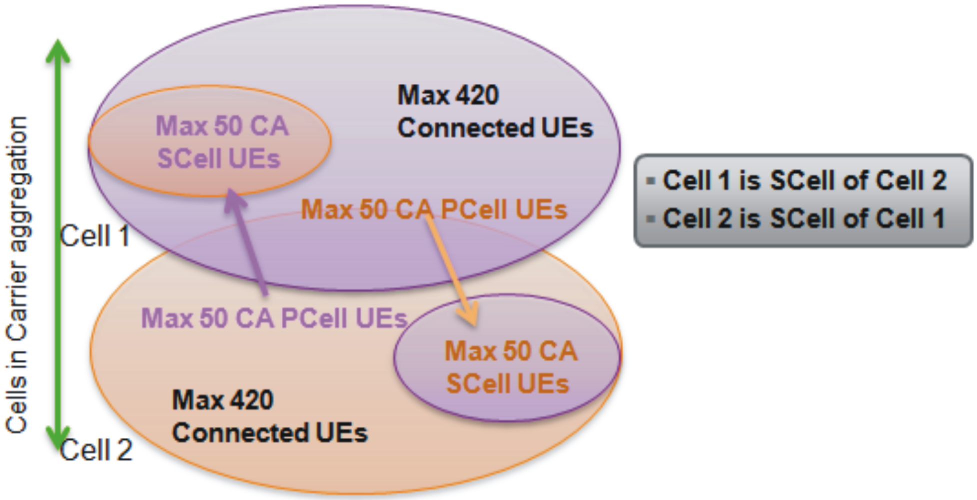
Feature provides also gains with respect to load balancing between cells - such balance could be smoothly achieved with co-operative schedulers working in RL50 without involving inter-frequency handovers (either load balancing or better cell ones).

As far as network dimensioning is concerned three major areas should be considered:

- Influence of Carrier Aggregation related load on the cell capacity
- Baseband load in case of Carrier Aggregation
- Link Budget calculations for the UE with two carriers

Cell capacity improvement was out of primary focus during feature specification and potential gains in this area will come rather as a "side effect". These gains will come from the improved scheduling flexibility especially for the traffic with highly bursty nature. Note however that even without CA the DL scheduler is already dealing with resource allocation in highly efficient manner.

Figure 47 Carrier aggregation cell capacity requirement

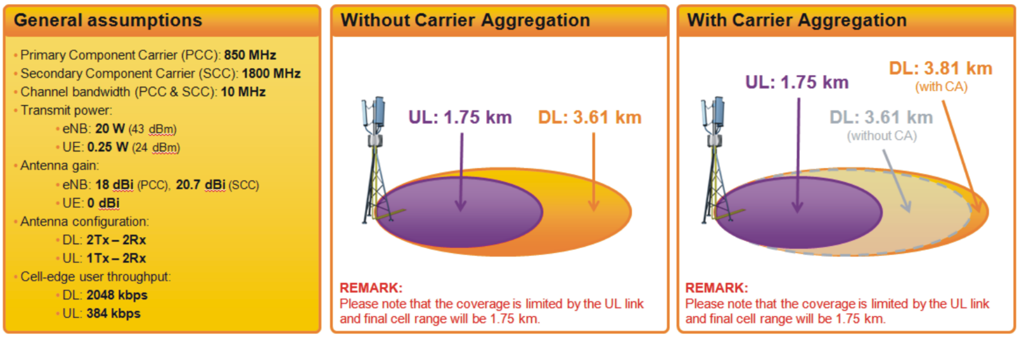


One of the significant influence on the baseband capacity is in the area of maximum amount of active users (so RRC connected UEs with DRB established): still 420 users per cell could be active (like in non-CA case with 6 cells) however maximum 50 out of them can have this cell configured as a primary one. Additionally, maximum other 50 UEs can have this cell configured as a secondary one.

This means that at maximum 50*6 = 300 users could be configured with Carrier Aggregation - in such a case the total number of active users per eNB is equal to 6*(420-50) = 2220. The concept is shown in the figure below .

Link Budget is calculated taking into account achievable DL/UL throughput for the single UE at certain distance/pathloss from the serving eNB. Considering the fact that the CA UE receives the data from two carriers the maximum allowable pathloss, for which the DL service requirements is still satisfied, will be increased. Note however that cause Carrier Aggregation is introduced solely in the downlink direction, the overall DL/UL budget would not benefit from CA activation once the service is UL limited.

Figure 48 Carrier aggregation cell capacity requirement



General assumptions

- Primary Component Carrier (PCC): **850 MHz**
- Secondary Component Carrier (SCC): **1800 MHz**
- Channel bandwidth (PCC & SCC): **10 MHz**
- Transmit power:
  - eNB: **20 W** (43 dBm)
  - UE: **0.25 W** (24 dBm)
- Antenna gain:
  - eNB: **18 dBi** (PCC), **20.7 dBi** (SCC)
  - UE: **0 dBi**
- Antenna configuration:
  - DL: **2Tx – 2Rx**
  - UL: **1Tx – 2Rx**
- Cell-edge user throughput:
  - DL: **2048 kbps**
  - UL: **384 kbps**

Without Carrier Aggregation

REMARK:
Please note that the coverage is limited by the UL link and final cell range will be 1.75 km.

With Carrier Aggregation

REMARK:
Please note that the coverage is limited by the UL link and final cell range will be 1.75 km.

6.6 Cell capacity estimation procedure

Step1: To obtain the SE figures for specific ISD and channel bandwidth interpolation is needed. Three sets of SE tables exist separately for 800MHz, 2.1GHz and 2.6GHz. The choice of underlying SE is based on the carrier frequency selected for link budget calculations.

SE = interpolate_SE (ISD, channel bandwidth)

Step2: Including impact of multi antenna (and/or scheduler type) usage.

C = C x (1+MIMO_gain (ISD))

Step3: Load dependent scaling is applied in order to align with planner-defined load settings. Scaling_factor(load) is obtained based on Figure 40: Victim cell throughput in function of neighbor cell load. This step is valid only for scenarios where load<100%. Otherwise, if load=100% then original SE values are used without a need for scaling (100% neighbour cell load assumed in simulations).

C = C x scaling_factor (load)

Step4: Conversion from the spectral efficiency (bps/Hz) to cell capacity (bps). In addition to that, the capacity is multiplied by load value to keep the whole network homogeneous.

C = SE x channel_bandwidth

7 Traffic model

Whereas Site Capacity describes the cell capacity calculation method, an additional step is needed to estimate the amount of traffic that is expected in the network. This is known as Traffic Modeling. The main purpose of Traffic Model (TM) is to describe the average subscriber behavior during the most loaded day period known as the Busy Hour (**BH**). The Traffic Model directly impacts the final site count computation and, for this reason, it is desirable. Otherwise it must be defined by the planner.

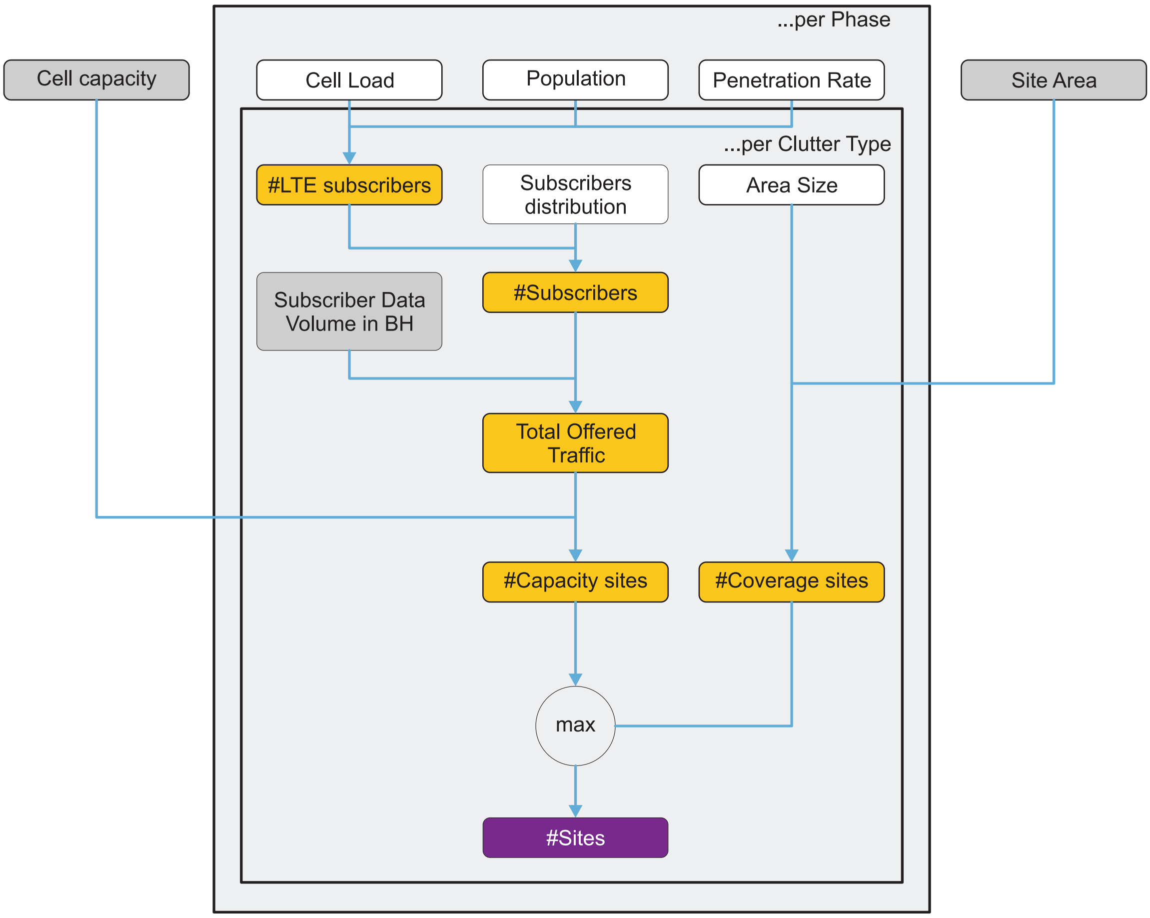
For more information see *Traffic Model* in LTE Radio Access operating documentation.

8 Site count computation

The term ”site count computation” represents the last step during a dimensioning campaign that aims at a calculation of the number of sites that are required to provide coverage and capacity as determined by the input parameters. In other words, the “site count computation” is used for estimation, the expected investments necessary to provide the (quality of) service in the geographical area.

The following figure shows the example of workflow of site count computation.

Figure 49 Site count workflow



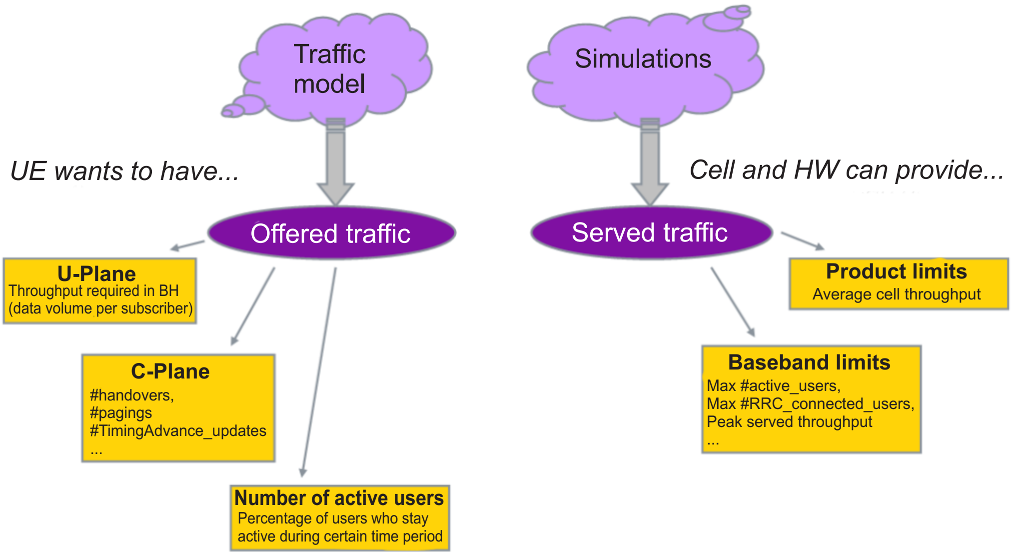
9 Baseband dimensioning

As described in the previous chapters, the basic dimensioning approach is to calculate the number of required sites based on two criteria: coverage (link budget) and site capacity (corresponding to site throughput, which in turn is the average throughput to be expected within a cell). However, the capacity figures calculated for the latter criterion only take typical PHY/RRM parameters into account (for example channel bandwidth, transmit power, scheduler type, etc.) but not the hardware capabilities of the base station.

For this reason, it is necessary to verify that the calculated number of sites is sufficient to fulfill all HW limitations. The following chapter describes the way the capacity of the baseband units in the BTS must be considered during the site count computation. In this case, the BTS capacity stands for the general processing capabilities of baseband units, whereas the baseband unit is a generic term for HW components performing baseband operations. These are steps taken before RF processing, which consists in about passing the baseband signal up to a higher frequency (carrier frequency).

Figure 50: Offered vs served traffic presents the general concept of baseband dimensioning and its purpose. While the offered traffic (in terms of U-/C-plane traffic and the number of connected users) can be derived from the traffic model definition (depending on how precise the definition is), the served traffic determines what can be handled from the system point of view. It refers to system specifics determining the average cell throughput as well as HW capabilities and the corresponding limitations such as the number of active UEs per eNB, peak served throughput, etc.

Figure 50 Offered vs served traffic



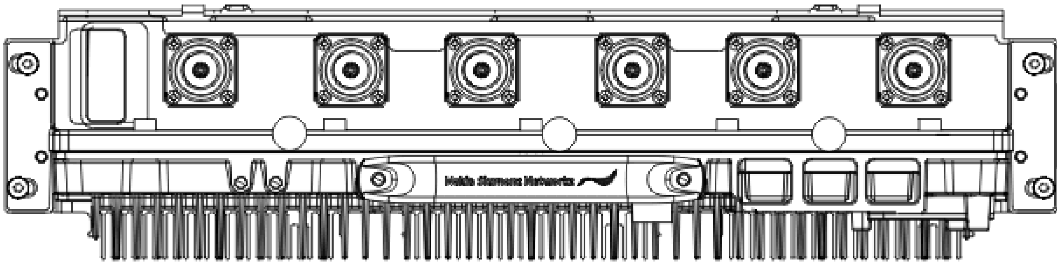
The dimensioning guidelines presented in the following chapters are valid for the Flexi Multiradio BTS operating in an LTE mode.

9.1 Flexi Multiradio BTS

9.1.1 Flexi Multiradio BTS main modules

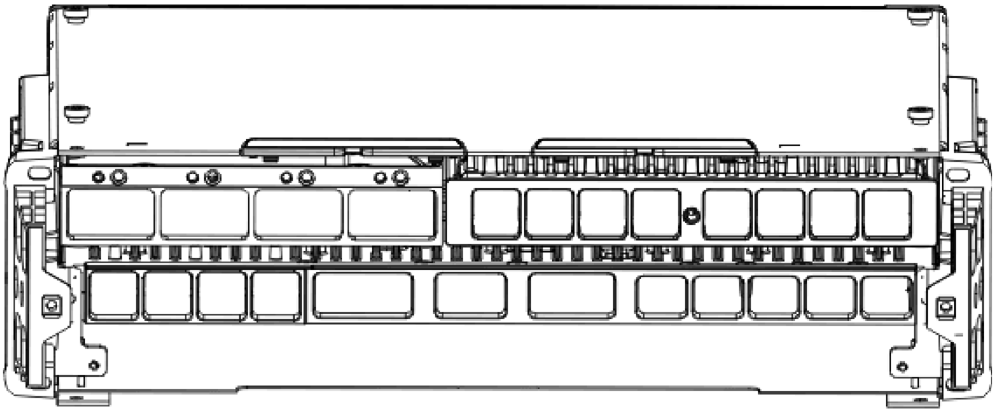
- RF part provides all the functionalities required to transmit the signal using the given carrier frequency (for example modulation, amplification, etc.).This part operates with the Radio Frequency (RF) and can be put into practice either as the Flexi Triple RF Module (see figure below) or the Flexi Remote Radio Head (RRH).

Figure 51 Triple RF Module



- System module (see Figure 52: System Module) provides baseband processing (processing U-/C-plane signals by DSP units) as well as control and transmission functionality.

Figure 52 System Module



Generally speaking, while the RF part provides an eUu interface (eNB <-> UE), the system module connects the RAN segment with the Evolved Packet Core (**EPC**) via S1 interfaces.

The system module is the essential and fundamental part the base station. Already mentioned U-/C-plane processing is performed by the complete implementation of RRM algorithms (for example Radio Admission Control, schedulers, Power Control, Link Adaptation, measurements handling, Mobility Control, etc.) interacting with O&M entity. A connection to Mobility Management Entity (**MME**) via S1 interface and to other eNBs via X2 interface is handled by the transport sub-module (an integral part of the system module). The system module also distributes a synchronization signal and power supply to other components of the base station.

The following table lists currently supported system modules. .

Table 46 Availability of Flexi System Modules

	RL10	RL20	RL30	RL40	RL15TD	RL30TD
FSMD (Release 2)	-	-	yes	yes	-	-
FSME (Release 2)	yes	yes	yes	yes	yes	yes
FSMF (Release 3)	-	-	-	yes	-	-

System module capabilities strictly depend on the number of included DSP sub-modules. One should have in mind that the old 3G-specific notation of system module capacity by means of Control Channel Elements (**CCE**) is no more valid and is not used in the proposed approach.

There are two versions of Flexi Multimode BTS Transport Modules:

- FTIB - mainstream product; the cost optimized solution for the majority of sites,
- FTLB - premium product supporting high capacity needs with IPsec enabled.

9.2 Number of supported cells

LTE Release: RL10

Table 47 RL10 System Module capability

	Number of supported cell per SM (assuming 2Tx MIMO)		
	5 MHz	10 MHz	20 MHz
FSME	3 cells	3 cells	3 cells

LTE Release: RL20

Table 48 RL20 System Module capability

	Number of supported cell per SM (assuming 2Tx MIMO)			
	5 MHz	**10 MHz**	**15 MHz**	**20 MHz**
FSME	3 cells	3 cells	3 cells	3 cells

LTE Release: RL30

Table 49 RL30 System Module capability

	Number of supported cell per SM (assuming 2Tx MIMO)			
	5 MHz	**10 MHz**	**15 MHz**	**20 MHz**
FSME	6 cells	6 cells	3 cells	3 cells
FSMD	3 cells	3 cells	2 cells	2 cells

LTE Release: RL40

Table 50 RL40 System Module capability

	Number of supported cell per SM (assuming 2Tx MIMO)			
	5 MHz	**10 MHz**	**15 MHz**	**20 MHz**
FSMF	6 cells	6 cells	3 cells	3 cells
FSME	6 cells	6 cells	3 cells	3 cells
FSMD	3 cells	3 cells	2 cells	2 cells

LTE Release: RL50

Table 51 RL50 System Module capability

	Number of supported cell per SM **(assuming 2Tx MIMO and IRC 2Rx)**					
	1,4 MHz	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
FSMF+FBBA	-	-	6 cells	6 cells	6 cells	6 cells
FSMF	3 cells	3 cells	6 cells	6 cells	3 cells	3 cells
FSME	-	-	6 cells	6cells	3 cells	3 cells
FSMD	-	-	3 cells	3 cells	2 cells	2 cells

Table 52 RL50 System Module capability

	Number of supported cell per SM **(assuming 4Tx MIMO and 4Rx)**					
	1,4 MHz	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
FSMF+FBBA	-	-	3 cells	3 cells	3 cells	3 cells
FSMF	-	-	3 cells	3 cells	-	-
FSME	-	-	3 cells	3cells	-	-
FSMD	-	-	3 cells	3 cells	-	-

FSME equipped with three baseband sub-modules is able to support three LTE cells with maximum 20 MHz channel bandwidth and 2Tx MIMO. In RL10 and RL20 is not possible to serve more than one cell per BB sub-module. For this reason, 6-sector deployment must be done with two separate system modules on site.System module extension is not possible in RL10/RL20/RL30/RL40. RL50 allows using one FBBA extension module in order to increase number of supported cells.

LTE Release: RL60

Table 53 RL60 System Module capability (2x2 DL MIMO and IRC 2Rx configuration)

	Number of supported cell per SM (assuming 2x2 DL MIMO and IRC 2Rx)					
	1,4 MHz	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
FSMF+2xFBBA/ FBBA+FBBC	-	-	6 cells	6 cells	6 cells	6 cells
FSMF+ FBBA/FBBC	-	-	6 cells	6 cells	6 cells	6 cells
FSMF	3 cells	3 cells	6 cells	6 cells	3 cells	3 cells
FSME	-	-	6 cells	6cells	3 cells	3 cells
FSMD	-	-	3 cells	3 cells	2 cells	2 cells

Table 54 RL60 System Module capability (4x2 DL MIMO and IRC 4Rx configuration)

	Number of supported cell per SM (assuming 4x2 DL MIMO and IRC 4Rx)					
	1,4 MHz	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
FSMF+2xFBBC	-	-	6 cells	6 cells	3 cells	3 cells
FSMF+ FBBA/FBBC	-	-	6 cells	6 cells	-	-
FSMF	-	-	3 cells	3cells	-	-
FSMD	-	-	3 cells	3 cells	-	-

9.3 Peak L1 throughput

Peak L1 throughput values confirm Flexi System Module as compliant with 3GPP Release 8. Refer to the tables below for the maximum Transport Block Sizes, which can be set for 2x2MIMO (dual-stream transmission) with all available frequency resources.

Table 55 DL peak L1 throughput

Release and max supported MCS index	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
RL10 (MCS28)	37	75	---	150
RL20 (MCS28)			110	
RL30 (MCS28)				
RL40 (MCS28)				
RL15TD (MCS28)	---	40.3 (2DL:2UL) 54.99 (3DL:1UL)	---	82.3 (2DL:2UL) 112.47 (3DL:1 UL)
RL25TD (MCS28)				

Table 56 UL peak L1 throughput

Release and max supported MCS index	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
RL10 (MCS20)	10.68	21.38	---	43.82
RL20 (MCS20)			32.86	
RL30 (MCS24)	13.54	27.38	40.58	55.06
RL40 (MCS24)				
RL15TD (MCS20)	---	8.6 (2DL:2UL) 4.3 (3DL:1UL)		17.5 (2DL:2UL) 8.8 (3DL:1UL)
RL25TD (MCS24)	---	10.95 (2DL:2UL) 5.48 (3DL:1UL)		22.02 (2DL:2UL) 11.01 (3DL:1UL)

Table 57 UL peak L1 throughput (PUSCH only; limited by PUCCH, PRACH)

Release and max supported MCS index	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
RL10 (MCS20)	8.5 (20 PRBs)	19.1 (45 PRBs)	---	43.82
RL20 (MCS20)		20.6 (48 PRBs)	30.6 (72 PRBs)	
RL30 (MCS24)	10.7 (20 PBRs)	25.7 (48 PBRs)	39.2 (72 PBRs)	51.0 (96 PBRs)
RL40 (MCS24)				
RL15TD (MCS20)	---	7.9 (2DL:2UL) 3.8 (3DL:1UL)	---	16.1 (2DL:2UL) 8.0 (3DL:1UL)
RL25TD (MCS24)		9.8 (2DL:2UL) 4.7 (3DL:1UL)		20.2 (2DL:2UL) 10 (3DL:1UL)

3GPP Release 8 specifies QPSK, 16QAM and 64QAM for PUSCH. In RL30/RL25TD there is no support for 64QAM transmission however it is possible to extend MCS range for 16QAM from MCS index 20 to 24. Flexi Rel.2 and Rel.3 are fully capable of handling the largest possible Transport Blocks. It means that the HW architecture (processing power of DSP boards) does not limit peak data rates.

9.4 Supported cell range

Maximum cell range is physically limited by supported RA preamble formats which are listed below.

Table 58 RA preamble formats

PRACH format	**CP length**	**Preamble sequence length**	**Total preamble length**	**Guard time**	**Maximum cell radius**
	[us]	**[us]**	**[us]**	**[us]**	**[us]**
0	103.13	800	903.13	96.87	14.5305
1	684.38	800	1484.38	515.62	77.343
2	203.13	1800	1803.13	196.87	29.5305

Table 58 RA preamble formats (Cont.)

PRACH format	CP length	Preamble sequence length	Total preamble length	Guard time	Maximum cell radius
	[us]	[us]	[us]	[us]	[us]
3	684.38	1600	2284.38	715.62	107.343

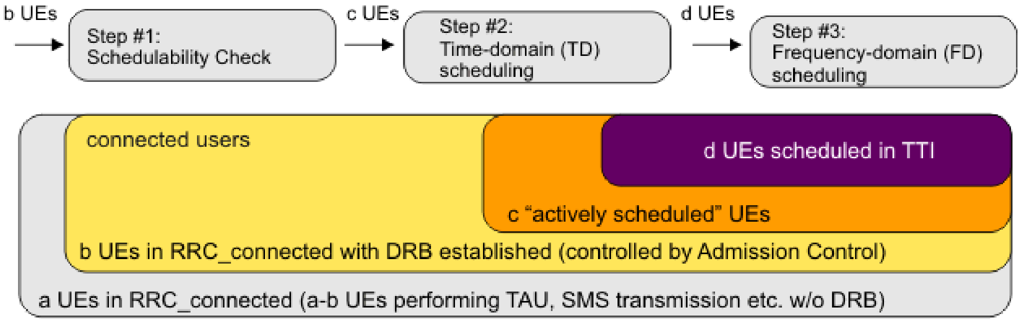
There are supported preamble formats 0 and 1 from RL10. One must consider that each RACH preamble format has its limitation regarding maximum cell radius - this fact should be taken into account when planning large cell deployments (for example popular wireless DSL in rural environment at 700/800 MHz).

9.5 Number of supported users

One shall differentiate between two types of users being important from baseband dimensioning point of view.

- **Connected users**: terminals attached to the network with a connection to an active application (*EMM-REGISTERED*, *ECM-CONNECTED*, *RRC_CONNECTED, DRB established*). The state includes UEs that have applications carrying out background polling even if the subscriber is not actively using an application. Both signaling and data radio bearers are established and active in this state. An IP address is assigned for the terminal. UE monitors System Information Block content to detect system information change, monitors control channels associated with the shared data channel to determine if data is scheduled for it, provides channel quality and feedback information, performs neighbor cell measurements and measurement reporting.
- **Actively scheduled users**: UEs which can be supported by the system module simultaneously during the time-domain scheduling phase.

Figure 53 Connected users and actively scheduled users



Please note that baseband dimensioning approach known from R99 is no more relevant for LTE. The best measure of System Module capabilities is the amount of connected users (similar to HSPA dimensioning).

9.5.1 Number of connected users

Table 59 RL10 max. number of connected users

	Max. number of connected users per cell		
	5 MHz	**10 MHz**	**20 MHz**
FSME	200	400	800

LTE Release RL20:

Table 60 RL20 max. number of connected users

	Max. number of connected users per cell			
	5 MHz	**10 MHz**	**15 MHz**	**20 MHz**
FSME	480	600	720	840

LTE Release RL30:

Table 61 RL30 max. number of connected users

	Max. number of connected users per cell			
	5 MHz	**10 MHz**	**15 MHz**	**20 MHz**
FSME (3 sectors per site)	480	600	720	840
FSME (6 sectors per site)	420	420	---	---
FSMD (2 sectors per site)	480	600	720	840
FSMD (3 sectors per site)	420	420	---	---

LTE Release RL40:

Table 62 RL40 max. number of connected users

	Max. number of connected users per cell			
	5 MHz	**10 MHz**	**15 MHz**	**20 MHz**
FSMF (3 sectors per site)	480	600	720	840
FSMF (6 sectors per site)	420	420	---	---
FSME (3 sectors per site)	480	600	720	840
FSME (6 sectors per site)	420	420	---	---
FSMD (2 sectors per site)	480	600	720	840
FSMD (3 sectors per site)	420	420	---	---

LTE Release RL50:

Table 63 RL50 max. number of connected users

	Max. number of connected users per cell					
	1,4 MHz	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
FSMF+FBBA (3 sectors per site)	---	---	480	600	1030	1200
FSMF+FBBA (6 sectors per site)	---	---	480	600	720	840
FSMF (3 sectors per site)	40	120	480	600	720	840
FSMF (6 sectors per site)	---	---	420	420	---	---
FSME (3 sectors per site)	---	---	480	600	720	840
FSME (6 sectors per site)	---	---	420	420	---	---
FSMD	---	---	480	600	720	840

Table 63 RL50 max. number of connected users (Cont.)

	Max. number of connected users per cell					
	1,4 MHz	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
(2 sectors per site)						
FSMD (3 sectors per site)	---	---	420	420	---	---

LTE Release RL60:

Table 64 RL60 max. number of connected users

	Max. number of connected users per cell					
	1,4 MHz	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
FSMF+2xFBBC (3 sectors per site)	-	-	480	600	1030	1200
FSMF+2xFBBC (6 sectors per site)	-	-	480	600	720	840
FSMF+2xFBBA/FBBC (3 sectors per site)	-	-	480	600	1030	1200
FSMF+2xFBBA/FBBC (6 sectors per site)	-	-	480	600	720	840
FSMF (3 sectors per site)	40	120	480	600	720	840
FSMF (6 sectors per site)	-	-	420	420	-	-
FSME (3 sectors per site)	-	-	480	600	720	840
FSME (6 sectors per site)	-	-	420	420	-	-

Table 64 RL60 max. number of connected users (Cont.)

	Max. number of connected users per cell					
	1,4 MHz	**3 MHz**	**5 MHz**	**10 MHz**	**15 MHz**	**20 MHz**
FSMD (2 sectors per site)	-	-	480	600	720	840
FSMD (3 sectors per site)	-	-	420	420	-	-

Note that all UEs in RRC_connected with a DRB established are considered as active even if they have no data to transmit. Active UEs are kept in the active state for immediate access to PDSCH and PUSCH resources and occupy control channel resources as well as processing resources in the eNB. This active user definition matches well the "always-on" smartphone with applications triggering constant background activity like heartbeats even when the user is not actively operating the device. Transition to RRC_idle is typically triggered by an inactivity timer which may never expire in the always-on smartphone case.

The default or user-specific traffic model provides the number of users per cell area. Depending on the subscriber profile (subscriber service agreement, traffic demand, mobility characteristic, terminal type), a different number of connected users will be considered as a percentage of the total amount of users. The more detailed traffic model is provided, the better estimation can be made. Traffic model provides the parameter “Share of Active Subscribers [%]” standing for the amount of subscribers being active during the busy hour.

$$\mathrm{ActiveUsers} = \mathrm{NumberOfSubscribers} \cdot \mathrm{ShareOfActiveSubscribers}$$

Alternatively, to calculate number of connected users we can use the Traffic per Site value from Capacity dimensioning and Mean Rate per UE.

$$\mathrm{ActiveUsers} = \left\lceil \frac{\mathrm{TrafficPerSite\ [kbps]}}{\mathrm{MeanRate\_UE\ [kbps]}} \right\rceil$$

Much more aggressive (not really recommended) would be to assume the number of connected users is equal to the mean value of subscribers divided by Overbooking Factor. This is not the recommended approach due to the fact that Overbooking Factor is related rather to user throughput than to the number of users. Typical OF value 25 will be comparable to Share of Active Subscribers = 4% - it can be true for voice traffic, but not for data traffic. For high smartphone penetration, over the years the OF may get less than two, for example more than 50% of the subscribers would be "always-on".

$$\mathrm{ActiveUsers} = \left\lceil \frac{\mathrm{NumberOfSubscribers}}{\mathrm{OverbookingFactor}} \right\rceil$$

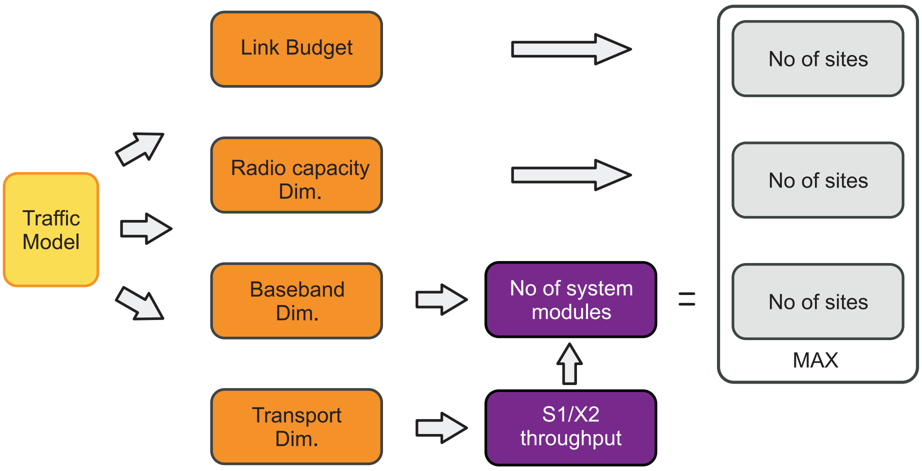
Number of connected users result should be compared with HW possibility of system module. If the number of calculated max connected users per cell is greater than HW capabilities the cell has to be split.

$$\mathrm{NumberOfSites} = \frac{\mathrm{ActiveUsers}}{\mathrm{FSMEmaxActiveUsers} \times \mathrm{NumberOfCellsInSite}}$$

The final number of sites is calculated as maximum number of sites from the link budget, capacity dimensioning and baseband dimensioning.

9.6 Example baseband dimensioning

Figure 54 Dimensioning flow chart



9.6.1 Assumptions:

Table 65 Example assumptions

Channel bandwidth	10 MHz
Antenna Configuration	2Tx - 2Rx
Cell edge throughput	512 kb/s / 128 kb/s (DL/UL)
Site layout	3-sector per site
Traffic Model: Flat rate, subscription rate DL	512 kb/s
Traffic Model: Flat rate, subscription rate UL	128 kb/s
Traffic Model: Overbooking Factor	25
Traffic Model: Share of active subscribers	30 % (data card)

Table 65 Example assumptions (Cont.)

Number of subscribers	30000 (dense urban) 3000 (rural)
Area size	10 km^2

The following outcome has been obtained after link budget and capacity dimensioning.

Link Budget:

- Dense Urban: 41 sites
- Rural: 1 site

Capacity:

- Dense Urban: 22 sites (DL), 12 sites (UL) -> 22 sites
- Rural: 6 sites (DL), 8 sites (UL) -> 8 sites

9.6.2 Connected users calculation (recommended)

The parameter Share of Active subscribers for data card, which is 30%, is used to calculate the number of connected users:

$$\mathrm{ActiveUsers} = 30000 \cdot 30\% = 10000$$

for Dense Urban and:

$$\mathrm{ActiveUsers} = 3000 \cdot 30\% = 1000$$

for Rural clutter.

$$\mathrm{NumberOfSites} = \left\lceil \frac{10000}{100 \cdot 3} \right\rceil = 34$$

for Dense Urban and:

$$\mathrm{NumberOfSites} = \left\lceil \frac{1000}{100 \cdot 3} \right\rceil = 4$$

for Rural clutter.

9.6.3 Connected users calculation (aggressive)

The parameter Overbooking Factor is used to calculate the number of connected users.

$$\mathrm{ActiveUsers} = \left\lceil \frac{30000}{25} \right\rceil = 1200$$

for Dense Urban and:

$$\mathrm{ActiveUsers} = \left\lceil\frac{3000}{25}\right\rceil = 120$$

for Rural clutter.

According to following equation, the number of sites is calculated using Table “Typical numbers for active UEs per cell” for Admission controlfor 10 MHz bandwidth.

$$\mathrm{NumberOfSites} = \left\lceil\frac{1200}{100 \cdot 3}\right\rceil = 4$$

for Dense Urban and:

$$\mathrm{NumberOfSites} = \left\lceil\frac{120}{100 \cdot 3}\right\rceil = 1$$

for Rural clutter.

9.6.4 Example summary

The final number of sites is calculated as the maximum number of sites of:

Table 66 Outcome summary

	Recommended		**Aggressive**	
	Dense Urban	**Rural**	**Dense Urban**	**Rural**
Link Budget	41	1	41	1
Capacity	22	8	22	8
Baseband	34	4	4	1
Max	**41**	8	**41**	**8**

FSME is currently the most powerful entity. For typical scenarios, baseband processing of FSME should not be a limiting part of dimensioning.

The recommended way of baseband dimensioning is to use Share of Active Subscribers parameter from the Traffic Model and the recommended Number of connected users HW limiting factor.

10 Dimensioning parameters overview

This chapter contains overview of all the parameters relevant for LTE air interface dimensioning with their brief descriptions (for more detailed descriptions, please refer to the previous sections of this document).

10.1 Coverage dimensioning (link budget)

10.1.1 General parameters

Table 67 General parameters

Parameter name	**FDD** **TDD**	**Description**
RF Unit Output Power	FDD & TDD	This parameter represents the RF output power at the antenna connector. Please note that one and the same Flexi RF Module HW can support, depending on the module type and SW licenses, 8W, 20W, 40W and 60 W RF power modes. Typical values • For TDD – Select value in dependency of applied RRH type. • For FDD – Select the Flexi RF part power configuration with respect to local Power Spectral Density restriction. – Typical settings: 20W in 10 MHz, 40W in 20 MHz. – 60W power license will usually be needed for specific cases (that are sites with long feeders operating in 15 MHz / 20 MHz. – Do not use higher power than really needed to make the links balanced (coverage should be UL limited for typical dimensioning scenarios) For DAS scenarios the user shall choose proper repeater power which is applied in the installation. 40W is supported by default.
UE Power Class	FDD & TDD	This parameter represents the UE power class that is to be assumed.
Channel Bandwidth	FDD & TDD	This parameter defines the **frequency bandwidth** that is available to the operator. The bandwidth basically determines the maximum capacity limits of the

Table 67 General parameters (Cont.)

Parameter name	**FDD** **TDD**	**Description**
		considered configuration - further capacity limiting factors (such as overhead and unused symbols) are to be considered in addition. Notes: • Small bandwidth suffers from increased system overhead. This makes the channel spectrum efficiency much worse (it should be used only in case of specific customer requirements). • If fair comparison between FDD and TDD is to be made, it is legitimate to set 2x wider bandwidth for TDD in order to reflect the same spectrum occupation.

10.1.2 Parameters for Transmitting & Receiving End

Table 68 Parameters for Transmitting & Receiving End

Parameter name	**FDD** **TDD**	**Description**
Tx Power per Antenna	FDD & TDD	This parameter must be separately considered for DL and UL. It corresponds to the **Tx power [dBm] of the used RF unit** (in DL) **or UE** (in UL).
Antenna gain	FDD & TDD	This parameter must be separately considered for DL and UL. It defines the antenna gain in DL and UL (in [dBi]). Typical values: DL: • 18 dBi (otherwise; 3-sector site) • 14.5 dBi in case of BF • 3 dBi for omni directional antenna (small one, ceiling mounted) • 8 dBi for typical directional panel antenna (wall mounted) • 17 dBi for direction high gain panel antenna with narrow beam width (wall mounted) UL: 0dBi

Table 68 Parameters for Transmitting & Receiving End (Cont.)

Parameter name	**FDD** **TDD**	**Description**
Feeder loss	FDD & TDD	This parameter defines the **loss induced by the feeder cable between RF unit and antenna**. The 'feeder-less' solution, using the Flexi RF Module (or Flexi RRH) mounted close to the antenna, is usually to be assumed. For active DAS installations cabling loss is calculated with Friis formula resulting with Noise Figure. Femto eNb does not introduce any cable loss due to specific role it is playing - "LTE router". Typical values: • 0.4 dB (for feeder-less and RRH sites) • 0 dB for femto equipment • 0 dB for DAS installations
Body loss	FDD & TDD	**Loss due to attenuation of the human body.** This attenuation is only relevant for the 'handheld' UE case - therefore it makes sense to consider it **only when dimensioning for VoIP** (typical value 3dB). Typical values: • 3 dB for handset mobile • 0dB for data card
User EIRP	FDD & TDD	This parameter represents the user EIRP, which is the **sum of Tx output power and all other gain and loss values in the radio path**.
Noise figure	FDD & TDD	This parameter defines the **noise figure of the receiver**. For **DL (UE receiver)**, the noise figure is typically 7dB, for **UL (eNB receiver)**. Typical values: • 7 dB for UE • 2 dB for eNodeB (with TMA) • 2.2 dB for eNodeB (w/o TMA) • 3 dB for TD-LTE eNodeB (w/o TMA; only RRH units)
Additional gains	FDD & TDD	This parameter represents **further gains (positive value) or losses (negative value) in dB**. Usually 0dB.

10.1.3 System Overhead parameters

Table 69 System Overhead parameters

Parameter name	FDD TDD	Description
Total Number of PRBs per TTI	FDD & TDD	Number of Resource Blocks in Frequency Domain - the value of this parameter is **determined by the channel bandwidth** - it determines how many PRBs are available in the entire bandwidth used in the cell.
Cyclic Prefix	FDD & TDD	This parameter defines the **type of cyclic prefix (normal or extended)** to be assumed. The cyclic prefix type influences the capacity of a PRB in the time domain: 1 TTI (1 slot) either contains 7 symbols (when cyclic prefix = normal) or 6 symbols (when cyclic prefix = extended).
Number of OFDM symbols per subframe	FDD & TDD	This parameter **depends on the Cyclic Prefix configuration**. It determines the no. of symbols available within one subframe. As a subframe consists of 2 timeslots(1 TTI = 1ms), the resulting value is 14 [symbols] (when cyclic prefix = normal) or 12 [symbols] (when cyclic prefix = extended).
Number of PDCCH symbols per subframe	FDD & TDD	This parameter defines **how many symbols are consumed by the PDCCH within one subframe** (range 1..4). It is relevant for the overhead calculation and only relevant for DL. 4 symbols are reserved in small bandwidth configuration due to the need for robustness and signaling capacity. Typical values: • 4 PDCCH symbols in 1.4 MHz bandwidth • 3 PDCCH symbols in 3, 5, 10, 15, 20 MHz bandwidths
Number of PRBs for PUCCH	FDD & TDD	This parameter defines **how many PRBs are consumed by the PUCCH** within one subframe.
RACH density per 10ms	FDD & TDD	This parameter defines the configured PRACH density, that is with which **frequency a PRACH reservation is repeated**. This parameter is relevant for the overhead estimation and only relevant for UL.
Reference signal	FDD & TDD	This parameter represents the **overhead (in [%]) used for the reference signals in DL and UL**. The number of reference signals depends on the number of deployed antennas/antenna ports.
Primary synchronization signal (PSS)	FDD & TDD	This parameter represents the **overhead (in [%]) used for the primary synchronization signals in DL and UL**.

Table 69 System Overhead parameters (Cont.)

Parameter name	**FDD** **TDD**	**Description**
		Mapping on the Resource Elements (PSS and SSS): Two last OFDM symbols in timeslot 0 and 10 in every radio frame. 72 subcarriers (1.08 MHz) occupied in every symbol dedicated for synchronization channel.
Secondary synchronization signal (SSS)	FDD & TDD	This parameter is automatically calculated and represents the **overhead (in [%]) used for the secondary synchronization signals in DL and UL**. Mapping on the Resource Elements (PSS and SSS): Two last OFDM symbols in timeslot 0 and 10 in every radio frame. 72 subcarriers (1.08 MHz) occupied in every symbol dedicated for synchronization channel.
PBCH/PRACH	FDD & TDD	This parameter defines the **overhead (in [%]) consumed by for the PBCH** (**DL**, calculated by dividing the PBCH resources by the overall amount of resources) **and PRACH** (**UL**, calculated considering the setting of 'RACH density').
PDCCH(incl. PCFICH,PHICH) /PUCCH	FDD & TDD	This parameter defines the **overhead (in [%]) consumed by for the PDCCH** (**DL**, calculated based on the setting of 'No. of PDCCH symbols per subframe' **and PUCCH** (**UL**, calculated considering the setting of 'No. of PRBs for PUCCH').
PUSCH UCI	FDD & TDD	Uplink Control Information multiplexed with user data when PUSCH is scheduled (CQI, PMI, RI and ACK/NACKs).
Number of PRBs used for PRS		This parameter **defines the number of PRBs utilized for Positioning Reference Signal (PRS)**. Typical values: Number of PRBs used for PRS should be the maximum allowed number within currently chosen channel bandwidth (whole bandwidth used for PRS).
PRS repetition period [ms]		This parameter **defines the time period between consecutive PRS signal repetitions**. Typical values: • • 160 ms
Number of PRS DL subframes per repetition period		This parameter **defines the number of subframes utilised for PRS signal per each repetition**. Typical values:

Table 69 System Overhead parameters (Cont.)

Parameter name	FDD TDD	Description
		• • 1 subframe per repetition period

10.1.4 Capacity parameters

Table 70 Capacity parameters

Parameter name	FDD TDD	Description
Modulation and Coding Scheme	FDD & TDD	This parameter defines the **MCS that shall be supported at the cell edge** in order to carry the throughput requirement defined by the parameter 'Cell Edge User Throughput (kbps). Notes: A low (robust MCS) allows for a large MAPL on the one hand. As a general rule, the link budget calculation aims at a maximum MAPL for a defined target cell edge user throughput. Normally the most robust MCS provides the best MAPL. In LTE, however, it can happen that switching to a higher MCS actually increases the MAPL (this effect depends on the cell-edge user throughput and the number of allocated PRBs and is caused by the varying coding efficiencies of low MCSs). Due to the aforementioned effect, the MCS that provides the best MAPL must be determined iteratively.
Service Type	FDD & TDD	This parameter was **implemented in order to facilitate the throughput requirement entry for VoIP dimensioning**. Possible values are either 'Data' or the narrow-band AMR codec types (source rates)'AMR-NB 1.8' to 'AMR-NB 12.2'.
Cell Edge User Throughput	FDD & TDD	This parameter defines the **minimum net user throughput (that is without coding overhead) that shall be supported for a single UE at the cell edge** with a certain probability (defined by the parameter 'Location/Cell Edge Probability'). This parameter defines the required QoS at the cell edge and is the main criterion that influences the MAPL (that limits the maximum possible cell size) from the user/subscriber perspective.
Residual BLER / Number of Transmissions	FDD & TDD	The field should be aligned with operator's requirement concerning the target BLER and allowable number of retransmissions. However, Link Adaptation targets are

Table 70 Capacity parameters (Cont.)

Parameter name	**FDD** **TDD**	**Description**
		set at 10% BLER after 1st transmission by default O&M configuration. In case of TTI bundling it is recommended to assume 4 HARQ transmissions with 1% residual BLER: rBLER=1% (4Tr) Recommendation: Use "rBLER=10% (1Tr)" for data dimensioning. In case of VoIP dimensioning it is recommended to use "rBLER=1%"(4Tr)
Number of PRBs per User	FDD & TDD	This parameter indicates the **number of RBs consumed by a single user**.
Channel Usage per TTI	FDD & TDD	This parameter indicates the percentage of PRBs used by a single cell-edge user. This factor does not reflect the average cell load but it is the instantaneous resource utilization at the cell-edge. It is not used to calculate the interference margin. It is used in order to estimate the FDPS gain (frequency scheduling gain).
Transport Block Size for PDSCH/PUSCH (bit/TTI)	FDD & TDD	This parameter defines the **number of user bits sent during a single TTI**.

Effective Coding Rate	FDD & TDD	This parameter indicates the **coding rate applied to PDSCH/PUSCH with respect to the selected MCS**, the number of allocated PRBs and the given TBS.
		ECR = TBS / (#PRB x (1-overhead) x 2 x #RE_per_PRB x ModOrder)
		TBS = Transport Block Size defined in terms of a single subframe
		#PRB = number of allocated PRBs
		#RE_per_PRB = number of resource elements per PRB per timeslot (0.5 ms); multiplying by 2 means the whole subframe is considered (1 ms) which is valid for the TBS.
		ModOrder - 2 (QPSK), 4 (16QAM), 6 (64QAM).

10.1.5 Channel parameters

Table 71 Channel parameters

Parameter name	**FDD** **TDD**	**Description**
Channel Model	FDD & TDD	The channel model determines the fading profile for the **'required SINR' values to be used during dimensioning** - therefore, for every dimensioning campaign, the used underlying channel model must be clearly defined. Recommendation: Typically used: Enhanced Pedestrian A 5 Hz' (EPA5)
Antenna Configuration	FDD & TDD	This parameter defines the antenna configuration with respect to redundancy in the DL and UL path, expressed as the no. of transmitters (Tx) and receivers Rx) used in the corresponding link direction. Typical values: DL: 2Tx-2Rx UL: 1Tx-2Rx
Frequency scheduler	FDD & TDD	This parameter is relevant for DL and UL and defines the **type of packet scheduler** to be considered (FDPS = Frequency Domain Packet Scheduler). Typical values: • DL: Channel aware • UL: – RL10/RL20: Channel unaware – RL30: Interference aware – RL15TD/RL40 onward: Channel aware
Number of Users per TTI (Loaded Cell)	FDD & TDD	This parameter defines the **Maximum number of users which can be scheduled in the frequency domain in a single TTI**. Its value also depends on the chosen bandwidth.
Frequency Scheduling Gain	FDD & TDD	This parameter indicates the coverage gain induced by the selected scheduler type
HARQ Gain	FDD & TDD	This parameter indicates the **coverage gain of HARQ in dependency on the no. of HARQ transmissions**.
Required SINR at Cell Edge	FDD & TDD	This parameter indicates the 'required SINR' value at the cell edge that is calculated.

Table 71 Channel parameters (Cont.)

Parameter name	**FDD** **TDD**	**Description**
Cell Load	FDD & TDD	This parameter defines the **average cell load that is to be assumed for interference estimation**. The higher the traffic load in the cells, the higher the interference and the higher the interference margin that must be assumed.
Interference Margin	FDD & TDD	This parameter defines the interference margin, which is a value that represents the MAPL reduction due to neighbor cell load dependent interference.
Number of Received Subcarriers	FDD & TDD	This parameter indicates the **number of OFDM subcarriers that are utilized in the entire configured OFDM frequency band**. This parameter is used, among others, to calculate the Rx sensitivity.
Thermal Noise Density	FDD & TDD	This parameter is also used for the calculation of the 'Receiver Sensitivity' - it represents the **thermal noise density**.
Subcarrier Bandwidth	FDD & TDD	This parameter defines the **bandwidth per OFDM subcarrier**.
Noise Power per Subcarrier	FDD & TDD	This parameter indicates the **noise power per subcarrier** that is calculated based on the 'Thermal Noise Density' and the 'Subcarrier Bandwidth'.
Receiver Sensitivity	FDD & TDD	Based on the aforementioned parameters, this parameter indicates the **calculated Rx sensitivity that is derived from the above listed parameters**.
Maximum Allowable Path Loss (clutter not considered)	FDD & TDD	This indicates the **clutter- and propagation independent MAPL**.
DL Reference Signal Received Power	FDD & TDD	This parameter indicates **Downlink Reference Signal Received Power** in dBm that is obtained using previously calculated MAPL value.

10.1.6 Propagation and attenuation parameters

10.1.6.1 Macro propagation model COST-231 (Okumura-Hata)

Table 72 Macro propagation model COST-231

Parameter name	**Description**
BTS antenna height	This parameter is a mandatory input for the propagation model calculation formula and defines the **average height of the BTS antennas** deployed in the network. Typical value: 30m
MS antenna height	This parameter is a mandatory input for the propagation model calculation formula and defines **the average height of the UE antennas**. Typical value: 1,5m
Average penetration loss	This parameter is a mandatory input for the propagation model calculation formula and defines the **average obstacle penetration loss of the related environment**.
Standard deviation outdoor	This parameter is a mandatory input for the propagation model calculation formula and defines the **standard deviation of the outdoor propagation attenuation**.
Standard deviation of Penetration loss	This parameter is a mandatory input for the propagation model calculation formula and defines the **standard deviation of the obstacle penetration loss**.
Location/Cell Edge probability	This parameter **defines the probability for a cell edge user to receive the minimum coverage needed to fulfill the minimum service requirement** (for example cell edge throughput). This required coverage probability is needed to determine the used Log Normal Fading Margin.
Cell Area probability	This parameter **defines the probability for user to receive the minimum coverage needed to fulfill the minimum service requirement (for example cell edge throughput) at any place in the cell**. This required coverage probability is needed to determine the used slow fading margin.
Log Normal Fading Margin	This parameter represents, as a dB value, a **margin to be subtracted from the overall MAPL in order to leave sufficient coverage reserves for the cell area probability target**.
Maximum Allowable Path Loss (clutter considered)	This value is the target MAPL value of the propagation related 'Link Budget' calculation.
Propagation Model	This parameter determines the propagation model to be used to calculate the cell range from the previously calculated clutter-dependent MAPL.

Table 72 Macro propagation model COST-231 (Cont.)

Parameter name	**Description**
	For the subsequent parameters, the propagation model 'COST 231' that has been defined in two variants: 'one-slope' and 'two-slope' is assumed
Intercept point	This parameter belongs to the **COST231** two-slope propagation model and **defines the transition point from Slope 1 to Slope 2**.
Slope 1	This parameter belongs to the **COST231** propagation model and **defines the 'slope' of the signal attenuation close to the base station**.
Slope 2	This parameter is only relevant for the **COST231** two-slope propagation model and defines the **second 'slope' of the signal attenuation in relative distance from the base station** (beyond the 'intercept point').
Clutter Correction Factor	This parameter belongs to the COST231 propagation model and defines the **clutter correction term in the propagation model formula** that has to be considered in the environment considered.
Site Layout	This parameter defines the site layout (Omni, 3-sector of 6-sector) that must be evaluated in order to determine the way how the cell range must be converted in to a basic cell area, site area and inter-site distance.
Number of Cells per Site	This parameter represents the number of cells per site and depends on the chosen site layout.
Cell Area	This parameter represents the cell area in [km2] that is calculated from the cell range considering the site layout.
Site Area	This parameter represents the site area in [km2] that is calculated from the cell range considering the site layout. While in case of omni cells, 'Site area' and 'Cell Area' are the same, in case of sectorized sites the 'Site area' is the <no.-of-sectors-per-site>-fold value of the cell area.
Inter Site Distance	This parameter represents the distance between two adjacent sites in [km] that is calculated from the site range and considering the site layout.
Site Count	The coverage driven number of required sites can be simply calculated by dividing the operator-defined deployment area by the previously calculated Site Area. This means: to calculate the coverage driven site count, the deployment area must be known as input parameter.

10.1.6.2 Indoor propagation model ITU-R P.1238

Table 73 Indoor propagation model ITU-R P.1238

Parameter name	Description
Environment	Indicates for which kind of environment the propagation is considered. This distinction is necessary in order to correctly reflect the different indoor environments type resulting from different propagation attenuation figures in different environments. From the model specification three different environment types are available: • Residential • Office • Commercial Recommendation: If not noted, Office environment type should be applied.
Number of Traversed Floors	Number of the floors the indoor cell is covering. Recommendation: If not noted, 1 traversed floor should be applied.
Average Penetration Loss - Floors (dB)	The overall floor attenuation calculated from the Number of Traversed Floors (see parameter above).
Standard deviation	This parameter is used in the propagation model calculation formula. This value is needed for Cell area probability and Log Normal Fading Margin.
Location/Cell Edge probability	This parameter **defines the probability for a cell edge user to receive the minimum coverage needed to fulfill the minimum service requirement (for example cell edge throughput) at any place in the cell**. This required coverage probability is needed to determine the used Log Normal Fading Margin.
Cell Area probability	This parameter **defines the probability for user to receive the minimum coverage needed to fulfill the minimum service requirement (for example cell edge throughput) at any place in the cell**. This required coverage probability is needed to determine the used slow fading margin.
Log Normal Fading Margin	This parameter represents, as a dB value, a **margin to be subtracted from the overall MAPL in order to leave sufficient coverage reserves for the cell area probability target**.
Maximum Allowable Path Loss (clutter considered)	This value is the target MAPL value of the propagation related 'Link Budget' calculation.
Intercept point	This parameter is calculated from ITU-R P.1238 Recommendation pathloss formula and it should not be modified.

Table 73 Indoor propagation model ITU-R P.1238 (Cont.)

Parameter name	Description
Slope	This parameter defines **slope of the attenuation** dependent on chosen **environment type**.

10.1.6.3 Indoor propagation model WINNER A1

Table 74 Indoor propagation model WINNER A1

Parameter name	Description
Environment	**Indicates for which kind of environment the propagation is considered.** This distinction is necessary in order to correctly reflect the different indoor environments type resulting from different propagation attenuation figures in different environments. Because WINNER A1 model is site specific and calculates propagation loss for single rays, please use worst case - the position in the building in highest distance and number of walls/floors traversed which is desired to be covered by the radiating point. From the model specification four different environment types are available: • LOS • NLOS Corridor-to-Room (or vice versa) • NLOS Room-to-Room • NLOS Corridor-to-corr Recommendation: If not noted because of irregularity of different indoor layouts, NLOS Corridor-to-Room environment type should be applied.
Dominant Wall Type	The parameter defines type of the wall dominating in the environment. There are two types of walls available from drop down menu: Light and Heavy. Decision of which of them should be applied must be based on the knowledge of environment.
Number of Traversed Walls	Parameter defines the number of the walls through the indoor cell is traversing. For aggressive cell range estimation the highest value available in straight line from radiating point to the place where we want to have coverage should be applied. In any other case the value of traversed walls should be averaged through the whole floor/building.
Average Penetration Loss - Walls (dB)	The overall wall attenuation calculated from the Number of Traversed Walls and Dominant Wall Type.
Number of Traversed Floors	Number of the floors the indoor cell is covering. Recommendation: If not noted, 1 traversed floor should be applied.

Table 74 Indoor propagation model WINNER A1 (Cont.)

Parameter name	Description
Average Penetration Loss - Floors (dB)	The overall floor attenuation calculated from the Number of Traversed Floors.
Standard deviation	Values are taken from Recommendation. Recommendation: Apply following parameters when majority of propagation paths is: • LOS = 3 dB • NLOS Corridor-to-Room = 3 dB • NLOS Room-to-Room – light walls dominant = 6 dB – heavy walls dominant (concrete) = 8 dB • NLOS Corridor-to-corr = 5 dB
Location/Cell Edge probability	This parameter **defines the probability for a cell edge user to receive the minimum coverage needed to fulfill the minimum service requirement** (for example cell edge throughput). This required coverage probability is needed to determine the used Log Normal Fading Margin.
Cell Area probability	This parameter **defines the probability for user to receive the minimum coverage needed to fulfill the minimum service requirement** (for example cell edge throughput) at any place in the cell. This required coverage probability is needed to determine the used slow fading margin.
Log Normal Fading Margin	This parameter represents, as a dB value, a **margin to be subtracted from the overall MAPL in order to leave sufficient coverage reserves for the cell area probability target**.
Maximum Allowable Path Loss (clutter considered)	This value is the target MAPL value of the propagation related 'Link Budget' calculation.
Intercept point	This parameter is calculated from WINNER A1 Recommendation pathloss formula and it should not be modified.
Slope	This parameter defines **slope of the attenuation** dependent on chosen **environment type**.

10.1.6.4 Propagation model Indoor COST-231 Multi-Wall with One-Slope

Table 75 Propagation model Indoor COST-231 Multi-Wall with One-Slope

Parameter name	**Description**
Different types of obstacles	Default set of walls/obstacles with their attenuation coefficients **(column Penetration Loss (dB)** is given. However it may be changed freely. Because this is site specific model, no default set of walls/obstacles is recommended and it should be verified with reality. In the column **Number of Traversed Walls** proper value for chosen types should be set.
Average Penetration Loss - Walls (dB)	The overall walls/obstacles attenuation calculated from multiplication of the number of traversed specific walls/obstacles and their appropriate attenuation..
Traversed Floors	Default set of **Number of the floors** the indoor cell is covering with the **Penetration Loss (dB)** of a single floor, taken from COST231 Multi-Wall. Recommendation: If not noted, 1 traversed floor should be applied.
Average Penetration Loss - Floors (dB)	The overall floor attenuation calculated from the Number of Traversed Floors and their Penetration Loss.
Environment	**Indicates for which kind of environment the propagation is considered.** This distinction is necessary in order to correctly reflect the different indoor environments type resulting from different propagation attenuation figures in different environments. Because COST231 Multi-Wall model is site specific and calculates propagation loss for single rays, please use worst case - the position in the building in highest distance and number of walls/floors traversed which is desired to be covered by the radiating point. Five different environment types are available: • Free Space (first column drop down menu) • Corridor (first column drop down menu) • Open Space • Semi-Open Space • Closed Space Type of the environment type has the influence only on the Slope value. Recommendation: If not noted because of irregularity of different indoor layouts, Semi-Open Space environment type should be applied.
Standard deviation	This parameter is used in the propagation model calculation formula. This value is needed for Cell area probability and Log Normal Fading Margin. Values are taken from Recommendation.

Table 75 Propagation model Indoor COST-231 Multi-Wall with One-Slope (Cont.)

Parameter name	**Description**
Location/Cell Edge probability	This parameter **defines the probability for a cell edge user to receive the minimum coverage needed to fulfill the minimum service requirement** (for example cell edge throughput). This required coverage probability is needed to determine the used Log Normal Fading Margin.
Cell Area probability	This parameter **defines the probability for user to receive the minimum coverage needed to fulfill the minimum service requirement (for example cell edge throughput) at any place in the cell**. This required coverage probability is needed to determine the used slow fading margin.
Log Normal Fading Margin	This parameter represents, as a dB value, a **margin to be subtracted from the overall MAPL in order to leave sufficient coverage reserves for the cell area probability target**.
Maximum Allowable Path Loss (clutter considered)	This value is the target MAPL value of the propagation related 'Link Budget' calculation.
Intercept point	This parameter is automatically calculated from COST 231 Multi-Wall Recommendation pathloss formula and it should not be modified.
Slope	This parameter defines **slope of the attenuation** dependent on chosen **environment type**.

10.2 Capacity Dimensioning

Table 76 Capacity dimensioning

Parameter name	**Description**
Cell Load	The cell load determines an interference margin for coverage calculation, however it has been agreed, that capacity calculation should reflect the average cell throughput under 100% loading to account for scenarios which are limited by the cell capacity.
Frequency Scheduler	This parameter defines the type of UL packet scheduler to be considered.

11 Flexi Zone Micro Radio interface dimensioning

This chapter provides general guidelines for Flexi Zone Micro air interface dimensioning activities, describing only most important differences comparing to the LTE macro sites dimensioning approach. It further discusses topology issues.

It focuses on the aspects that need to be additionally considered when creating the detailed link budget and capacity estimations for LTE Flexi Zone Micro air and transport interfaces.

All recommendations and assumptions presented in this chapter are valid for NSN LTE Flexi Zone Micro release RL50FZ.

11.1 Coverage dimensioning

11.1.1 Flexi Zone Micro hardware capabilities

Operating band

RL50FZ supports three operating bands:

- 2100 MHz (3GPP band 1), 1700/2100 MHz (3GPP Band 4) and 2600 MHz (3GPP band 7)

ℹ It is advised that the FZM product manager be consulted to ensure FZM supports the operating band and channel.

Channel bandwidth

RL50FZ supports four channel bandwidths:

- 5 MHz, 10 MHz, 15 MHz and 20 MHz

Transmit power

Flexi Zone Micro hardware supports much lower power levels than Flexi Macro sites:

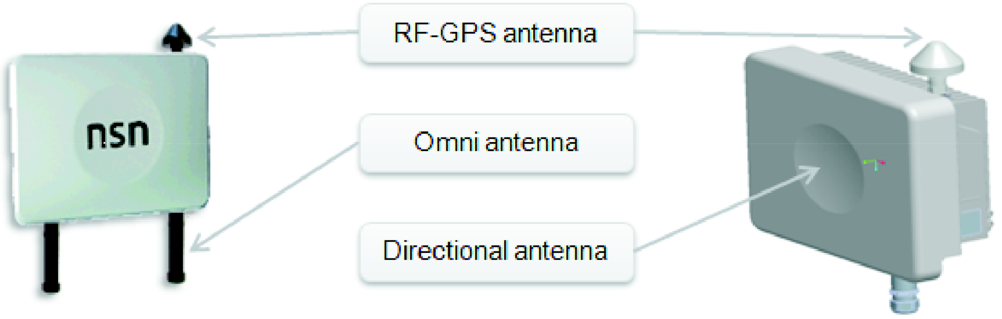
- 0.25 W (24 dBm) .. 5 W (37 dBm), adjustment resolution of 1dB

Antenna gain

Flexi Zone Micro hardware supports omni or built-in directional antennas (there is possibility to attach external antennas using in-built “N” connectors and jumpers):

- 1 dBi for Omni antenna below 2.6 GHz and 2 dBi for 2.6 GHz
- 6 dBi for directional antenna

Figure 55 Flexi Zone Micro antenna configuration



Calculations for the case with integrated directional antennas can be performed by changing the Site layout parameter to one sector (directional) and following the recommendation to change Antenna gain to 6 dBi in link budget calculation.

In case of scenarios using external antennas connected to FZM with jumpers, there should be assumed 0.4 dB Feeder loss.

Antenna configuration

Flexi Zone Micro hardware in RL50FZ can serve only one cell per site (single carrier) with 2Tx / 2Rx antenna configuration supporting DL transmission modes:

- Transmit diversity (TxDiv), Open Loop MIMO (OL MIMO), Closed Loop MIMO (CL MIMO) for two transmit antennas (2Tx)

Noise Figure

Flexi Zone Micro hardware complies with 3GPP 36.104 Medium Area Base Station performance requirements that allow for slight sensitivity degradation comparing to macro sites:

- 7 dB to be assumed for FZM

Sensitivity levels (SINR thresholds)

As the Flexi Zone Micro hardware uses the same PHY as Flexi Macro sites the SINR thresholds used in coverage calculations are the same in both cases.

11.1.2 Cell-edge user throughput requirements

It could be predicted that the throughput requirements should be higher for Small Cells than for Macro, however as they will be in most cases placed in the hotspot areas with higher users density the recommended cell-edge user throughput requirements remain unchanged comparing to Macro scenarios:

- 1024 kbps / 384 kbps in DL / UL respectively

Voice / VoIP throughput requirements are defined by the chosen voice codec:

- AMR-NB 12.2 (same as for Macro)
- AMR-WB 12.65 recommended for HD voice only

11.1.3 Interference Margin estimation

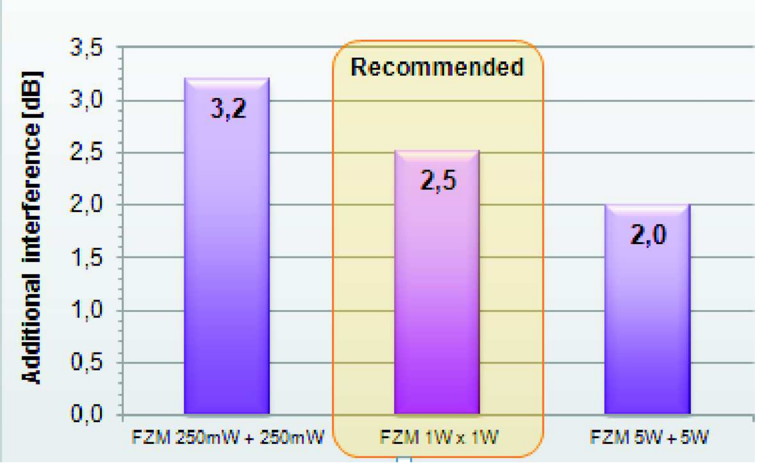
As the Small Cells will be in most cases placed in the hotspot areas with higher traffic (users) density than in case of regular macro sites it is recommended to assume 80% cell load for Small Cells dimensioning for both DL and UL.

Impact of Macro on Small Cells

In case of co-channel deployment scenarios there should be included additional interference from Macro sites that impacts Small Cell layer coverage calculations.

The interference rise depends on the Small Cell transmit power as shown in the following diagram.

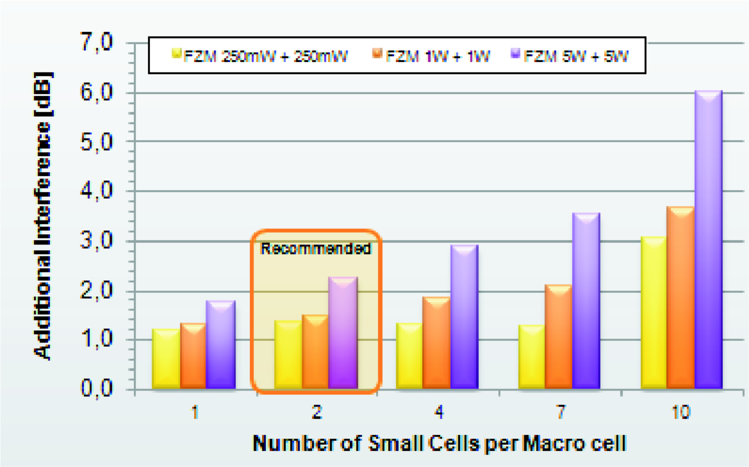
Figure 56 Interference rise of Small Cell (1)



In case of co-channel deployment scenarios there should be included additional interference from Small Cell sites that impacts Macro layer coverage calculations.

The interference rise depends on the Small Cell transmit power and the number of Small Cells deployed in Macro cell.

Figure 57 Interference rise of Small Cell (2)



11.1.4 Small Cells cell range estimation

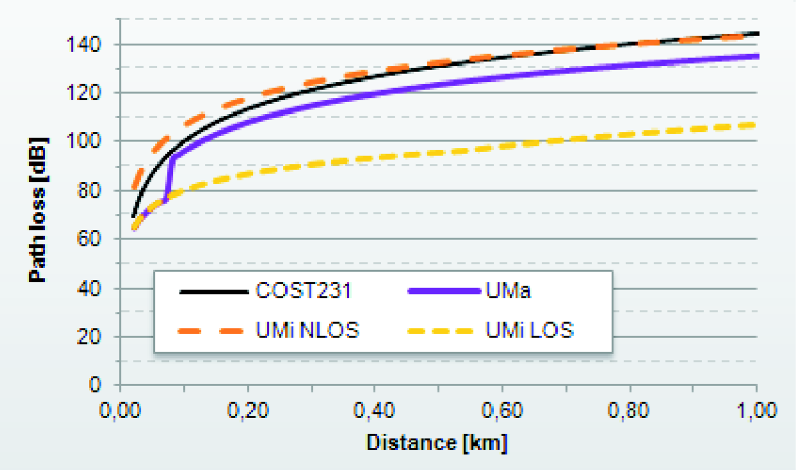
Different propagation characteristics of Small Cell deployments; lower power, antennas below clutter, suggest that propagation model different from the Macro be used for Small cell coverage estimates. The Urban Micro non line of sight (UMiNLoS) from 3GPP 36.814 is recommended.

$PL = 26\log_{10}(f[GHz])+22.7+36.7\log_{10}(d[m])$

COST231-Hata model used commonly for Macro dimensioning is too optimistic for Small Cell scenarios resulting in cell range differences of up to even 30 m.

In “down the street coverage” scenarios it could seem that the propagation conditions are close to near Line of Sight (nLOS) or even Line of Sight (LOS), nevertheless UMiNLoS model is still recommended as there may be some obstacles present on the propagation path (for example trees, cars, billboards).

Figure 58 Small Cell range estimation



Small Cells coverage will be highly dependent on the unit installation method (street lamp poles, walls, ceilings, etc.) and the antenna used:

- A 5 to 10 dB shadowing impact to path loss can be observed when using Omni antennas connected to the FZM installed on that pole (User is on opposite side of the pole from where the Small cell unit and Omni antennas are mounted).

One should keep in mind that the range estimate for the Small cell obtained using an analytical propagation model is an estimation only. Each propagation model reflects an average environment impact only and which in turn may not be suitable for each and every Small Cell deployment scenario as the propagation environment in the Small Cells coverage area varies more significantly between different sites than in case of Macro sites.

For more precise Small Cells coverage predictions it may be suitable to use more advanced planning tools using digital environment maps, 3D building databases and a 2D/3D ray tracing propagation models.

11.1.5 Flexi Macro vs. FZM – differences summary

Table 77 Flexi Macro and FlexiZone Micro comparison

	Flexi Macro	**FlexiZone Micro**
Main purpose	Coverage (outdoor and indoor), capacity	additional capacity, improve coverage
Operating bands	700MHz to 2600MHz	1700/2100MHz, 2100MHz, 2600MHz
Channel bandwidths	1.4MHz, 3MHz, 5MHz, 10MHz, 20MHz	5MHz, 10MHz, 15MHz, 20MHz
Transmit power	8W, 10W, 20W, 40W, 60W, 80W	2 x 5W
Number of supported cells	see section Number of supported cells, table 53 and 54	1cell/1sector
Number of connected users	see section Number of connected users	5MHz: 480 10MHz: 600 15MHz: 600 20MHz: 600
Site solutions	Feeder-less, feeder, feeder with TMA	Integrated antennas, feeder-less
Antenna gain	Typically 18 dBi to 22 dBi	2 dBi (omni), 6 dBi (directional)
Antenna configurations DL	1Tx, 2Tx, 4Tx, 8Tx	2Tx
Antenna configurations UL	1Rx, 2Rx, 4Rx, 8Rx	2Rx
eNB noise figure	2.2 dB	7 dB
eNB installation type	Towers, rooftops	Lamp poles, wall surfaces, ceilings
eNB height	typical 30 m	typical 7-10 m
DL / UL throughput	1024 kbps / 384 kbps	1024 kbps / 384 kbps
Interference margin	1 dB @ 50% cell load	4.5 dB @ 80% cell load
Propagation model	COST-231 Hata (Two slope)	3GPP 36.814 UMiNLoS

Performance of real networks may vary as a basic link budget analysis assumes homogeneous cell layout and traffic distribution whereas the real world will have non-homogeneous cell layout, traffic distribution and a mixture of propagation environments.

11.1.6 Exemplary Small Cell Link Budget calculations

As the Small Cells will be in most cases placed in the hotspot traffic areas with relatively high user density, there can be distinguished two deployment scenarios that could possibly be met most commonly:

- main city streets / squares with dense pedestrian traffic but with a very limited number of shops / boutiques / restaurants where only outdoor (down-the-street) coverage is required
- promenades / streets / squares with dense pedestrian traffic and with many shopping venues (shops / restaurants) where indoor coverage is required as well

As the Small Cells will be deployed for capacity enhancement solution, all cell range estimations should be treated as the general overview only – actual Small Cells coverage will vary strongly (even in different directions from the same Small Cell) depending on the environment.

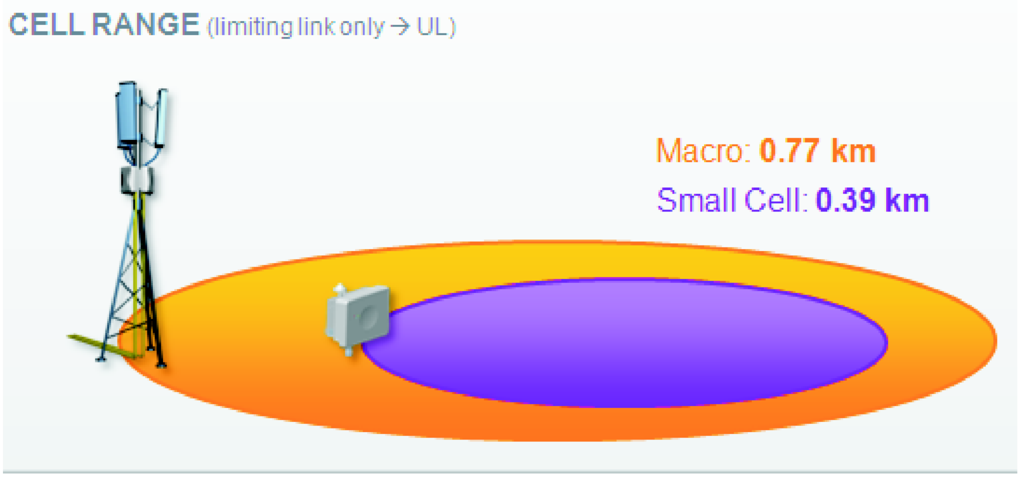
11.1.7 Coverage dimensioning scenarios

Scenario 1 – down-the-street Small Cell deployment (co-channel)

Table 78 Assumptions

	Macro	**Small Cells**
Clutter	Urban	
Operating bands	2600 MHz	2600 MHz
Channel bandwidths	20 MHz	10 MHz
Transmit power	20 W + 20 W	5 W + 5 W
Site solutions	feeder-less, feeder, feeder with TMA	Integrated antennas, feeder-less
Antenna gain	22 dBi	8 dBi (directional)
MIMO mode	CL MIMO 2Tx	CL MIMO 2Tx
DL / UL throughput	1024 kbps / 384 kbps	1024 kbps / 384 kbps
Penetration loss	15 dB	0 dB

Figure 59 Down-the-street Small Cell deployment



CONCLUSIONS

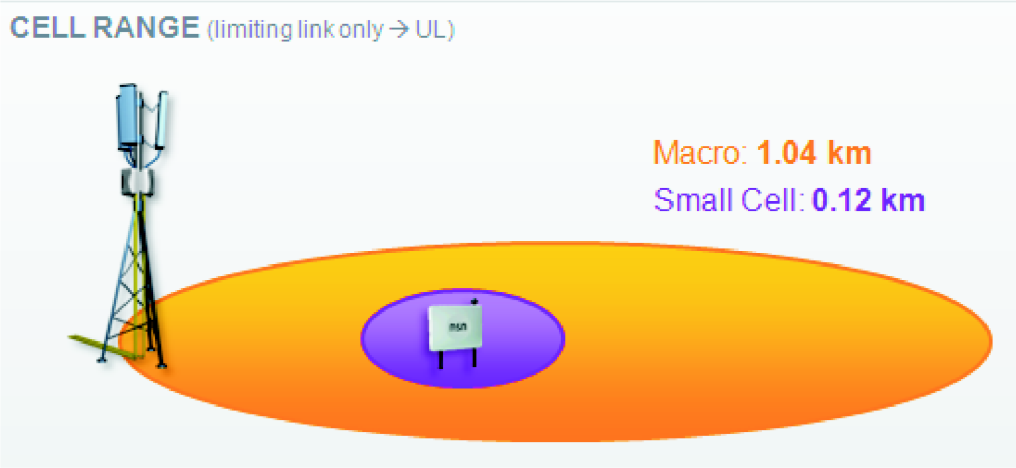
- As the Macro and Small Cell sites are operating on the same band there have to be assumed additional Interference Margin.
- No penetration loss assumed for Small Cells as no indoor coverage is required, however Macro sites are still required to assure indoor coverage (thus the penetration loss for Macro is assumed).
- Comparison of the Macro and Small Cell coverage results should be done carefully in case of different penetration loss assumptions).
- UL is the limiting link for both Macro and Small Cells.

Scenario 2 – promenade (shopping area) Small Cell deployment

Table 79 Assumptions

	Macro	**Small Cells**
Clutter	Urban	
Operating bands	1800 MHz	2600 MHz
Channel bandwidths	20 MHz	10 MHz
Transmit power	20 W + 20 W	5 W + 5 W
Antenna gain	22 dBi	2 dBi (omni)
MIMO mode	CL MIMO 2Tx	CL MIMO 2Tx
DL / UL throughput	1024 kbps / 384 kbps	1024 kbps / 384 kbps
Penetration loss	15 dB	15 dB

Figure 60 Promenade Small Cell deployment



CONCLUSIONS

- As the Macro and Small Cell sites are operating on different bands no additional Interference Margin should be assumed.
- Penetration loss assumed for Small Cells as the indoor coverage is required as well (inside shops / restaurants).
- UL is the limiting link for both Macro and Small Cells.

11.2 Air interface capacity dimensioning

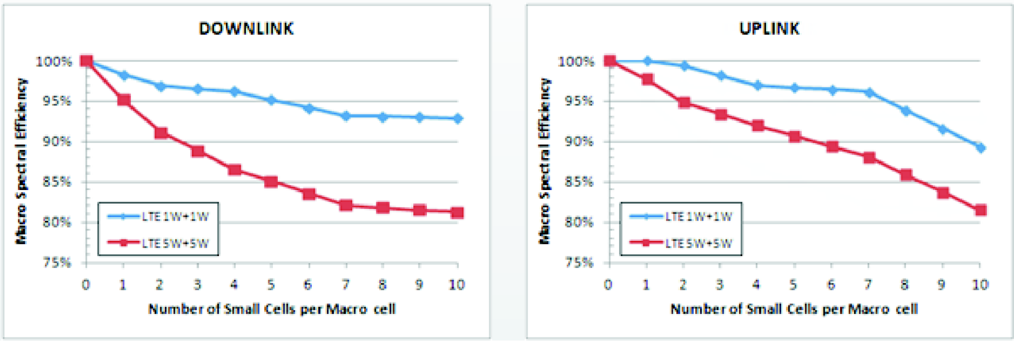
11.2.1 Impact of number of deployed Small Cells on Macro capacity

Deploying Small Cells in existing Macro network leads to a slight Macro sites' Spectral Efficiency degradation due to the additional interference.

The greater number of Small cells, the higher the interference (assuming same frequency for Macro and Small cell), resulting in the reduction of the Macro cell Spectral Efficiency.

The downlink is more interference limited than uplink.

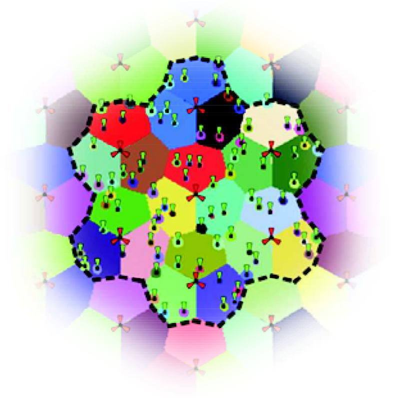
Figure 61 UL/DL interference limitation



The previous graphs are based on a simulation with the sites deployed as described below and represented by the following figure:

- 21 central Macro cells (ISD 500m) with randomly distributed Small Cells
- a Small Cell ↔ Small Cell minimum distance of 40m
- a Small Cell ↔ Macro site minimum distance of 70m

Figure 62 System level simulation (1)



11.2.2 Small Cells Spectral Efficiency values

Significantly smaller coverage area provided by each Small cell, along with the placement of the Small cell in the traffic hotspot with a high user density results in higher Small Cell Spectral Efficiency (translated to average cell capacity) when compared to the underlaying Macro cell.

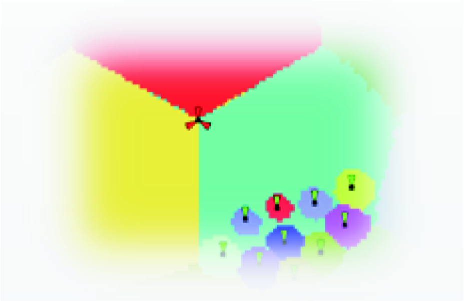
As the Small cells are not overlapping each other (low interference between small cells), the higher Spectral Efficiency does not depend on the quantity of Small Cells deployed within the Macro cell.

Table 80 Average Small Cells' cell capacity comparing to overlaying Macro cells

Average Small Cells' cell capacity comparing to overlaying Macro cells	
Downlink	**Uplink**
116%	115%

The following figure represents the scenario modeled in simulation with Small cells placed at a hotspot traffic location with a high user density.

Figure 63 System level simulation (2)



11.2.3 Small Cells site count estimation

For precise Small Cells site count estimations for contractual commitments more detailed RF design activities should be performed. It is also important to take into account hotspot traffic areas for the Small Cell locations that may result in the site count reduction comparing to the homogenous distribution.

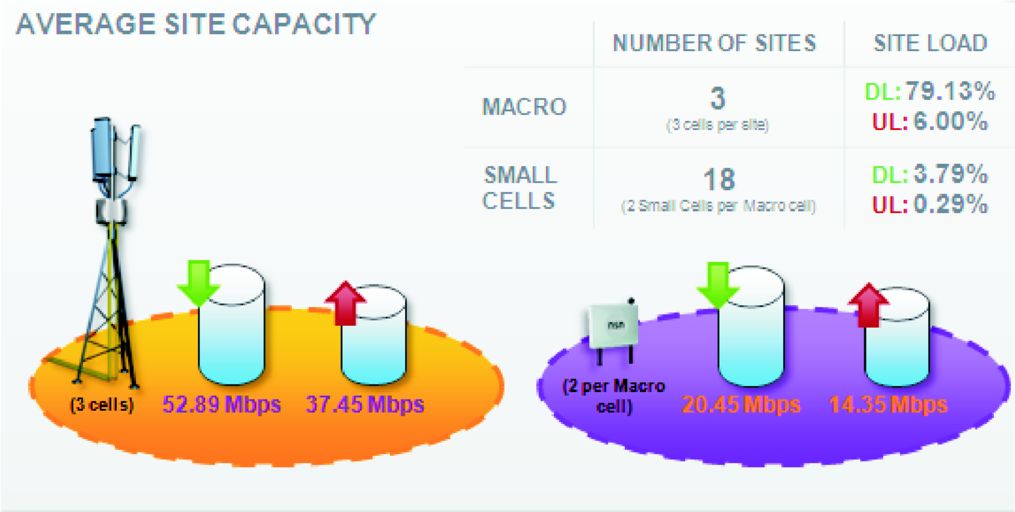
A high level link budget and simulation activity may assume fully homogenous sites, users and traffic distribution in the network – such approach is enough for the rough Small Cells impact estimation, however may not be precise enough for the Small Cell contractual commitments!

11.2.4 Homogenous traffic across entire area

Table 81 Assumptions

	Macro	**Small Cells**
Clutter	Urban	
Area size	20 km^2	
Operating bands	1800 MHz	2600 MHz
Channel bandwidths	10 MHz	10 MHz
Transmit power	20 W + 20 W	5 W + 5 W
Uplink scheduler	Channel aware	Channel aware
MIMO mode	CL MIMO 2Tx	CL MIMO 2Tx
Service	Internet Static Application	
Subscribers	45000 (2250 subs./km^2)	5000
Offered traffic (BH)	DL: 125.55 Mbps UL: 6.74 Mbps	DL: 13.95 Mbps UL: 0.75 Mbps

Figure 64 Average site capacity (1)



	NUMBER OF SITES	SITE LOAD
MACRO	3 (3 cells per site)	DL: 79.13% UL: 6.00%
SMALL CELLS	18 (2 Small Cells per Macro cell)	DL: 3.79% UL: 0.29%

CONCLUSIONS

- Homogenous traffic (subscribers) distribution in the area requires many lightly loaded (DL: 3.79%, UL: 0.29%) Small Cells to serve assumed number of Small Cell subscribers (5000 in the whole area) due to their low density (250 subs./km^2)
- Assuming big area size does not reflect hotspot traffic locations expected in the Small Cell deployments

11.2.5 Hotspot traffic area

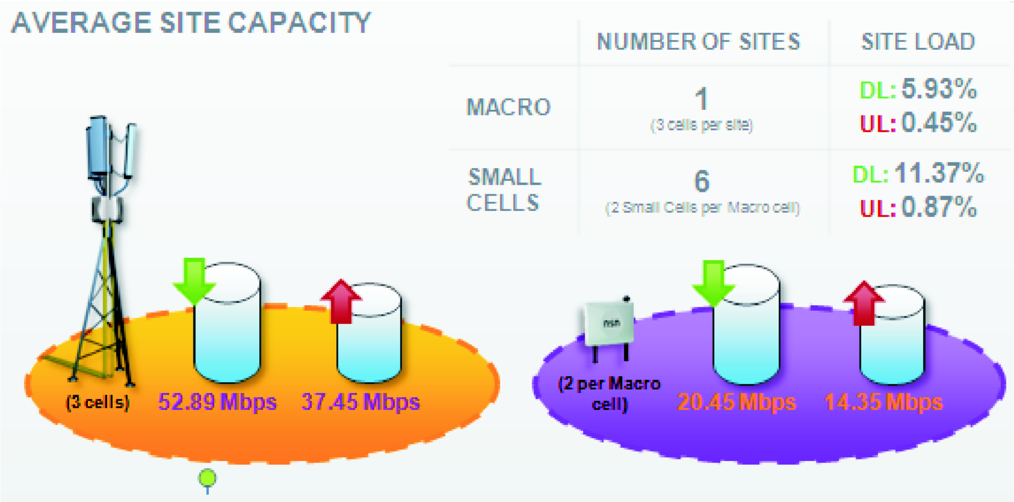
Table 82 Assumptions

	Macro	**Small Cells**
Clutter	Urban	
Area size	0.5 km^2(hotspot area)	
Operating bands	1800 MHz	2600 MHz
Channel bandwidths	10 MHz	10 MHz
Transmit power	20 W + 20 W	5 W + 5 W
Uplink scheduler	Channel aware	Channel aware
MIMO mode	CL MIMO 2Tx	CL MIMO 2Tx
Service	Internet Static Application	
Subscribers	1125 (2250 subs./km^2)	5000

Table 82 Assumptions (Cont.)

	Macro	**Small Cells**
Offered traffic (BH)	DL: 3.14 Mbps UL: 0.17 Mbps	DL: 13.95 Mbps UL: 0.75 Mbps

Figure 65 Average site capacity (2)



CONCLUSIONS

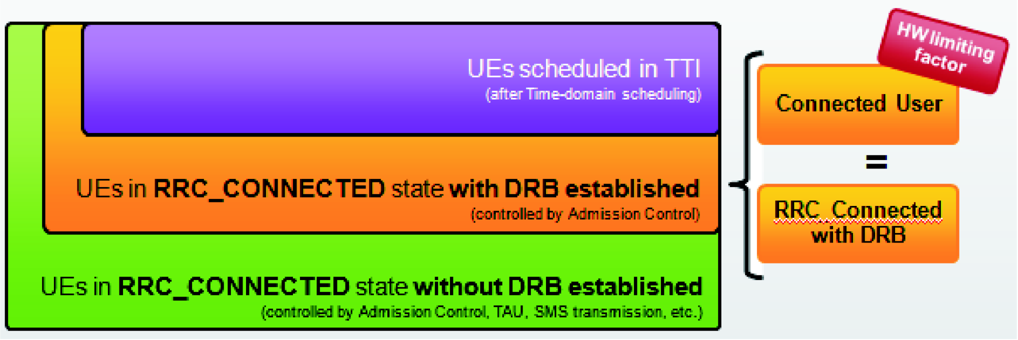
- Lowering the area size (0.5km^2) with the same Macro subscribers density (2250 subs./km2) and the same number of Small Cell users (5000) lowers the number of needed small cells (from 18 to 6) but being more loaded (11.37% vs. 3.79% on the DL).
- Narrowing the area allows for the hotspot traffic location modeling making calculations more precise.

11.3 Baseband dimensioning

Number of Connected Users supported in RL50FZ depends on the channel bandwidth:

- 480 for 5MHz channel bandwidth and 600 for 10MHz, 15MHz and 20MHz channel bandwidth (both with 2x2 MIMO)

Figure 66 Connected user definition



12 References

1. 3GPP TS 36.211 Physical channels and modulation
2. 3GPP TS 36.104 Base Station (BS) radio transmission and reception
3. 3GPP TS 36.101 User Equipment (UE) radio transmission and reception
4. 3GPP TS 36.213 Physical layer procedures
5. M. Casado-Fernandez, H.M. Al-Housami. Calculation of soft handover gain for UMTS. 8-10 May 2002, Conference Publication No. 489, IEEE