

THE EXPERT'S VOICE® IN NETWORKING

4G: Deployment Strategies and Operational Implications

*MANAGING CRITICAL DECISIONS IN
DEPLOYMENT OF 4G/LTE NETWORKS
AND THEIR EFFECTS ON NETWORK
OPERATIONS AND BUSINESS*

Trichy Venkataraman Krishnamurthy and Rajaneesh Shetty

Apress®

For your convenience Apress has placed some of the front matter material after the index. Please use the Bookmarks and Contents at a Glance links to access them.



Apress®

Contents at a Glance

About the Authors.....	xiii
Introduction	xv
■ Chapter 1: Network Planning	1
■ Chapter 2: Self-Organizing Networks in LTE Deployment.....	37
■ Chapter 3: Deployment Challenges in Evolving 4G.....	65
■ Chapter 4: Network Roadmaps.....	89
■ Chapter 5: Network Roadmap Evolution.....	117
■ Chapter 6: A Process for Network Roadmap Evolution	139
Index.....	165

Introduction

This book evaluates a range of design and deployment strategies for LTE network business development, and presents a process for planning and evolving network roadmaps.

Among those who will find this book useful are new field engineers who have been entrusted with the arduous tasks of deploying 4G networks. The initial chapter in the book endeavors to arm you with enough information to understand what you are doing, and why. The book also demonstrates how self-organizing networks (SON) can help improve the deployment process and help reduce the round trip time in optimizing and tuning your network. Subsequent chapters cover roadmap development and how it improves your ability to plan, build, and deploy more successful networks.

From a broader perspective, this book is for all people involved or entrusted with the maintenance of 4G networks, including architects, product managers, and program managers. Senior management executives will also find the book valuable, as it give them the requisite knowledge to better ensure that relevant stakeholders are involved in the process of roadmap management and evolve strategies to ensure that their 4G networks remain operational, meaningful, and successful. We cover potential roadblocks to successful deployments, and how to avoid or overcome them. We also delve into roadmap management, with suggestions on how to keep them relevant using reliability engineering, organizational culture, and evolution concepts.

How This Book Is Structured

Chapter 1, “Network Planning,” covers the nuts and bolts of deployment, and gives a speedy tour of the whole process.

Chapter 2, “Self-Organizing Networks and LTE Deployment,” gives a general overview of SON concepts, and helps explain how SON attempts to solve various deployment issues.

Chapter 3, “Deployment Challenges in Evolving 4G,” introduces readers to the challenges of LTE deployment, and highlights trends in user and traffic profiles , as well as newer trends like the Internet of Things, which need to be accounted for by LTE networks.

Chapter 4, “Network Roadmaps,” introduces roadmap concepts for networks and provides further coverage of factors that can affect stakeholders.

Chapter 5, “Network Roadmap Evolution,” focuses on how network roadmaps have to evolve and adapt to changes in technology, markets, deployments, and traffic patterns.

Chapter 6, “A Process for Network Roadmaps Evolution,” presents a detailed set of processes for network roadmap management and evolution.

Prerequisites

For the deployment-related sections of the book, readers are expected to have knowledge of LTE and radio basics, and have some practical idea of what is to be accomplished. For sections covering network roadmap management and evolution, readers should have a basic understanding of network product development.



Network Planning

Network planning, especially for a cellular network, can be an extremely complex as well as time-consuming procedure. There are many steps and parameters that should be considered to ensure a well-planned radio network.

This chapter gives a fast tour through the network planning and optimization of a Long Term Evolution (LTE) radio network. We also present a strong grounding through the various aspects of the LTE standard and features that you can use as a guide through the various options for deployment. This will equip you with the knowledge to understand the choices you can make when selecting a system and need to shortlist solutions. In some cases, you may already understand the options based on decisions you have already made for network options using some other method.

We start by going through some basic concepts and steps that should be followed for deployment of any radio technology. After covering these basics, we deal with the different aspects of LTE features in terms of the deployment impact in the dimensions of coverage, capacity, and performance.

We then cover some advanced features intended to make LTE deployments easier. We also cover the various services offered and what types of implications these hold for the solution being deployed. We revisit the generic topics of deployment with LTE radio frequency (RF)-specific deployment inputs and discuss issues that can arise during that process.

Finally, we end the chapter with inputs on the performance matrix and how the different aspects of LTE-evolved node B (eNodeB) performance can be tested.

The main goal in network planning is to ensure that the planned area is covered completely. Every cellular network needs cell-site planning to ensure coverage requirements, to maximize capacity requirements, and to avoid interference. The cell-planning process consists of many different tasks, which together make it possible to achieve a well-working network. The major activities involved in the cell-planning process are represented in Figure 1-1. Broadly, the radio network planning and optimization activity can be subclassified into the following phases:

- Dimensioning phase
- Planning and implementation phase
- Optimization phase

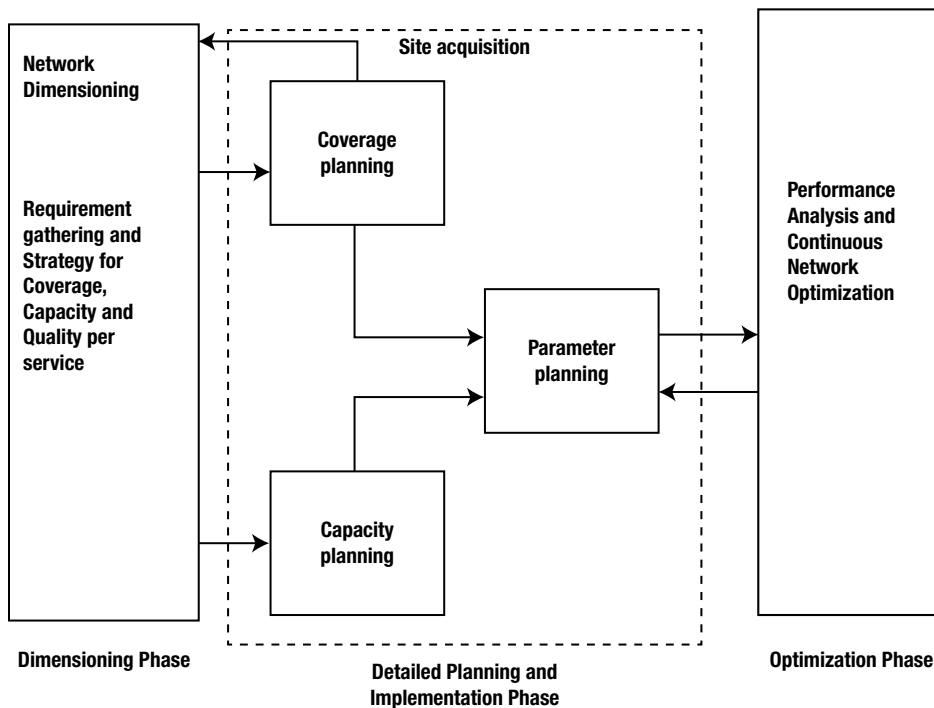


Figure 1-1. Radio network planning phases

Dimensioning Phase

The dimensioning phase will mainly involve information and requirement gathering from the customer from which the initial objectives for the radio network planning can be set. Some of the key inputs that are considered or required to be performed in the dimensioning are outlined in the sections that follow.

Configuration for the Site

As part of the configuration details, it is important to understand whether the site will be configured for a multiple-input and multiple-output (MIMO) or single-input and single-output (SISO) system. If the system is MIMO, then the transmission mode needs configuration. Also, as a part of site configuration, it is important to understand how many cells will be installed or eNodeB (i.e., sector configuration) for each site.

User and Traffic Volume Estimation

As a part of dimensioning, it is important to estimate the user volume and the traffic volume for each site; for example, the number of users in an urban site will be very high compared with the volume for a rural site. Similarly, the traffic volume will be higher in an area that has small offices set up in comparison with a highway deployment. The user and traffic volume estimation directly impacts the cell size that can be supported for a particular area and the capacity requirement. It also is useful for parameter settings like physical random access channel (PRACH) configuration settings, scheduler settings, and so forth. Apart from the traffic volume, it is also important to understand the traffic type that will dominate the cell so the dimensioning can be done accordingly by calculating the net bit rate for the traffic type, 4G voice over Internet protocol traffic (VOIP), streaming traffic, hypertext transfer protocol (HTTP) traffic, and so forth.

Coverage and Capacity Estimation

The customer should be able to provide the information on the area that is planned for service and also the quality of service offered for each user terminal (UE) within the service area. With this input from the customer, the cell coverage and capacity estimates are performed. Radio link budgeting is performed to understand the cell size that can be achieved with the input given from which the number of sites or cells required to plan the network area can be determined.

Interface Requirement

The interface requirements mainly deal with the S1 (interface between the mobility management entity [MME] and eNodeB) and X2 interface (interface between two eNodeBs) dimensioning. Based on the number of sites required (derived from the link budget activity) and the operator's allocated budget, the interfaces for each eNodeB will be dimensioned.

Budget Information

Budget information is very important because the number of resources (hardware) can be derived from the this, and in cases of limited budgets, the capacity or coverage planning will need to be accomplished with limited resources for a given area. Figure 1-2 presents a flow chart of the budget planning process.

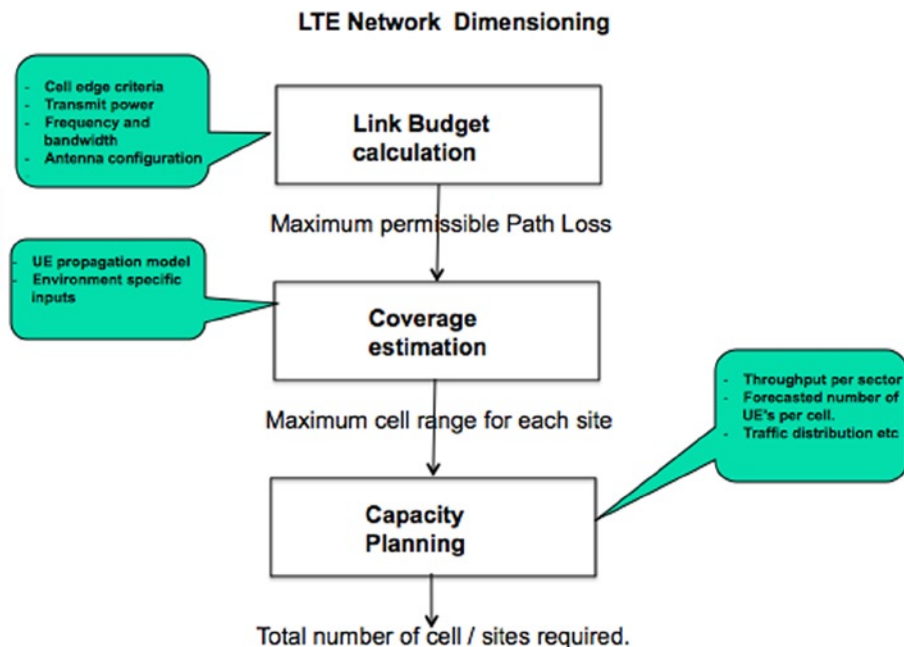


Figure 1-2. Network dimensioning based on budget

Planning and Implementation Phase

In the dimensioning phase, the equipment requirements are determined based on the number of cells or sites needed to provide a network to the complete area. During the planning and implementation phase, the exact location of where these eNodeBs should be placed is determined. Site selection activity is performed to accomplish the planning done in the dimensioning phase.

Upon determination of the sites where the eNodeBs will need to be placed, the network planning tools (i.e., Mentum, atoll) can be used to reconfirm that the capacity and the coverage planning that was performed in the dimensioning phase has been accomplished.

During the planning phase, backhaul planning must also be done. In cases where the site is a colocated site, the backhaul planning should be carried out for both colocalites as well as the new site.

Parameter planning and setting is a major part of this phase. Some of the parameters that will impact the coverage and capacity planning are:

- Uplink/downlink (UL/DL) frequency
- Bandwidth of operation
- Transmission mode
- Transmission power
- Quality of service (QoS) parameters
- Population distribution and density
- Outdoor environment type (urban, rural, small office, residential, etc.)
- Maps and clutter details for the area
- Fading model type (Extended Vehicular A model [EVA], Extended Typical Urban model [ETU], Extended Pedestrian A model [EPA], etc.)
- Predicted traffic type and its distribution

These factors will be discussed in detail later as they all impact the capacity and coverage planning.

As part of the planning process, signal-to-interference-plus-noise ratio (SINR) vs. throughput mapping is performed for different propagation models (i.e., EVA, ETU, EPA, etc.) and for different transmission modes (spatial multiplexing, transmit diversity, etc.).

Cell edge definition would depend on the SINR mapping.

Optimization Phase

Once the planning and implementation are complete, it is very common practice to run drive tests for the planned sites. Drive tests verify the predictions made by the planning tools, and the results from the drive tests are compared against the results from the simulations. Fine tuning is performed after the drive tests to ensure that the deviation in the results between simulation and drive tests is minimal.

A part of the drive test, parameters like reference signal receive power (RSRP), reference signal received quality (RSRQ), or SINR the UL and DL throughputs at different points of the cell are noted. The results are then compared with the SNR predictions made by the planning tool and deviations are noted and tuned wherever required.

Coverage Planning

Coverage planning targets for the complete service area are tested to ensure there are no coverage holes (i.e., the UE never experiences a no-service condition within the entire service area). Coverage plans, however, do not take into consideration any quality of service that the user experiences within a cell or site. The end aim is to provide the count of the resources or eNodeBs and cells that are required for the complete service area.

Some of the most important aspects that need to be considered as a part of the coverage planning are:

1. *The eNodeB transmitting power and the type of cell that is being planned.* The eNodeB transmitting power is the key for any coverage planning, and the transmitting power will vary based on the cell size. For example, a macro cell will have a transmission power of 10 watts per port (40 watts per cell in cases of MIMO cells). The DL coverage cell radius should be derived based on the transmission power of the antenna added with the gains (antenna gain, diversity gain, etc.) with the assumption of path loss (receiver loss, propagation loss, etc.). Cell radius calculation will be covered in detail in the link budget calculation section.
2. *The eNodeB receiver sensitivity.* In the uplink, in order to calculate the cell radius, one of the most important parameters that the operator relies on is the receiver sensitivity of the eNodeB. The eNodeB receiver sensitivity is a deciding factor for the maximum allowed path loss between the UE and the eNodeB in the uplink direction, beyond which the eNodeB cannot differentiate accurately between signal and noise. Better receiver sensitivity of the eNodeB will directly result in a larger cell radius (coverage radius) in the uplink. The 3GPP 36.141 defines the test for deriving the reference sensitivity of a receiver. The specification also requires that a receiver sensitivity of less than -100.8 decibel milliwatts (dbm) is acceptable. However, many vendors have a receiver sensitivity value of around -102 dbm or better.
3. *UE receiver sensitivity and transmission power.* Similar to the eNodeB receiver sensitivity, UE receiver sensitivity is an important factor in determining the DL cell radius for coverage planning. Typically for a macro cell, the UL cell radius will be a limiting factor in comparison with the DL cell radius simply because of the difference in the transmission powers. In LTE category 2 UE and onward, the maximum uplink transmit power is 23 db.
4. *Terrain.* Terrain is an important consideration for any site planning and will impact the absorption or attenuation capability of a site. For example, a site with irregular heights will not have linear loss and is subjected to shadow areas or reflection, whereas a site with fairly regular height will have a more predictable linear loss. Similarly, the indoor to outdoor ratio of a site also makes a difference when it comes to cell radius calculation (i.e., the penetration losses for an indoor user is higher compared with that for an outdoor user); therefore, planning an urban cell will be subject to more losses due to a higher percentage of indoor to outdoor users in comparison with a rural cell.

Improving Coverage for a Given Service Area

Some common practices to improve the coverage for a given service area are:

- *Receiver selection.* Selecting an eNodeB with a better receiver sensitivity will help to improve the coverage for a service area.
- *Implementing receiver diversity.* In UL higher frequencies, the chances of correctly decoding the received signal from the UE improve the coverage.
- *Beamforming.* For uneven heights, beamforming can be a very handy feature to compensate for any coverage hole.

- *Improving the antenna gain.* This is particularly useful for smaller cells, wherein the DL cell radius is limited in comparison with the UL cell radius.
- *Adding more sites.* In case none of these techniques can be used to compensate for a coverage hole, the last option would be to add a new site.

Capacity Planning

The capacity of an eNodeB indicates the maximum number of users that can be served by the eNodeB with a desired quality of service or the maximum cell throughput that can be achieved for a particular site at a given time. Increasing the capacity would mean increasing the number of users that can be accommodated by a cell or eNodeB, which in turn means that the number of eNodeBs or cells required to accommodate a volume of users inside a given area would be lessened, thereby reducing the cost of deployment for an operator.

Capacity planning, like coverage planning, also aims at providing an estimate on the number of resources or eNodeBs required for a given service area. However, in capacity planning, the quality of service that is provided to the users within the service area is the key factor.

Typically, the resource calculation from capacity planning for a given service area is higher in comparison with the resource calculations made by coverage planning. Capacity planning is initially done by using a simulation tool (e.g., Opnet, Radiodim tool, etc.), which takes in various parameters and plots an SINR graph for a UE at different distances from the transmitter. The simulations are performed to at least derive these results:

- Average throughput for a close-range user
- Average throughput for a midrange user
- Average throughput for a far-range user
- Number of UEs that can be placed inside the cell with a throughput for each UE above the acceptable levels.

With these results and an estimate on the total number of users within the service area, the total number of cells that would be required can be calculated.

Later, during the drive test phase, some of these tests are repeated and the SINR plotting is performed at the actual site and matched with the simulated results for accuracy.

Improve Capacity for a Particular Service Area

Some of the common practices to improve the capacity for a given service area are:

Adding more cells. Adding more cells to the service area would mean that the number of UEs that need to be accommodated by a single cell will be reduced, therefore, the quality of service for each UE can be achieved.

More sectors for a site. This again would mean adding more cells to the planned area; however, this activity involves sectorization for specific sites that provide service to a larger number of users with higher traffic.

MIMO implementation. MIMO features enable capacity within a service area, and spatial multiplexing ensures that the user's throughput (in good channel conditions) is improved. The transmit diversity feature ensures the same for UEs in poor channel conditions. Also, there are advanced MIMO features like beamforming that target improvement of UE throughput, thereby enhancing the capacity of a particular cell.

Increasing bandwidth. Another method to increase the capacity of a cell is to increase the bandwidth of the frequency. This method is very expensive and not very practical.

Radio Link Budget for LTE

Radio link budgeting is where the maximum permissible path loss is calculated for a planned site. Budgeting is done in both UL as well as DL directions, and the cell radius is calculated for either capacity or coverage in both the directions and the minimal cell radius is decided upon.

The link budget calculation depends on various parameters on the transmitter end or the receiver end, which contribute to the effective path loss calculation as presented in the equation:

$$PL = Tx \text{ Power} + Tx \text{ Gain} + Rx \text{ Gain} - Tx \text{ Loss} - Rx \text{ Loss},$$

where PL is the total path loss of the signal in decibels, Tx Power is the transmission power in decibel milliWatts, Tx Gain is the transmitter gain (antenna gain) in decibels, Rx Gain is the receiver gain (antenna gain) in decibels, Tx Loss is the transmitter loss in decibels, and Rx Loss is the receiver losses in decibels. Figure 1-3 diagrams this process.

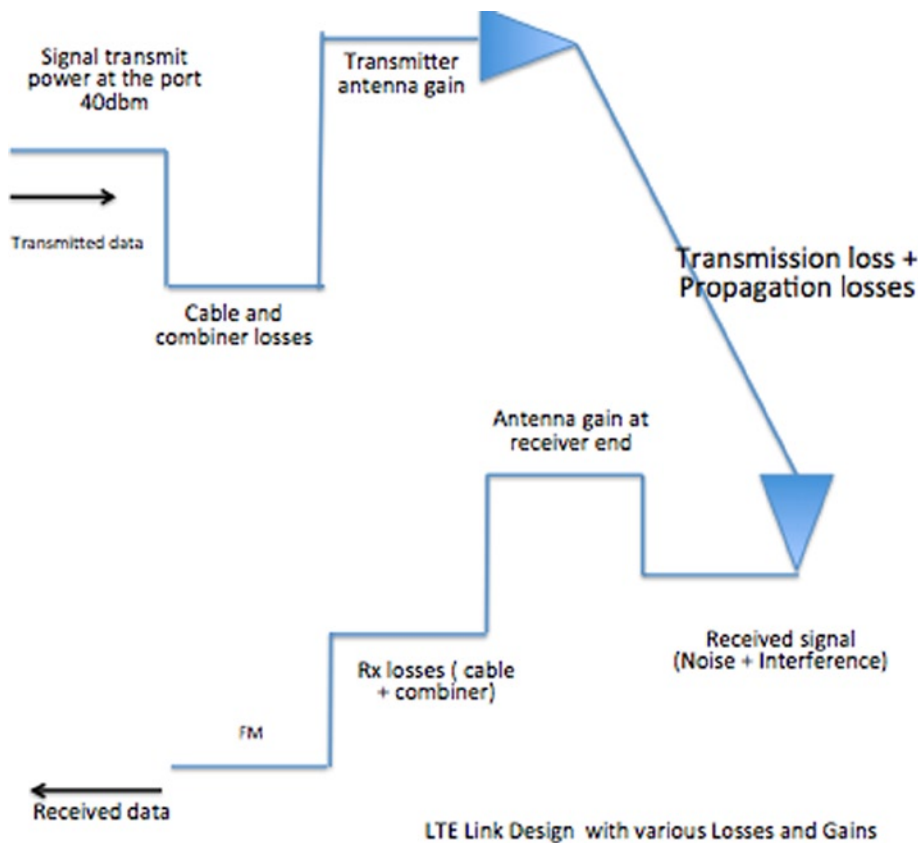


Figure 1-3. Process of gains and losses in transmission path

Transmission Power

Transmission power is the key to any link budget calculation. The higher the transmission power, the higher the permissible path loss and the greater the cell radius.

Depending on the cell size, the transmission powers are of different levels, for example, a macro cell transmits at 10 to 20 watts per port, whereas for a pico cell, the power would be in the range of 2 watts.

Radio link budgeting is performed separately for the UL and DL as the transmission power of the signal will be of different power levels (i.e., the maximum UE transmit power is around 23 db, which is used for radio link budget calculation or acceptable path loss calculation for the UL).

Features like MIMO increase the transmission power of the antenna and therefore increase the coverage and capacity of the cell.

Antenna Gains

Antenna gains, especially on the transmitter side (eNodeB antenna gain), are the most significant gain contributors for a link budget calculation. The reason for the gain is because of the directional behavior of the antenna (i.e., the power emitted or received by the antennas is focused in one particular direction). For a macro site, typically the antenna gain is in the order of around 18 dbm and the receiver gain on the UE side is in the order of 0 or 1 dbm. If there is no external antenna for the UE, then the gain is 0.

Diversity Gain

Diversity on the receiver side is useful when decoding the original signal, especially at the cell edge where the path loss is higher. The diversity capability at the receiver end helps in reducing the required energy per information to noise power spectral density (Eb/No) ratio at the receiver side. Typically, the diversity gain amounts up to 3 db both on the UE side as well as the eNodeB receiver side.

Cable and Connector Losses

Typically, the cable and connector losses can amount to between 2 to 3 db, depending on the quality of the cables and connectors used.

Propagation Loss

Propagation loss accounts for the largest variable in the link budget calculation. The propagation loss depends on a number of factors such as carrier frequency, UE distance from the transmitter, terrain and clutter, antenna height and tilt, among others.

Path loss calculation is purely theoretical, and there are various propagation models that can be used to determine the path loss and, in turn, a cell radius for a particular site. Some of the popular propagation models are the Okumura-Hata model, free space model, irregular terrain model, Du Path loss model, and diffracting screens model.

To calculate the path loss for a dense urban site using the Okumura-Hata model, the following formula is used:

$$L = A + B \log_{10} f_c - 13.82 \log_{10} h_b - a(h_m) + [C - 6.55 \log_{10} h_b] \cdot \log d$$

where L is the Path loss in decibels, hB is the height of the antenna (eNodeB antenna) in meters, hm is the height of the UE antenna in meters, f is the carrier frequency in megahertz, d is the distance between the UE and eNodeB in kilometers, and A, B, and C are constants.

Table 1-1 is a sample RF link budget with various losses and gains on the transmitting and receiving sides.

Table 1-1. *Link Budget Parameters for the Transmitting and Receiving Entities*

	UPLINK	DOWNLINK
TRANSMITTING ENTITY	UE	eNodeB
Tx RF Output Power	23dBm	40dBm
Body Loss	3dB	0dB
Combiner Loss	0dB	0dB
Feeder Loss	0dB	1.5dB
Connector Loss	0dB	2dB
Tx Antenna Gain	0dB	17.5dB
EIRP	20dBm	54dBm
RECEIVING ENTITY	eNodeB	UE
Rx Sensitivity	-104dBm	-102dBm
Rx Antenna Gain	17.5dB	0dB
Diversity Gain	3dB	0dB
Connector Loss	2dB	0dB
Feeder Loss	1.5dB	0dB
Interference Degradation Margin	3dB	3dB
Body Loss	0dB	3dB
Duplexer Loss	0dB	0dB
Rx power	-118dBm	-96dBm
Fade Margin	4dB	4dB
Required Isotropic Power	-114dBm	-92dBm
Maximum Permissible Path Loss	134dB	146dB

With these parameters, a cell dimensioning is performed for 384 Kbps of data, assuming the Okumura-Hata propagation model in a dense urban area. The cell sizing is calculated as shown in Table 1-2.

Table 1-2. Cell Range Calculation for 384 Kbps Data Rate Using the Okumara-Hata Path Loss Model

Allowed Propagation Loss = 146 dB in DL and 134 db in UL	Unit
Carrier frequency	2300 MHz
BS antenna height	25 M
UE antenna height	1.5 M
Parameter A value	46.3
Parameter B value	33.9
Parameter C value	44.9
UE antenna gain function	-0.00092
Pathloss exponent	3.574349
Pathloss constant	137.3351 Db
Downlink range	1.496663 Km
Uplink range	1.191201 Km
Cell range	<u>1.191201</u> Kms
Site hexagon coverage area	2.911 sq kms

LTE Band

The Evolved Universal Terrestrial Radio Access (E-UTRA) band for frequency division duplex (FDD) and time division duplex (TDD) modes is provided in Table 1-3 as derived from 3GPP spec 36.104. It can be seen from the table that the range at which the LTE cell can operate is quite huge. Logically, every operator, if given a choice, would want to deploy their network with the E-UTRA band, which operates at a very low frequency, because the losses associated with lower frequencies are much less in comparison with higher frequency losses. This would have an impact on the cell size and, in turn, the coverage planning for an operator.

Table 1-3. Operating Bands for 3GPP TS 36.104

E-UTRA Operating Band	Uplink (UL) operating band BS receive UE transmit	Downlink (DL) operating band BS transmit UE receive	Duplex Mode
	$F_{UL_low} - F_{UL_high}$	$F_{DL_low} - F_{DL_high}$	
1	1920 MHz – 1980 MHz	2110 MHz – 2170 MHz	FDD
2	1850 MHz – 1910 MHz	1930 MHz – 1990 MHz	FDD
3	1710 MHz – 1785 MHz	1805 MHz – 1880 MHz	FDD
4	1710 MHz – 1755 MHz	2110 MHz – 2155 MHz	FDD
5	824 MHz – 849 MHz	869 MHz – 894 MHz	FDD
6	830 MHz – 840 MHz	875 MHz – 885 MHz	FDD
7	2500 MHz – 2570 MHz	2620 MHz – 2690 MHz	FDD
8	880 MHz – 915 MHz	925 MHz – 960 MHz	FDD
9	1749.9 MHz – 1784.9 MHz	1844.9 MHz – 1879.9 MHz	FDD
10	1710 MHz – 1770 MHz	2110 MHz – 2170 MHz	FDD
11	1427.9 MHz – 1447.9 MHz	1475.9 MHz – 1495.9 MHz	FDD
12	699 MHz – 716 MHz	729 MHz – 746 MHz	FDD
13	777 MHz – 787 MHz	746 MHz – 756 MHz	FDD
14	788 MHz – 798 MHz	758 MHz – 768 MHz	FDD
15	Reserved	Reserved	FDD
16	Reserved	Reserved	FDD
17	704 MHz – 716 MHz	734 MHz – 746 MHz	FDD
18	815 MHz – 830 MHz	860 MHz – 875 MHz	FDD
19	830 MHz – 845 MHz	875 MHz – 890 MHz	FDD
20	832 MHz – 862 MHz	791 MHz – 821 MHz	FDD
21	1447.9 MHz – 1462.9 MHz	1495.9 MHz – 1510.9 MHz	FDD
...			
23	2000 MHz – 2020 MHz	2180 MHz – 2200 MHz	FDD
24	1626.5 MHz – 1660.5 MHz	1525 MHz – 1559 MHz	FDD
25	1850 MHz – 1915 MHz	1930 MHz – 1995 MHz	FDD
...			
33	1900 MHz – 1920 MHz	1900 MHz – 1920 MHz	TDD
34	2010 MHz – 2025 MHz	2010 MHz – 2025 MHz	TDD
35	1850 MHz – 1910 MHz	1850 MHz – 1910 MHz	TDD
36	1930 MHz – 1990 MHz	1930 MHz – 1990 MHz	TDD

(continued)

Table 1-3. (continued)

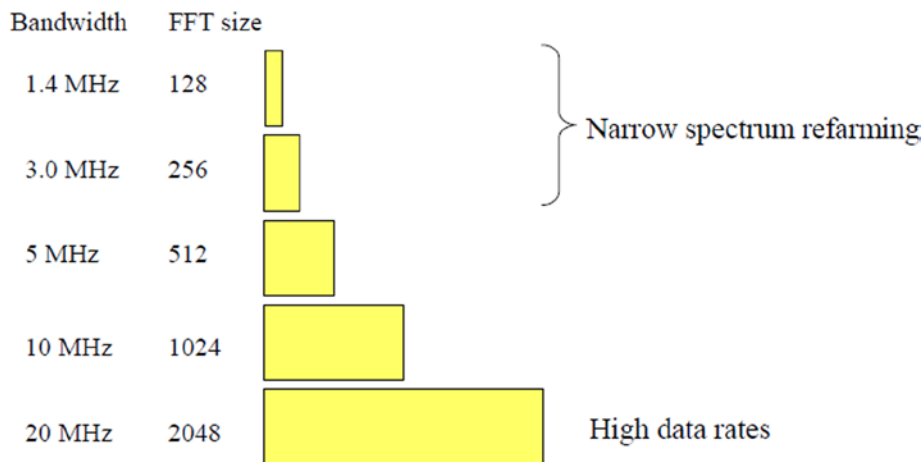
E-UTRA Operating Band	Uplink (UL) operating band	Downlink (DL) operating band	Duplex Mode
	BS receive UE transmit $F_{UL_low} - F_{UL_high}$	BS transmit UE receive $F_{DL_low} - F_{DL_high}$	
37	1910 MHz – 1930 MHz	1910 MHz – 1930 MHz	TDD
38	2570 MHz – 2620 MHz	2570 MHz – 2620 MHz	TDD
39	1880 MHz – 1920 MHz	1880 MHz – 1920 MHz	TDD
40	2300 MHz – 2400 MHz	2300 MHz – 2400 MHz	TDD
41	2496 MHz – 2690 MHz	2496 MHz – 2690 MHz	TDD
42	3400 MHz – 3600 MHz	3400 MHz – 3600 MHz	TDD
43	3600 MHz – 3800 MHz	3600 MHz – 3800 MHz	TDD

Note 1: Band 6 is not applicable.

The bands are regulated in terms of the allowed operating bandwidth. This is driven largely by the amount of available spectrum in each of the bands. Band allocation is mainly based on the availability of the spectrum for LTE deployment. Also, the UEs will need to support these bands to be able to latch on to the network and, depending on the area of selling, the UEs are enabled for a particular set of LTE bands. For example, for North America, the bands that are reserved for deployment of LTE are bands 2, 4, 5, 7, 8, 10, 12, 13, 14, 17, 18, and 19. For China, the reserved bands are 1, 3, 34, 39, and 40.

Bandwidth Options

In LTE, as shown in Figure 1-4, there are multiple bandwidth options ranging from 1.4 to 20 MHz. In cases of carrier aggregation, multiple 20 MHz carriers are aggregated to obtain a higher bandwidth.

**Figure 1-4.** Multiple bandwidth options

Why is such a range of bandwidth required? The main target of operators using a lower bandwidth of 1.4 or 3.0 MHz is to perform spectral refarming, wherein the operator can maximize the global system for mobile communications (GSM) spectrum by refarming to LTE.

Operators can refarm using a much narrower spectrum than before and deliver GSM and wideband code division multiple access (WCDMA) with less spectrum and also lower total cost of ownership. Moreover, they can deliver a vastly improved user experience and potentially attract more customers to increase revenues.

Larger bandwidths of 10 MHz, 20 MHz, or more are used to provide higher data rates in a network.

TDD vs. FDD

This section compares TDD and FDD, and we will stick to the differences for these modes purely from an operational and implementation (deployment) point of view. However, the two modes of LTE have many more differences when compared from an architectural, designing, and testing point of view. A few differences that are seen between TDD and FDD are:

1. In LTE TDD mode, there is no concept of a paired spectrum. This also means that in any given instance, the eNodeB or the UE will be involved only in transmission or reception of the data, but never both.
2. For a TDD setup, the hardware design is much simpler, because at any given time, there is either transmission or reception happening, but not both. In other words, there is no need for a duplexer to have an isolated UL/DL path on the receiver/transmitter implementation for an LTE TDD device (UE/eNodeB). This also makes the equipment a little less expensive.
3. Because there is no difference in frequency for UL and DL for LTE TDD, the channel estimation or path loss calculation in both directions is similar. This eases the link budget planning activity. This also means that the channel estimation can be more robust in LTE TDD under load conditions and fast-fading conditions wherein the eNodeB need not always rely on UE reported channel feedback for corrective actions.
4. A large guard period is required for the eNodeB to switch from DL transmission to UL transmission. This results in a drop in efficiency and throughput for LTE TDD cell in comparison with an LTE FDD cell.
5. In LTE TDD, it is possible for 3GPP to allow different configurations that have a different mix of UL and DL subframes. Based on the traffic volume, the TDD configuration mode can be selected (i.e., for sites where higher usage of UL data is predicted, TDD config 0 can be configured whereas for sites where higher DL data are predicted, TDD mode 2 or 5 can be used). TDD config mode not only depends on the amount of UL and DL data but it also depends on the nature of traffic that is being used and the block error rate (BLER) history of the site. For example, if for a site the majority of the data are display sensitive, then a faster switching time (5 ms) is required, whereas if throughput and spectral efficiency are the criteria, then a switching time of 10 ms will be good. Similarly, for an area that is subject to very few retransmissions and higher DL data, TDD mode 5 would be ideal, whereas if the error rate is higher, then TDD mode 0, 1, or 2 would be preferred.

MIMO

This section will explain what MIMO is and the different transmission modes and advantages of each mode. The basic intent of this section is to explain the implication of MIMO on radio network planning and how or which MIMO settings can help for different deployment types.

Transmit Diversity Mode

In transmit diversity mode, each antenna transmits the same stream of data. At the receiver end, because there are multiple streams being received by multiple receivers, and the probability of reconstruction of the data is much higher, thereby improving the signal to noise ratio.

The transmit diversity mode of MIMO, if implemented in an area, will improve the coverage area by around a 3-dB margin. The transmit diversity mode is useful for cells that are planned for rural areas where the cell size is typically large and users are typically spread across the cell.

Closed Loop Spatial Multiplexing

Closed loop spatial multiplexing is useful when the user's throughput or cell capacity needs to be improved in general. Because the closed loop spatial multiplexing mode of MIMO works on the feedback mechanism (Precoding Matrix Index [PMI] feedback) provided by the UE to the network, it is important that the UE is not fast moving and is either stationary or very slow moving for best results.

The urban small office model and dense urban model are two main deployment types where the cell can be configured for transmission mode 4 (TM4) (closed loop spatial multiplexing).

Open Loop Spatial Multiplexing

Open loop spatial multiplexing, like closed loop spatial multiplexing, is also targeted to improve the cell or sector throughput for a particular area of deployment. However, open loop spatial multiplexing does not rely on the PMI reporting from the UE but works on a predefined set of precoding selection for spatial multiplexing.

More often, the cyclic delay diversity (CDD) technique is used for open loop spatial multiplexing. In CDD, the transmitting unit adds cyclic time shifts and creates multipath transmission. The eNodeB tries to ensure that the transmission happens on the resource blocks for which the UE has reported better channel quality indicator (CQI) value. By doing this, the UE is able to receive the original stream as well as the delayed stream of data, and the delay on the transmit side ensures that there is no signal cancellation on the receiver side.

This is more useful for areas where the UE moves at a higher speed or the channel conditions change faster, for example, TM3 (open loop spatial multiplexing) can be set for cells that are modeled for highway deployment, which has many fast moving users.

Beamforming

Beamforming is a MIMO technique wherein the eNodeB transmitter tries to improve the quality of the signal that is received by specific users. This can be done by adjusting the tilt and power of the transmitter in the direction of the UE. Implementing beamforming can be very complicated, wherein the UE positioning has to be determined and the UE specific reference signals have to be configured for a cell. Also, the antenna calibration and maintaining the timing between the antennas will be quite challenging.

In practice, beamforming is useful for places where the cell geography is such that some users are in shadow areas and the only way to provide them with sufficient coverage is by beamforming.

UE Capabilities

Apart from the other factors discussed previously that can impact the LTE radio network planning and optimization, UE capability can also significantly influence the process of cell planning.

The cell throughput will depend on the average UE category within the area (i.e., if a site has higher distribution of category 4+ UEs, then the spectral efficiency for that cell will be higher).

Tables 1-4 and 1-5 are derived from 3GPP spec 36.306 and give an idea of the supported throughput for each category of UE in DL and UL.

Table 1-4. UE Category vs. Downlink Throughput Support

UE Category	Maximum number of DL-SCH transport block bits received within a TTI	Maximum number of bits of a DL-SCH transport block received within a TTI	Total number of soft channel bits	Maximum number of supported layers for spatial multiplexing in DL
Category 1	10296	10296	250368	1
Category 2	51024	51024	1237248	2
Category 3	102048	75376	1237248	2
Category 4	150752	75376	1827072	2
Category 5	299552	149776	3667200	4
Category 6	301504	149776 (4 layers) 75376 (2 layers)	3654144	2 or 4
Category 7	301504	149776 (4 layers) 75376 (2 layers)	3654144	2 or 4
Category 8	2998560	299856	35982720	8

Table 1-5. UE Category vs. Uplink Throughput Support

UE Category	Maximum number of UL-SCH transport block bits transmitted within a TTI	Maximum number of bits of an UL-SCH transport block transmitted within a TTI	Support for 64QAM in UL
Category 1	5160	5160	No
Category 2	25456	25456	No
Category 3	51024	51024	No
Category 4	51024	51024	No
Category 5	75376	75376	Yes
Category 6	51024	51024	No
Category 7	102048	51024	No
Category 8	1497760	149776	Yes

The UL MIMO capability of the UE will also impact the link budget calculation in the UL direction, as will the 4×4 MIMO support in the DL. However, in order for the planning to consider these inputs, it is important that a larger percentage of UEs in the area of deployment support these features.

Cell Sizes: Femto vs. Micro vs. Macro

Table 1-6 provides a brief estimate of the cell types, their usage, range, and the transmission power level that is typically used.

Table 1-6. *Different Cell Types and Use Cases*

Cell Type	Cell Range	Transmission Power and Other Characteristics
Macro cell	1 km to 100 kms	Transmission power = 10–20 watt port. Usually an outdoor deployment (e.g., rural deployment, dense urban deployment, etc.)
Micro cell	0.5 km to 1 km	Typical transmission power = 4 watt port. Usually an outdoor deployment (e.g., small office deployment, stadium deployment, etc.)
Femto cell	~500 m	Typical transmission power = <2 watt port. Ideal for indoor deployment.

LTE Performance Testing

Performance testing for LTE eNodeBs can broadly be classified into four test areas:

- Key performance indicator (KPI) verification
- Traffic model-based testing
- Overload testing
- Long-duration testing

To perform these tests, you must simulate traffic and generate load conditions with multiple UEs and simulate failures. Also, it is not possible to test all these cases as part of drive tests or field tests because some of these scenarios are not easy to re-create.

There are many tools available in the market that specifically target performance and load testing, such as Azimuth, TM500 (Aeroflex), ERCOM, and JDSU.

These tools are able to simulate multiple UEs performing different actions at the same time, and it is also possible to distribute the UEs at different distances from the cell center and simulate different fading models for these UEs (e.g., EPA, EVA, ETU, etc.).

It would be ideal to perform these testings with a performance test tool and then verify a subset of these tests again as part of a drive test or field test and match the results, so there will not be much difference between the lab results and the field results.