وزارة التعليم العالي والبحث العلمي

BADJIMOKHTAR-ANNABAUNIVERSITY
UNIVERSITE BADJI MOKHTAR ANNABA

جامعة باجي مختار- عنابـة

Année: 2017

Faculté: Sciences de l'ingénieur
Département: Électronique
MEMOIRE
Présenté en vue de l'obtention du diplôme de : MASTER

Intitulé

Comparaison entre les modes de transmission dans un réseau haut débit LTE (4G)

Domaine: Science et technologie

Filière: Electronique

Spécialité: Télécommunication avancée

Par: Mr Khirani Mohammed Bilal

DEVANT Le JURY

- **Président : Mr. TOUMI Saleh** (Professeur) U.ANNABA
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- **Examinateur : Mr. Lafifi S** (Professeur) U.ANNABA

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Dedications

To my dearest Parents KhiraniBrahim and Khiranikhira (malika) For their preciouslove and all the sacrifices they made for my success in studying,for all they has done for me, to each of my brothers and my sister for their support, encouragement and their presence.

To all my friends wherever they are, and especially tomy friends in UNJA(union national jeunessealgérien)those who are very close to my heart,Their encouragement, support, comfort and love have been precious and indispensable to me.

To my classmates, especially my friend Behadid Ibrahim and his dearest mother to me (my aunt),For their perfect collaboration.

THANKS

First of all, I thank God for the health, courage, strength, patience and understanding He has given me throughout my academic and academic career. Particular tribute to my parents for your love and the sacrifices you made so that I could finish and succeed in my studies. May God grant you a very long life accompanied by a very good health.

My gratitude goes to the entire faculty of the electronics department who participated in my intellectual training with a special mention to Mrs. BoukhariKarima as a coach and a mother who spared no effort to The success of this project.

I thank all my uncles, aunts, cousins, friends for the moral support you have shown me.

Abstract

The LTE(Long Term Evolution) succeeds the UMTS 3G mobile radiocommunicationstandard and its evolutions. It's instituted as a response to the skyrocketinggrowth of mobile data traffic. The LTE proposes high transport rates(100Mbps in downlinkand 50 Mbps in uplink), and a better QoS level to its subscribers, by introducing newnetwork architectures and by using latest technologies such as OFDMA, SC-FDMA and MIMO.Thus, the transmission capability is increased and the same transport ratecan be achieved for more users and more, higher transport rates can be furnishedto the same number of users.On the other hand, latency cutback should considerably improve network reactivity.Its usage implies the bettering of existing stations, the installation of morebase stations and the creation of new mobile terminals that support the LTE, whichappears to be its main handicap.In the current work, in addition to the theoretical description, we do simulationsthat confirm the performances.

Key words: LTE, OFDMA, MIMO, turbocodes, and Channel Estimation

Resumé

Le LTE (Long Term Evolution) succède à la norme de radiocommunication mobile UMTS 3G et ses évolutions. Son introduction répond à la croissance exponentielle du trafic mobile de données. Le LTE propose des débits élevés (100Mbps en downlink et 50 Mbps en Uplink), et un meilleur niveau de QoS pour ses abonnés en introduisant de nouvelles architectures du réseau et en employant des nouvelles technologies comme l'OFDMA, le SC-FDMA et le MIMO. Cela augmente la capacité de transmission et permet ainsi d'offrir le même débit à davantage d'utilisateurs ou de fournir des débits plus élevés au même nombre d'utilisateurs. En outre, la réduction de la latence devrait améliorer considérablement la réactivité du réseau. Son utilisation implique le réaménagement des stations existantes, la mise en place de stations de base supplémentaires et la création de nouveaux terminaux mobiles qui supportent le LTE ce qui paraît comme son principal inconvénient. Dans ce travail, en plus de la description théorique, nous faisons des simulations qui confirment ces performances.

Mots clés :LTE,OFDM,MIMO, ,turbocodes et Estimation canal

ملخصال تي إي (تطور طويل الأمد)هو تطوير لمعيار " يو أم تي أس" في شجرة تقنيات شبكات الهاتف النقال الجيل الثالث و تطوراتها. إدخاله يرد على النمو المتسارع لحركة البيانات المتنقلة ال تي إي يعرض تدفقات مرتفعة (100 Mbps عند التحميل و 50 Mbpsعند الرفع) ومستوى أعلى من جودة الخدمة لمشتركيها من خلال تقديم هندسات شبكة جديدة , واستخدام تقنيات جديدة مثل ال"أو أف دي أم آ" و ال" أم إي أم أو" أو "الميمو" هذا يزيد من , ال" اس سي – أف دي أم آ" قدرة الإرسال، وبالتالي يسمح لتوفير نفس السرعة أو أكثر من المستخدمين لتوفير تدفقات أعلى إلى نفس العدد من المستخدمين. وعلاوة على ذلك، ينبغي الحد من الكمون تحسن إلى حد كبير استجابة الشبكة. استخدامه ينطوي على إعادة تطوير المحطات القائمة، وإنشاء محطات إضافية قاعدة وإنشاء الأجهزة النقالة الجديدة التي تدعم "ال تي إي"ما يبدو وكأنه العائق الرئيسي. في هذا العمل، بالإضافة إلى وصف النظرية، ونحن جعل المحاكاة التي تؤكد أدائها.

الكلمات المفتاح: توربو، ام اي ام او، تقدير قناة، او اف دي ام ا، ال تي اي

List of Acronyms

3GPP	Third Generation Partnership Project
BLER	Block Error Rate
BTS	Base Transceiver Station
CQI	Channel Quality Indicator
DCI	Downlink Control Channel
DL-SCH	Downlink Shared Channel
E-UTRAN	Evolved Universal Radio Network
ECDF	Empirical Cumulative Distribution Function
EPC	Evolved Packet Core
EPA	Extended Pedestrian A model
ETU	Extended Typical Urban model
EVA	Extended Vehicular A model
FDD	Frequency Division Duplex
GPRS	General Packet Radio Service
GSM	Global System for Mobile communication
HSPA	High Speed Packet Access
IPv4	Internet Protocol Version 4
IPv6	Internet Protocol Version 6
LTE	Long Term Evolution
MIMO	Multiple Input Multiple Output
MME	Mobile Management Entity
MT	Mobile Termination
OFDM	Orthogonal Frequency Division Modulation
OFDMA	Orthogonal Frequency Division Modulation Access
P-GW	Packet data GateWay
PAPR	Peak Power Ratio
PBER	PDSCH Bit Error Rate
PDCCH	Physical Downlink Shared Channel
PDN	Packet Data Network
PDSCH	Physical Downlink Shared Channel
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
RB	Ressource Block

S-GW	Serving GateWay
SC-FDMA	Single Carrier Frequency Division Modulation Access
SIM	SubscriberIdentity Module
SNR	Signal Noise Ratio
TDD	Time Division Duplex
TE	Terminal Equipement
TTI	Transmission Time Interval
TxD	Transmit Diversity
UE	User Equipement
UMTS	Universal Mobile Telecommunication System
USIM	UniversalSubscriberIdentity Mobile
WCDMA	Wideband Code Division Mutiple Access

List of figures and tables

SUMMARY

Workplan

My work is divided into two main parts:

The theoretical part and the practical part (the simulation)

- In the first chapter, I describe the LTE standard: the LTE radio access network and its characteristics, the SAE core network and its characteristics, the entities of the global EPS network, and the performance LTE.
- Then, a practical part, also, characterized by a single chapter constituting the background of our research work.

In this chapter, we will discuss the performance of the LTE standard and the analysis and interpretation of the results obtained using simulations on Matlab and LTE Level System Simulator (v1.8), we will evaluate its effectiveness .

- Finally, we will close the whole by a General Conclusion, in order to synthesize all the work done.

General Introduction

Within a few decades, the use of mobile communications services has grown remarkably. It is truly a new sector of the global industry that has grown, including electronic circuit makers, mobile device manufacturers, network infrastructure manufacturers, application and service developers, and mobile network operators.

Originally designed to offer a mobile (voice) service only, mobile radio communications technologies have evolved considerably and now allow for a broadband connection in a mobility situation, Analog to digital. Mobile device users can browse the Web, use their favorite applications and services, view their mail, download videos, play music, watch TV, share photos, all on the same terminal and on the move. The history of mobile networks is marked by three main steps, commonly referred to as generation. We speak of first, second and third generations of mobile networks, generally abbreviated in 1G, 2G and 3G respectively. These three generations differ mainly by the techniques used to access the radio resource that determine their performance.

The evolution of these techniques is guided by the desire to increase the capacity as well as the flows offered by the system in a restricted band of frequencies. Indeed, frequencies are very scarce resources because coveted by multiple applications (television, radio, microwave links, satellite links, private networks, military communications, etc.). In the different countries of the world, the spectrum available in the early 1980s was already very limited. So the development of mobile networks has been, and still is, mainly conditioned by the ability of engineers to make the best use of available spectrum resources. Initially, the capacity of the mobile networks was reflected in the maximum number of telephone calls that could be maintained simultaneously under the cover of the same cell. Nowadays, with the development

Of the use of data services, the capacity of a network is also reflected in the number of users that can be connected simultaneously to the data services, as well as the average throughput per user during a data transfer session .

More generally, the capacity of a network can be represented by the maximum total throughput that can be discharged by a heavily loaded cell. The current 3G and

3G + networks have limitations in terms of bit rates required by the increasing success of these multimedia services. It is therefore necessary to find a technology which is capable of offering, on the mobile Internet networks, rates similar to the fixed Internet, of the order of 100 Mbits / s, to a large number of users, while reducing the Cost of Megabit data transport. One of the most successful solutions is the LTE (Long Term Evolution), also known as 4G.

In this study, after conducting a descriptive study of 4G, I will discuss the various key technologies that led to the explosion of LTE performance, including OFDM, MIMO and Turbocodage, and made 4G so efficient. I will close this study by simulating these performances under the Matlab software and a general conclusion will be made to evaluate the results obtained.

Chapter 1: Analysis and theoretical study of 4G (LTE)

Introduction of LTE systems

Long Term Evolution (LTE) is the result of the standardization work done by 3GPP to achieve a high speed radio access in mobile communications. 3GPP is a collaboration of groups of telecom associations working on Global System for Mobile Communication (GSM). 3GPP published and introduced the various standards for LTE in Release 8 in 2008. In 2010, the Release 9 was introduced to provide enhancements to LTE. In 2011, its Release 10 was brought as LTE-Advanced, to expand the limits and features of Release 8 and to meet the requirements of the *International Mobile Telecommunications Advanced* (IMT-Advanced) for the fourth generation (4G) of mobile technologies. LTE radio transmission and reception specifications are documented in TS 36.101 for the user equipment (UE) and TS 36.104 for the eNB (Evolved Node B). As per these specifications, LTE is theoretically capable of supporting up to 1 Giga Bits per second (1 Gbps) for fixed user and up to 100 Mega Bits per second (100 Mbps) for high speed user. This is considerably high speed. For this reason, both research and industrial communities are making considerable effortson the study of LTE systems, proposing new and innovative solutions in order to analyse and improve their performance.

Architecture ofLTE

The LTE radio access network architecture is shown in Figure 1. LTE encompasses the evolution of the radio access through the Evolved Universal Terrestrial Radio Access Network (EUTRAN). LTE is accompanied by an evolution of the non-radio aspects under the name 'System Architecture Evolution' (SAE) which includes the Evolved Packet Core (EPC) network. Together LTE & SAE comprise the Evolved Packet System (EPS) [1].

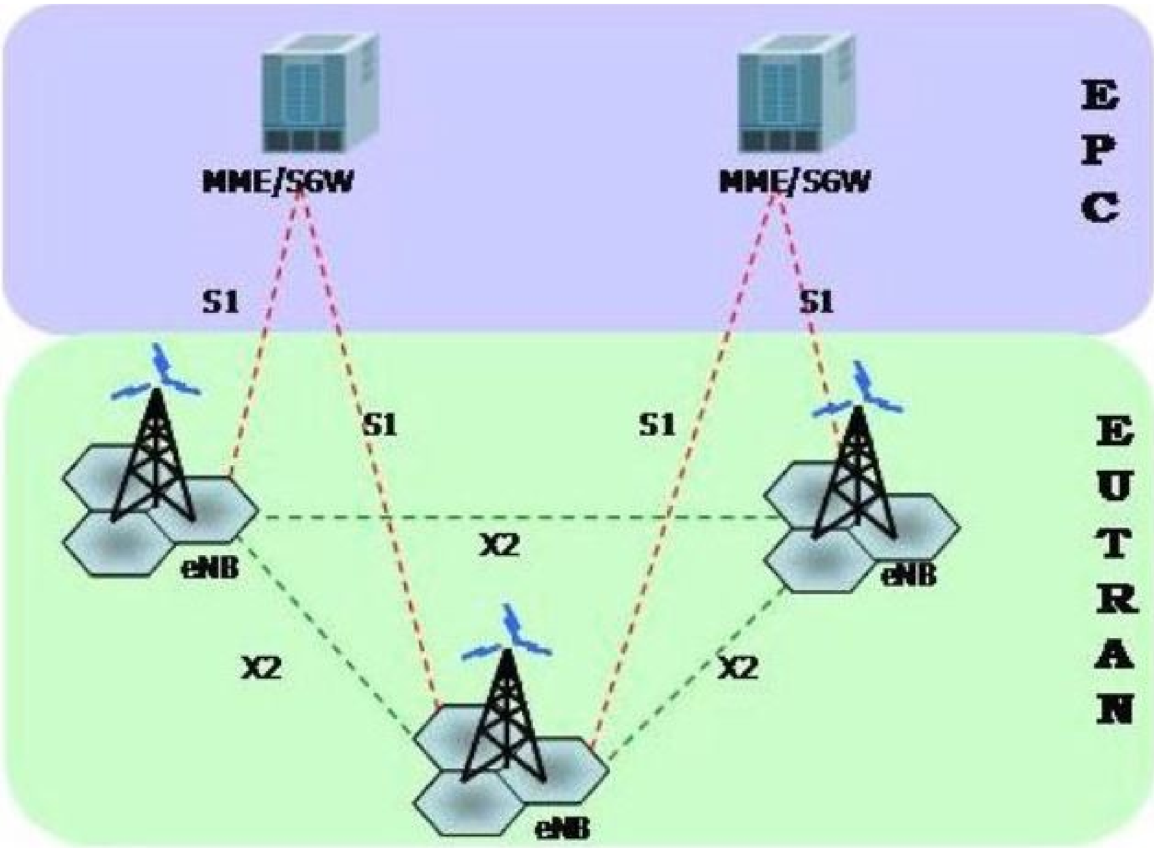


Fig 1: LTE radio access network architecture

E-UTRAN

The E-UTRAN consists of eNodeBs (eNB) which provide E-UTRA user plane (PDCP/RLC/MAC/PHY) and control plane (RRC) protocol terminations toward the user
equipment (UE). The eNBs are interconnected with each other by means of the X2 interface. The eNBs are also connected by means of the S1 interface to the Evolved Packet Core (EPC), more specifically to the Mobility Management Entity (MME) by means of the S1-MME
interface and to the Serving Gateway (SGW) by means of the S1-U interface. The S1 interface supports manyto- many relations between MMEs/Serving Gateways and eNBs.

EPC

Evolved Packet Core (EPC), also known as System Architecture Evolution (SAE) core. The EPC will serve as the equivalent of GPRS networks (via the Mobility Management Entity, Serving Gateway and PDN Gateway subcomponents) [2].

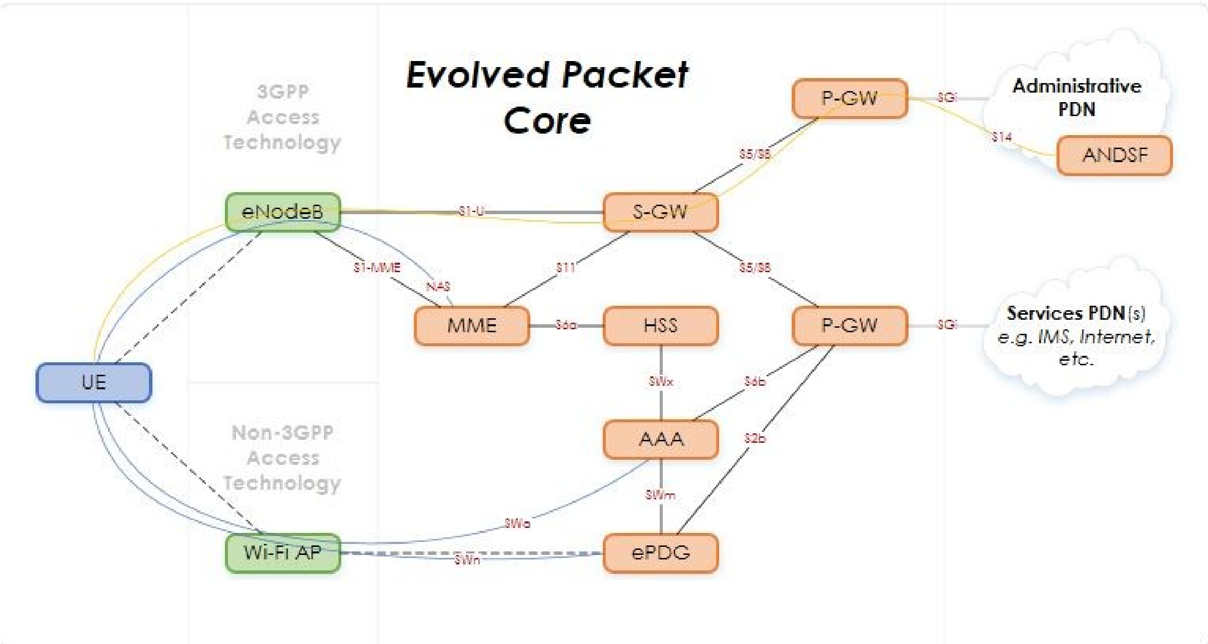


Fig2: EPC nodes and interfaces

Modulations of LTE andmethod of access, techniques and mode of transmission MIMO

Modulation techniques of LTE Advanced

Like all modulation schemes, QAM conveys data by changing some aspect of a carrier signal, or the carrier wave, (usually a sinusoid) in response to a data signal. In the case of QAM, the amplitude of two waves of the same frequency, 90° out-of-phase with each other (in quadrature) are changed (*modulated* or *keyed*) to represent the data signal. Amplitude modulating two carriers in quadrature can be equivalently viewed as both amplitude modulating and phase modulating a single carrier[3].

Phase modulation (analog PM) and phase-shift keying (digital PSK) can be regarded as a special case of QAM, where the magnitude of the modulating signal is a constant, with only the phase varying. This can also be extended to frequency modulation (FM) and frequency-shift keying (FSK), for these can be regarded as a special case of phase modulation.

- LTE devices use several modulation techniques to modulate data and control information. These modulation techniques include: QPSK (2 bits per symbol), 16QAM (4 bits per symbol), and 64QAM (6 bits per symbol). All of these modulation techniques are supported in the downlink direction; and all but 64QAM, which is optional, are supported in the uplink direction.
- A modulation technique is selected based on the measured signal to interference plus noise ratio (SINR). Each modulation scheme has a threshold SINR. Subscribers located farther from the eNodeB (i.e. with lower SINR values) use a more robust modulation scheme (lower throughput), while subscribers closer to the eNodeB (i.e. with higher SINR values) can use less robust modulation schemes (higher throughput).
- Both the eNodeB and the UE measure signal quality using the Reference Signals. The Reference Signals carry a known (pseudo-noise) bit pattern at a boosted power level.
- The eNodeB always controls and selects the modulation and coding scheme for both the downlink and uplink[4].

Method of accessOFDMA& SC-FDMA
OFDMA in the LTE downlink

The RF channel also represents a time resource and, as mentioned previously, the OFDMsymbols are generally orthogonal in time in a fashion analogous to the frequency orthogonalitynof the subcarriers. In an OFDMA system, then, the smallest identifiable elementof data transmission is a single subcarrier for one symbol period. However in LTE, WiMAXand other systems the data transmissions are scheduled in larger units consisting ofmultiple subcarriers for one or more symbol periods. The fundamental spectrum/symbolunit of LTE is the resource block, as shown the form of a resource grid in Figure 3.

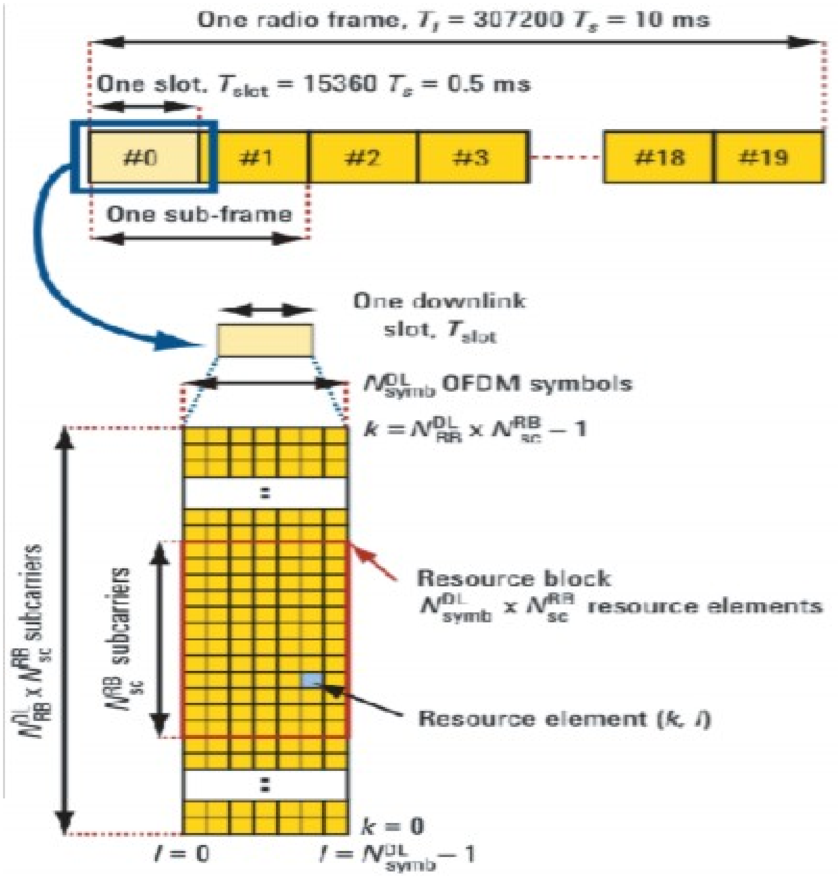


Figure 3. This diagram shows how LTE allocates channel capacity in terms of both time(symbols) and frequency (subcarriers). The resource block is the principal unit of datatransmission and consists of 12 adjacent subcarriers for a duration of one slot or 7 symbols.

SC-FDMA system as LTE uplink

In contrast to OFDMA, the SC-FDMA uses an additional N-point DFT stage at transmitter and an N-point IDFT stage at receiver. The basic block diagram of SC-FDMA transmitter is shown in Figure 15. In SC-FDMA, the data is mapped into signal constellation according to the QPSK, 16-QAM, or 64-QAM modulation, depending upon the channel conditions similarly as in OFDMA. Whereas, the QPSK/QAM symbols do not directly modulate the subcarriers; these symbols passes through a serial to parallel converter followed by a DFT block that produce discrete frequency domain representation of the QPSK/QAM symbols. Pulse shaping is followed by DFT element, but it is optional and sometimes needs to shape the output signal from DFT. If pulse shaping is active then in the actual signal, bandwidth extension occurs. The Discrete Fourier symbols from the output of DFT block are then mapped with the subcarriers in subcarrier mapping block. After mapping the frequency domain; the modulated subcarriers pass through IDFT for time domain conversion. The rest of transmitter operation is similar as OFDMA[5].

Method and Mode of transmission MIMO

PRINCIPLE OF MIMO

MIMO is based on the principle of diversity and spatial multiplexing. The key advantages of employing multiple antennas lie in the more reliable performance obtained through diversity and the achievable higher data rate through spatial multiplexing.

Blocks diagram of MIMO.

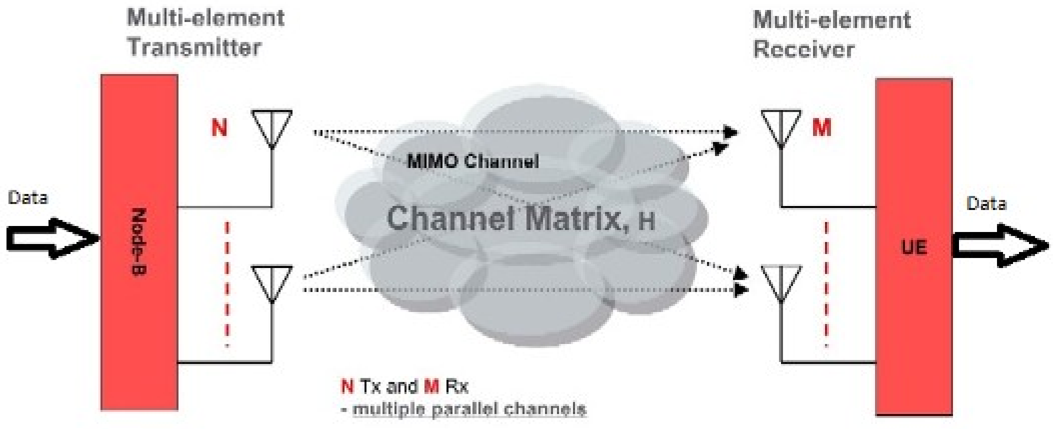


Fig14: Block diagram of a MIMO Transmission using Transmit Diversity

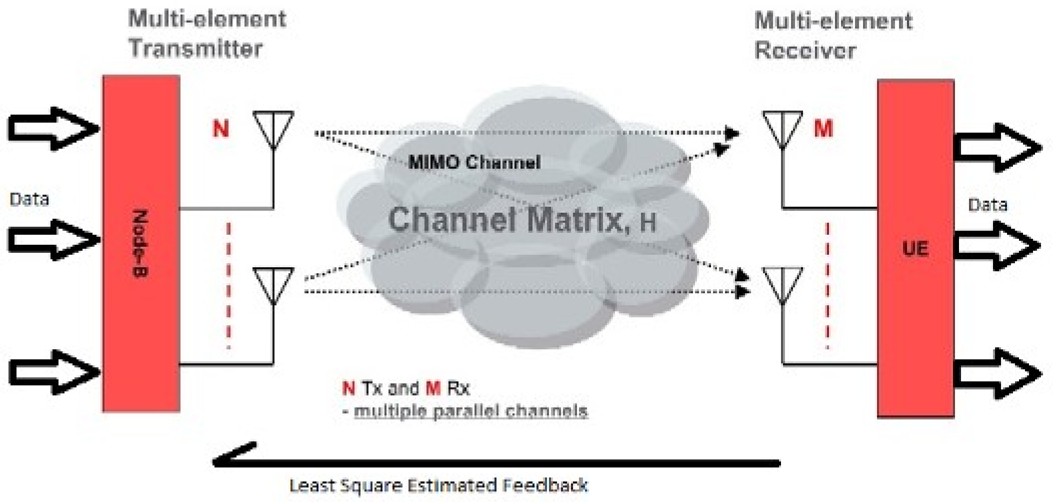


Fig15: Block diagram of a MIMO Transmission using CLSM.

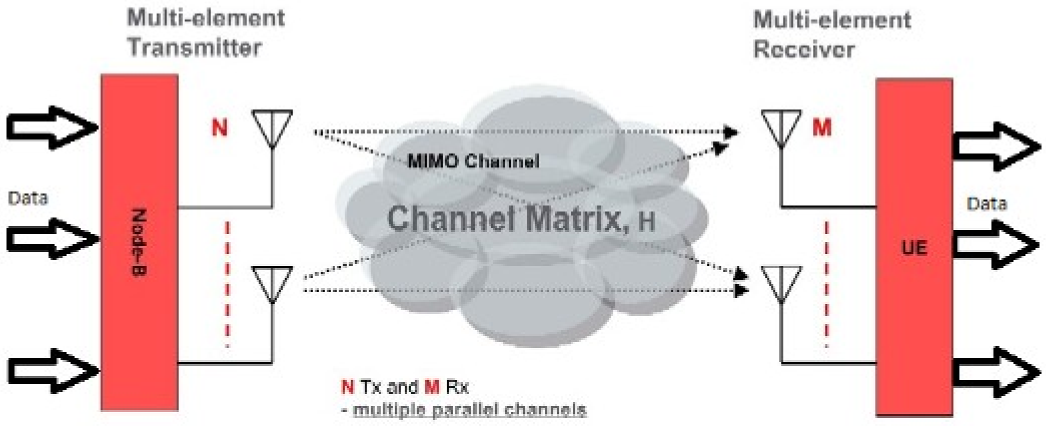


Fig16: Block diagram of a MIMO Transmission using OLSM

- **Mode 1: TransmissionDiversity (TxD)**

Instead of transmitting on a single antenna, the same stream of data is transmitted through several antennas and the base station uses two antennas to pick up two copies of the transmitted signal. The signals reach the receiving antenna with different phase changes but these can be corrected by antenna specific channel estimation. The base station can then add together the signals in phase without any risk of interference Destructive between them which reduces the error rate and the signal quality becomes more robust.

- **Mode 2: Open Loop Space Multiplexing (OLSM)**

This mode involves transmitting two data streams of information (two code words) on two or more antennas (up to four in LTE). There is no reaction from the user's equipment (UE) but the Transmit Rank Indication (TRI) Transmit Rank Indication is used by a base station to select the number of spatial layers. Since several data streams are transmitted at the same time, it is noted that the OLSM mode offers better bit rates compared to the TxD (transmission diversity) mode.

- **Mode 3: closed loop spatial multiplexing (CLSM)**

This mode is similar to OLSM because it also allows the transmission of two information streams on two or more transmit antennas. The difference lies in the EU's reaction to the base station. This reaction allows the BTS to precode the data to optimize transmission over the wireless channel so that the received data stream can be easily separated into the original data stream by the receiver.

- **Mode 4: Multi user MIMO**

This mode is similar to CLSM, but data streams are routed to different users. Although the data rate per user can be the same, the data rate of the total network is increased. The number of spatial layers limits the number of users. Users are separated in the spectral domain. If the layers are not completely orthogonal, then each user may experience interference from other users.

- **Mode-5, closed loop rank 1 with pre-coding.**

This mode involves transmitting a single stream of data on a single spatial layer. In this mode, the UE returns channel information to the base station to indicate the appropriate precoding to be applied to perform the beamforming operation. It should be noted that of all of these modes Only four can be simulated by the simulation software used: single antenna, Transmission Diversity (TxD), Open Loop Spatial Multiplexing (OLSM) and ClosedLoop Spatial Multiplexing (CLSM). Others Are not yet implemented with the multi user MIMO example) in the LTE System level simulator software until the last version (LTE_System_Level_1.6_r885).

Receive and Transmit Diversity

Receive diversity, MRC, makes use of the highest signal quality, combining signals from both antennas.

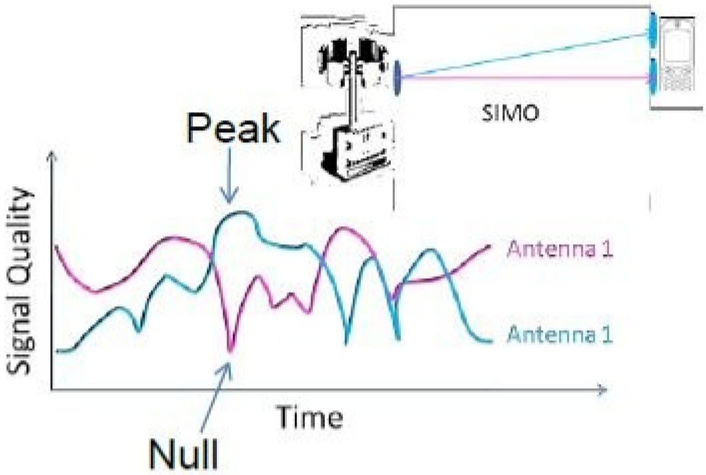


Fig4: shows Receive diversity

Transmit diversity techniques, CDD or SFBC, spread the signal so as to create artificial multipath to decorrelate signals from different antennas with the goal of delivering a peak on one receive antenna while there may be a null on another.

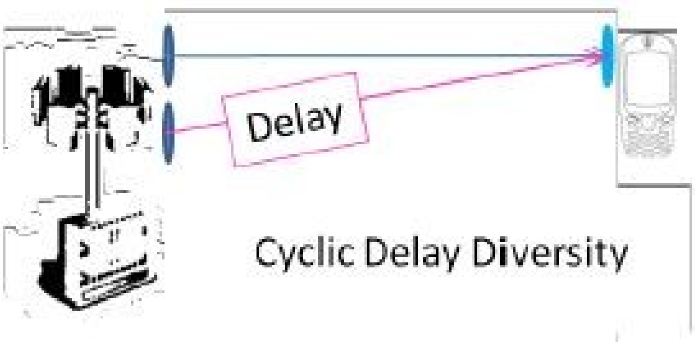


Fig5: shows Transmit diversity

UE Diversity Reception

UE diversity reception refers to the Single Input Multiple Output (SIMO) mode and is mandatory for the UE. It is typically implemented using maximum ratio combining.

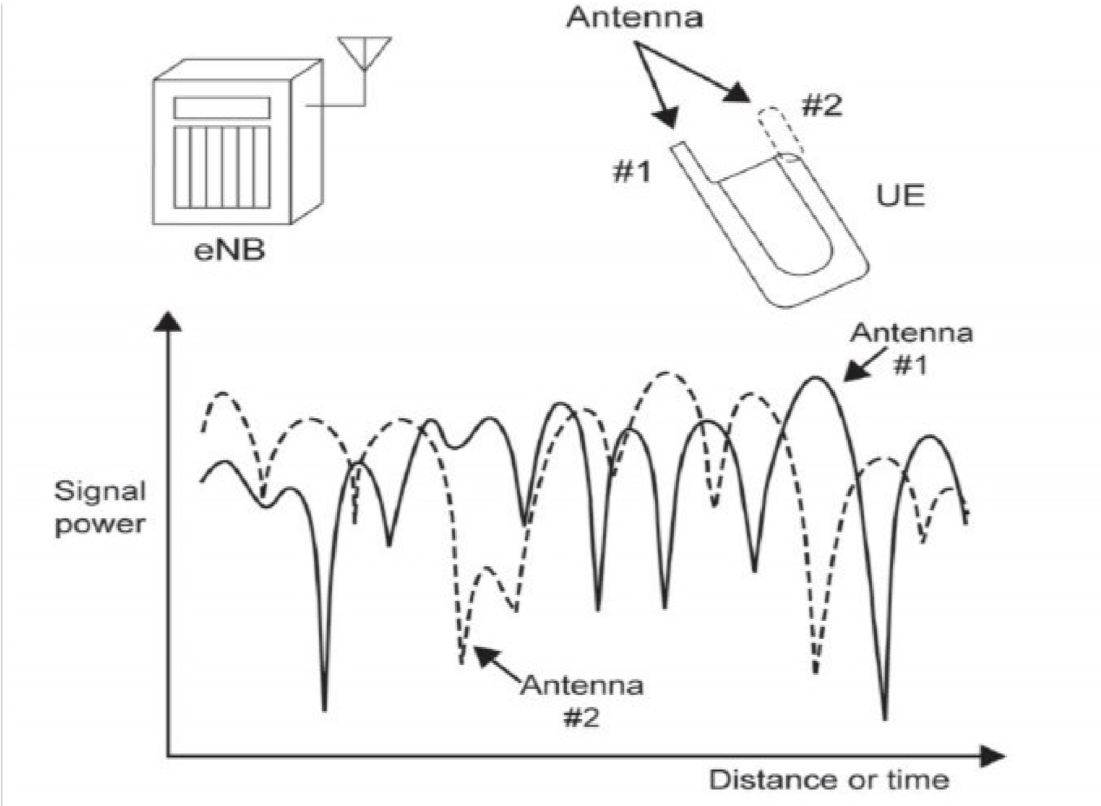


Fig6: Example of diversity reception through loosely correlated paths

Single User and Multi User MIMO

Figure 7 shows how both codewords are used for a single user to provide downlink SU-MIMO. It is also possible for the codewords to be allocated to different users to create downlink MU-MIMO.

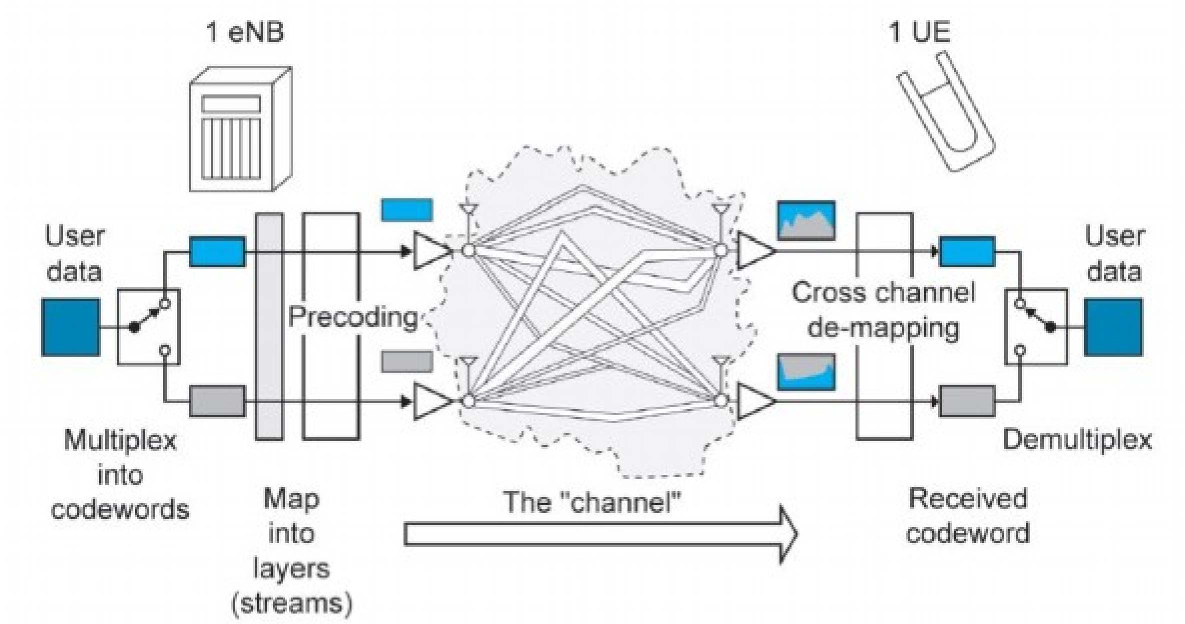


Fig7. SU-MIMO in the downlink with two antennas; Codebook 0 shown

Benefits of LTE/SAE

Increased data rates: Up to 86 Mbps in the UL, 326 Mbps DL with 4 layers (streams).

High mobility: Up to 162 km/h (300 Hz Doppler); standard evolving to support up 500 km/h.

Scalable channel widths :1.4, 3, 5, 10, 15 and 20MHz

Improved spectral efficiency 2x to 5x, depending on antenna configuration, vs. UMTS.

MIMO, FDD and TDD improve throughput and access efficiencyPart of 3G and LTE.

Flat architecture, lower latency (< 5 ms)Key for real-time applications such as VoIP, video conferencing gaming.

Backwards compatibility to legacy networks.

Support for an all-IP network.

Conclusion

The multiple antenna techniques used in LTE include transmit and receive diversity and spatial multiplexing.

Diversity techniques increase the robustness of the signal path but do not increase the data rates.

Spatial multiplexing leverages the addition of transmit and receive antennas to increase the fundamental channel capacity.

Suitable channel conditions are needed to make this practicable, and LTE supports the combination of transmit diversity with spatial multiplexing to improve the likely performance.

Chapter 2: Simulation, Analysis and Interpretation of Results

Introduction

This part is the most important part of our work because it allows us to simulate analyzing and interpreting the performance of technologies in general and of techniques in particular used in LTE.

Our work will be structured into two main parts. First, we will analyze the performance of the LTE physical layer using Communications System Toolbox integrating the LTE Downlink PDSCH Transmit Diversity, CLSM, and OLSM on Matlab R2014a. We will study the binary error rate PBER as a function of the signal SNR (Signal Noise Ratio) ratio and the different types of modulation, MIMO techniques, bandwidth and different models. In a second step, we will simulate the real LTE model using Matlab-based LTE System Level Simulator V1.8 software. We will study the the transmission technics used in MIMO and BLER (Block Error Rate) error rate per block of data, the CQI (Channel Quality Indicator) according to which is the channel quality indicator; The fading of the signal as a function of the distance, in urban environment and the Debit according to the number of Base Station eNodeB and the number of UE.

LTE System Level Simulator

Based on Matlab, LTE System Level Simulator is software that uses predefined programs that can be modified according to the simulation parameters to study the operation of the transmission in a 4G LTE broadband mobile network.

In our study, we will use the version V1.8 and V1.6.

Description and operation.

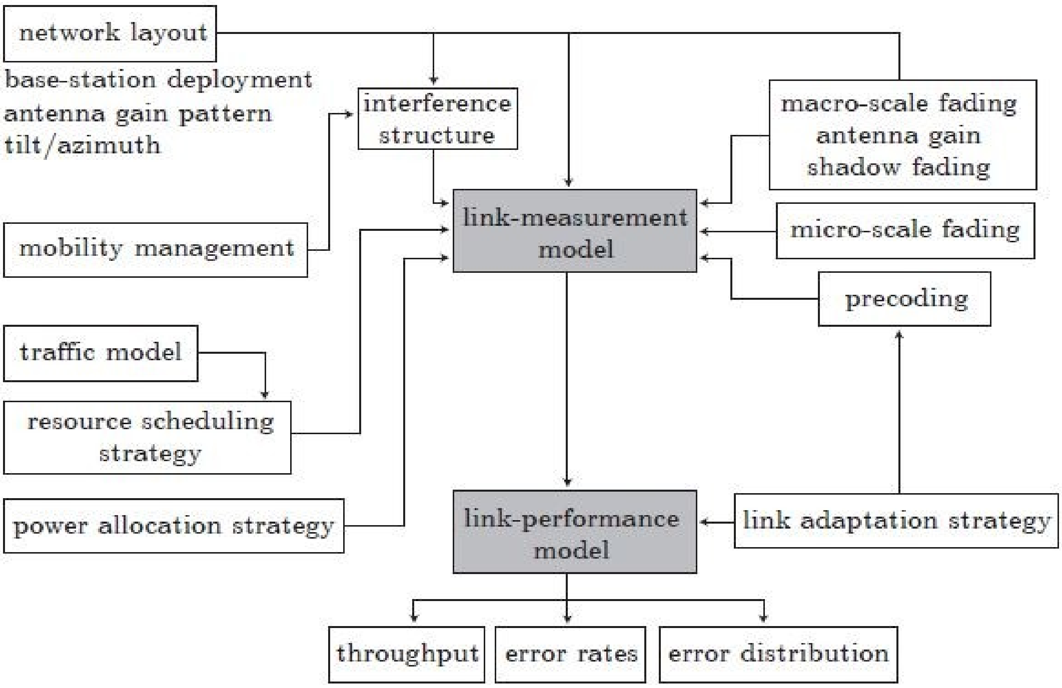


Fig13: Diagram Schematic of the LTE System Level Simulator

This figure shows the schematic diagram of the LTE System Level Simulator. The central parts are Link Measurement Model and Link Performance Model. The Link Measurement Link contains the quality of link capacity used for link adaptation and resource allocation. On the other hand, the Link Performance Model determines the Block Error Rate (BLER) with reduced complexity. At the output, the simulator calculates the flow and the BLER to evaluate the performance of the link. The simulation is performed by defining a region of interest (ROI) in which eNodeB and UE are positioned. The length of the simulation is measured in Transmission Time Interval (TTIs).

In the implementation, execution by the simulator is done in the following way. For each TTI, the UE is moved when the UE moves outside the ROI then the UE is randomly reassigned to the ROI. All eNodeBs receive feedback. For the scheduling of the EU, the simulator performs the following processing:

- Channel State →Link Quality Model → SINR

- SINR, Modulation and Coding Scheme (MCS) →Link performance Model→ BLER
- Feedback to the UE
- Note: " → " represents the data flow of the simulator

LTE Simulated Model Downlink

Description of the model

This model consists of two parts

- LTE Down Link Parameters
- Simulate Link

a- **LTE General DownlinkParameters** [8]

Parameters	Description
Frequency range	UMTS FDD bands and TDD bands
Duplexing	FDD, TDD, half-duplex FDD
Channel coding	Turbo code
Mobility	350 km/h
Channel Bandwidth (MHz)	• 6 ,15 , 25 , 50 , 75 , 100
Transmission Bandwidth Configuration NRB : (1 resource block = 180kHz in 1ms TTI)	• 6 , 15 , 25 , 50 , 75 , 100
Modulation Schemes	UL: QPSK, 16QAM, 64QAM(optional)
	DL: QPSK, 16QAM, 64QAM
Multiple Access Schemes	UL: SC-FDMA (Single Carrier Frequency Division Multiple Access) supports 50Mbps+ (20MHz spectrum)
	DL: OFDM (Orthogonal Frequency Division Multiple Access) supports 100Mbps+ (20MHz spectrum)
Multi-AntennaTechnology	UL: Multi-user collaborative MIMO
	DL: TxAA, spatial multiplexing, CDD ,max 4x4 array
Peak data rate in LTE	UL: 75Mbps(20MHz bandwidth)

	DL: 150Mbps(UE Category 4, 2x2 MIMO, 20MHz bandwidth)
	DL: 300Mbps(UE category 5, 4x4 MIMO, 20MHz bandwidth)
MIMO (Multiple Input Multiple Output)	UL: 1 x 2, 1 x 4
	DL: 2 x 2, 4 x 2, 4 x 4
Coverage	5 - 100km with slight degradation after 30km
QoS	E2E QOS allowing prioritization of different class of service
Latency	End-user latency< 10mS

b- Simulate link

This part is a button to start the simulation once all the desired parameters are selected. It is after executions that the results are displayed in the Results section where you can see:

- The BER
- Number of errors
- Number of bits.

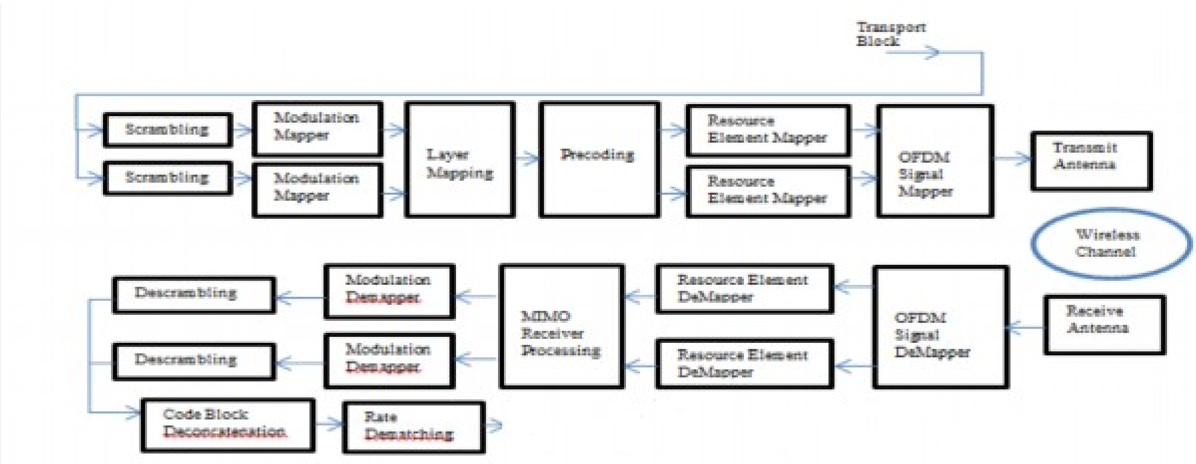


Fig8: Structural diagram of LTE Downlink at Transmitter and Receiver level.

- Scrambling: The source data bits (transport coded channel bits) are scrambled by a sequence level of the scrambling bits. The scrambling sequence depends on the cell identity of the physical layer to ensure randomization of interference between cells.

- Modulation Mapper: The modulation of the descending data converts the scrambled bits into complex modulated symbols. The set of supported modulation schemes include QPSK, 16QAM and 64QAM, corresponding to two, four and six bits per modulation symbol respectively.
- Layer Mapping and Precoding The LTE TD Encode function combines the mapping of the emission diversity (TxD) and precoding layer.
- Resource Element Mapper: The precoded symbols to be transmitted on each antenna are a function of resource blocks (RB) resource elements available for the current transmission. The number of resource blocks available depends on the Bandwith settings.
- OFDM Transmission: The OFDM complex value signal-by-antenna time domain is generated from the fully filled-in resource grid, using the comm.OFDMModulator system object. The number of FFT points depends on the bandwidth of the specified channel.
- MIMO Receiver Processing: The simulator uses the MIMOChannel system object to model the fade of Rayleigh on several links. One can choose from a choice of flat frequency static characteristic to a situation where maximum Doppler change, path gains, path delays and correlation levels can be specified individually for each link.
- Receiving Party: This section only performs operations that are unlawful.

studying and analysis of transmission diversity (TxD)

- Used Simulation Settings

Parameters	Value
Channel Bandwith	[10MHz-20MHz]
Control region size	2
Number of transmit antennas	[2-4]
Number of receive	[2-4]
modulation type	QPSK, 16QAM, 64QAM
MIMO Rayleigh fading channel	User-defined, Frequency-flat static
Correlationlevel	Low, Medium, High
SNR (dB)	[0 5 10 15 20 25 30]
Enable estimation canal	Ideal Channel and Estimated Channel
Number of subframes to simulate	30

Study of the BER according to the SNR and the different types of Modulation:

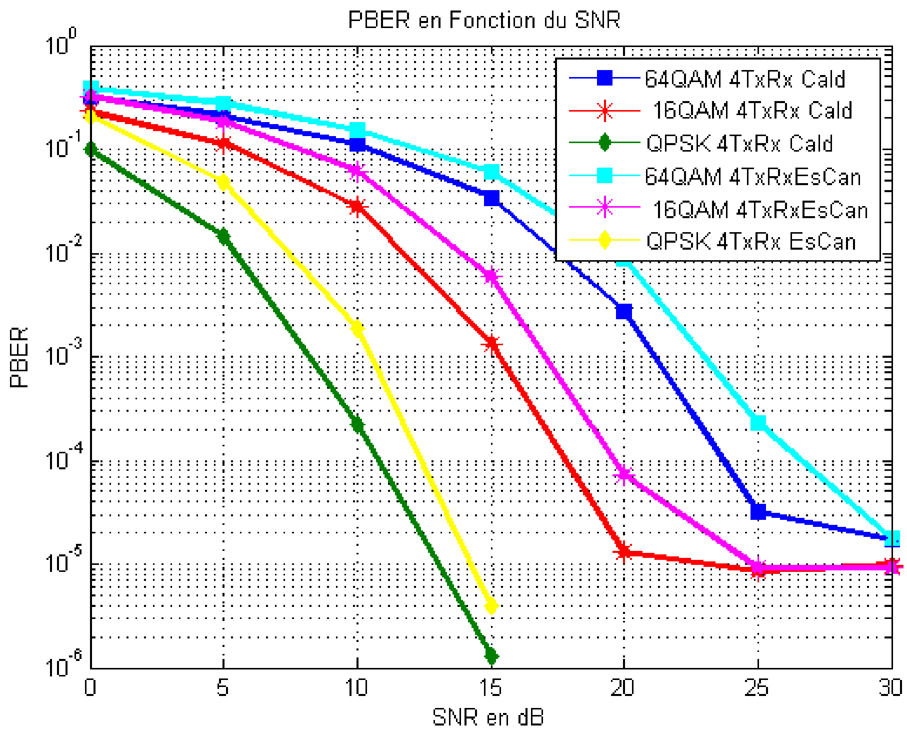


Fig9: PBER according to the SNR and performance system according to the different types of modulation.

The figure above illustrates the variation of the bit error rate PBER as a function of the SNR signal-to-noise ratio for different modulations and for the ideal and estimated channels. It can be seen at first sight that the PBER is inversely proportional to the SNR. The higher the SNR, the lower the error rate. Moreover, with the ideal channels, a better error rate is obtained compared to the estimated channels for all types of modulation. Indeed the estimated channels introduced other parameters such as multitrack effect which can lead to a fade of the signal. Moreover, the best or lowest error rate is obtained with the QPSK modulation which becomes almost zero for an ideal channel and an estimated channel for a SNR equal to 15 dB. For the other types of modulation, namely the 16QAM and the 64QAM, the error rate begins to decrease only for an SNR of 20dB. For the lower values, the signal remains embedded in the noise.

Study of the PBER according to SNR and MIMO techniques

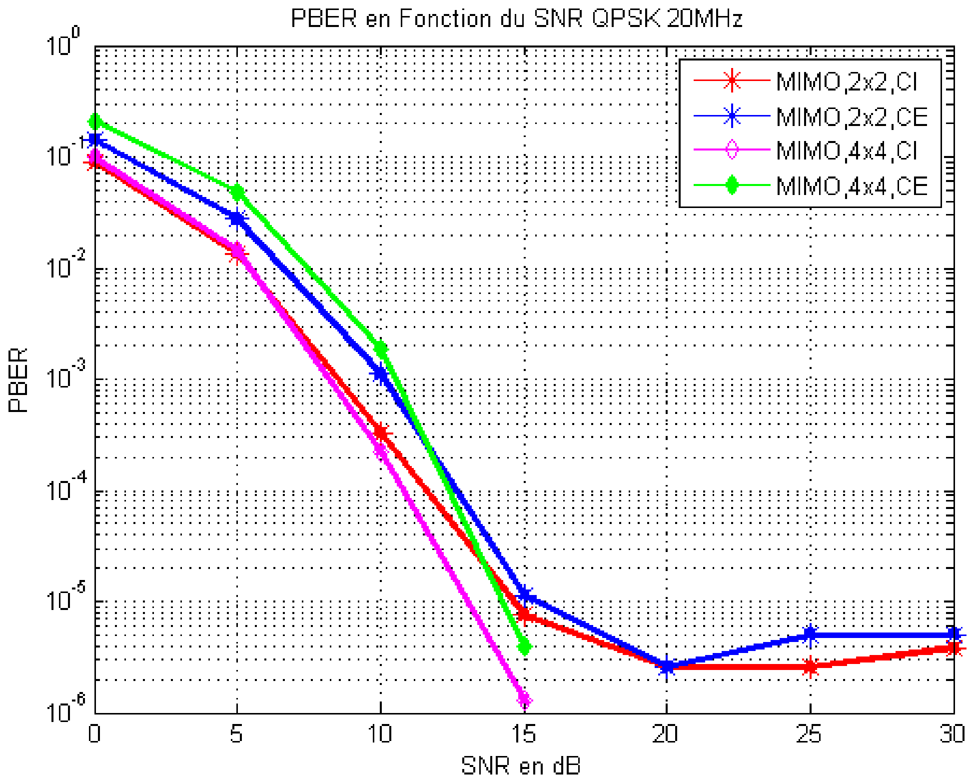


Fig10: PBER as a function of the SNR and performance of the system according to different MIMO techniques.

For the study of the PBER as a function of the SNR and of the different MIMO techniques, namely the antenna configurations 2x2 and 4x4 and for the ideal and estimated channels, one finds that the lowest error rates are obtained with the 4x4 MIMO configurations , - with four transmitting and receiving antennas, respectively. Indeed, with MIMO technology in LTE as much as there are antennas for transmission and reception at the EU level, plus PBER is low when transmitting at the base station.

Study of the PBER according to the SNR and the width of the Bandwidth (10MH-20MHz)

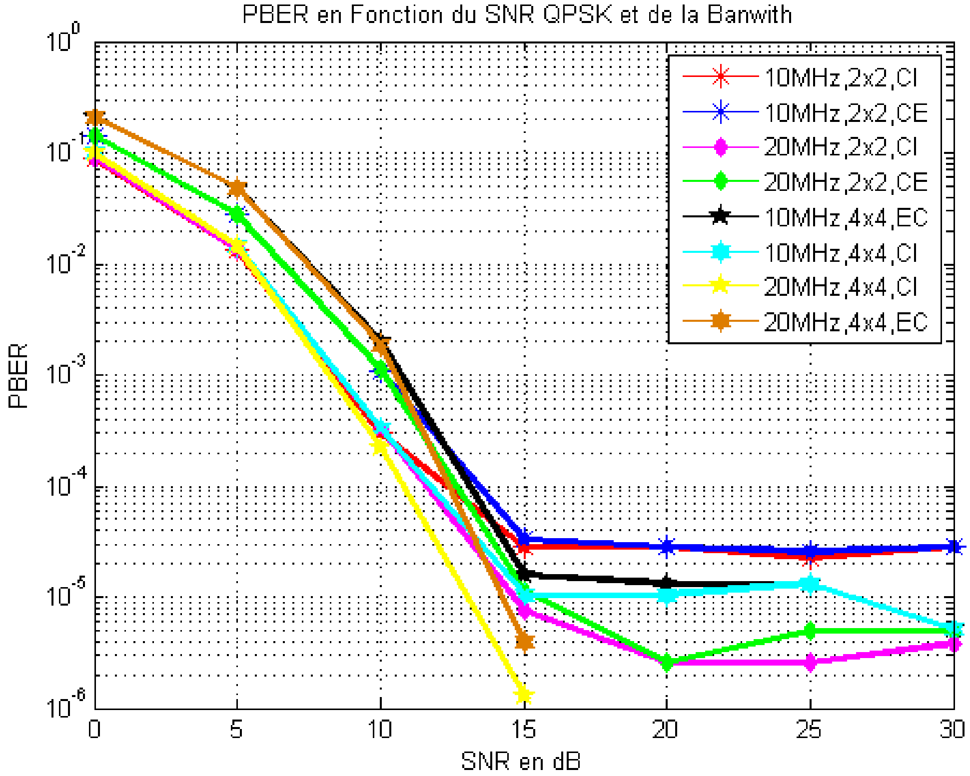


Fig11: PBER according to the SNR and system performance according to the different Bandwidths and QSPK modulation.

The variation of the PBER according to the different bandwidths shows that the wider transmission frequency band the lower bit error rate. Better yet, this becomes much more optimized with the number of antennas at the transmitter. The best error rates are obtained with the 4x4 MIMO configurations. The most interesting case is obtained with the band 20MHz, 4x4 for an ideal channel (CI) where the PBER is zero for a SNR equal to 15dB.

Study of the PBER according to the SNR and the different Models

The model illustrates the speed of displacement of the UE in a cell taking into account the Doppler effect.

We have four cases with three different displacement profiles.

- Extended Pedestrian A model EPA (Pedestrian): High
- Extended Vehicular A model EVA (Medium)
- Extended Typical Urban model ETU (urban): High

Channel Model	Mobile Velocity (Km/h)	Maximum Doppler Shift	Delay Spread
EPA	2	5	Low
EVA	30	70	Medium
ETU	130	300	High

Table (II.2): Variation of the displacement speed of the UE according to its environment.

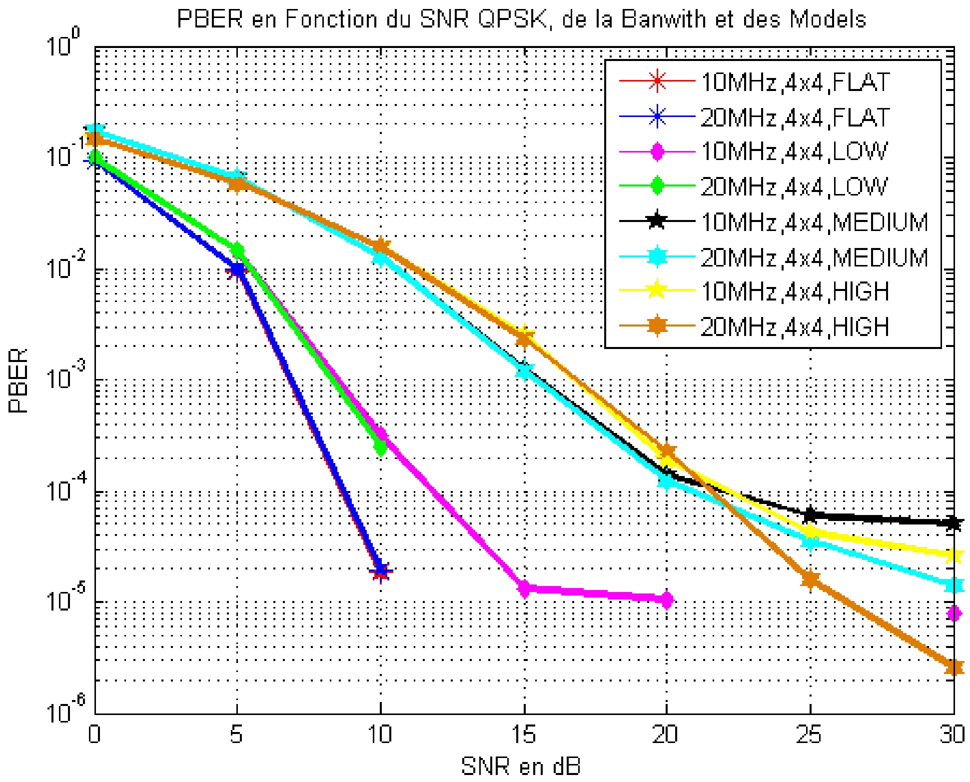


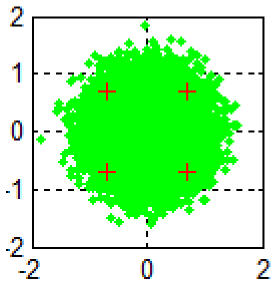
Fig12: PBER according to the SNR and system performance according to the different models.

The study of the PBER according to the SNR for the different modes of displacement of the user was done for the QPSK modulation and the 4x4 MIMO configurations and through an ideal channel. First it can be seen that the bit error rate is lower for the FLAT mode for a 10 dB SNR and becomes zero from 15 dB for the bandwidths 10 MHz and 20MHz.

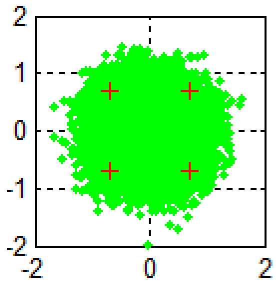
Then we have the bands of 20MHz and 10MHz which have a zero PBER for the Low mode for SNRs respectively equal to 10dB and 25dB. For the other modes, Medium and High, the error rate is rather important. In other words, the transmission signal is strongly embedded in noise for SNRs below 30 dB. It is therefore possible that the higher the speed of movement of the UE and the Doppler Shift, the more the quality of transmission is corrupted.

Influence of SNR on constellations:

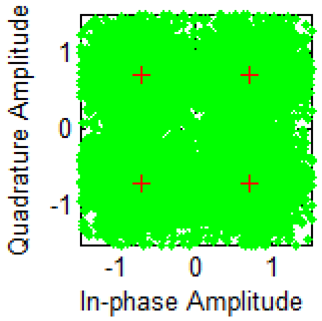
This study will be carried out for a 5dB SNR, a 20MHz bandwidth, a 4x4 MIMO configuration for QPSK modulation and an ideal channel.



Post OFDM Received data Stream 3rd RX



Post OFDM Received data Stream 4th RX



Post OFDM RX Combined Stream

Fig13: Influence of the SNR on constellations for SNR = 5dB, 4x4.

The graphs above represent the influence of the SNR on the constellations following the four receiving antennas. The SNR becomes more important, the received signal is less noisy and therefore easier to demodulate at the receiver (UE) and the probability of error decreases considerably. This is demonstrated on the Post OFDM Combined Stream graph showing the restitution of the data streams received at the four receiver antennas.

The following attenuation for SNR and CQI in the coverage area for Trisectorisation

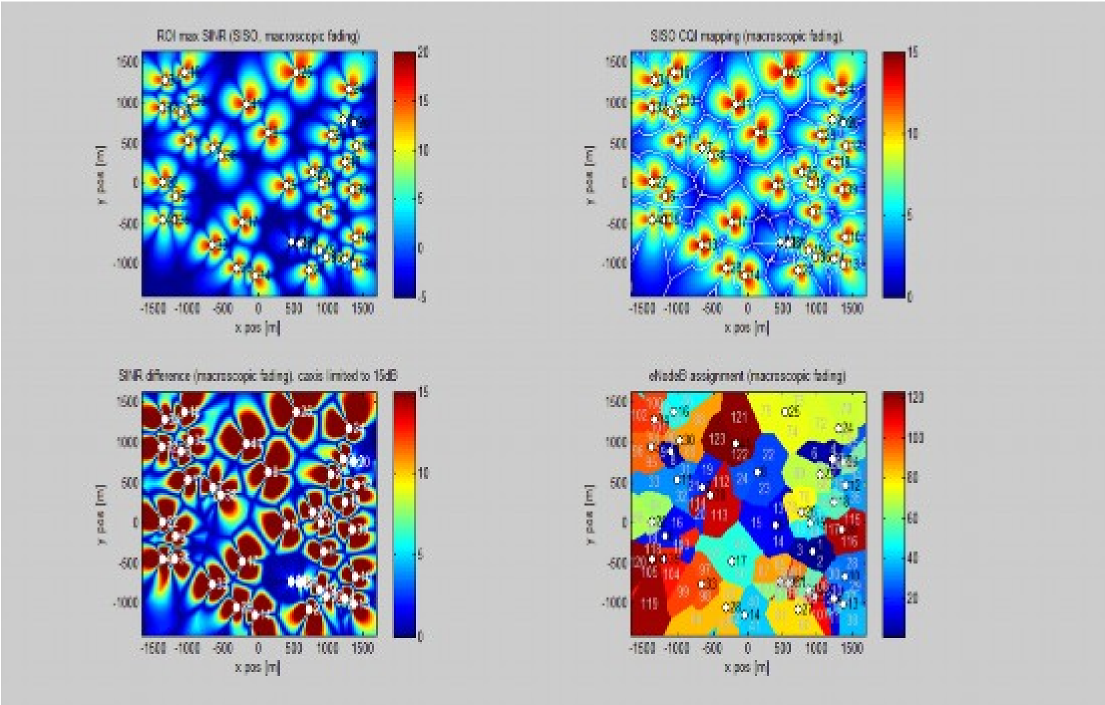


Fig23: SNR and CQI according to coverage area.

The following graphs represent the variation of the SINR and the CQI in the coverage area.

Network coverage is provided by the Trisectorization technique. In order to limit the number of BTS, this technique is used, which is an emission and reception system in three different directions in azimuth for a BTS with directional antennas, each antenna pointing in a given direction. In this case, a cell becomes a sector.

The first and second graphs show the variation in the power intensity of the SINR and the CQI as a function of distance and fading (Macroscopic Fading) in the different sectors. Note that as the user approaches or moves away from the sector, the SINR varies. The best signal-to-noise ratio is obtained when the user is in the vicinity of the BTS. This same observation is made for the graph increasing the variation of the CQI. The CQI index becomes larger as we approach the sector, so the quality of transmission is better.

The diagrams show the variation of the SINR Difference and the area coverage of the sectors and cells. Indeed, the coverage area to be theoretically insured in a cell is not fullyachieved in comparison with the SINR Difference graph. To remedy this, secondary cells such as pico cells, microcells and macros cells are placed according to whether they are found in megacities, urban areas and rural areas respectively.

The Channel Quality Indicator (CQI) and the BLER as a function of the SNR

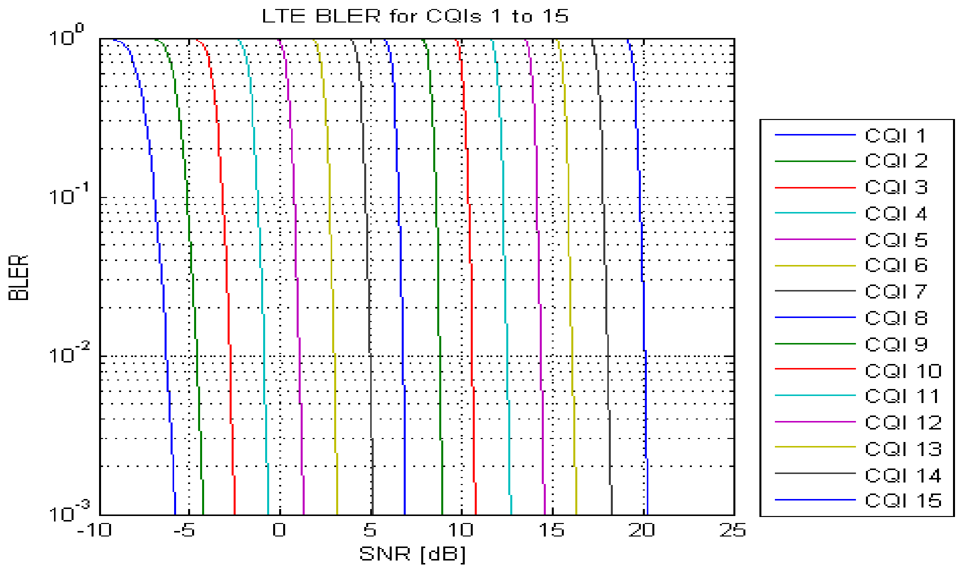


Fig24: The BLER according to the SNR for the different CQI.

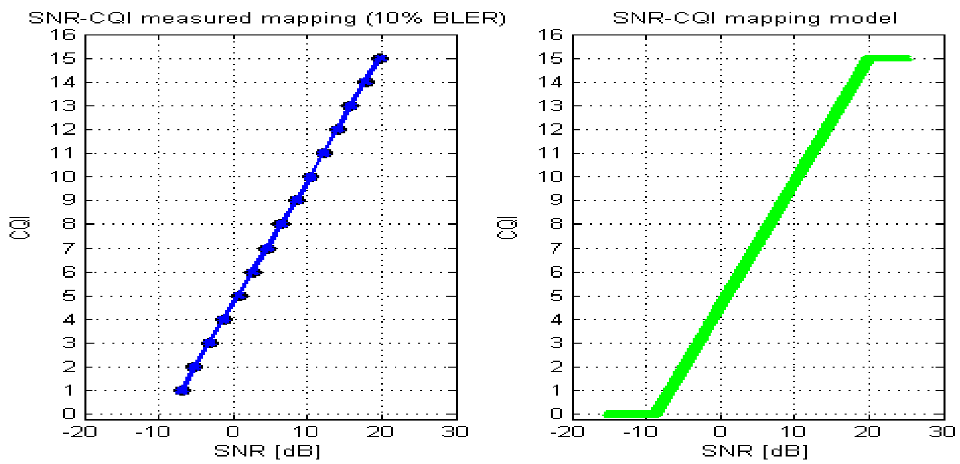


Fig25: Channel Quality Indicator (CQI) according to the SNR.

The graph above showing the variation of the SNR as a function of the CQI shows that these two parameters are proportional. Indeed the CQI indicates the highest possible modulation schema as well as the encoding rate for which the block error rate (BLER) does not exceed 10%. The CQI can adopt a discrete value from 0 to 15. The index 0 indicates that the UE has not received any exploitable LTE signal and that the channel is therefore unusable. The reason for this is that the linear curve from left to blue begins with the CQI index 1. The CQI is not only dependent on the SNR, it is also influenced by the signal processing used in the EU. In an identical channel a UE with a powerful signal processing algorithm can transmit to the BS a higher CQI than a less efficient UE. And according to the graph the higher the CQI index the higher SNR and the better transmission quality.

Study of the Debit as a function of the UE and of the bandwidth of its SNR:

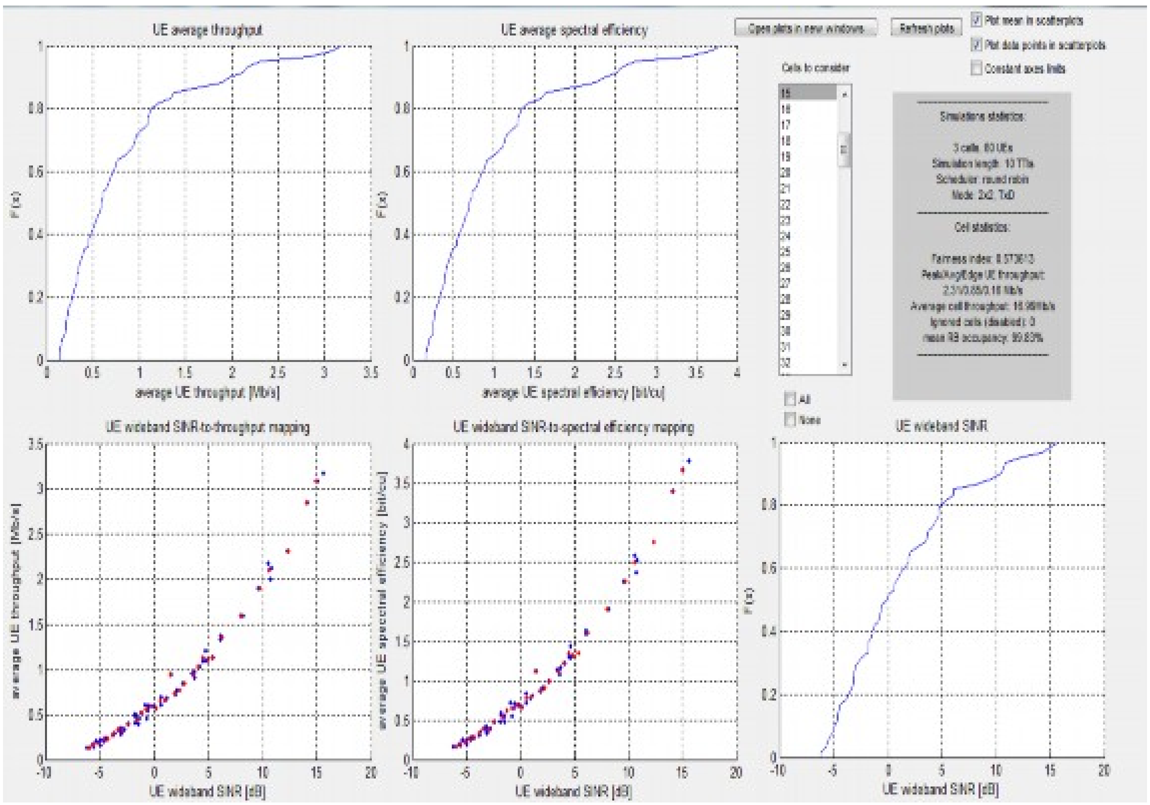


Fig26: Variation of the flow as a function of the UE and the bandwidth of its SNR.

The table of graphs and tables above represents the results of the study of the Throughput as a function of the cells considered (15, 16 and 17), the bandwidth of the UE of SNR of the MIMO 2 × 2 configuration And the Transmit Diversity TxD transmission mode as shown in the Simulations Statics section of the gray table at the top right. We have two parts of flow study:

- ✓ The first two graphs at the top represent the variation of the average flow rate of the UE as a function of the cumulative distribution function F (x) in | Mbit / s ECDF and in bit per cell [bit / C] for the spectral efficiency of the average flow rate.

The first two graphs at the bottom represent respectively the average bit rate of the UE [Mbit / s] and the spectral efficiency of the bit rate [bit / c] as a function of the bandwidth of SNR of the UE. We note from the curve variations that the change in flow rate is proportional to the bandwidth of the SNR. This further justifies that the more the SNR is raised the BER decreases, the better the transmission is so more flow becomes important. However, from a certain saturation of the SNR (15dB), one notices that the flow becomes constant. This is because the Transmit Diversity TxD mode transmits a single data stream (Stream) over several antennas.

- ➢ Blue dots represent the flow value for the 60 UE.
- ➢ Red dots are the average values of the flow rate UE.

The last graph at the bottom left-hand corner corresponds to the study of the flow rate by the distribution function F (x).

To finish the different results obtained are represented in the gray table at the top, on the right. We have :

- ➢ Peak rate of 2.31Mbit / s
- ➢ An average bit rate of 0.85Mbit / s
- ➢ An Edge per UE rate of 0.16Mbit / s
- ➢ An average bit rate of 16.99Mbit / s per cell.

Position of eNodeB and EU within their coverage area:

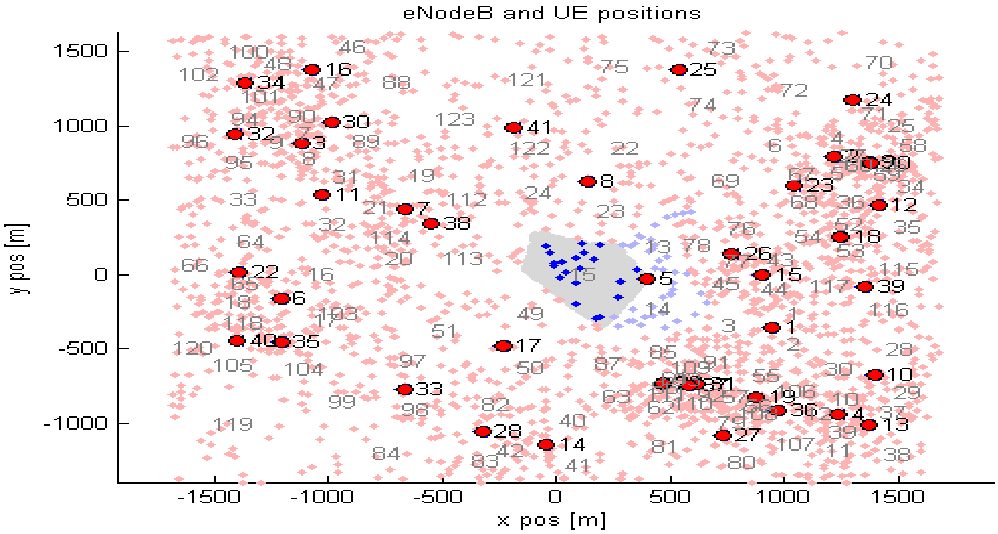


Fig27: eNodeB and UE positions in the coverage area

This graph represents the coverage area provided by the eNodeB of the cell number 15 studied with the 20 UEs connected.

- Shade in Gray color represents the coverage area provided by cell 15
- The Blue dots correspond to the 20 UEs connected to the eNodeB 15
- The red circular points represent the other cells that are not taken into consideration by our simulation thus deactivated.

Depending on the position of the UE, it may be between the coverage of several base stations, so if it wishes to connect to the network it compares the strength of the signals it receives from the different base stations and selects where It receives the signal better and if it moves and it leaves the location area, a Handover operation will be set up to maintain the connection in progress. It should be noted that the more the UE moves away from the server base station, the more it receives less bandwidth than a UE close to its server base station and this due to propagation losses.

General conclusion

The main objective of this thesis was to analyze and evaluate the performance of the new LTE mobile radio communication standard known as 4G. Given that this system is regarded by operators as the technology capable of solving the challenge of increasing bandwidth requirements in the future as a result of the growth of smartphones and large data applications, Improve spectral efficiency, reduce latency, increase network performance, offer high bit rates in high or low speed mobility, enable and facilitate interconnection and interoperability between different existing technologies.

In this work, we tried to understand its strengths and we concluded that its success is driven by the introduction of new architectures and technologies. We have discovered that its architecture is an improvement of the core network and even networks (UTRAN) of the existing systems and those other modulation techniques more powerful than the CDMA encountered in 3G were thought and adopted in the new system LTE. This is SC-FDMA and OFDMA based on OFDM. These two techniques have been proposed respectively for uplink and downlink communications each having its advantages and disadvantages.

The main interest that these modulation techniques have brought is their robustness to the effects of multiple paths inflicted by the propagation channel. By the simulation carried out in this work, we have shown that the MIMO antenna system associated with these Modulation techniques, Provides good flow to users who have the best momentary conditions of the transmission channel.

In the course of this work, an analogical study was made between OFDMA and SC-FDMA and revealed that the SC-FDMA has the merit of having a low PAPR which made it suitable for transmission in the sense By users of mobile terminals, which in this case benefit from a reduction in the power consumption of the power amplifiers. Despite the interest of these modulation techniques, for transmission in a mobile environment, the algorithmic complexity associated with their implementation and their equalization constitutes a major obstacle to their adoption. This work also allowed us to improve our knowledge of channel coding; By a study on the turbocodes which offer a good efficiency of correction and of detection of error making it possible to approach the limit of Shannon in terms of channel capacity.

During the simulation carried out under the matlab software, we have been able to demonstrate our initial objective, especially concerning the rate of flow according to the different parameters (code rate, modulation, MIMO and bandwidth) (BLER, CBER and PBER) as a function of the parameters such as (SNR, modulation type and MIMO configuration), the attenuation according to the different propagation media and the gain of the Antenna as a function of the angle of Opening and type of antenna. We were satisfied with the results obtained even if we did not touch all the aspects of the simulation that we had set because of the time and the software that is incomplete. Before closing, even if the LTE seems to be promising, the performance achieved in terms of throughputs and latency times are still insufficient in relation to the expectations of the customer. This is why other systems are emerging as LTE-Advanced with speeds of up to 1Gbit / s and a bandwidth of up to 120MHz.

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