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4G LTE : eMBMS with MBSFN Service Simulation using OPNET

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Abstract

Long Term Evolution (LTE) known in the market as 4G LTE, it is an evolution of the GSM/UMTS standard. The overall aim of LTE was to provide a new radio access technology focusing on packet-switched data only. LTE has provided a new peak download rates, low data transfer latencies, and improved the support for mobility. 3Th Generation Partnership Project (3GPP) specialized that LTE released 10 and beyond known as LTE-advanced it is the second evolution of LTE. It has some services such as Coordinated Multipoint Transmission and Reception (CoMP), evolved Multimedia Broadcast and Multicast Service (eMBMS) with Multicast-Broadcast Single-Frequency Network (MBSFN). The development still continuous on LTE-advanced, it is intended to meet the requirement of advanced application that will become common in the wireless marketplace in future. The goals of this project is to simulate one of LTE-A services on LTE standard such as CoMP or/and eMBMS with MBSFN using OPENT LTE, and measure some statistic such as spectral efficiency and also some other statistics, describe centralization vs. decentralization in LTE, and synchronization in the base station in LTE. OPNET LTE support eMBMS with MBSFN, and don't support CoMP, the simulation has been done by using eMBMS with MBSFN. Finally the objectives of the project has achieved, the result show that when eMBMS with MBSFN is implemented the throughput increased in the downlink to about 5.52 Mbps and in the uplink to about 5.18 Mbps, and also the system spectral efficiency increased in eNB1 from about 10.25 (bits/s/Hz/cell) to about 13.75 (bits/s/Hz/cell) and in eNB2 from about 10.25 (bits/s/Hz/cell) to about 17.25 (bits/s/Hz/cell). The project also answers if it is possible to have centralization in LTE, describe synchronization in the base station in LTE, and if OPNET is useful for big research.

Keywords: 3G, 3GPP, 4G, CoMP, CSI, CSI-IM, CSI-RS, eMBMS, eNB, EPC, EPS, E-UTRAN, GSM, HSPA, IGMP, IGRP, ITU-T, LTE, LTE-A, MAC, MBSC, MBSFN, MCE, MCS, MFN, MME, OFDM, OFDMA, OPNET, OSPF, PDN-GW, PDSCH, PMCH, PUCCH, PUSCH, QoS, SAE, SC-FDMA, S-GW, TDD, TD-SCMDA, UE, UTMS, WCDMA.

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Terminology

Acronyms

3G	Third generation of mobile telecommunication technology
3GPP	Third Generation Partnership Project
4G	Fourth generation of mobile telecommunication technology
CoMP	Coordinated Multi-Point transmission/reception
CSI	Channel-Sate Information
CSI-IM	Channel-Sate Information Measurement
CSI-RS	Channel-Sate Information-Reference Symbol
eMBMS	evolution Multimedia Broadcast Multicast Service
eNB	evolved Node B
EPC	evolution Packet Core
EPS	evolution Packet System
E-UTRAN	evolution Universal Terrestrial Radio Access Network
GSM	Global System for Mobile Communication
HSPA	High Speed Packet Access
IGMP	International Group Management Protocol

IGRP	Interior Gateway Routing Protocol
ITU-T	International Telecommunication Union-Telecommunication Standardization Sector
LTE	Long Term Evolution
LTE-A	Long Term Evolution - Advanced
MAC	Media Access Control
MB-SC	Broadcast Multicast -Service Center
MBSFN	Multi Broadcast-Single Frequency Network
MCE	Multi-Cell Coordination Entity
MCS	Modulation and Coding Scheme
MFN	Multi Frequency Network
MME	Mobility Management Entity
OFDM	Orthogonal Frequency- Division Multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
OPNET	Optimized Network Engineering Tools
OSPF	Open Shortest Path First
PDN-GW	Packet Data Network Gateway
PDSCH	Physical Downlink Shared Channel
PMCH	Physical Multicast Channel
PUCCH	Physical Uplink Control Channel

PUSCH	Physical Uplink Shared Channel
QoS	Quality of Service
SAE	System Architecture Evolution
SC-FDMA	Single Carrier- Frequency Division Multiple Access
S-GW	Serving Gateway
TDD	Time Division Duplexing
TD-SCMDA	Time Division-Synchronous Code Division Multiple Access
UE	User Equipment
UTMS	Universal Mobile Telecommunications System
WCDMA	Wide-Band Code-Division Multiple Access

1 Introduction

This chapter describes the general introduction which provides information about the background and problem, the overall aim of the thesis, scope and the report structure. Section 1.1 provides background information and problem motivation. Section 1.2 provides the scope of the thesis. Section 1.3 provides the concrete and verifiable goals. Section 1.4 consist the outline of the report.

1.1 Background and problem motivation

By completing the evolution of 3G in telecommunication the researchers started to look and investigate the next generation 4G LTE (long term evolution), and 4G LTE – advanced. This revolution changed the telecommunication market, and the overall aims was to provide a new radio technology focusing on packet switched data only. A new requirements have been added in LTE – advanced and also the network architecture has been changed by 3[Th] Generation Generation Partnership Project (3GPP), because of this change there is need to simulate, investigate and try to understand the problem in LTE and LTE – advanced and the new services. Also in previous course some labs material in OPNET has developed for the master's and bachelor's students in the applied engineering course. Simulation tools give a better understanding about the problems and the availability in LTE and OPNET LTE special model is model for LTE that support the topologies and the equipments in LTE. This thesis focuses in LTE technologies and topologies, how the LTE topologies can be created in OPNET LTE and analysis those topologies. The goals of the thesis is to try to simulate LTE CoMP and/or eMBMS with MB-FSN and measure the spectral efficiency and some other statistics, describes centralization vs. decentralization in LTE, synchronizations in the base station in LTE. The most important questions this thesis will give answers to it if OPNET is useful for big research and if it is possible to have centralization in LTE.

1.2 Overall aim

The thesis overall aim is to simulate LTE CoMP and /or eMBMS with MB-FSN, measure the spectral efficiency, describes centralization and decentralization in LTE and synchronizations in LTE. The result of the simulation will be starting point for more investigate in LTE and LTE-A and it will be also a start point for more work in LTE and LTE-A using OPNET LTE. The thesis will give abetter understanding of how to create topologies in LTE, how to measure spectral efficiency and how to analysis the result.

1.3 Scope

The scope of this thesis is to simulate the available LTE-A services in OPNET LTE like CoMP and/ or eMBMS with MBSFN service into LTE standard topology, describe centralization .vs decentralization in LTE, describe synchronization in LTE base station, and give answers if is possible to have centralization in LTE and if OPNET is useful for big research. Through the implementation of eMBMS with MBSFN service the spectrum can be managed efficiently and increase the coverage area. The idea is that when used eMBMS with MBSFN service the different base stations can work as a single base station or central base station, also the coverage area will increase after integration of signals from different stations.

1.4 Concrete and verifiable goals

The concrete and verifiable goals of the project are:

- Simulate LTE CoMP and /or eMBMS with MB-FSN.
- If it is possible to implement centralization in LTE.
- Measure the spectral efficiency.
- Describes Centralization vs. Decentralization in LTE.
- Describe Synchronizations in the base station.

1.5 Outline

Chapter 1 introduces the thesis. Chapter 2 present the theory that the thesis based on, Chapter 3 present the methodology used to find the relevant theory for the solution. Chapter 4 presents the simulation design, Chapter 5 present the result of the simulation, Chapter 6 present the conclusion, future work and the ethical aspect of the project. The thesis end with references and appendixes.

2 Theory

This chapter presents the 4G LTE, Transmission scheme in LTE, LTE architecture, LTE-advanced, CoMP, eMBMS, MBSFN, Synchronization in LTE, centralization vs. decentralization in LTE descriptions; those are the basic needs to give a better understanding of the project.

2.1 LTE

long term evolution (LTE), it is an evolution of the third generation 3G system in telecommunications to 4G, and the overall goal was to provide a new radio access technology that focuses on the packet-switched data only. The first phase of the 3GPP has been working on LTE to define a set of performance goals for the ability to LTE. The targets were at peak data rate, user/system throughput, spectral efficiency, and latency. Furthermore, to develop the new system were to override the old mobile standard (UTMS, HSPA, e.g.) and also the requirement was set on spectrum flexibility, also the compatibility with 3GPP radio access technology (GSM, WCDMA/HSPA, and TD-SCMDA). LTE supports up to 300 Mbps (peak rate) downlink and 75 Mbps (peak rate) uplink. The physical layer of LTE designed for full duplex in downlink and uplink and the modulation uses in LTE for downlink is OFDMA and for the uplink SC-FDMA.
The first release of LTE specification, was released 8 in spring 2008 and commercial network operation began in 2009. This version of the LTE, has been followed by other LTE releases (9 Rel, Rel 10, Rel and 11) introducing more functionality in different area. Release 11, which ended in 2012, and 3GPP working on the release of 12. At the same time, in parallel to the development of LTE, there has been also a big evolution of the overall 3GPP architecture, describe as the System Architecture Evolution (SAE), and this both including radio access and core network. The requirement also set on the architecture evolution, which directly leads to a new flat radio access network architecture with the signal type of node, the eNodeB, and also new core-network architecture [1]. Figure 1 and Figure 2 shows the evolution of LTE. Table 1 show the targets of LTE.

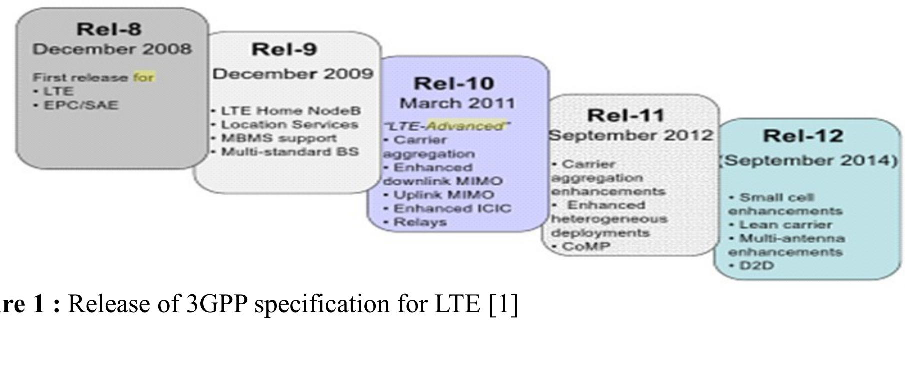


Figure 1 : Release of 3GPP specification for LTE [1]

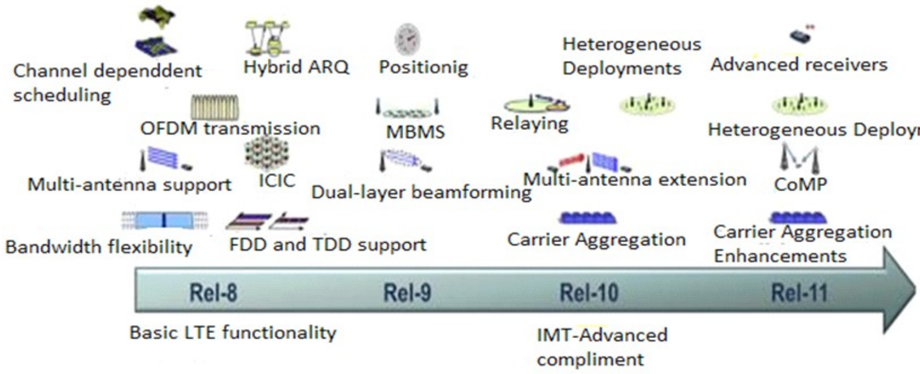


Figure 2: LTE and its evolution [2]

Table 1: LTE targets [10]

Services	Targets
Peak data rate	Downlink :100 Mbps , Uplink 50 Mbps.
Spectral Efficiency	2-4 times better than 3G system.
Cell-Edge Bit-Rate	Increased whilst maintaining same site location as deployed today.
Mobility	Optimized for low mobility up to 15 Km/h. High performance for speed up to 120 km/h. Maintaining connection up to 350 Km/h.
User Plane Latency	Below 5 ms 5MHz bandwidth or higher
Scalable Bandwidth	For 1.4 to 20 MHz
Radio Resource Management	Enhanced support for end-to-end QoS. Efficient transmission and operation for higher layer protocol.
Service Support	Efficient support of several services (web-browsing, FTP, Video-Streaming, VoIP, e.g.). VoIP should support with at least a good quality as voice traffic over the UTMS network.

2.2 LTE transmission scheme

LTE uses OFDM as base modulation in downlink and uplink, there are two different versions used in LTE: Orthogonal Frequency - Division Multiple Access (OFDMA) in the downlink and because it provides a high degree of durability against channel frequency selectivity and signal deterioration due the frequency selective channel that can be processing by equalization at the receiver side, also because of the advanced multi-antenna transmission scheme like spatial multiplexing. LTE on the other hand also uses Single Carrier Multi-band Frequency to Access (SC-FDMA) that, based on OFDM transmission, this means that it will minimize cubic metric of transmission transmission and by enabling higher efficiency power amplifier in the terminal side [3][4].

2.2.1 OFDM

Orthogonal Frequency- Division Multiplexing (OFDM) is a method of encoding digital data on multiple carrier frequency. The basis of OFDM signal is split the signal into a large number of smaller and narrower bandwidth channels , which is known as sub-channels. The sub-range channels in OFDM means the channels are orthogonal channels to each other, and due to the lack of an interval between sub-channels which would increase the spectral efficiency. The frequency representation on OFDM sub channels is a Sinc function (a Sinc function that uses in signal processing and Fourier transmission, it defines as Sinc(x) = Sin(x)/x), where the sampling is done at exact spacing the result will be at the sub-carrier of the sub-channel and zeros at every other sub-carrier frequency. Figure 3 shows the orthogonal principle of OFDM, Figure 4 shows OFDM modulation, and Figure 5 shows OFDM demodulation [5][6].

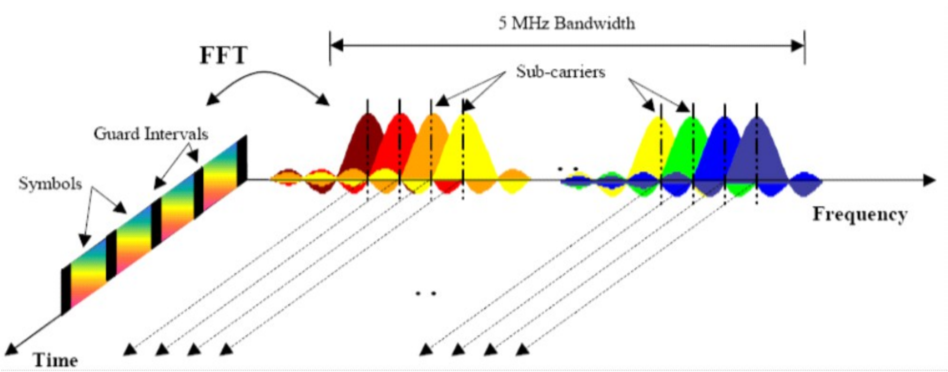


Figure 3: OFDM signal in frequency and time domain [5]

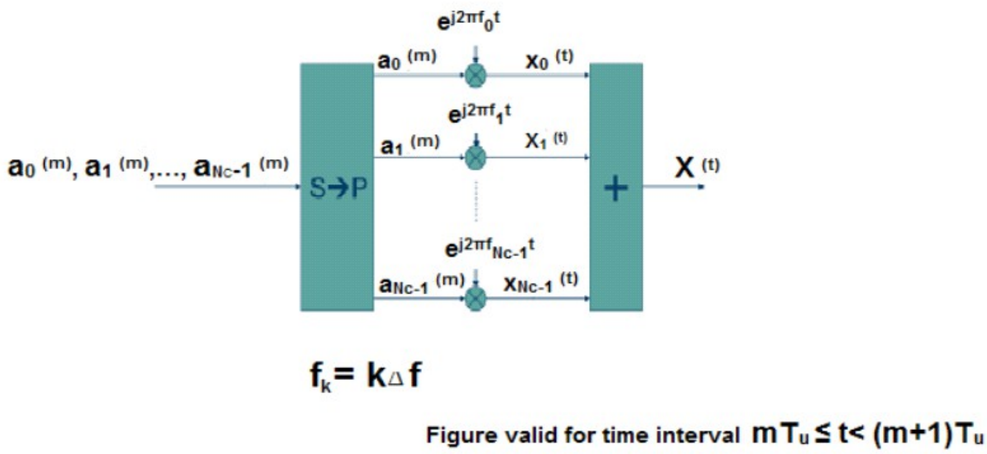


Figure 4: OFDM modulation [6]

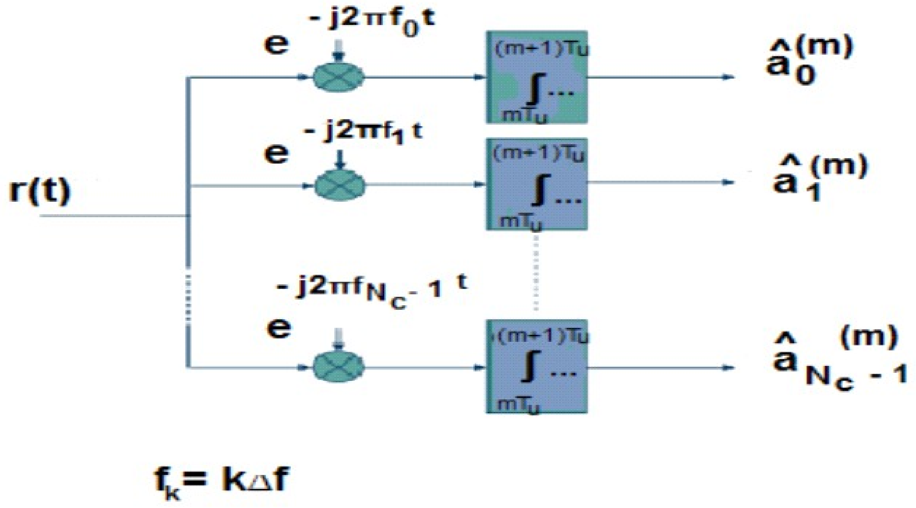


Figure 5: OFDM demodulation [6]

2.2.2 OFDMA

Orthogonal Frequency-Division Multiple Access (OFDMA) it is based on OFDM, the different that OFDM can be used as user-multiplexing or multiple-access scheme to allow simultaneous frequency-separated transmission from/to multiple terminals. And OFDM downlink used as user-multiplexing scheme for each OFDM symbol interval, a different subset of the sub-carrier that available are used for transmission to different terminals. In OFDM uplink transmission is also used as a user-multiplexing or multiple-access scheme for each OFDM symbol interval system known as OFDMA, different sub-carrier are available and used to transfer data from different terminals [5]. Figure 6 and Figure 7 shows the OFDM as user multiplexing and multiple access schemes [7].

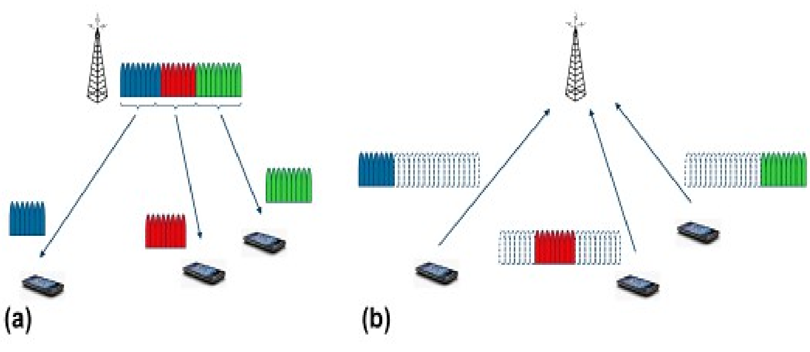


Figure 6: OFDM as user-multiplexing / multiple–access scheme [7]

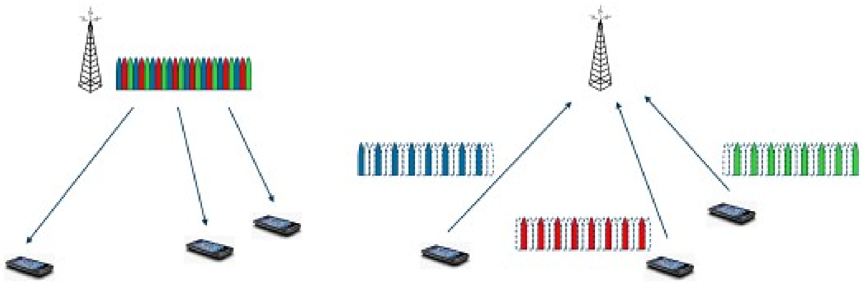


Figure 7 : distributed user multiplexing [7]

2.2.3 SC-FDMA

Single Carrier- Frequency Division Multiple Access (SC-FDMA) it is the uplink transmission for both LTE / LTE-advanced, and the main reason behind adapting SC-FDMA as the transmission characteristics in their operations, which has a low Peak Average Power Radio (PAPR) the problem with LTE. The SC-FDMA and OFDMA signals contains many modulations signals by shift keys (PSK) or quadrate amplitude modulation (QAM). OFDMA signal is transmitted in separately by using many sub-carriers in orthogonal way and the corresponding spectrum is rectangle shaped and because of that it can achieve high data rate and also high frequency efficiency, OFDMA has by using multi-carrier a high PAPR, the solution of this problem was SC-FDMA that adapted in the uplink of the LET-advanced [8]. Figure 8 shows OFDMA and SC-FDMA [9].

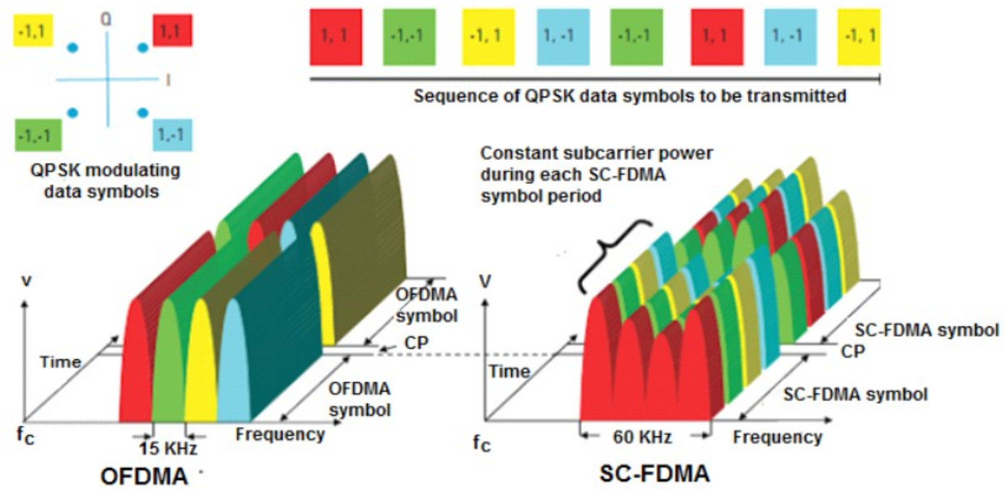


Figure 8: SC-FDMA and OFDMA [9]

2.3 LTE network architecture

The 3GPP has developed new network architecture of LTE specification contents those components describes below, it is known also as Service Architecture Evolution, which based on flat architecture building on 3G network. Because of its flat architecture it supports mobility, high data rate and signaling.

2.3.1 UE

The User Equipment (UE) it is acutely a Mobile Equipment (ME), it uses to connect to the LTE network and establish their connectivity. The UE can take several types mobile, Data card used by computer or notebook. Like 3GPP systems, UE can contents tow forms, a SIM-card that knows as User Service Identity Module (USIM) and the real equipment knows as Terminal Equipment (TE). SIM- card has the important information that uses from the operator to identification the user and for the authentication process. The terminal equipment provides the users with necessary hardware (processing, storage, operating system, e.g.) that run application and use LTE system services [11].

2.3.2 E-UTRAN

Evolution Universal Terrestrial Radio Access Network (E-UTRAN), it is the evolution from UMTS radio access network. Because of the drawback of (UMTS / HSPA) system, where there is a need to connect eNB via RNC (Radio Network Controller), which can be a failure and to solve this problem the 3GPP used new E-UTRAN architecture that contains of the directly interconnected eNBs which are connected to each other via X2 interface and to the core network via the S1 interface. The idea that evolved Node B (eNodeB) works like a bridge between the EPS and the UE, which provides radio protocol to the user devices to send and receive data and also make a security tunnels to transport user data across LTE through the PDN-GW, and the GTP tunneling protocol used in top of UDP/IP protocols. eNodeB and also responding for scheduling which are the most important functions of the radio, it is the frequency spectrum resources between different users by exploiting time and frequency, and gives a different quality of service to end users. The eNodeB also has some mobility management function like radio link measurement and handover signaling for other eNodeBs, Figure 9 shows E-UTRAN architecture [11].

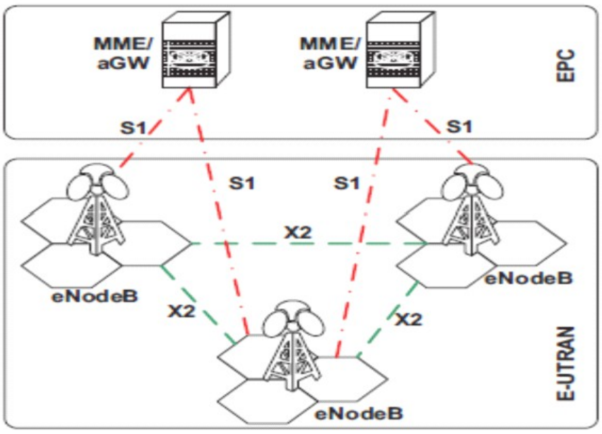


Figure 9: E-UTRAN architecture [11]

2.3.3 EPC

Evolution Packet Core also known as LTE core network (EPC), it contains three important key things: mobility management entity (MME), Serving Gateway

(S-GW), The packet data network gateway (PDN-GW). There are also some other logical entities such as Home Subscriber Service (HSS), the Policy and the laws of shipping function (PCRF). The main objective of the EPC is to provide significant functional list to support users and established their bearers [11].

2.3.4 MME

Mobility management entity, it provides control function and signaling for EPC and they are used only in the control plane. Some of MME can support some functions, such as authentication, security, roaming, delivery, and track user movement or mobility, and dedicated bearer established [11].

2.3.5 S-GW

Serving Gateway, it is the main gateway for user's traffic, and the connecting point for inter-eNodeB handover, and mobility connecting point for inter-3GPP mobility. Also S-GW can provides some other functions like, routing, forwarding, charging/accounting information gathering [11].

2.3.6 PDN-GW

Packet Data Network Gateway, it works like connectivity point for the user traffic and responsible for assigning the user IP address and classifying the user traffic into different QoS classes, also in addition it works like mobility connecting point for inter-working with 3GPP technologies (Wireless LAN, WiMAX), Figure 10 shows LTE architecture [11].

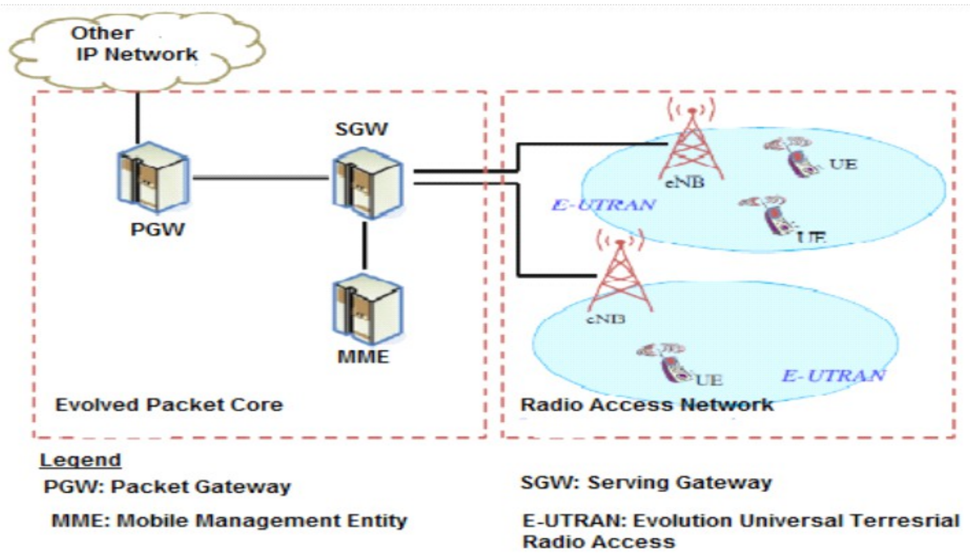


Figure 10: LTE architecture [10]

2.4 LTE -advanced

3GPP LTE Release 10 and beyond knows as LTE-advanced. The second evolution of LTE, it has some feature and the work still continues on LTE-advanced, it is intended to meet the diverse requirements of advanced application that will become common in the wireless market place in future. The goal is to lower the Capital Expenses (CAPEX) and Operating Expenses (OPEX) of future broadband wireless networks and provides backward compatibility with LTE and moreover will meet or change IMT-advanced requirement, Figure 11 shows the time line for LTE & LTE-advanced [12].

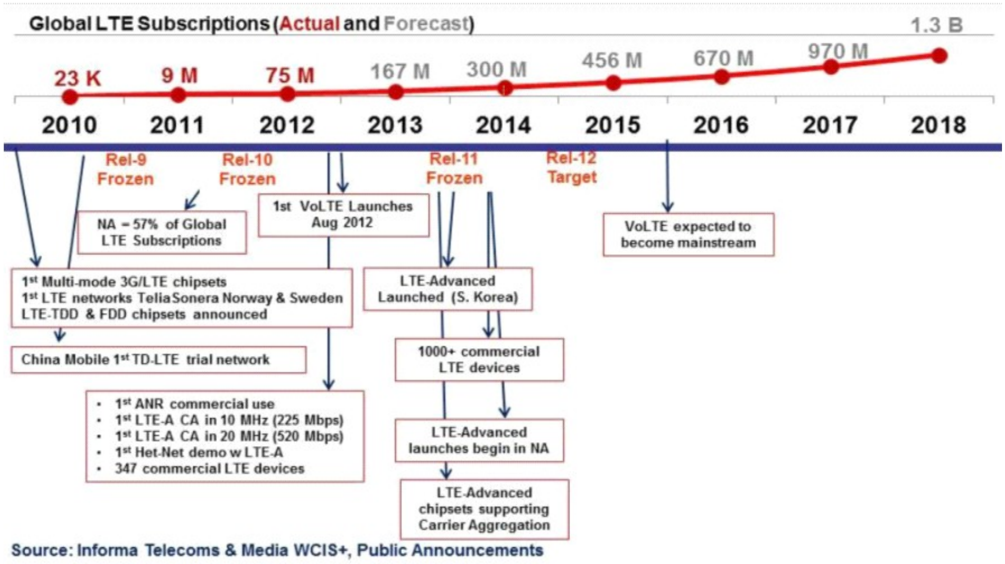


Figure 11: 4G LTE-LTE advance time line to 2018 [12]

2.4.1 CoMP

Coordinated Multi-Point transmission/reception (CoMP) it is tool improves coverage area, cell-edge throughput and/or spectral efficiency. The 3GPP add it in release 11 and completed in December 2012 and the main idea behind CoMP, it depending on the location of UE, it can received signals from multiple cells and transmission can be received in multiple cells in any load. In the downlink if the transmissions become from multiple cells are coordinated, the system can be increased significantly. This coordination can be simple or complex where the data is transmitted from multiple cells. In the uplink the system can take advantages of reception at multiple cells to significantly improve the link performance like throughput technologies such as interference cancellation [13].

2.4.1.1 CoMP architecture

There are two types of transmission in CoMP, Intra-site or Inter-site. Intra-site CoMP has advantages and that is a significant amount of information exchange is possible between coordinating cells because the backhaul connection between base stations are not used. In other hand inter-site CoMP used the coordination of multiple sites for CoMP transmission, it can exchange the information by using backhaul transmission and this type can add additional requirements and load in the backhaul design. Figures 12, 13 shows Inter-site and Intra-site CoMP [13].

The 3GPP evaluated four scenarios under the assumption of backhaul characteristic idea [13]:

1. Homogeneous macro-cellular network with intra-site CoMP.
2. Homogeneous macro-cellular network with inter-site CoMP.
3. Heterogeneous network with CoMP operation between the macro cell and lower power cells with in converge area, where the low power cells have different cell ID form the macro cell.
4. Heterogeneous network with low power PRHs with macro cell coverage, here the transmission / reception pointers are created by the PRHs and have the same ID that the macro cell have.

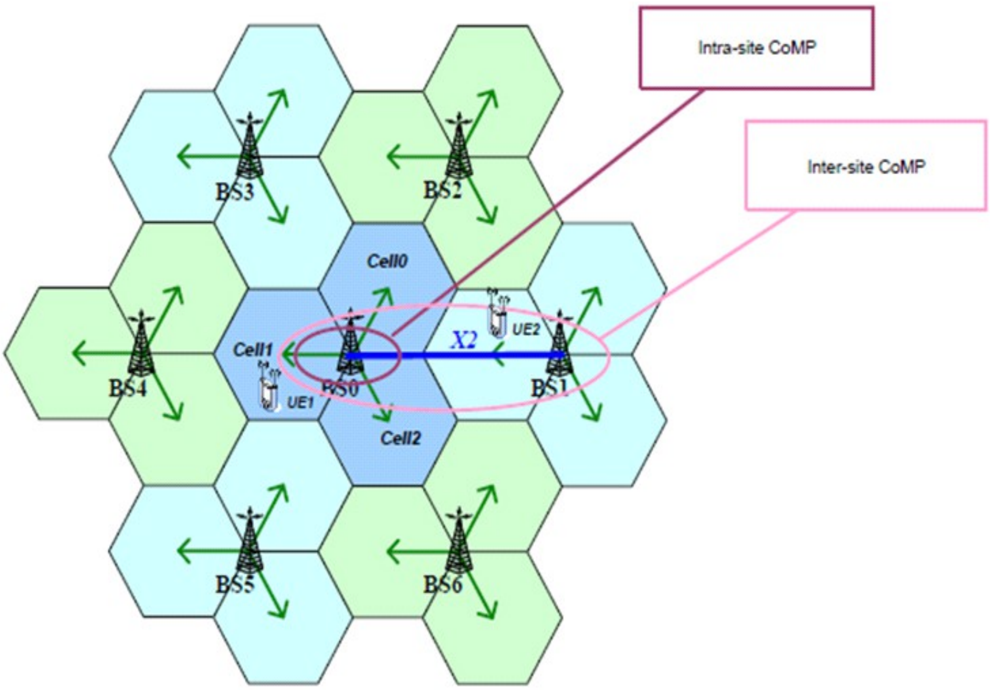


Figure 12: Inter-site and Intra-site COMP [13]

The Intra-site CoMP has a special architecture include a distributed evolved Node B (eNB), here the Radio Remote Units (RRU) of the eNB is located at different locations in space and by using this architecture CoMP coordination is inside a single eNB and the transmission act like Inter-site CoMP, Figure (14) shows Intra-eNB with Distributed eNB [13].

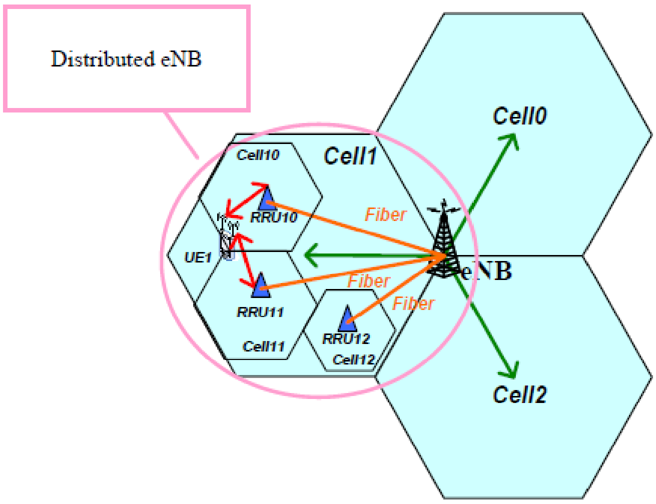


Figure 13: Intra-eNB with Disturbed eNB [13]

2.4.1.2 Downlink in CoPM

Downlink in CoMP has three different approaches:

- **Coordinated Scheduling or Coordinated Beam forming (CS/CB):**

The idea of CS is, to transmit from the serving cell only to single UE, that its, the UE data need only to be available in one serving transmission point not in all cells, it's like the is non – CoMP transmission. In other hand in case of the scheduling where there is any beam forming functionality in case (CB) in order to control and/or reduce interface between transmissions from different point it dynamically coordinated between the cells. In this case the best serving set will be selected and by that the transmitter beam will be constructed to reduce the interface to other neighboring users and in the same time increasing the served user's signal. And in order to support CS/CB different CSI (Channel-Sate Information) processes most be configure to become responsible for different cooperating transmission points and any given UE CSI feedback on the CSI processes of the serving cell can provides Channel Quality Indications (CQI) that means decodable the transport block size, and provide also preferred pre-coder Passive Inter Modulation (PIM) for serving the cell's transmission to the UE and the same UE PIM for other transmission points they use for the feedback other CSI process and point to the pre-coder to be avoided by other transmission points and that pre-coder will generate the biggest interference [14].

- **Dynamic Point Selection (DPS):**

The UE, is being served by a single transmission points at any one time. However, this single point can be dynamically change from sub frame to other within a set of possible transmission points and in this case each UE data become available in all possible transmission points and ready for selecting and to support DPS every CSI should provide CSI and PIM for different point. The dynamic downlink control signaling point to the Physical Downlink Shared Channel (PDSCH) rate that is match and resource element mapping and that according to selected transmission point in each sub frame, this will include CRS ports around the (PDSCH) data that are mapped, by starting form OFDM symbol for the data in sub frame and locations of the zero-power CSI-RS, also dynamic control signaling that show the CSI-RS and RS the demodulation can be assumed to be (quasi-co-located : a new concept introduced in Rel-11 it is reference signal antenna ports that are assumed by the UE to be quasi-co-located have the same large-term channel properties, including some or all of delay spread, Doppler spread, Doppler shift, average gain, and average delay) [14].

- **Joint Processing / Joint Transmission (JP/JT):**

The transmission to a single UE is simultaneously transmitted from multiple transmission points across cell sites and the multiple point transmission will be coordinated as a single transmission with antennas that geographically separated. This method has a higher performance compared with to coordination only in the scheduling, but at the same time required more on backhaul compunction. JT is assumed to be (coherent) that means the co-phasing of the signals from the different cooperating transmission points is start to use by pre-coding at the transmitters. There is no support provide for JT in Rel-11, even that Time Division Duplexing (TDD) system has often possibility to take advantage of channel exchange to get the necessary inter-transmission-point channel sate information to support JT [14].

In LTE- advanced Rel -11, the main support for the strengthening of the downlink CoMP is to save of a new Physical Downlink Shared Channel (PDSCH) Transmission Mode 10 (TM10), which includes a common feedback and signaling framework that can support CS/CB and DPS. Also the framework allows for multiple non-zero-powers Channel-Sate Information-Reference Symbol (CSI-RS) resources and measuring channel interference, incandescent measuring the information-interference (CSI-IM) needed to be configured for the UE resources to be configured for the UE through Radio Resource Control (PRC) signaling for the measurement of the channel and interference respectively. The set of CSI-RS that start to use in UE to measure and report channel sate information is defined as CoMP measurement set and the maximum size of CoMP measurement set are three and to support CSI for multiple CoMP transmission hypotheses to support CS/CB and DPS, there is need to configure multiple CSI feedback processes for a UE and up to 4 CSI can be configuring depending on the UE capability, where each CSI feedback processes can provides CSI corresponding to group of channel measurement from non-zero-power CSI-RS and interference measurement form CSI-IM [14].

2.4.1.3 Uplink in CoMP

Uplink in CoMP displays reception of the transmission signal at multiple geographically separated area or points. To control the interference, schedule decision can make to coordinate among the cells and the main network implementation is a scheduler and receivers in the uplink CoMP, and to support standard uplink CoMP the UE-specific Physical Uplink Shared Channel (PUSCH) Demodulation Reference Signal (DMRS) base sequence and cyclic shift hopping that can be configure through Radio Resource Control (RRC) signaling to add demodulation by reducing interference or increasing the reuse factor of DMRS. Furthermore, because the uplinks CoMP reception point may be decoupled (because of that they are different) form the downlink transmission point, the completed correspondence between the downlink assignment and the physical Uplink Control Channel (PUCCH) Acknowledgment/Negative Acknowledgment (ACK/NACK) feedback not used and new dynamically ACK/NACK are used where the base sequence and cyclic shift hooping of the PUCCH are generated by replacing the ID of the cell within the UE-specific parameter [14].

2.4.2 eMBMS

Evolution Multimedia Broadcast Multicast Service (eMBMS) it is point-to-multipoint content delivery solution designed for LTE/ LTE-advanced. It distributes efficiently the broadcast and multicast services to numbers of mobile devices located in givens geographical area. 3GPP specification introduced eMBMS in Rel-6 for Universal Mobile Telecommunications System (UMTS) to provide broadcast services over cellular network. In Rel-7, MBMS over a single Frequency Network (MBSFN) was intercede to work around the cell-edge problem of MBMS, because in FSN operation an identical waveform is transmitted from multiple cells with a tightly synchronized in time. In Rel-9, MBMS over SFN was introduced in Evolved Universal Terrestrial Radio Access Network (E-UTRAN) and that with a new name Evolved MBMS (eMBMS), the UE equipment cannot realize the difference in signal from multiple cells in MBMS transmission as the same signal received with multi-path effect from one big cell [15][16].

2.4.2.1 eMBMS architecture

3GPP have created new architecture for eMBMS that has new logical network entities proposed for eMBMS operations, those new entities make availability to connect as broadcast in eMBMS using eMBMS gateway and map incoming server traffic on broadcast/multicast bearers and this called Broadcast Multicast -Service Center (MB-SC), Figure 14 shows eMBMS architecture :

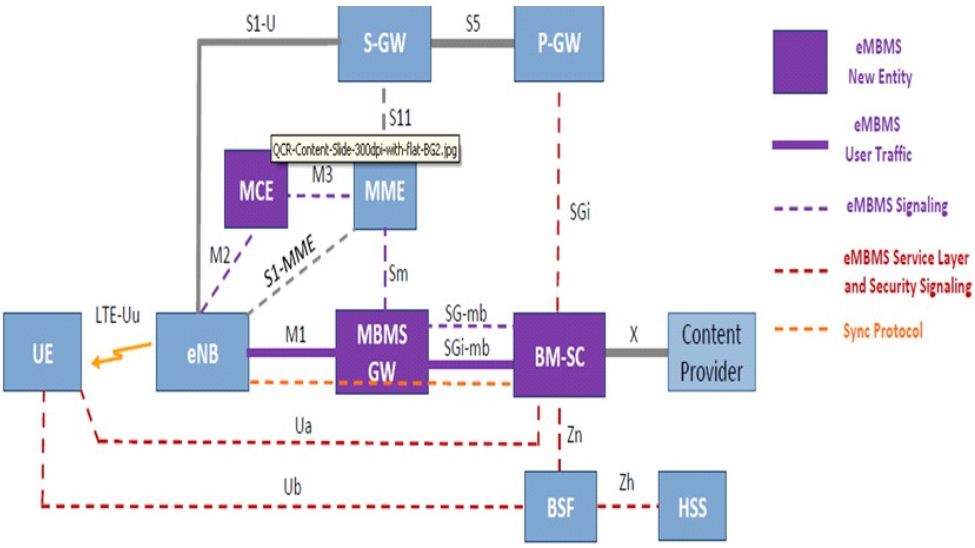


Figure 14: eMBMS architecture [15][16][17]

- BM-SC (Broadcast Multicast – Service Center)

Is the entity that connects between the Content Providers and the Evolved Packet Core. By allowing authorizing the content provider/terminal request it applied the role of traffic and also in charge of the SYNC protocol to synchronize the data sent between the eNBs. The SYNC protocol applied a special header to IP packet that provide time stamped and session information [15][16].

- eMBMS gateway

It is the entity between the MBSC and all eNBs and responsible to deliver MBMS packet user data to eNBs by IP multicast. It has simple work functionality, when the MBMS session is arriving it has a responsibility to allocate an IP multicast address to which the eNB that should join to receive MBMS data and chose the IP multicast group, and also the eMBMS gateway responsible for MBMS session declaration and performs MBMS session control signaling (Session Start/Stop) to E-UTRAN [15][16].

- MCE (Multi-Cell Coordination Entity)

It is a logical entity responsible for admission control and allocation of the radio time/frequency resource, deciding the radio configure, Modulation and Coding Scheme (MCS) using for MB-SFN operation. There are two ways to implement MCE, first as part of eNB and here will consider as distributed MCE architecture, second it can stand alone as centralized MCE architecture [15][16].

- M1 interface

It is user plane interface locates between the eMBMS gateway and eNB. The IP Multicast uses to deliver point-to-multipoint MBMS data packet over M1 interface and SYNC protocol used over M1 to keep content synchronization in MBMS data transmission. The good purpose that there is no control information over this interface [15][16].

- M2 interface

This interface will not present if there was use MCE distributed architecture, it is a control plane interface located between MCE and eNB. The (M2AP) application Protocol defines for this interface for the transfer of configuration data for multi-cell transmission mode eNBs and Session Control Signaling [15][16].

- M3 interface

This interface connects MME and MCE and supports Session Control Signaling, for the MBMS session start and end (MBMS Start/Stop and MBMS Session Update), M3 application use to allow the MBMS Session Control Signaling at the level of ERAB session, but does not transfer radio configuration data [15][16].

2.4.2.2 MB-SFN

When there is the use of the Multi Frequency Network (MFN), there is necessary to use of different carrier frequency in different cells to provide high levels of interference especially for UEs located at the cell edge also reuse of low frequency because the cells are not allowed to reuse the frequency. On the other hand, in Multi Broadcast-Single Frequency Network (MB-SFN), during MB-SFN operation a group of cells is synchronized to transmit the same broadcast/multicast content in geographical area called the MB-SFN area. There are some services provided in this area and classified into different groups based on their requirement in Quality of Service (QoS), those services with the same quality they will operate in the same group. MB-SFN uses one common carrier frequency for all eNBs for the simultaneous transmission in a multi-cell network. All eNBs should be tight time-synchronized to generate that transmitted of the information at the same time on the same set of OFDM sub carriers at every base-station. The receiver in the MB-SFN will pick up multiple versions of the same signal from different eNBs with different time delay depending to the distance of the UE from the eNBs and the synchronization enable the receiver to process the multiple signal versions like multipath propagation, there is no additional complex required for discrete-time channel equalization as long as the CP (Cyclic Prefix) is not exceeded because the signals will appears as echoed paths from a single transmitter in SFN. SFN also increases the spectral efficiency and that because the enhanced signal to interference–plus-noise ratio (SINR) compared to the unicast transmission. The combination of the different received signal path from different eNBs will increase the received signal energy, in other hand the inter-cell interference is reduced practically for users which are located at the all borders. The size of the MB-SFN used as parameters, when the SFN area size increases the spectral efficiency improves at equal coverage, Figure 15 shows MFSN vs. MB-SFN [15][16][18].

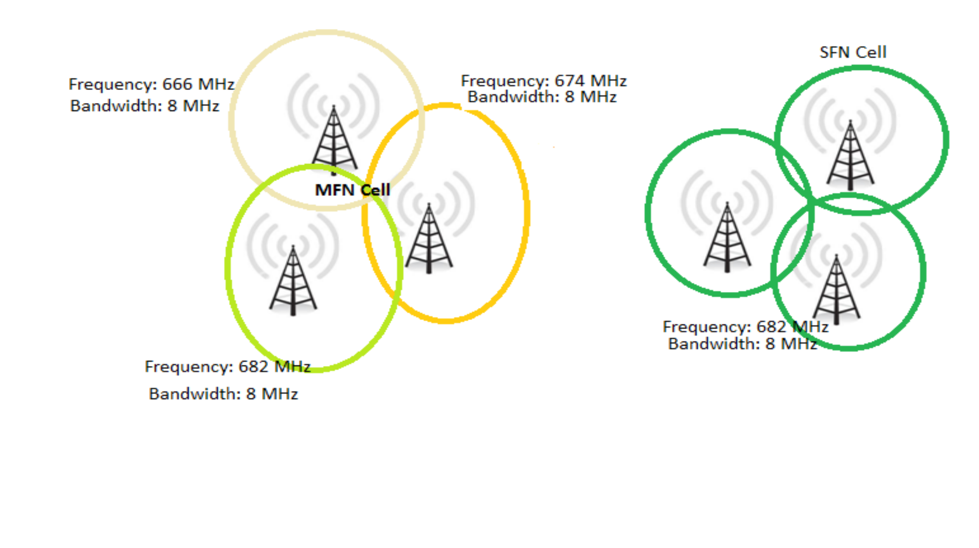


Figure 15: MFN vs. SFN network [18]

2.5 Centralization vs. decentralization in LTE

In LTE the term centralization means that a central master cell manages all resources of the cooperating cells, the UE reports Channel State Information (CSI) to its serving cell then the serving cell forwards this information to the master cell over the X2 interface (X2 interface, a protocol to separate between the radio network and transport network layers), the master cell distributed scheduling decisions to the transmitting cells over X2, Figure 16 show centralization [19].

They are some advantages and disadvantage of using centralization:

- Advantage :
  - Allows optimal scheduling since the master knows the CSI of all UEs.
  - Only two X2 usages are required.
- Disadvantage:
  - CSI needs to be sent over X2 for each active UE.

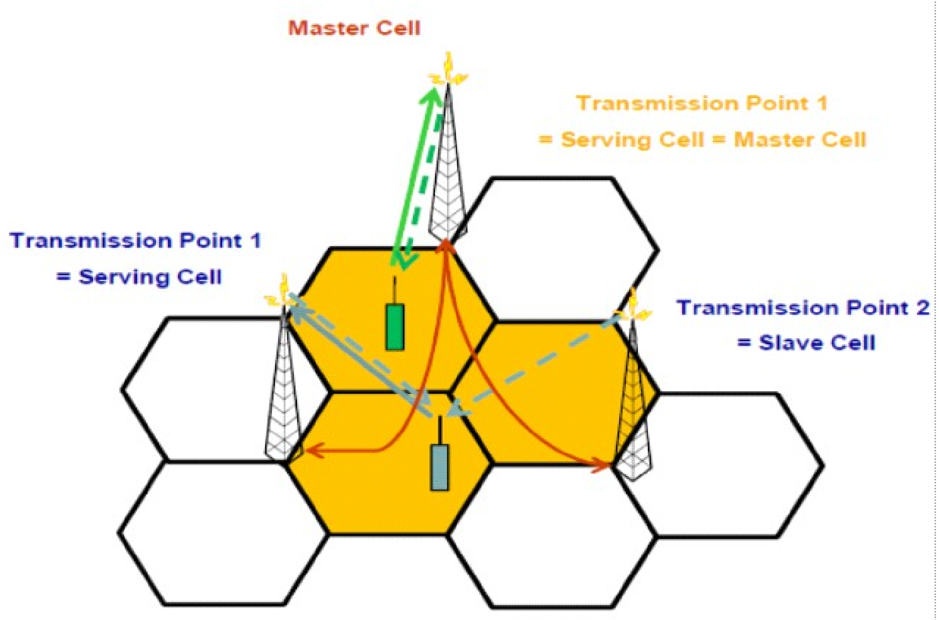


Figure 16: centralization in LTE [19]

On the other hand, decentralization means that user data is available in one sector known as serving cell, but the scheduling is made with coordination between the sectors. The idea is to determine the worst interference and avoid collision in the spatial domain, that by blocking the interference from using most destructive preceding matrices, interference cell can serve as non-destructive beams.

There are some approaches to use coordination in LTE:

- The active UE send information about the most destructive interfering preceding matrices to their serving cells.
- Serving cell forward the received messages to the interfering cells over X2.
- The cells negotiate their beams to improve a utility metric.

Figure 17 show decentralization idea, Figure 18 show Centralized /Autonomous Decentralized control [19].

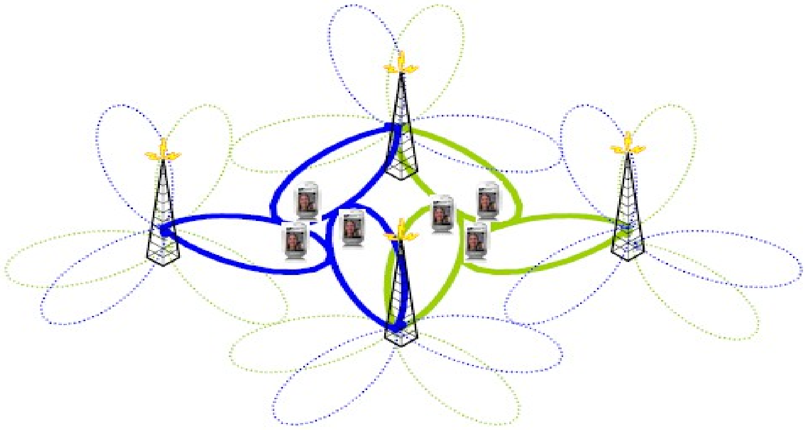


Figure 17: Decentralization in LTE [19]

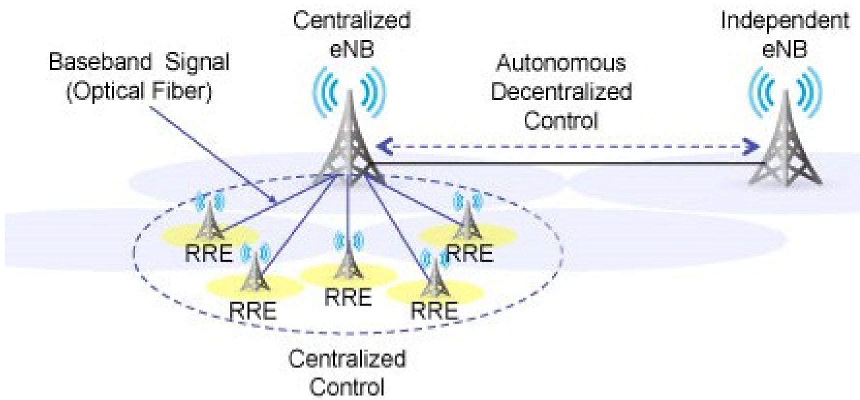


Figure 18: Centralized /Autonomous Decentralized control [21]

2.6 Synchronization on base station in LTE

In LTE the ITU-T (International Telecommunication Union-Telecommunication Standardization Sector) has defined synchronization as, the network synchronization is the most important key and solution that need to meet precisely of timing and delivering requirements of LTE network quality and availability. It is technically applied to ensure that radios in the target LTE base station are operating in the framework of the performance criteria specified by the 3GPP standard. This synchronization achieved by delivering a specifically formatted clock signal or signals to base stations radio circuitry and departments of these signals in turn are used to generate the modulation methods RF air interference frequency/phase components. The RF air interface requirements of LTE are determined by the 3GPP and they standardized includes radio, core, network, and service architecture.

The types of the synchronization exits in LTE are frequency synchronization, phase synchronization, and time synchronization:

- The frequency synchronization is required by all mobile systems to minimize the handover and disturbance between the base stations, and accomplish regulatory requirements and the radio signal must be generated in tough docility with frequency precision requirements. According to 3GPP specification the same source should be used in the radio frequency and the data clock generation. The modulation carrier frequency of the base station observed over a period of one sub frame (for example 1m) should be accurate to within -+ 50 ppb for wide area base station and the requirement in the case of Pico base station can be relaxed to 100 ppb. Also this frequency synchronization requirements are applicable to the other 3GPP radio access technologies, including GSM and WCDMA [20].

- The Phase synchronization is required in case of TDD system because uplink and downlink transmission use the same frequency bands but different time slot and in order to avoid interference between cells the base stations need to be phase aligned. In particular LTE is based on TDD, the timing between base stations must be accurate to within 3μ (for cells of equal or less than 3 km radius) and 10μ (for cells of more than 3 km radius) [20].

- The time synchronization is the distribution of an absolute time reference to real-time clocks of a telecommunication network. That means all nodes have to access to information about absolute time and share a common time scale. It is also one of archived way to phase synchronization. Figure 19 shows types of synchronization, Figure 20 shows example of synchronization in LTE, MBMS synchronization area in LTE [20].

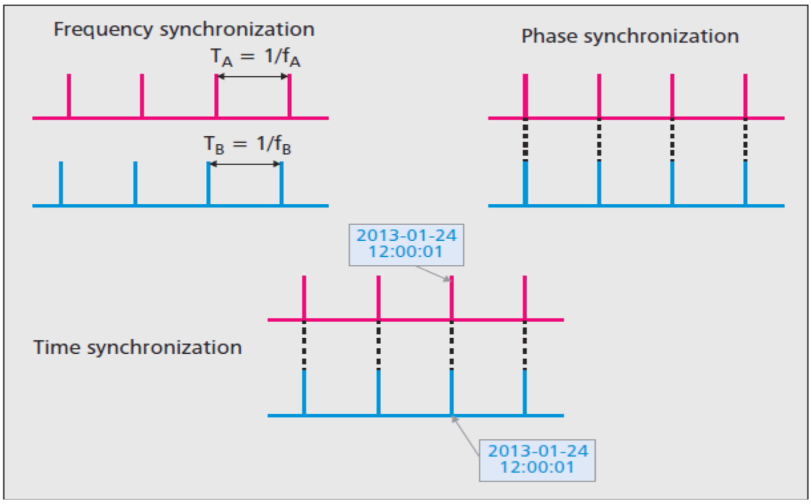


Figure 19: Type of Synchronization [20]

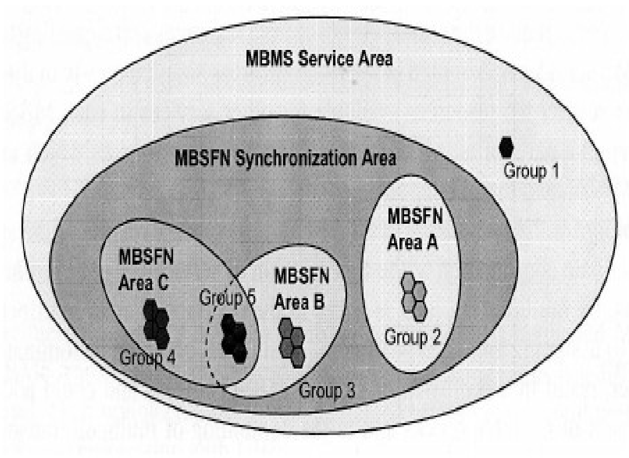


Figure 20: MBMS synchronization area in LTE [18]

2.7 Spectral efficiency

In wireless the spectral efficiency is the measure the ability of a wireless system to deliver information with a given amount of radio spectrum and provides another key metric of the wireless system quality. There is a different way to measure the spectral efficiency but in this project because after the simulation the result will show the throughput (according to OPNET) and the amount of the bandwidth is knowing and by using the law below to calculate the system spectral efficiency:

$$System\ Spectral\ Efficiency = \frac{Total\ throughput}{Total\ bandwidth}\left(bits/s/Hz/number\ of\ cells\right)$$

[24]

Here,

System Spectral Efficiency = the information rate that can be transmitted over a given bandwidth in specific communication system.

Total throughput = total throughput in all eNBs.

Total bandwidth = total bandwidth in all eNBs.

Because of the use of eMBMS with MBSFN, the interest system spectral will be in the eNBs they have this service, the throughput will include error correcting codes, and there is assume that there are 100 simultaneous TV channels per cell, and each base station divides to the number of cells and that means number of cell directional sector antenna. Then, get the system spectral per site in (bit/s/Hz) per site. But the need is the amount in the cell, therefor divide by the number of cells to get the system spectral efficiency per (bits/s/Hz/cell) [24].

2.8 OPNET LTE Specialized Model

OPNET is standard for Optimized Network Engineering Tools, created by OPNET Technologies. OPNET LTE Specialized Model is available for OPNET Modeler Wireless Suite and OPNET Modeler Wireless Suite for Defense. This modeler support Rel-8 of 3GPP standard. Many manufactures, telecoms service providers, and defense origination uses this model to design an LTE network and devices to study the behavior and protocols on it like:

- Evaluating custom scheduling algorithms for LTE base and subscriber stations.
- Developing and testing QoS mechanisms for applications.
- Validating overall network behavior encompassing LTE access network and IP backbone.
- Visualizing live application performance over a simulated LTE network infrastructure.

There are two ways to develop LTE in OPNET the first one by using LTE wizard and the second by doing it manually, LTE wizard is not available in many OPNET versions because it is not free [22].

3 Methodology

Chapter 3 present methodology used in this project, by doing high level search in PhD projects, master's projects, and books. There are some good resources found to build the method, and different approaches used to keep this thesis simple.

3.1 Initial literary study

Initially, in order to understand the general idea and necessary information for the thesis. Thorough search in books, projects, and websites to get the information, and then some approaches were selected to study in order to develop the simulation and explain the results. The selected sources are [1], [2], [3], [4], [8], [10], [11], [16], [17], [25] and it has been summarized and presented in Chapter 2.

Books, projects, and websites are then used to be references to the report, in order to provide the information contained in the thesis. Those authoritative references, grant the information contained in this report to become a reliable and relevant information.

3.2 Solution approach

By reading the books and projects, some information appeared. This information has been used to implement and design the simulation, and some criteria have been used in order to complete the thesis:

- The design should be simple.
- Measurement spectral efficiency and analysis statistic and compare the result.
- Describe Centralization vs. decentralization in LTE.
- Describe synchronization in the base station.

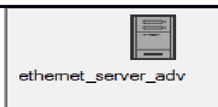
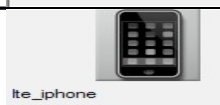
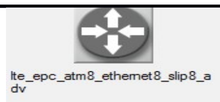
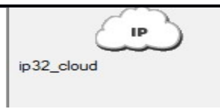
4 Simulation Design

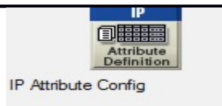
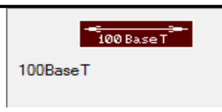
Chapter 4 describes the simulation design and the implementation in the OPNET LTE model, as well as their parameters and tools. Two scenarios have been developed, first scenario is LTE standard and the second LTE standard with used of eMBMS with MBSFN service.

4.1 OPNET LTE environment

In order to develop LTE scenarios, there are some important components used in OPNET LTE model to implement those scenarios, table 2 below shows the symbols components uses in OPNET LTE:

Table 2: sample components in OPNET [25]

Node	Symbol picture
Application(Application Config)	
Profile (Profile Config)	
LTE configuration node (lte_attr_difiner_adv)	
Server (Ethernet_server_adv)	
LTE user workstation (lte_iphone)	
LTE eNodeBs (lte_enodeb_slip4_adv)	
LTE EPC node(lte_access_gw_atm8_ethernet8_slip8_adv)	
IP Cloud(ip32_cloud)	

Gateway(Ethernet_tr_slip8_gtwy_base)	
IP attribute configuration	
100BaseT_int Link	
PPP_SONET_OC48_int	

4.2 OPNET LTE components

The definitions and some general functionality of those components shows in table 2, described below in subsection 4.2.1, 4.2.12.

4.2.1 Application

The “Application Config” node can be used for the following specifications:

- “ACE Tier Information”: Specifies the different tier names used in the network model. This attribute will automatically populate when the model is created using the “network->Import Topology->Create from ACE…” option.

  The tier name and the corresponding ports at which the tier listens to incoming traffic are cross-referenced by different nodes in the network [25].
- “Application Specification”: Specifics applications using available application types. You can specify a name and the corresponding description in the process of creating new applications. For example, “Web Browsing (Heavy HTTP 1.1)” indicates a web application performing heavy browsing using HTTP 1.1.The specified application name will be used while creating a user profile on the “Profile Config” object [25].
- “Voice Encoder Schemes”: Specifies the encoder parameters for each of the encoder schemes used to generate Voice traffic in the network [25].

4.2.2 Profile

The “Profile Config” node can be used to create user profiles. It can then identify these user profiles on different nodes in the network to generate traffic on the application layer level. It uses a specific application in the "Application Configuration" object from this object to configure profiles. Thus, you must create applications using the "application configuration" object before using this object. You can specify the following traffic patterns of applications, as well as the configured features of this object [25].

4.2.3 LTE configuration node

The lte_attr-difiner_adv node is used to store PHY configurations and EPS Bearer definitions, which be referred by all LTE nodes in the network [25].

4.2.4 Server

The Ethernet_server_adv model represents a server node with the server application running over TCP / IP and UDP / IP. This node supports one underlying Ethernet and 10 Mbps connection, 100 Mbps, or 1 Gbps. Operational speed is determined by the data rate on the link connected. Ethernet MAC in this node can be made to work in either full-duplex or half-duplex mode. Note that when you connect it to the hub, it should always be set to "half-duplex". A fixed amount of time is required to route each packet, the ad is determined by "IP forwarding Rate" attribute of the node. The package is routed on a FCFS basis and may encounter queuing at the lower protocol layers, depending on the transmission rates of the corresponding output interface. Some of the server criteria are shown below [25]:

- Protocols used in server: RIP, UDP, IP, TCP, Ethernet, Fast Ethernet, Gigabit Ethernet.
- Interconnections: 1 Ethernet connection at 10Mbps, 100 Mbps, or 1000 Mbps.
- Attributes:
  - Ethernet operational mode: Specifies the mode in which the Ethernet MAC operates (Half Duplex or Full Duplex)
  - Server Configuration Table: This attribute allows for the specification of application servers running on the node.
  - Transport Address : This attribute allows for the specification of the address of the node.
  - “IP Forwarding Rate”: Specifies the rate (in packet/second) at which the node can perform a routing decision for an arriving packet and transfer it to the appropriate output interface.
  - “IP Gateway Function”: Specifies whether the local IP node is acting as a gateway. Workstations should not act as gateway, as they only have one network interface.
  - “RIP Process Mode”: Specifies whether the RIP process is silent or active. Silent RIP processes do not send any routing update but simply receive update. All RIP process in a workstation should be silent RIP processes.
  - “TCP connection Information”: Specifies whether diagnostic information about TCO connection from this node will be displayed at the end of the simulation.
  - “TCP Maximum Segment Size”: Determines the size of segments sent by TCP. This value should be set to large segment size that the underlying network can carry unregimented.

- "TCP Receives Buffer Capacity": Specifies the size of the buffer used hold received data before it is forwarded to the application.

4.2.5 LTE user workstation

It is the LTE workstation and here it is an IPhones based TCP parameters [25].

4.2.6 IP attribute configuration

It determine attributes configuration details of the protocols supported in the IP layer. These specifications can be referenced by the individual nodes using symbolic names (character strings) [25]:

- "IP Ping Parameters": Defines different"Ping" option setting that individual hosts/routers in the network can use to determine connectivity to the specified destination.
- "IP Compression Information": Provides details of various compression schemes used in the network.

4.2.7 LTE eNodeBs

The lte_enodeb_slip4_adv device represents a LTE eNodeB [25].

4.2.8 LTE EPC node

The lte_access_gw_atm8_ethernet8_slip8_adv device is created using the device create utility and contains the flowing technology [25] , table 3 shows the technology and the ports used in this node:

Table 3: LTE EPC node technologies [25]

Technology	IF/Port Count
ATM	8
Ethernet	8
SLIP	8

4.2.9 IP Cloud

General Node Functions:

The ip32_cloud node model represents an IP cloud supporting up to 32 serial line interface at a selectable data rate through which an IP traffic can be modelled.

When the IP packet arrived on any cloud interface the packets are routed to the suitable output interface based on their destination IP address. The Routing Information Protocol (RIP) or Open Shortest Path First (OSPF) protocol may be used to automatically and dynamically create the cloud's routing table and routes in an adaptive manner. The cloud requires a fixed amount of time to route each packet, as planned by the "Packet Latency" attribute of the node. Packets are routed on a first-come-first-serve basis and many encounter queuing depending on the transmission rates of the corresponding output interface. Some of the IP Cloud characteristics are shown below [25]:

- Protocol: RIP, UDP, OSPF, BGP, IGRP, and TCP.
- Interconnections: 32 serial Line IP connections at a selectable data rate.
- Attributes:
  - “Packet Latency”: Specifies the delay (in second) after which the incoming IP datagram’s get transferred through the cloud
  - “Packet Discard Ratio”: Determines the number of the packets to be dropped out of the total packets transferred.

4.2.10 Gateway

General Node Function:

The Ethernet_tr_slip8_gtwy_base node represents an IP-based gateway supporting one Ethernet interface, one 4 or 16Mbps Token Ring interface, and up to 8 serial line interface at a selectable data rate .IP packet arriving on any interface are routed to the appropriate output on based on their destination IP address . And Routing Information Protocol (RIP) or Open Shortest Path First protocol (OSPF) can be used to automatically and dynamically to create the table gateways guidance and choose ways in an adaptive manner.

This gateway requires a fixed amount of time to route each packet , as determined by “IP Forwarding rate” attribute of the node. Packets are rounded on a first-come-first-serve basis and may encounter queues at the lower protocol layers , depending on the transmission rates of the corresponding output interfaces.

Some of the Gateway characteristics are shown below [25]:

- Protocols: RIP, UDP, IP, Ethernet, Fast Ethernet Gigabit Ethernet, Token Ring (IEEE 802.5) ,OFPF.
- Interconnections:
  - 1 Ethernet connection to selectable data rate.
  - Token Ring hub connection at 4 or 16 Mbps.
  - 8 Serial Line IP connection at a selectable data rate.
- Attributes:
  - “IP Forwarding Rate”: specifies the rate (in packet/second)at which gateway can perform routing decision for an arriving packet and transfer it to the appropriate output interface.
  - “IP Gateway Function”: Specifies whether the local IP node is acting as a gateway. Nodes with only one network interface should not act as network gateway.
  - “RIP Start Time”: Specifies the simulation time (in sec) at which the gateway start sending routing updates to build IP routing tables.
  - “RIP Process Mode”: Specifies whether the RIP process is silent or active. Silent RIP processes do not send any routing updates but

simply receive update. All RIP processes in a gateway should active RIP processes.

- Restrictions: Token Ring addresses must be consecutive (no gaps in numbering) and they must increase sequentially in the direction of the ring.

4.2.11 100BaseT_int Link

General Description:

The 100BaseT Duplex link represents an Ethernet connection operating at 100 Mbps. It can connect any combination of the following nodes (except Hub-to-Hub, which cannot be connected) [25]:

- Station
- Hub
- Bridge
- Switch
- LAN nodes

Some of the 100BaseT_int Link characteristics are shown below:

- Packet Formats: Ethernet
- Data Rate: 1000 Mbps 1Gbps
- Model Attributes: “Propagation Speed”: Specifies the propagation speed (in meters/sec) for the medium. If the “delay “ attribute of the link is set to “Distance Based”, this speed can be used to calculate the propagation delay based on the distance between two nodes.
- Restrictions: this link cannot be used to connect two Ethernet hubs.

4.2.12 PPP_SONET

General Description:

The PPP_SONET_OC48 point-to-point link Connects two nodes running IP (e.g., gateways) at OC48 speed.

Some of the PP_SONET characteristics are shown below [25]:

- Packet Formats: ip_dgram_v4
- Data Rate: OC48 (2488.32 Mbps) this is data rate available to the user after accounting for the SONET overhead, only 2377.728 Mbps is available for user hosts.

4.3 Scenario 1: LTE standard

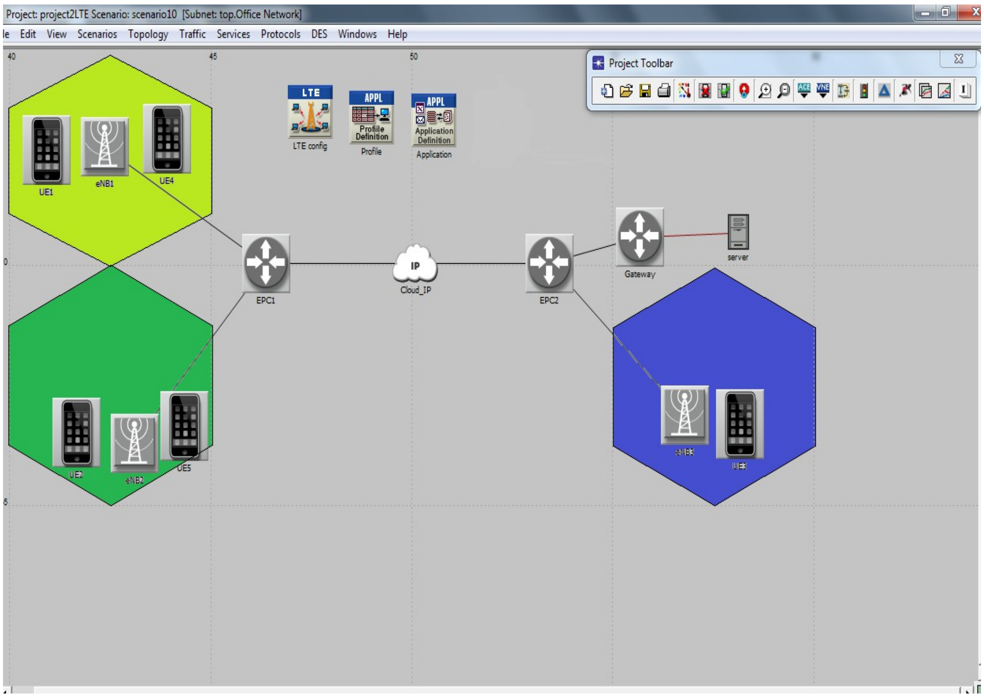


Figure 21: Scenario 1 standard LTE

The First scenario shown in Figure 21, the first step is to start by creating a new project in OPENT 17.4 , then select new scenario and specify the scenario to be empty. After that select the scale to be 100 km * 100 km. The mode family is: LTE (advanced) by doing this part, the first part is finished and it is called Network mode where the topologies can be create.

The second step is in the Node mode where the nodes can be specifies, start by choosing LTE Nodes form Object Palette (the nodes can be selected from Palette). The LTE Nodes are : Application, Profile, Server, LTE configuration, 2 LTE EPC, IP_Cloud, Gateway, 3 LTE eNBs, 5 UEs, 100BaseT_int Link, 6 PPP_SONET_OC48_int nodes.

The next step is to connect the nodes with the links and the other nodes:

- The server to the gateway using 100 BaseT_int.
- The gateway to the LTE EPC2 using PPP_SONET_OC48_int.
- The eNB3 to the LTE EPC2 using PPP_SONET_OC48_int.
- The IP_Cloud to both EPC1,EPC2 using PPP_SONET_OC48_int.
- Both eNB1, eNB2 using PPP_SONET_OC48_int to the EPC1.

The distance between the eNB1 and eNB2 estimated at 5 km and by that each one will cover 5 km. In this scenario the bandwidth will be shared between the UEs, that means the eNBs will divides the bandwidth between the UEs. By right-clicking on the nodes the attribute parameters can be set and assign to all nodes.

4.3.1 Scenario 1 configurations

The tables in subsections 4.2.1.1, 4.2.1.8 shows the configurations which used in this scenario.

4.3.1.1 Application

Table 4 below shows the attributes and the values of the application.

Table 4: Application attributes and values.

Attribute	values
Set application definitions	Number of browser =1
Set the application name	APP1
Set the application description	Video Configuration= Low Resolution Video

4.3.1.2 Profile

Table 5 below shows the attributes and the values of the profile.

Table 5: Profile attributes and values.

Attribute	values
Set profile Configuration	Profile name=PRO1 Number of row= 1 Applications: Enter application name = APP1 Start Time Offset(second)= Constant (60) Duration (second)= End of Profile Repeatability: Inter-repetition Time = exponential (300) Number of Repetitions=Unlimited Repetition Pattern=serial For the profile: Operation mode= serial (Ordered) Start Time(second)= Constant(40) Duration (second)= End of the Simulation Repeatability= Unlimited

By specify the Start Time(second) to be 60 second for the application and 40 for the profile, the application will be start in 60 second = 1 minute.

4.3.1.3 LTE Configuration

Start by EPS Bearer (the EPS bearer is effecting a connection-oriented transmission network and it is requires the establishment of virtual connection between tow endpoint like UE and PDN-GW before any traffic can be sent between them). EPS Bearer should be set to be Gold, and then specify the LTE PHY profile and this parameters will be for the eNBs and by choosing different FDD the interference between the eNBs can be cancel. Table 6 show the prametters of LTE Bearer.

Table 6: LTE EPS Bearer attributes and values.

Attribute	values
EPS Bearer Profile	Number of rows= 1 Row1= Name=Gold, QoS Class Identifier= 1(GBR) Allocation Retention=1 Uplink Guaranteed Bit Rate(bps)= 1Mbps Downlink Guaranteed Bit Rate(bps)=1Mbps Uplink Maximum Bit Rate(bps)=1 Mbps Downlink Maximum Bit Rate(bps)=1Mbps
LTE PHY Profile	FDD Profiles: Number of rows = 3 Row 0: Name=LTE 20MHz FDD1 UL SC-FDMA Channel Configuration: Base Frequency(GHz)= 1.92 Bandwidth (MHz)=15 MHz Cyclic Prefix Type= Extended(7 symbols per slot) DL OFDMA Channel Configuration: Base Frequency(GHz)= 2.11 Bandwidth (MHz)=20 MHz Cyclic Prefix Type= Extended(7 symbols per slot)
	Row 1: Name =LTE 20MHz FDD2 UL SC-FDMA Channel Configuration: Base Frequency(GHz) = 1.95, Bandwidth (MHz)=15 MHz, Cyclic Prefix Type = Extended(7 symbols per slot) DL OFDMA Channel Configuration: Base Frequency(GHz) = 2.15, Bandwidth (MHz)= 20 MHz Cyclic Prefix Type = Extended(7 symbols per slot)
	Row 2: Name = LTE 20MHz FDD3 UL SC-FDMA Channel Configuration:Base Frequency(GHz) = 1.97, Bandwidth (MHz) = 15 MHz Cyclic Prefix Type = Extended(7 symbols per slot) DL OFDMA Channel Configuration: Base Frequency(GHz) = 2.5, Bandwidth (MHz) =20 MHz Cyclic Prefix Type = Extended(7 symbols per slot) TDD profile :Default TDD

4.3.1.4 Server

This configuration will generate video application to be sent to the entire network UEs. Table 7 below shows the parameters of the application:

Table 7: Server attributes and values.

Attribute	values
Applications	Application: Destination Preferences : APP1: Application =APP1 Symbolic Name= Video Destination Application: profile name= PRO1 Application: support services = ALL

4.3.1.5 EPC1

EPC will serve the eNodeBs to handle the payload or the data traffic in an efficiency way, and it was designed to separate the user data. By setting the parameters in table 8 below EPC1 and EPC2 can serve the eNodeBs:

Table 8: EPC1 attributes and values.

Attribute	values
LTE Parameters	DRX Parameter for Idle Mode=256 EPC ID=1 GTP Parameters = Default Times = Default

4.3.1.6 EPC2

Table 9 shows the attributes and the values in EPC2.

Table 9: EPC2 attributes and values.

Attribute	values
LTE Parameters	DRX Parameter for Idle Mode=256 EPC ID=2 GTP Parameters = Default Times = Default

4.3.1.7 eNBs

E-UTRAN Node B (eNodeB) or base stations use for managing the radio resources and mobility in the cell and sector to optimize all the UEs communication in flat radio network structure, and by setting the parameters in table 10 the configurations can done for eNBs:

Table 10: eNBs attributes and values.

Attribute	values
LTE	PHY: Antenna Gain(dBi)=15 dBi Battery Capacity= Unlimited MIMO Transmission Technique= Spatial Multiplexing 2 Codewords 2 Layers Maximum Transmission Power(W)=0.5 Number of Receive Antennas=2 Number of transmit Antennas=2 Operating Power=20 PHY Profile=LTE 20 MHz FDD1 for eNB1 PHY Profile=LTE 20 MHz FDD2 for eNB2 PHY Profile=LTE 20 MHz FDD3 for eNB3 Pathless Parameters= Hata Extension Suburban/Rural(COST-231) Receiver Sensitivity (dBm)=-200dBm EPCs Served:1 MBMS=Non Paging Subframes per Frame(nB)=1 RRC Connection Release Timer=5.0 Scheduling Mode=Link Adaptation and Channel dependency Tracking Area ID=1 for eNB1 Tracking Area ID=2 for eNB2 Tracking Area ID=3 for eNB3 X2 Capability = Disabled eNodeB ID=1 for eNB1 eNodeB ID=2 for eNB2 eNodeB ID=3 for eNB3 eNodeB Selection Threshold=-110dBm And the other parameters Default configuration

4.3.1.8 UE

User Equipment (UE) it is any device use directly by an end user to communicate, and by setting the parameters in table 11 below the configurations of all UEs can be done:

Table 11: UEs attributes and values.

Attribute	values
LTE	Number of rows =1 Row0: EPS Bearer Configuration =Gold PDCP Compression : Serving EPC ID=1 for UEs belong to eNB1 and eNB2 Serving EPC ID=2 for UEs belong to Enb3 eNodeB Selection Policy=Best Suitable eNodeB And the other parameters Default configuration
Applications	Set application definitions: Number of Rows =1 APP1: application =APP1 Symbolic Name= Low Resolution Video Application :Supported Profile: Number of Rows=1 PRO1: Profile Name=PRO1 Traffic Type =All Distance Application Delay Tracking: Start Time(second)=Start of Simulation End Time(second)=End of Simulation Sample Every N Applications=All Maximum Sample=Tracking Disables Application :Supported Services=All And the other parameters Default configuration

By completing this configuration, the network will work in steps, first the netwrok will generate an application and the profile will serve that application to connect with the server.

The server will serve the users to get this application by transmitting the packets through the gateway and the first EPC, then to the eNB3.

Then the packets will transmit through the IP_Cloud to reach the second EPC and that will serve the eNBs belong to this EPC.

Lastly, the eNBs will serve the UEs in order to receive the packets that sent to them.

4.4 Scenario 2: LTE eMBMS with MB-SFN

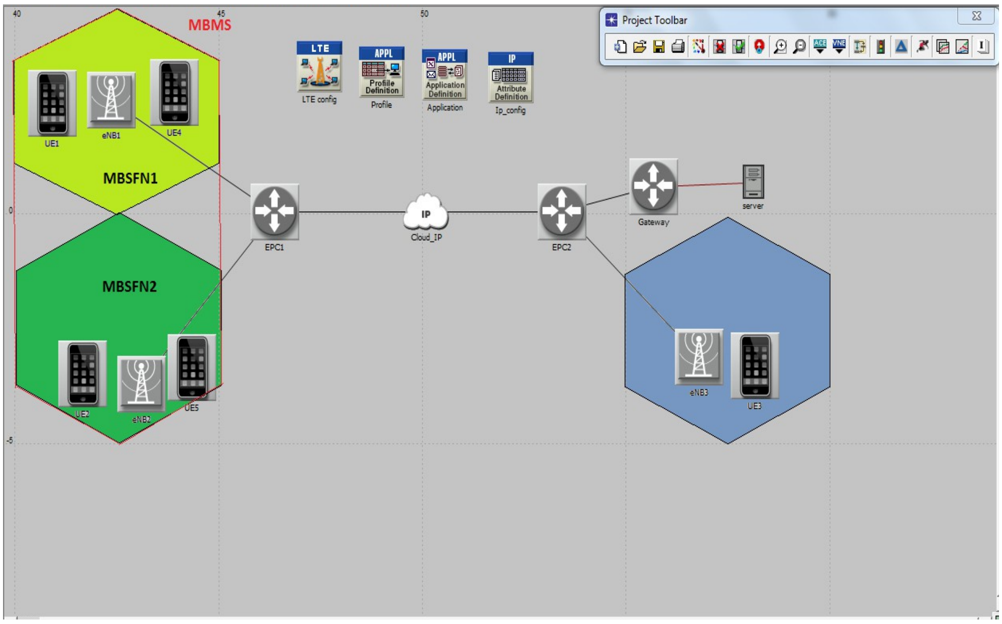


Figure 22: Scenario 2 LTE eMBMS with MBSFN

This scenario show how the implement of an LTE eMBMS service and use of MB-SFN to create one single area, by changing some parameters in the first scenario and create IP multicasting. Figure 22 shows scenario 2 LTE eMBMS with MBSFN in OPNET LTE.

In order to create IP multicasting in OPNET LTE, some nodes should be selected, where the traffic will go through it:server, gateway, EPC 2, IP_Cloud, EPC1, eNB1.

The steps below show how the IP multicast can be configured in OPNET LTE:

- Select protocols->IP->Multicasting.
- Enable the IP multicasting in the select nodes.
- Enable the multicasting on those links.
- Specify IP for the UEs group those they will get multicasting packets from the eNB1, table 12 shows the attributes and the values used to configer the IP multicasting group address.
- Set multicasting group on select destination nodes.

Table 12: IP multicasing attributes and values.

Attribute	Value
Application	APP1
IP multicasting Group Address	224.0.1.0
Join Time(seconds)	60 second
Leave Time (seconds)	End of Simulation

- Specify group address as International Group Management Protocol (IGMP) Membership Group on selected set of routers, the packets will go through those routers in order to reach the destinations UEs.
- Choose IP multicast Group Address =224.0.1.0
- Apply the above selection to selected routers.
- Enable Aout-RP (Aout- Rendezvous Point) in selected routers.
- Configure Static RP (StaticRP can be combined with any cast RP to manage RP load sharing and redundancy).
- Configure Rendezvous Point using static RP configuration. (This option is setting automatically from OPNET LTE).

OPNET LTE will generate IP attribute automatically after this configurations and it will be seen in the topology.

By completing this configuration, the IP multicasting is working now in the network. The second part is to change the parameters of the LTE configuration, server, eNB1, eNB2, and UEs those they will get multicasting packets.

In eNB1 and eNB2 set the parameters for MBMS and select the MBSFN areas for both eNBs, that will create one signal area in tow different MBSFN areas.

Each eNBs has their own frequency but the MBMS will generate one transmitted signal in the MBMS covering an area after merge the frequencies. The bandwidth will be send without sharing between the UEs in eNBs those having MBMS service and that means each UEs will get the same full bandwidth from the eNBs that have MBMS service.

4.4.1 Scenario 2 Configurations

The configurations used in this scenario show in subsection 4.3.1.1, 4.3.1.5 and the tables below show the new configurations in order for MBMS with MBSFN to work.

4.4.1.1 LTE Configuration

In the new setting there is a need for changing the parameters of the MBSFN and leave the old setting in the same mode. Table 13 below showing the new configuration:

Table 13: LTE Configuration attributes and values.

Attribute	Values
LTE PHY Profile	In both row0 FDD 1 and row1 FDD2 we will change the Cyclic Prefix Type= Extended (6 symbols per slot) in order mange our slots because MBMS works with 6 slots.
MBSFN Area Profile	Number of rows= 2 , Row=0
	MBSFN Area Name=1, Common Subframe Allocation Period= 4 frames , Common subfame Allocation Patten= Subframe 1 and 6 Every frame MBSFN Bearer List: PHY Profile =LTE 20 MHz FDD1, Synchronization Delay(suframe)= 1
	MBSFN Area Name=2, Common Subframe Allocation Period= 4 frames Common subfame Allocation Patten= Subframe 1 and 6 Every frame MBSFN Bearer List: PHY Profile =LTE 20 MHz FDD2, Synchronization Delay(suframe)= 1

4.4.1.2 Server

Table 14 below shows the server attributes and values.

Table 14: Server attributes and values.

Attribute	Values
Applications	Application: Application: Multicasting Specification Application Name=APP1 Membership Address =224.0.1.0 Join Time(second)=60 second Leaving Time(second)= End of Simulation And leave the old configurations.

4.4.1.3 eNB1

Table 15 below shows the eNB1 attributes and values.

Table 15: eNB1 attributes and values.

Attribute	Values
MBMS	MBSFN: MBSFN Area = 1 Serving MBMS EPC ID= 1 And leave the old configuration.

4.4.1.4 eNB2

Table 16 below shows the eNB2 attributes and values.

Table 16: eNB2 attributes and values.

Attribute	Values
MBMS	MBSFN: MBSFN Area = 2 Serving MBMS EPC ID= 1 And leave the old configuration.

Then after completing this configuration the MBMS with MBSFN is configured in both eNB1 and eNB2. Finally, table 17 shows the new attributes and values those should be set in the UE 1 and UE 2 in order for them to get multicasting packets.

4.4.1.5 UE1 and UE2

Table 17 shows the attributes and values of UE1,UE2.

Table 17: UE1 and UE2 attributes and values.

Attribute	Values
Applications	Application: Application: Multicasting Specification Symbolic Name= Video Destination Application Name=APP1 Membership Address =224.0.1.0 Join Time(second)=60 second Leaving Time(second) = End of Simulation And leave the old configurations.

By setting those parameters in the UEs, the network becomes ready to send multicast packets to those specifics UEs not to all. In other hand all other UEs they will get a normal broadcast.

5 Results

This Chapter presents the result of the simulation, measurement statistical, analysis statistical, and summarize the result.

In order to make comparisons between both scenarios in OPNET LTE, some important setting should be set:

- Overlaid statistic in statistics windows result to specify the type of the result.
- Select which scenarios to compare between them.
- Select ensemble average (ensemble average, it is an average that is taken from different scenarios).

In other hand, the results in OPNET LTE has been divided in two types:

- The Global statistic is used for the network, to compare the results in different networks in the same project in general.
- The Object statistic is used for Nodes, to compare the results between nodes in different networks in the same project.

In scenario 2, there are more statistics depending on the network type and here the type is LTE eMBMS with MBSFN. This statistic shows the MBSFN in two eNBs where the implementation of the eMBMS with MBSFN, it shows in measure of tables statistic. Unfortunately, until now in OPNET 17.4 they don't have statistic for IP multicast and also for eMBMS in measure of graphic or any other statistic way except tables where MBSFN statistic can be seen and that means the eMBMS service it is working in the network.

The simulation duration was 60 minutes for each scenario, and it took about 15 simulations to achieve the best result. OPNET 17.4 gives the result in (bit/sec), after that the result should be converted to (Mbps).

The statistics available in version OPNET 17.4 LTE:

- Global statistics mode:
  - Downlink Throughput (bits/sec): Total downlink traffic delivered from LTE layers to higher layers in bits/sec. It is collected by all the UEs in the network [25].
  - Uplink Throughput (bits/sec): Total downlink traffic delivered from LTE layers to higher layers in bits/sec. It is collected by all the eNodeBs in the network [25].
- Node statistics mode:
  - EPS Bearer Traffic Received (bits/sec): Higher layer data traffic received via this EPS Bearer in bits/sec. This statistic doesn't include

any LTE overhead, hence it report the"good" throughput achieved by this EPS bearer [25].

- EPS Bearer Traffic sent (bits/sec): Higher layer data traffic sent via this EPS Bearer in bits/sec. This statistic doesn't include any LTE overhead [25].
- MAC Traffic Received (bits/sec): Total LTE MAC traffic received by this node in bits/sec. This statistic includes MAC and RLC overhead [25].
- MAC Traffic Sent (bits/sec): Total LTE MAC traffic sent by this node in bits/sec. This statistic includes MAC and RLC overhead [25].
- Throughput (bits/sec): Traffic delivered from LTE layers to higher layers in this node in bits/sec [25].

In order to see the tables of the MBSFN in the second scenario, there is need to check the Discrete Event Simulation (DES) Run tables. The DES Run tables shows the Global tables of LTE and Object Tables in Office Network mode.

The report will include eNodeB DL Capacity Report, eNodeB Neighbor-Cell/Jammer Frequency Overlap, and eNodeB UL Capacity Report. The EPS Bearer Traffic sent will show the compare statistics where it can show if the eMBMS with MBSFN working or not.

In the first scenario the signals should be different signals and in the second should be one signal in both eNB1 and eNB2 because of eMBMS with MBSFN used.

5.1 Global statistics results

5.1.1 Throughput in downlink and uplink in (bits/sec)

The first result is the throughput in downlink and uplink for the LTE network, in this result the two scenarios compares in graphic statistic way shows in Figure 23, Figure 24 OPNET results:

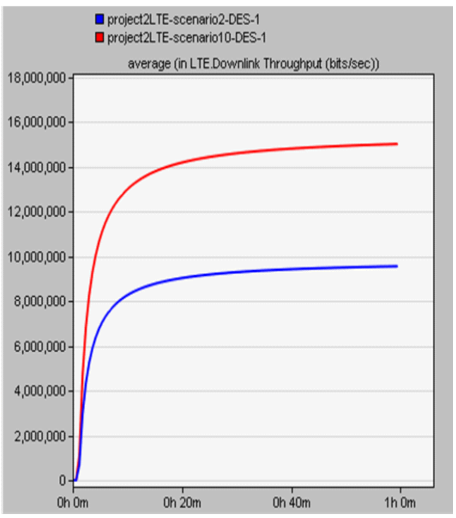


Figure 23: Global Downlink Throughput

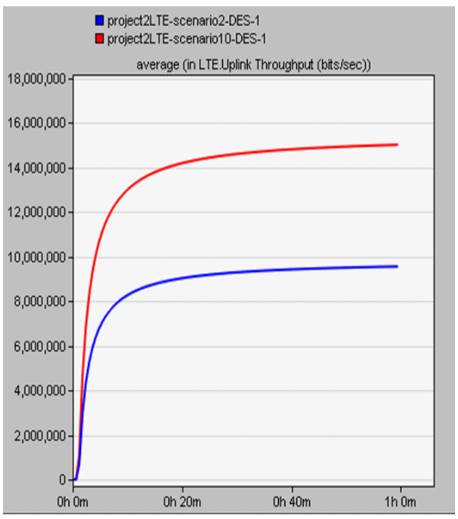


Figure 24: Global Upnlink Throughput

In order to show the result as chart diagram to see the change in the numbers, there is a need to get the numbers in each scenario by moving the mouse over the compared result graph, because in OPNET LTE the numbers do not show on the graph when take a shortcut screen. The charts below show all results as chart after the comparison.

Figure25 show Global statitic chart in downlink and uplink throughput:

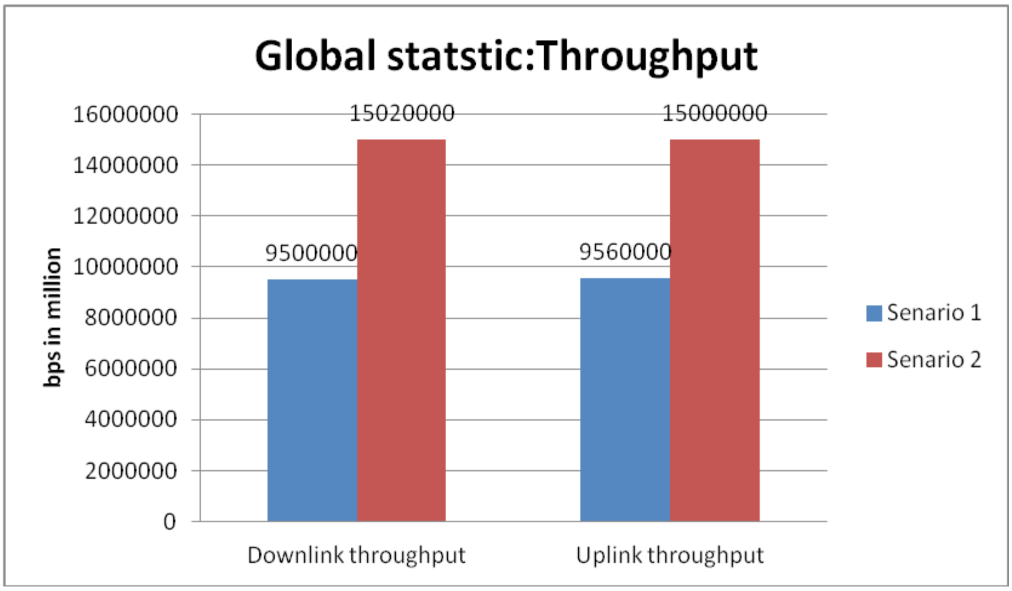


Figure 25: Chart result Global statistic throughput

The result shows that the downlink has been increased up to 15020000 bps (15.2 Mbps) an increase of 5520000 bps (5.52 Mbps), and the uplink also increased up to 15000000 bps (15.0 Mbps) an incearse of 5440000 bps (5.18 Mbps).

This change happend in the second scenario after using eMBMS with MBSFN, and that means each UE belong to the eMBMS area got more bandwidth in both downlink and uplink, in other hand the bandwidth in the first scenario has been shared between the UEs and that prove that the eMBMS working properly and will cover more area.

5.1.2 Throughput in eNBs in (bits/sec)

This result shows the throughput in eNBs in the LTE network where there is interest to change the throughput in eNB1 and eNB2 in order to calculate the spectral efficiency in the cells, the result show the comparison between the two scenarios in graphic result. Figures 26, 27, 28 shows OPNET simulating result:

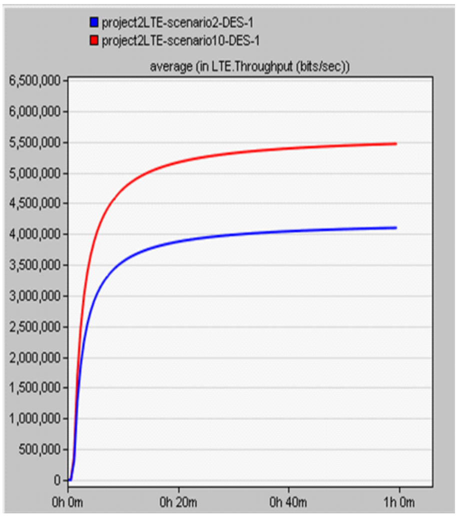


Figure 26: eNB1 Throughput

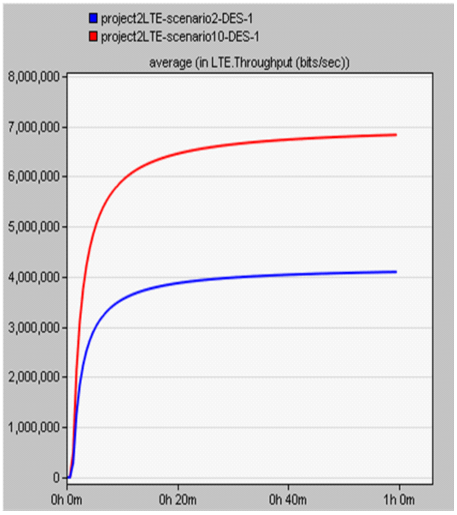


Figure 27: eNB2 Throughput

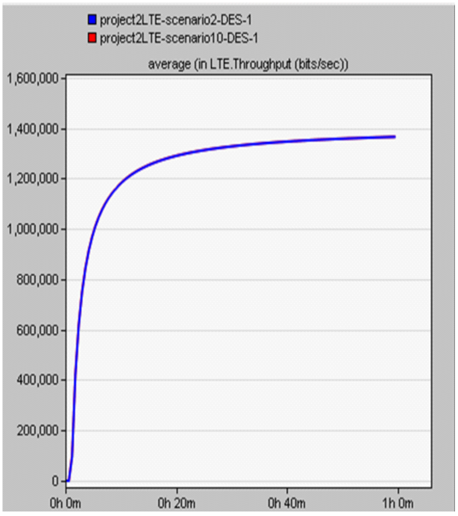


Figure 28: eNB3 Throughput

The chart below shows the comparison result between the eNBs, Figure 29:

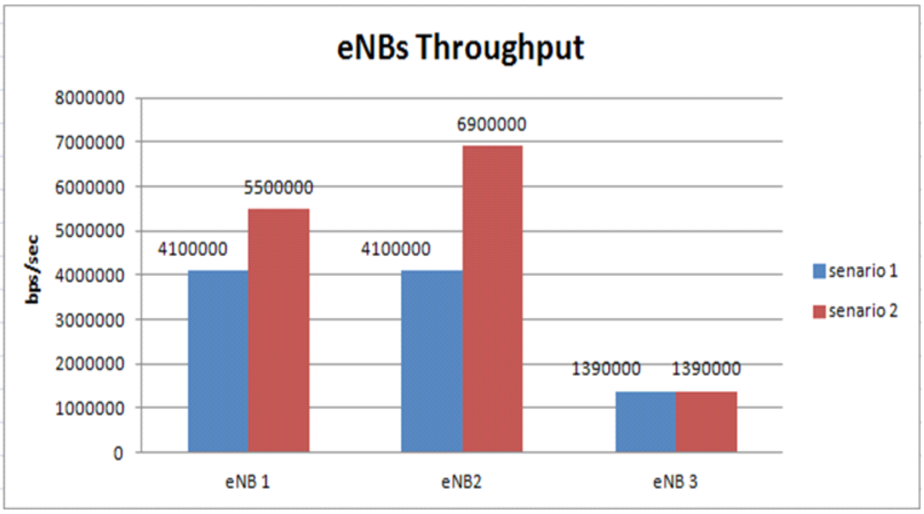


Figure 29: eNBs Throughput chart

The result shows that the throughput has increased in eNB1 from 4100000 (bps/s) about 4 (Mbps) to 5500000 (bps/s) about 5.2 (Mbps), and in eNB2 from 4100000 (bps/s) about 4 (Mbps) to 6900000 (bps/s) about 6.5 (Mbps) when eMBMS with MBSFN has been implemented in the network, and there is no change in eNB3.

5.2 Node statistics results

5.2.1 eNBs results

- EPS Bearer Traffic Received (bits/sec): This results show the LTE.EPS traffic received in the UEs and it showing in the graphs below, Figures 30, 31, 32, 33, 34:

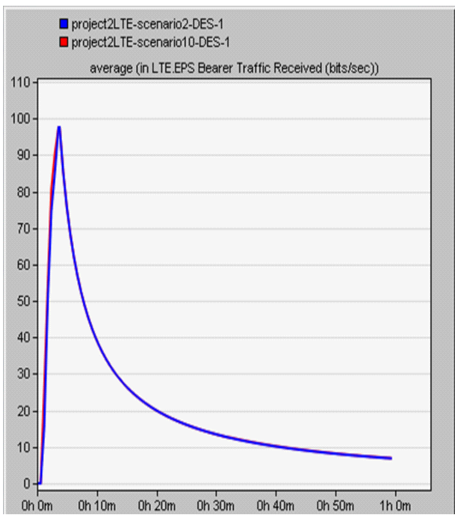


Figure 30: Object statistic LTE EPS Bearer traffic received in UE1

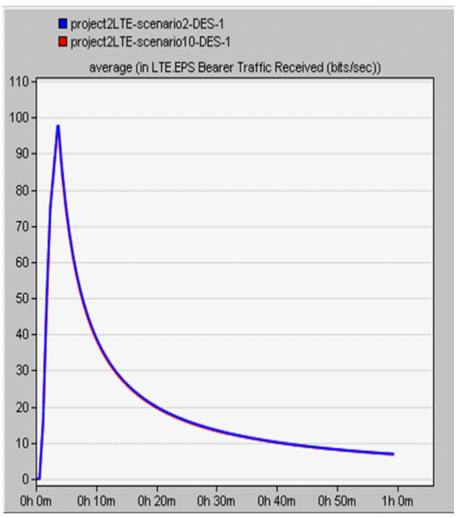


Figure 31: Object statistic LTE EPS Bearer traffic received in UE2

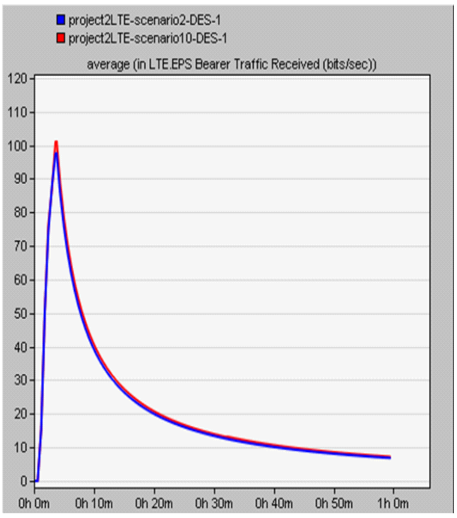


Figure 32: Object statistic LTE.EPS Bearer traffic received in UE3

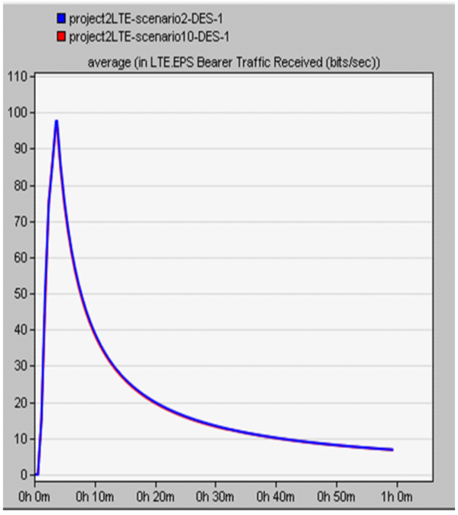


Figure 33: Object statistic LTE.EPS Bearer traffic received in UE4

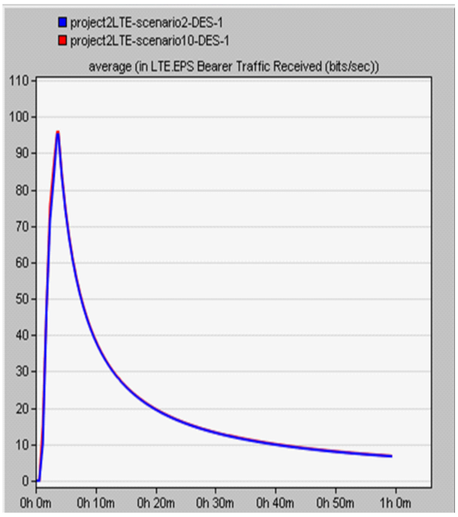


Figure 34: Object statistic: LTE.EPS Bearer traffic received in UE5

The chart below in Figure 35, show the object statistic LTE traffic received in downlink in UEs:

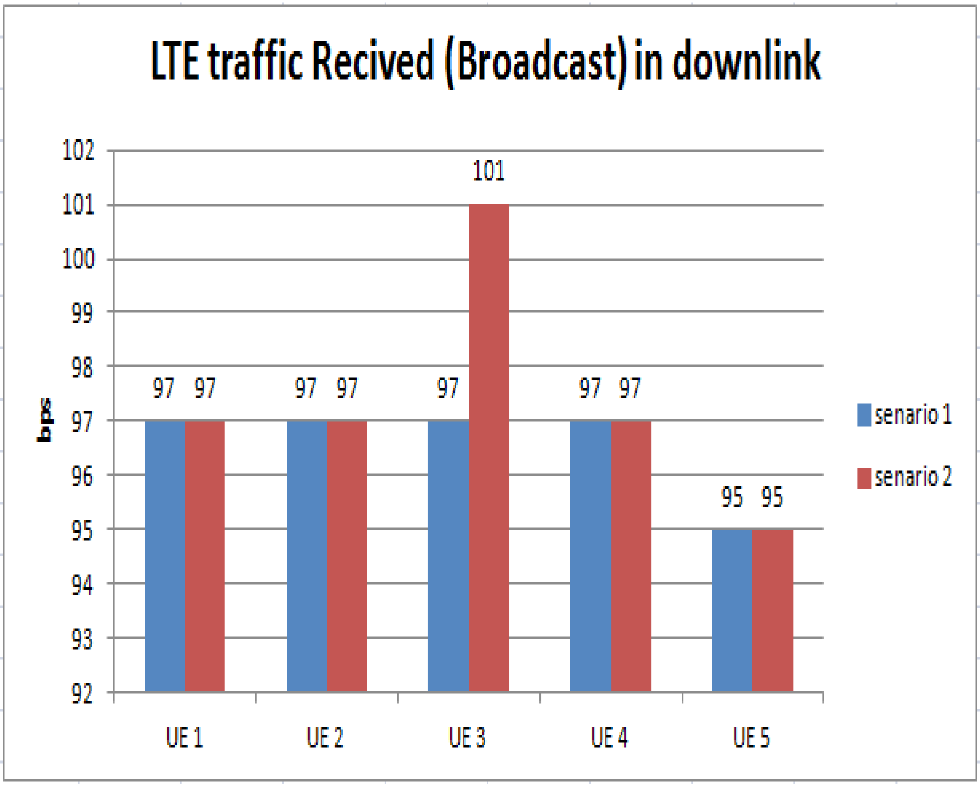


Figure 35: Object statistic LTE traffic received in UEs

The results show, a good traffic received by the UEs in both scenarios. In UE1 the good traffic is 97 bps (0.000097 Mbps) in both scenarios. A good traffic received in UE2 is also 97 bps (0.000097 Mbps) in both scenarios.

In UE3 in scenario 1 a good traffic received was 97 bps (0.000097 Mbps) but in scenario 2 it increased to 101 bps (0.000101 Mbps), because of the load in the network. That means the traffic received start first in second scenario in UE3, and this UE have gotten more traffic than the MBMS area because it is start first even if there is no more services on it.

Finally, in UE 4 a good traffic received was 97 bps (0.000097 Mbps) in both scenarios, and in UE 5 a good traffic received was 95 bps (0.000095 Mbps) in both scenarios.

• EPS Bearer Traffic sent (bits/sec): This results show the LTE.EPS traffic sent from the eNBs, Figures 36, 37, 38 showing the graphs results in OPNET LTE:

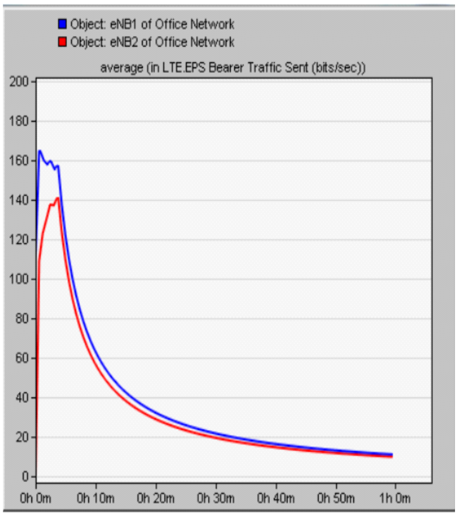


Figure 36: Scenario 1
EPS Bearer Traffic sent in
both eNB1 and eNB2

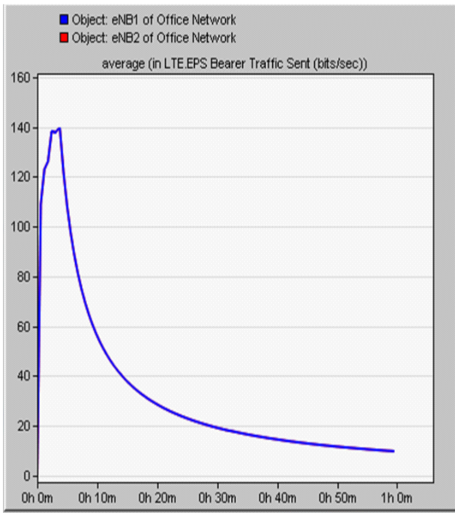


Figure 37: Scenario 2
EPS Bearer Traffic sent in
both eNB1 and eNB2

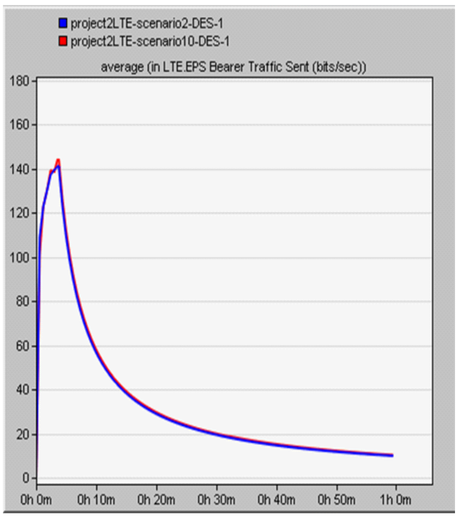


Figure 38: Scenario1 and 2 EPS Bearer Traffic sent in eNB3

The chart below in Figure 39, show the comparison result between the eNBs traffic sent:

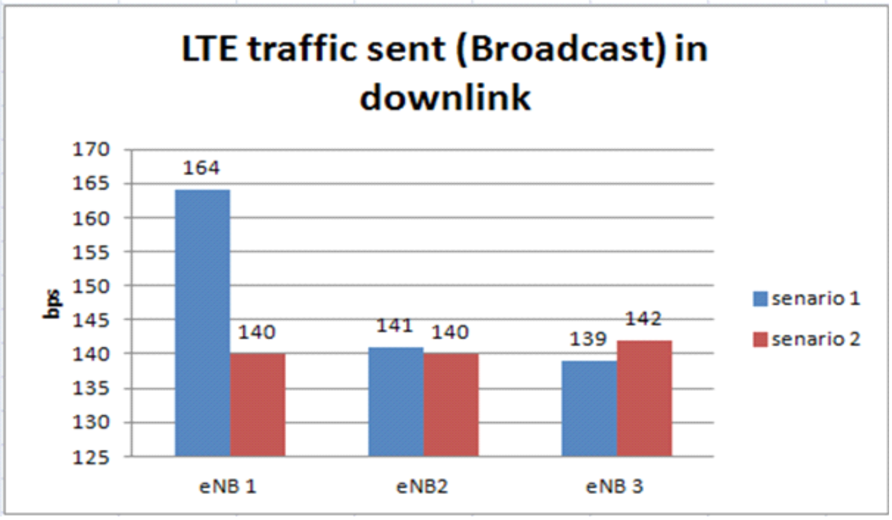


Figure 39: LTE traffic sent chart

The result show that the broadcast in scenario 1 in eNB1 is 165 bps (0.000165 Mbps) and in eNB2 is 141 bps (0.000141 Mbps), and when implementing the eMBMS with MBSFN in scenario 2 the broadcast changed to be 140 bps (0.00014 Mbps) in both eNBs. That mean, there is now an area with one single broadcast signal. In eNB3 the broadcast was 139 bps (0.000139 Mbps) in scenario1 and it becomes 142 bps (0.000142 Mbps) in scenario 2, because of the load in the network.

• MAC Traffic Received (bits/sec):This results show the differences between the received traffic in LTE eNBs in the first scenario and the second scenario and how it is increased in the second scenario. In eNB1 and eNB2, by implementing the eMBMS with MBSFN the traffic has been increased, but in eNB3 No change in the traffic. Figures 40, 41, 42 show the results in OPNET LTE.

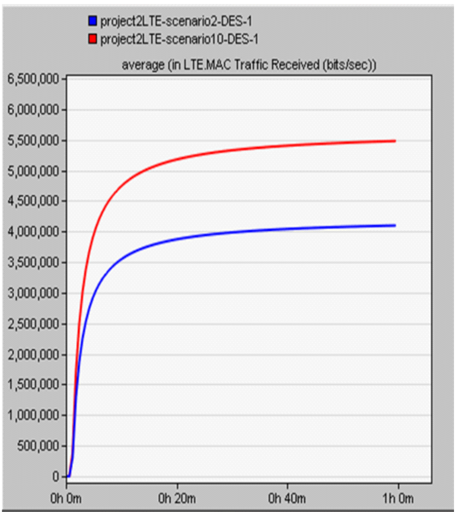


Figure 40:eNB1 MAC Traffic Received

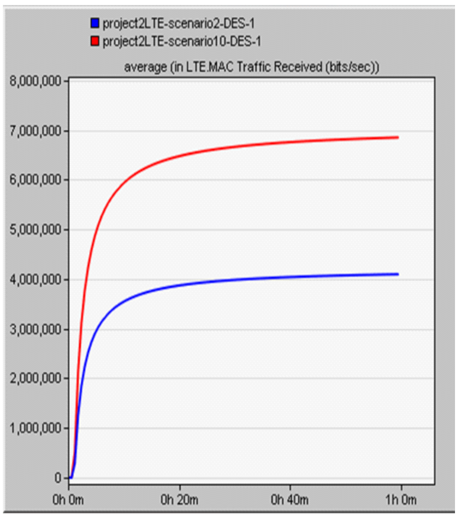


Figure 41:eNB2 MAC Traffic Received

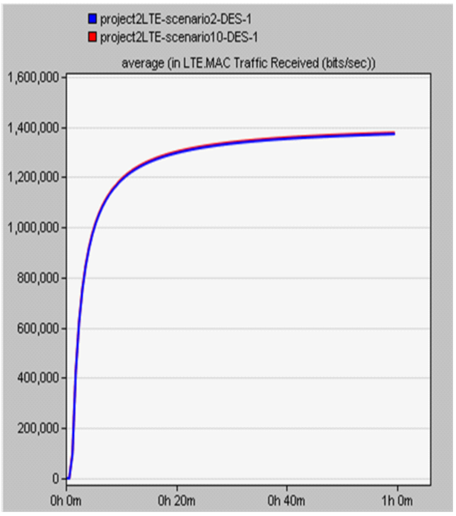


Figure 42: eNB3 MAC Traffic Received

The chart below in Figure 43 show the comparison results in in MAC traffic received in the eNBs:

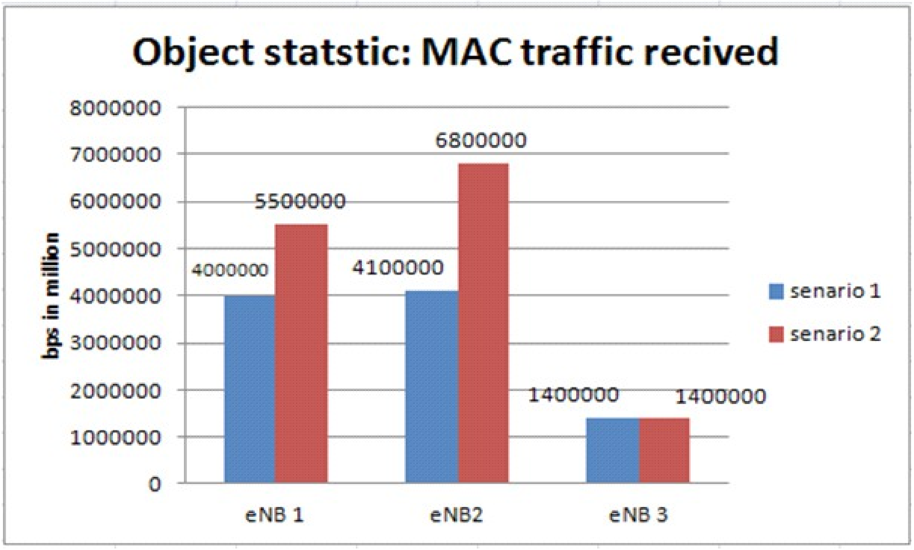


Figure 43: Object statistic MAC traffic received

The results show that the traffic received in both eNB1 and eNB2 has increased, in eNB1 the MAC received have been increased from 4000000 bps (4Mbps) to 5500000 bps (5.5 Mbps) an increase of 1500000 bps (1.5 Mbps).

In eNB2 the MAC received have been increased from 4100000 bps (4.1Mbps) to 6800000 bps (6.8 Mbps) an increase of 2700000 bps (2.7 Mbps) because of the implementation of eMBMS with MBSFN.

In other hand, eNB3 get the same amount of MAC traffic received in both scenarios and it was 1400000 bps (1.4 Mbps).

• MAC Traffic Sent (bits/sec): This results show the LTE.MAC traffic sent from the eNBs. Figures 44, 45, 46 show the results in OPNET LTE:

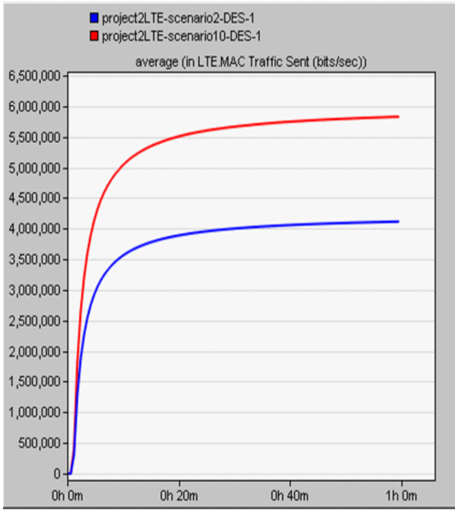


Figure 44: eNB1 MAC traffic sent

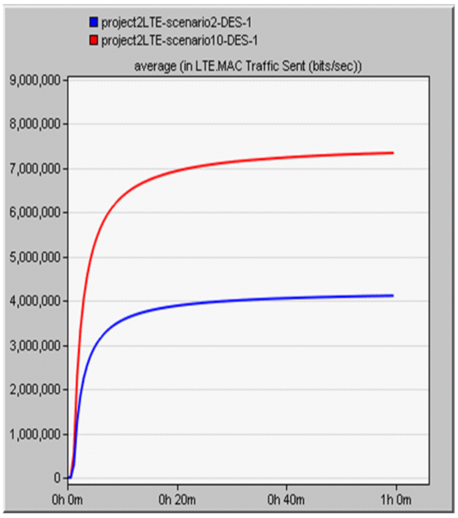


Figure 45: eNB2 MAC traffic sent

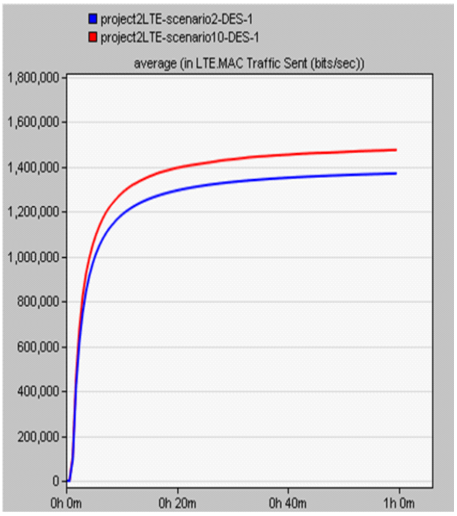


Figure 46: eNB3 MAC traffic sent

The chart below in Figure 47 show the comparison result in MAC traffic sent:

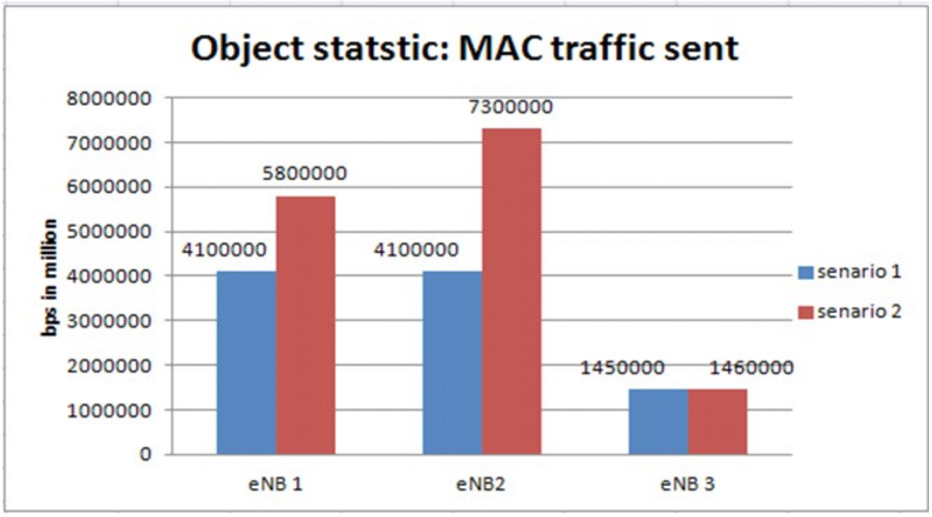


Figure 47: Object statistic MAC traffic sent

The results show that the eNBs received more traffic from the UEs, in eNB1 the traffic received in first scenario was about 4000000 bps (4 Mbps) and it is increaseing in the second scenario to about 5500000 bps (5.5 Mbps), in eNB2 the traffic received was about 4100000 bps (4.1 Mbps) and it increased to about 6800000 bps (6.8 Mbps), and in the eNB3 the traffic received was about 1370000 bps (1.37 Mbps) and it also increased to about 1470000 bps (1.47 Mbps).

In eNB3 the traffic received has increased because of the load has become more in their own UEs.

5.2.2 UEs results

• Throughput: This results show the LTE.Throughput (bit/sec) in the UEs, Figures 48, 49, 50, 51, 52 below show graphic results in OPNET LTE:

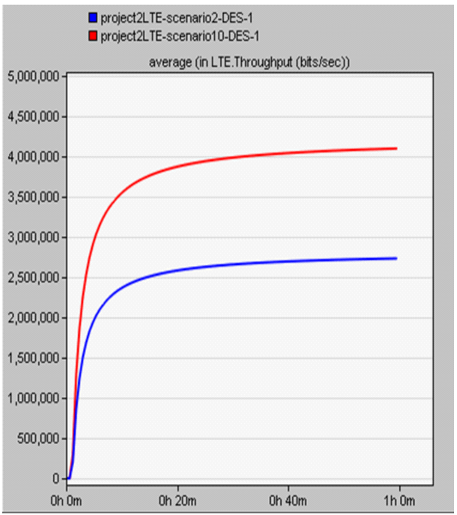


Figure 48: Object statistic LTE Throughput in UE1

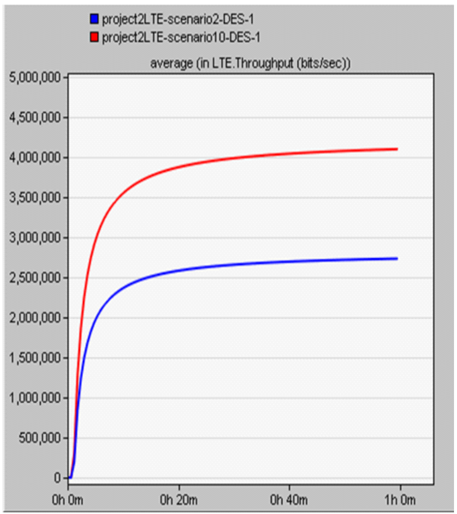


Figure 49: Object statistic LTE Throughput in UE2

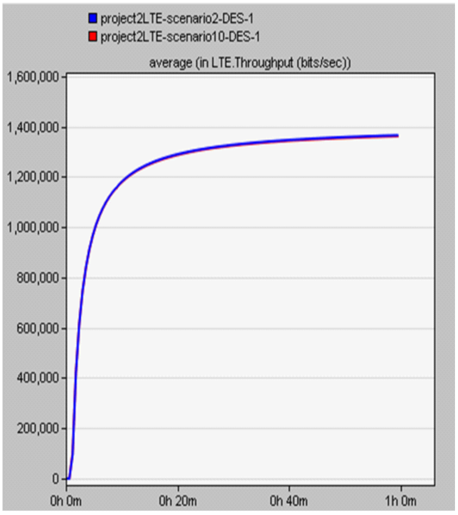


Figure 50: Object statistic LTE Throughput in UE3

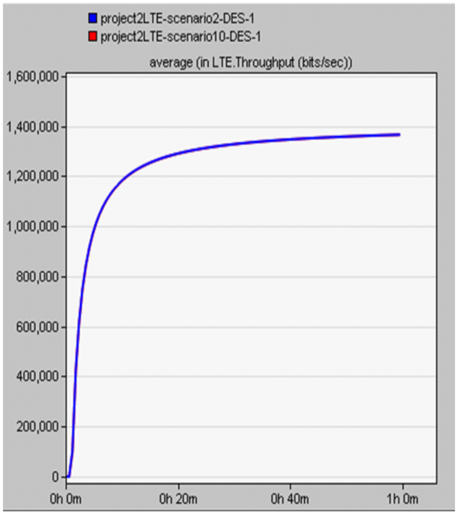


Figure 51: Object statistic LTE Throughput in UE4

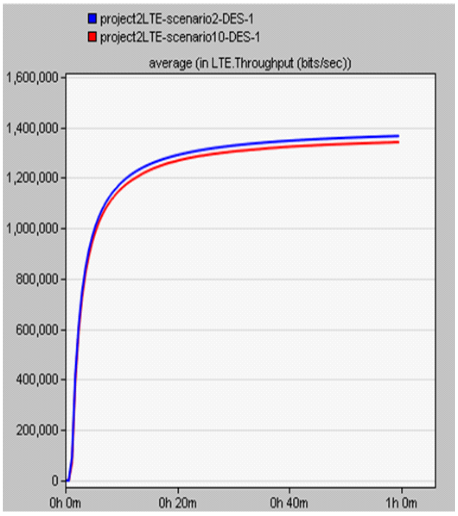


Figure 52: Object statistic LTE Throughput in UE5

The chart below in Figure 53 show UEs throughput and the comparison results:

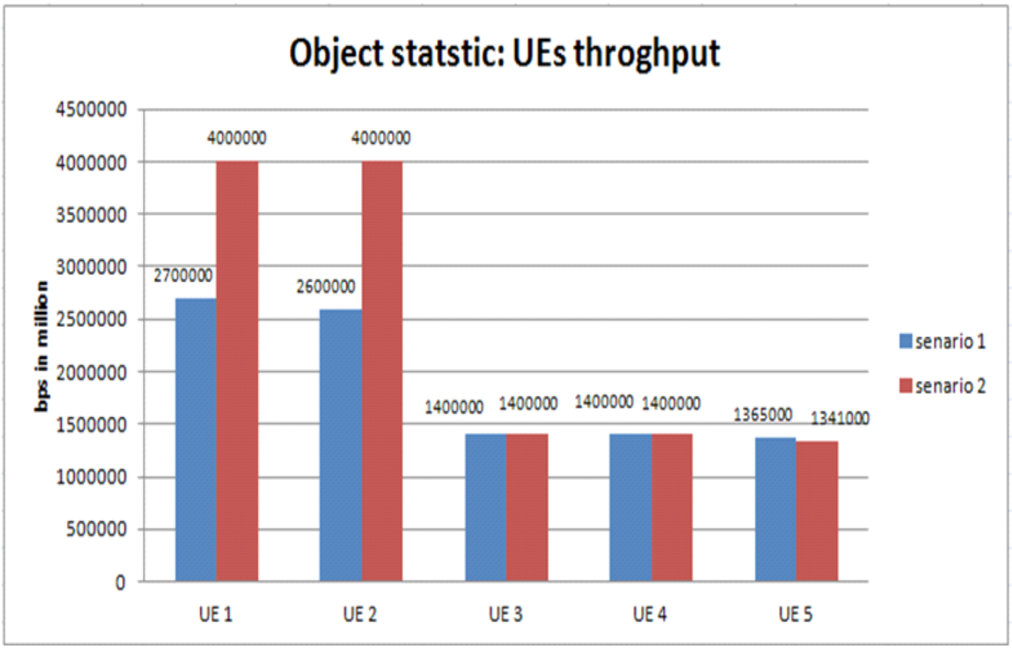


Figure 53: Object statistic UEs Throughput chart

The results show that the throughput has been increased in the UE1 and UE2 in the eMBMS area where the implementation of IP multicast, and that means they will have more throughput.

The UE 5 in eMBMS area has obtained low throughput, and that means there is less traffic received or sent from this UE depend on the distance from the eNB2.

UE1 in scenario 1 has got about 2700000 bps (2.7 Mbps) and in scenario 2 the throughput increased to about 4000000 bps (4 Mbps), in UE2 the throughput was in scenario 1 about 2600000 bps (2.6 Mbps) and it increased to about 4000000 bps (4 Mbps) in the second secnario, in UE3 the throughput was 1400000 bps (1.4 Mbps) and it is the same in scenario 2, in UE4 the throughput was in scenario 1 about 1400000 bps (1.4 Mbps) and it is the same in scenario 2, in UE5 the throughput was in scenario 1 about 1365000 bps (1.36 Mbps) and it decreased to about 1341000 bps (1.341 Mbps).

• MAC Traffic sent (bits/sec): This results show any changed in the UEs in MAC traffic sent in (bit/sec), Figures 54, 55, 56, 57, 58 shows the graphs results in OPNET LTE :

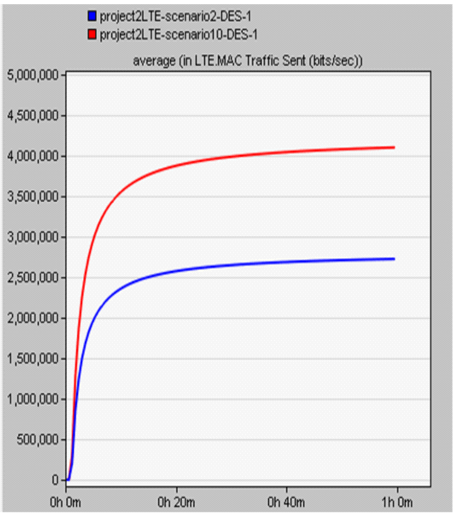


Figure 54: Object statistic UE1

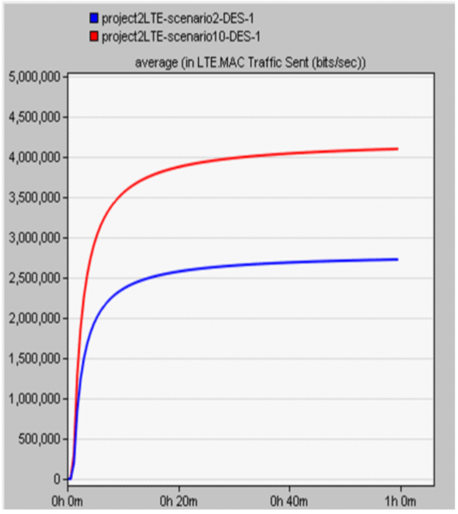
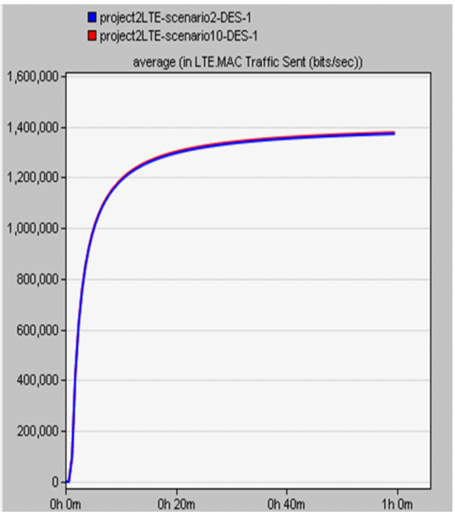
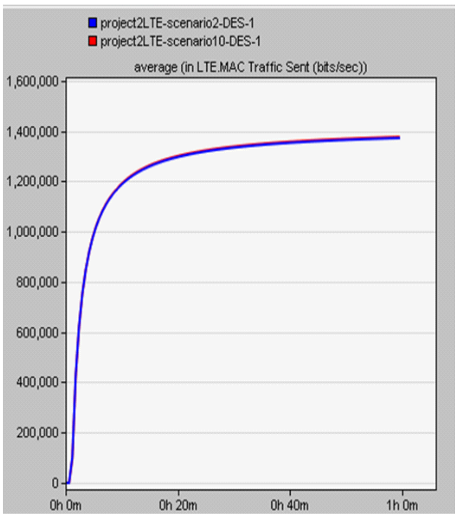


Figure 55: Object statistic UE2





MAC traffic sent MAC traffic sent **Figure 56:**
Object statistic UE3 **Figure 57:** Object statistic UE4
MAC traffic sent MAC traffic sent

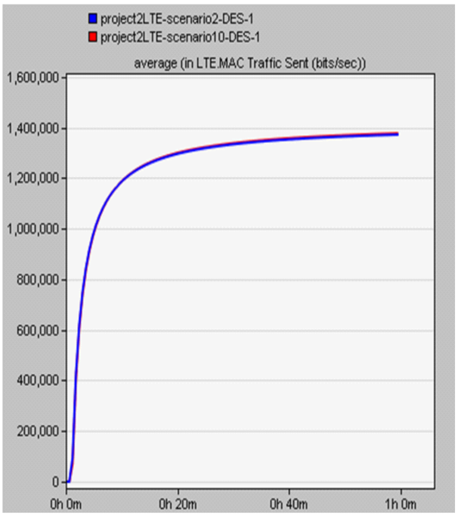


Figure 58: Object statistic UE5 MAC traffic sent

The chart below in Figure 59 show the UEs MAC traffic sent comparison results:

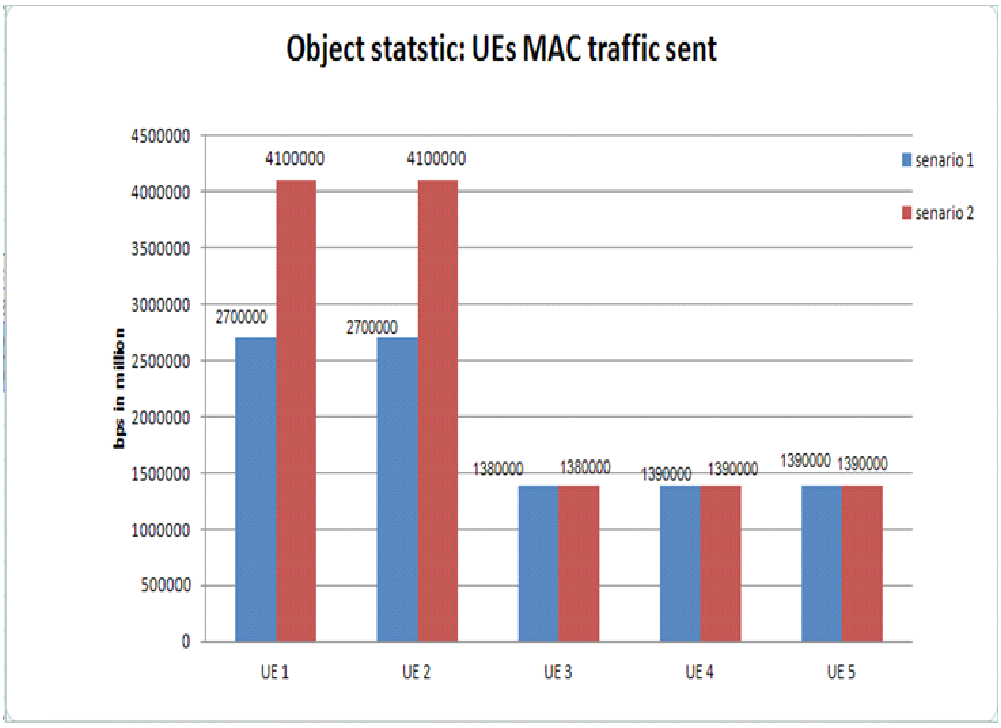


Figure 59: Object statistic UEs MAC traffic sent chart

The results show that the MAC traffic sent has been increased in the UE1 and UE2 in the eMBMS area where the implementation of IP multicast, and that means they will have more MAC traffic sent and all other UEs No changed happened to them.

UE1 in scenario 1 has got about 2700000 bps (2.7 Mbps) and in scenario2 the throughput increased to about 4100000 bps (4.1Mbps), in UE2 the MAC traffic sent was in scenario 1 about 2700000 bps (2.7 Mbps) and it increased to about 4100000 bps (4.1 Mbps), in UE3 the MAC traffic sent was 1300000 bps (1.3 Mbps) and it is the same in scenario 2, in UE4 the MAC traffic sent was in scenario 1 about 1390000 bps (1.39 Mbps) and it is the same in scenario 2, in UE5 the MAC traffic sent was in scenario 1 about 1390000 bps (1.39 Mbps) and it the same for scenario 2.

• MAC Traffic Received (bits/sec): This results show the changed in the MAC traffic received in UEs in (bit/sec), Figures 60, 61, 62, 63, 64 shows the graphs results OPNET LTE:

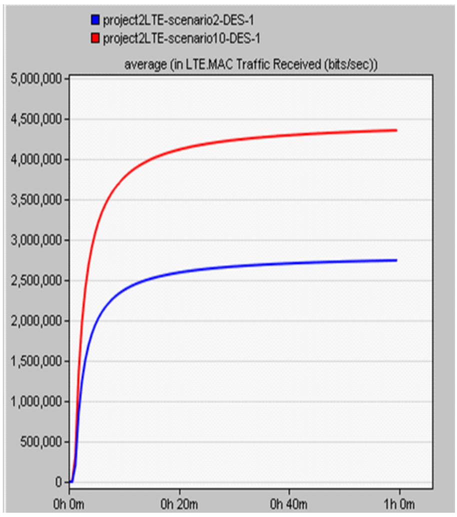


Figure 60: Object statistic UE1 MAC traffic received

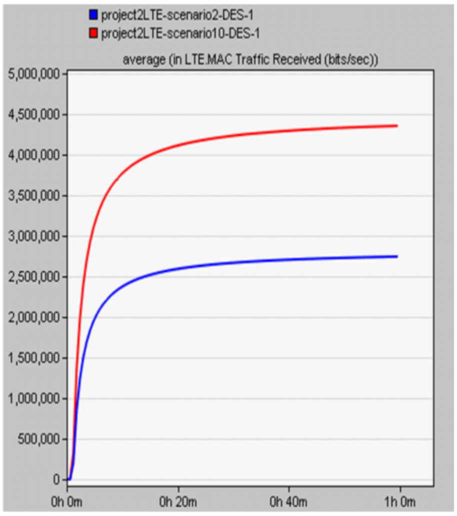
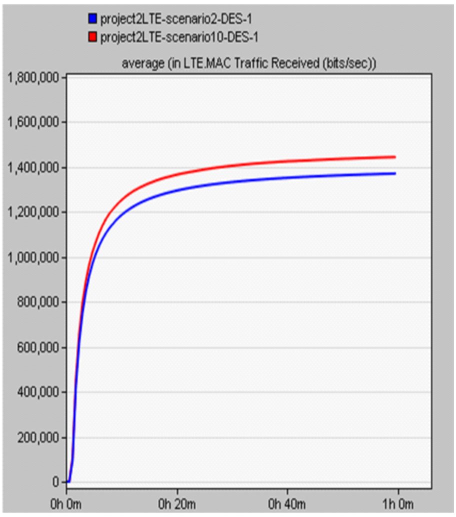


Figure 61: Object statistic UE2 MAC traffic received



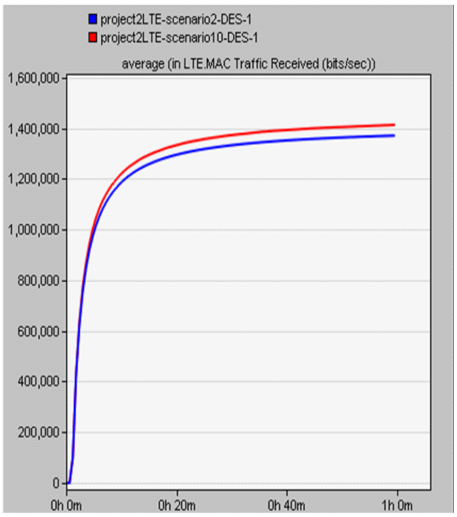


Figure 62: Object statistic UE3 MAC traffic received

Figure 63: Object statistic UE4 MAC traffic received

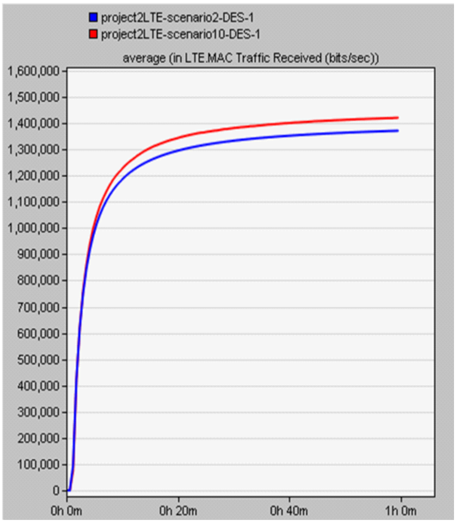


Figure 64: Object statistic UE5 MAC traffic received

The chart below in Figure 65 show UEs MAC traffic received and the comparison results:

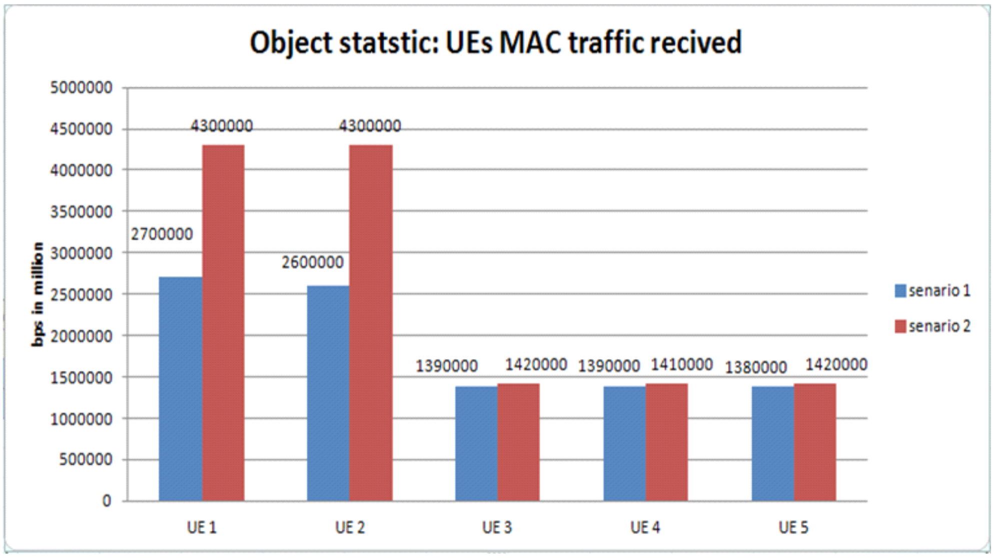


Figure 65: Object statistic UE5 MAC traffic received chart

The results show that the MAC traffic received increased in UE1 and UE2 in the eMBMS area where the implementation of IP multicast, and that means they will receive more traffic. In other hand, all other UEs some small change happened on them.

UE1 in scenario1 has got about 2700000 bps (2.7 Mbps) and in scenario 2 the throughput increased to about 4300000 bps (4.3 Mbps). In UE2 the MAC traffic received was in scenario1 about 2600000 bps (2.6 Mbps) and increased to about 4300000 bps (4.3 Mbps). In UE3 the MAC traffic received was 1390000 bps (1.39 Mbps) and increased to about 1420000 bps (1.42 Mbps) the in scenario 2. In UE4 the MAC traffic received was in scenario 1 about 1390000 bps (1.39 Mbps) and increased to about 1410000 bps (1.41 Mbps) the in scenario 2. In

UE5 the MAC traffic received was in scenario 1 about 1380000 (bps) (1.38Mbps) and increased to about 1420000 (bps) (1.42 Mbps) in scenario 2.

5.3 MBSFN

This results collected by OPNET as a result of eMBMS with MBSFN and shows how the modulation happened in MBSFN in eNBs where the implementation of eMBMS with MBSFN. Also it has proved that the MBSFN works properly. Unfortunately this is the only way to see the results of the implementation of eMBMS with MBSFN in this version. The results show three different tables:

- The first result show that the MBSFN modulations and how the MBSFN works in different MCS (MCS it is modulation and coding scheme) and how it used PMCH (PMCH it is Physical Multicast Channel and contains MBMS traffic and control information and is transmitted with MBSFN-RS), PMCH used different modulations types and it can be QPSK, 16QAM, and 64QAM it transmitted periodically in the MBSFN sub frame. Also the result shows PDSCH (PDSCH is the Physical Downlink Shared Channel used to carry DL-SCH or PCH, this channel will allocate most of the capacity in a cell) [25].
- The second result shows that no overlap between any eNB and other eNBs, and that means the network succeeded to avoid interference between eNBs [25].
- Finally, the result shows how the PUSCH works (PUSCH is the Physical Uplink Shared Channel and it used for fined the transport blocks of UL-SCH on which all radio bearer uplink occur) and the capacity by Admission Control in (Mbps) [25].

The screens shortcut in Appendix A,B,C and the tables below show MBSFN results:

eNB1: The result shows the MBSFN modulations, how the MBSFN works and also the PDSCH. Table 18 below represents the important information. See Appendix A.

Table 18: eNB1 MBSFN and PDSCH information

Title	MCS 0	MCS 4	MCS 9	MCS15	MCS20	MCS24	MCS28
Estimated Total Downlink Capacity for Data (Mbps)	4.14	10.68	23.68	42.37	59.26	81.18	90.53-108.50
Estimated PDSCH Capacity for Data (Mbps)	3.31	8.54	18.95	33.89	47.40	64.94	72.42-86.80
Estimated PDSCH Capacity by	3.31	8.54	18.95	33.89	47.40	64.94	86.80

Admission(Mbps)							
Estimated PMCH Capacity for Data in MBSFN (Mbps)	0.83	2.14	4.74	8.47	11.85	16.24	18.11-21.70

The second result shows that there is no overlap between eNB1 and any other eNBs, and that means the network succeeded to avoid the interference between the eNBs. See Appendix A.

The last result, show the PUSCH and how it works. Table 19 below represents the important information. See Appendix A.

Table 19 : eNB1 PUSCH Capacity by Admission Control information

Title	MCS0	MCS4	MCS9	MCS15	MCS20	MCS24	MCS28
Estimated PUSCH Capacity for Data (Mbps)	0.95	2.84	6.54	13.27	19.91	25.60	34.13
Estimated PUSCH Capacity by Admission(Mbps)	0.95	2.84	6.54	13.27	19.91	25.60	34.13

eNB2:

The result shows that the MBSFN modulations, how the MBSFN works and also the PDSCH and how it works. Table 20 below represents the important information. See Appendix B.

Table 20: eNB2 MBSFN and PDSCH information

Title	MCS0	MCS4	MCS9	MCS15	MCS20	MCS24	MCS28
Estimated Total Downlink Capacity for Data (Mbps)	4.14	10.68	23.68	42.37	59.26	81.18	90.53-108.50
Estimated PDSCH Capacity for Data (Mbps)	3.31	8.54	18.95	33.89	47.40	64.94	72.42-86.80
Estimated PDSCH Capacity by Admission(Mbps)	3.31	8.54	18.95	33.89	47.40	64.94	86.80

Estimated PMCH Capacity for Data in MBSFN (Mbps)	0.83	2.14	4.74	8.47	11.85	16.24	18.11-21.70

The second result show that there is no overlap between eNB2 and any other eNBs, and that means the network succeeded to avoid the interference between the eNBs. See Appendix B.

The last result, show the PUSCH and how it works. Table 21 below represents the important information. See Appendix B.

Table 21: eNB2 PUSCH Capacity by Admission Control information

Title	**MCS0**	**MCS4**	**MCS9**	**MCS15**	**MCS20**	**MCS24**	**MCS28**
Estimated PUSCH Capacity for Data (Mbps)	0.95	2.84	6.54	13.27	19.91	25.60	34.13
Estimated PUSCH Capacity by Admission(Mbps)	0.95	2.84	6.54	13.27	19.91	25.60	34.13

eNB3:

The result below in Table 22 , show the PDSCH and how it works. Because eMBMS with MBSFN did not used here, there is no information about MBSFN like other eNBs. Table 22 below represents the important information. See Appendix C.

Table 22: eNB3 PDSCH information

Title	**MCS0**	**MCS4**	**MCS9**	**MCS15**	**MCS20**	**MCS24**	**MCS28**
Estimated PDSCH Capacity for Data (Mbps)	2.79	7.22	15.84	28.34	39.23	55.06	63.78-75.38
Estimated PDSCH Capacity by Admission(Mbps)	2.79	7.22	15.84	28.34	39.23	55.06	75.38

The second result show that there is no overlap between eNB3 and any other eNBs, and that means the network succeeded to avoid the interference between the eNBs. See Appendix C.

The last result show PUSCH and how it works. Table 23 below represents the important information. See Appendix C.

Table 23:eNB3 PUSCH Capacity by Admission Control information

Title	MCS0	MCS4	MCS9	MCS15	MCS20	MCS24	MCS28
Estimated PUSCH Capacity for Data (Mbps)	1.93	4.83	10.62	20.62	30.89	38.61	53.09
Estimated PUSCH Capacity by Admission(Mbps)	1.93	4.83	10.62	20.27	30.89	38.61	53.09

5.4 Spectral efficiency

The spectral efficiency of a LTE system can be calculated as [24]:

$$System\ Spectral\ Efficiency = \frac{Total\ throughput}{Total\ bandwidth}\left(bits/s/Hz/number\ of\ cells\right)$$

5.4.1 eNB1(evolved Node B 1) Spectral efficiency

- **First scenario:**

In the first scenario the Total throughput in eNB1 = 4100000 (bps) this throughput include error correcting codes and it is total throughput in eNB1 and spread over 20 (MHz) bandwidth.

The corresponding throughput in the link:

Link Spectral efficiency = Total throughput/Total bandwidth (bit/s/Hz).

Link Spectral efficiency = 4100000/20000000= 0.205 (bit/s/Hz) in the link.

By assume that there is 100 simultaneous TV channels per cell, and each base station divide into 2 cells and that means 2 directional sector antennas, This corresponds to a system spectrum efficiency of over 1 × 100 × 0.205 = 20.5 (bit/s/Hz) per site.

System spectrum efficiency = 20.5/2 =10.25 (bit/s/Hz/cell).

- **Second scenario:**

Throughput = 5500000 (bps) throughput as total in eNB1 scenario 2

And it spread over 20 (MHz) bandwidth.

The corresponding throughput in the link = 5500000/20000000=0.275 (bit/s/Hz) in the link.

By assume that there is100 simultaneous TV channels per cell, and each base station divide to 2 cells and that means 2 directional sector antennas, This corresponds to a system spectrum efficiency of over 1 × 100 × 0.275 = 27.5 (bit/s/Hz) per site.

System spectrum efficiency = 27.5/2 = 13.75 (bit/s/Hz/cell).

5.4.2 eNB2 (evolved Node B 2) Spectral efficiency

- **First scenario:**

Throughput = 4100000 (bps) throughput as total in eNB2 scenario 1

And it spread over 20 (MHz) bandwidth.

The correspond throughput in the link = 4100000/20000000=0.205 (bit/s/Hz) in the link.

By assume that there is 100 simultaneous TV channels per cell, and each base station divide to 2 cells and that means 2 directional sector antennas, This corresponds to a system spectrum efficiency of over 1 × 100 × 0.205 = 20.5 (bit/s/Hz) per site.

System spectrum efficiency = 20.5/2 = 10.25 (bit/s/Hz/cell).

- **Second scenario:**

Throughput = 6900000 (bps) throughput as total in eNB2 scenario 2

And it spread over 20 (MHz) bandwidth

The correspond throughput in the link = 6900000/20000000=0.345 (bit/s/Hz)in the link.

By assume that there is 100 simultaneous TV channels per cell, and each base station divide to 2 cells and that means 2 directional sector antennas, This corresponds to a system spectrum efficiency of over 1 × 100 × 0.345 = 34.5 (bit/s/Hz) per site.

System spectrum efficiency = 34.5/2 = 17.25 (bit/s/Hz/cell).

The chart below in Figure 66 show the spectral efficiency in eNB1 and eNB2 in both scenarios:

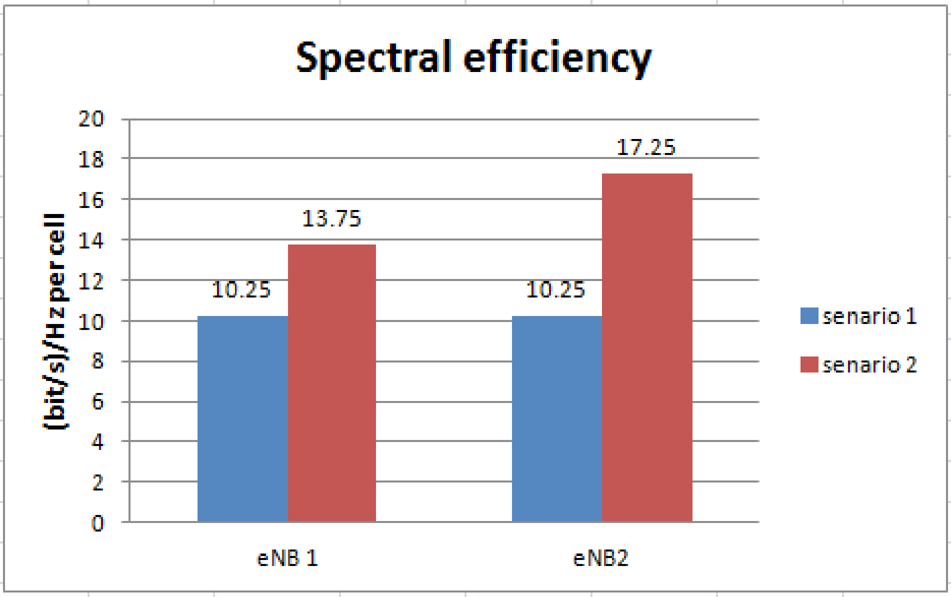


Figure 66: Spectral efficiency in eNB1 and eNB2

6 Conclusions

This chapter represents the conclusion of this thesis, and it includes some answers from the results, future work and the ethical aspect.

By completing the simulation of eMBMS with MBSFN using OPNET LTE the thesis achieved the goal. The result shows that, eMBMS with MBSFN created centralization area in the network and that by having two eNBs or more and when those eNBs synchronized by using time synchronization mechanism they will generate one single signal and central coverage area, whenever the nodes belong to any of those eNBs move in the coverage area they will receive signal without detecting which eNB send this signal, because the eNBs working such as one big eNB. That proved it is possible to have a centralized area in LTE.

The throughput has increased in the downlink to about 5.52 (Mbps), and in the uplink to about 5.18 (Mbps) after using eMBMS with MBSFN. The system spectral efficiency increased in eNB1 from about 10.25 (bits/s/Hz/cell) to about 13.75 (bits/s/Hz/cell), and in eNB2 from about 10.25 (bits/s/Hz/cell) to about 17.25 (bits/s/Hz/cell).

The other important answers to describe centralization vs. decentralization in LTE, and synchronizations in the base station has been described in chapter 2 in subsection 2.5, 2.6.

By investigating if OPNET is useful for big projects, some problems with current version OPNET 17.4 have been detected during the implementation part, there is a problem when implementing heavy traffic in OPNET 17.4, OPNET LTE statistics are not complete, also there is a need for supporting from OPNET. In other hand, OPNET is useful for labs to learn more using small topologies but those labs should match what OPNET requires, because some functions are not complete yet. Finally, by trying to use C++ language to change OPNET library to change anything for example traffic or channels, some problems have been detected because the compiler saves the codes and stop running the simulation and any new simulations and the feedback show problem with the simulation. The C++ part will need more investigation in the future. Therefore, because of all those problems and the limitation of version 17.4 that used during the project, OPNET is not useful for big projects and that the answer to important question this project gives answer for it.

In the future work, the simulation of LTE eMBMS with MBSFN using OPNET LTE can be done by following the steps in this thesis and more investigation with LTE services can be completed such as moving the UEs inside or outside MBSFN to detect the change, increase the number of the eNBs in the eMBMS, use mobility to move UEs between the eNBs and investigate the effect of that in the network, and more investigation in the C++ language part.

6.1 Ethical aspect

The ethical aspect of this project can be seen as privacy and authentication issue of user data and information in the network, because there is the use of IP multicast through the internet without security, the IP can be hacked from for example man-in-the-middle attack. Then the IP can be used to change or send information or change the user information and also join the IP multicast group, because of that there is need to investigate more in future implementation to add more security in the network and as a suggestion solution for this problem is to add full IPSec (Internet Protocol Security) that use to secure the IP that communicate over the internet.

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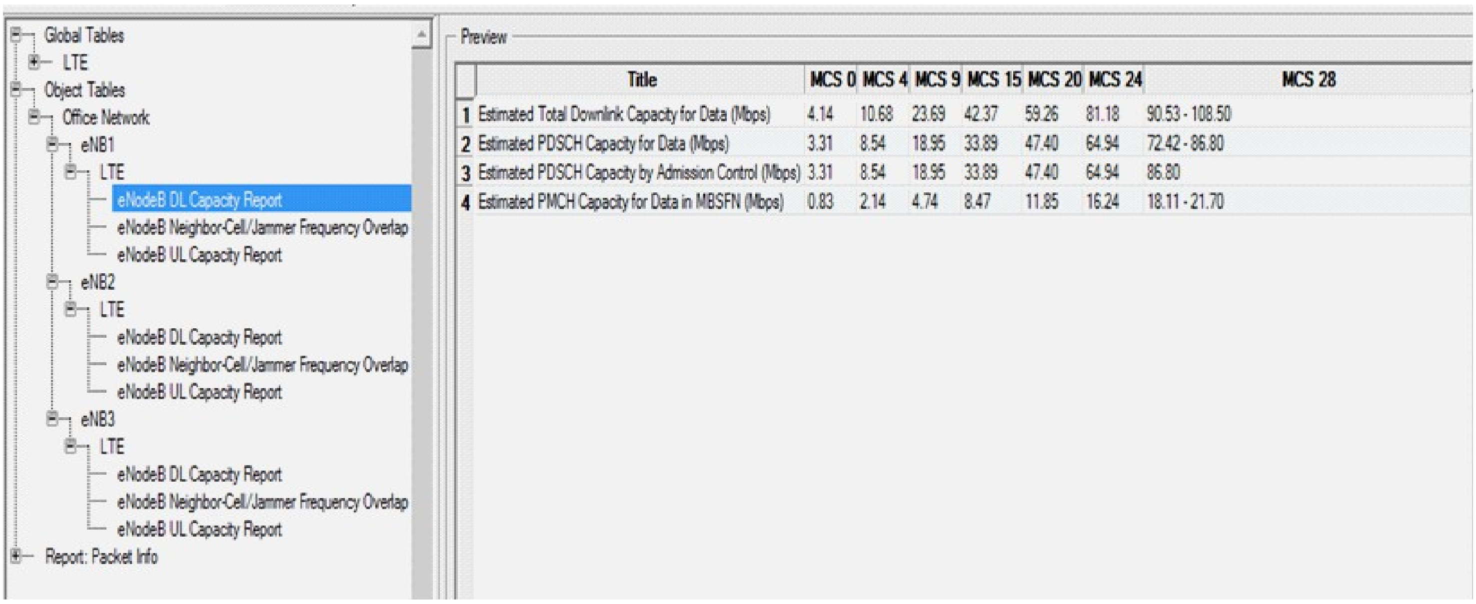
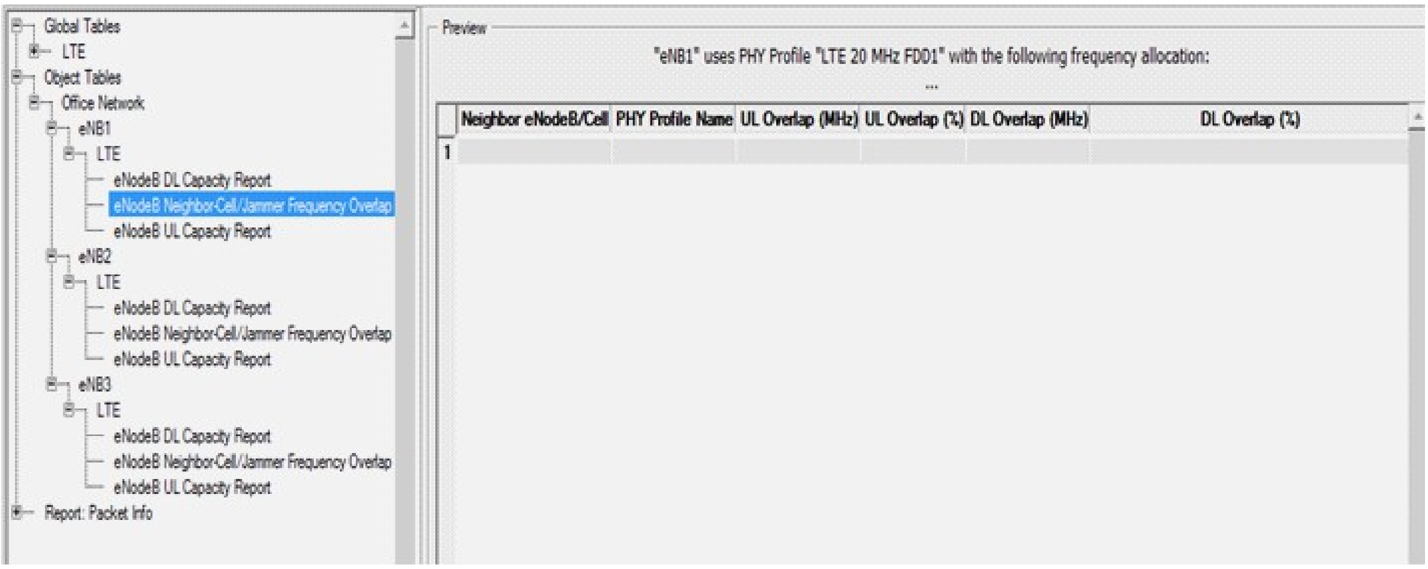
Appendix A: MBSFN results in eNB1

The result shows the MBSFN modulations, how the MBSFN works and also the PDSCH in eNB1.



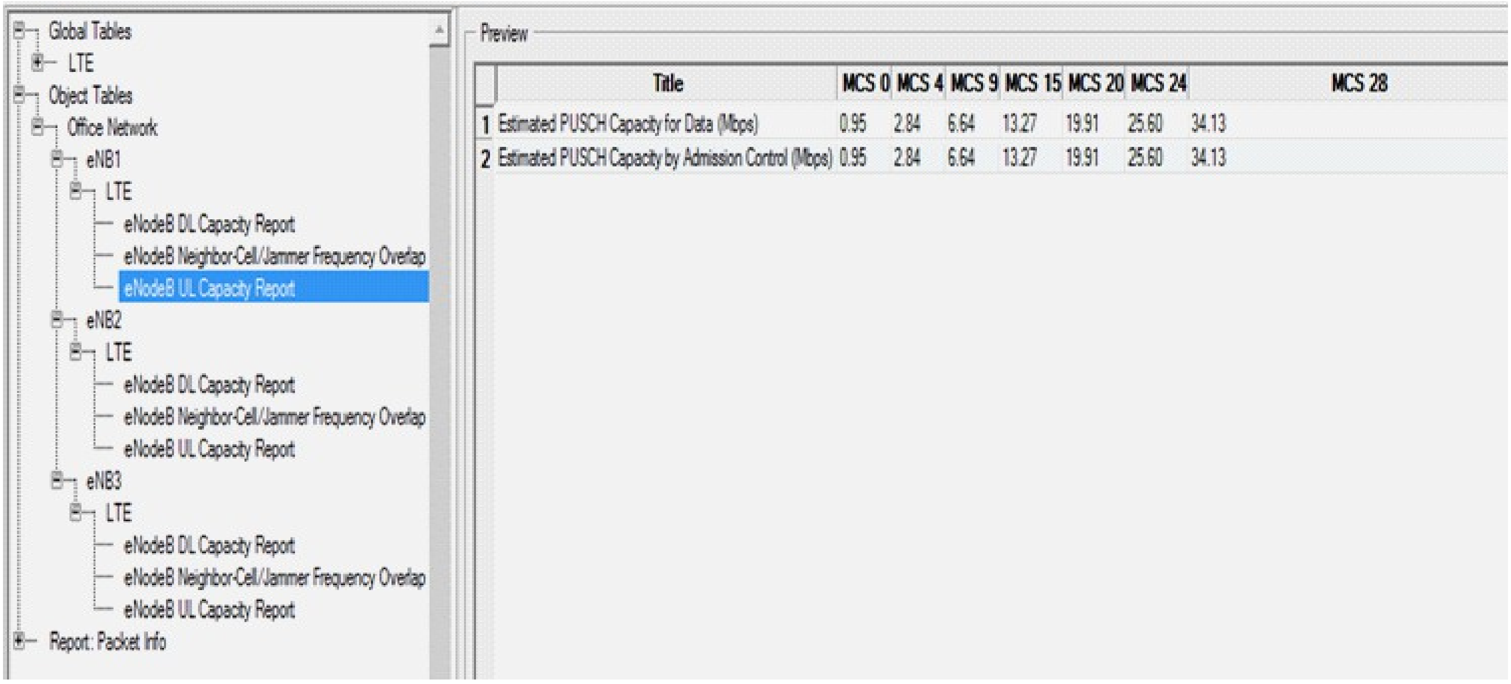
	Title	MCS 0	MCS 4	MCS 9	MCS 15	MCS 20	MCS 24	MCS 28
1	Estimated Total Downlink Capacity for Data (Mbps)	4.14	10.68	23.69	42.37	59.26	81.18	90.53 - 108.50
2	Estimated PDSCH Capacity for Data (Mbps)	3.31	8.54	18.95	33.89	47.40	64.94	72.42 - 86.80
3	Estimated PDSCH Capacity by Admission Control (Mbps)	3.31	8.54	18.95	33.89	47.40	64.94	86.80
4	Estimated PMCH Capacity for Data in MBSFN (Mbps)	0.83	2.14	4.74	8.47	11.85	16.24	18.11 - 21.70

The second result shows that there is no overlap between eNB1 and any other eNBs, and that means the network succeeded to avoid the interference between the eNBs.



	Neighbor eNodeB/Cell	PHY Profile Name	UL Overlap (MHz)	UL Overlap (%)	DL Overlap (MHz)	DL Overlap (%)
1						

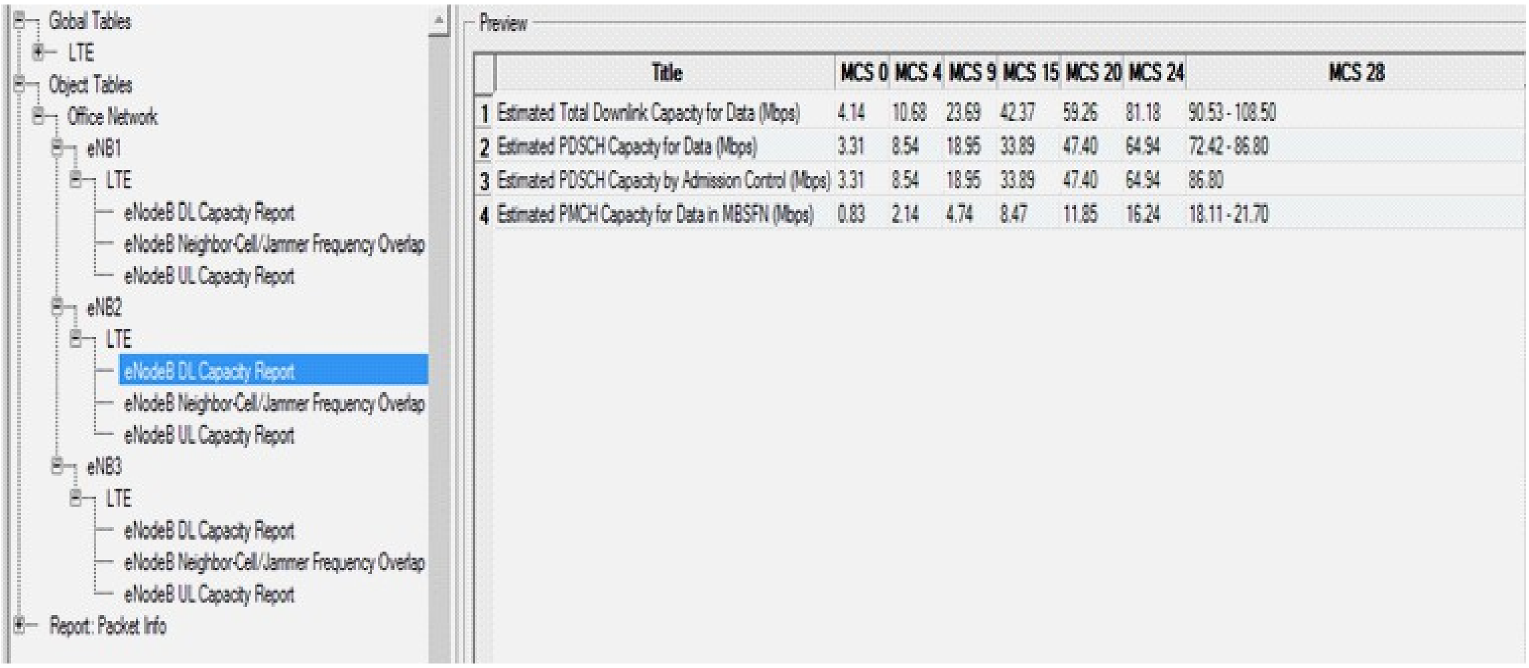
The last result, show the PUSCH and how it works in eNB1.



	Title	MCS 0	MCS 4	MCS 9	MCS 15	MCS 20	MCS 24	MCS 28
1	Estimated PUSCH Capacity for Data (Mbps)	0.95	2.84	6.64	13.27	19.91	25.60	34.13
2	Estimated PUSCH Capacity by Admission Control (Mbps)	0.95	2.84	6.64	13.27	19.91	25.60	34.13

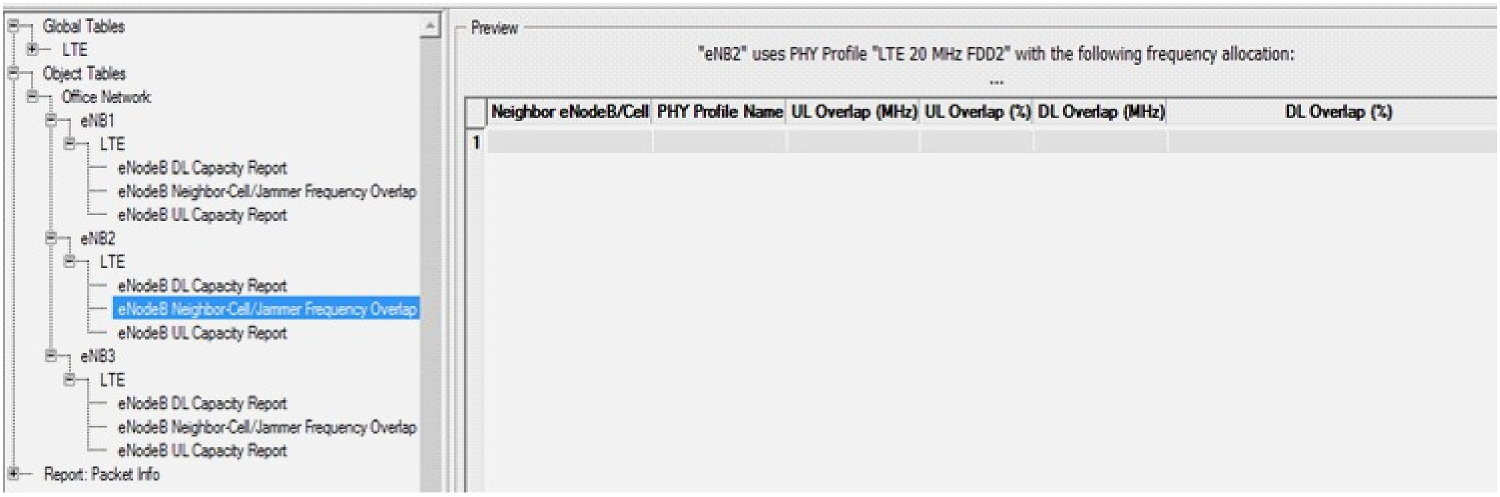
Appendix B: MBSFN results in eNB2

The result shows the MBSFN modulations, how the MBSFN works and also the PDSCH in eNB2.



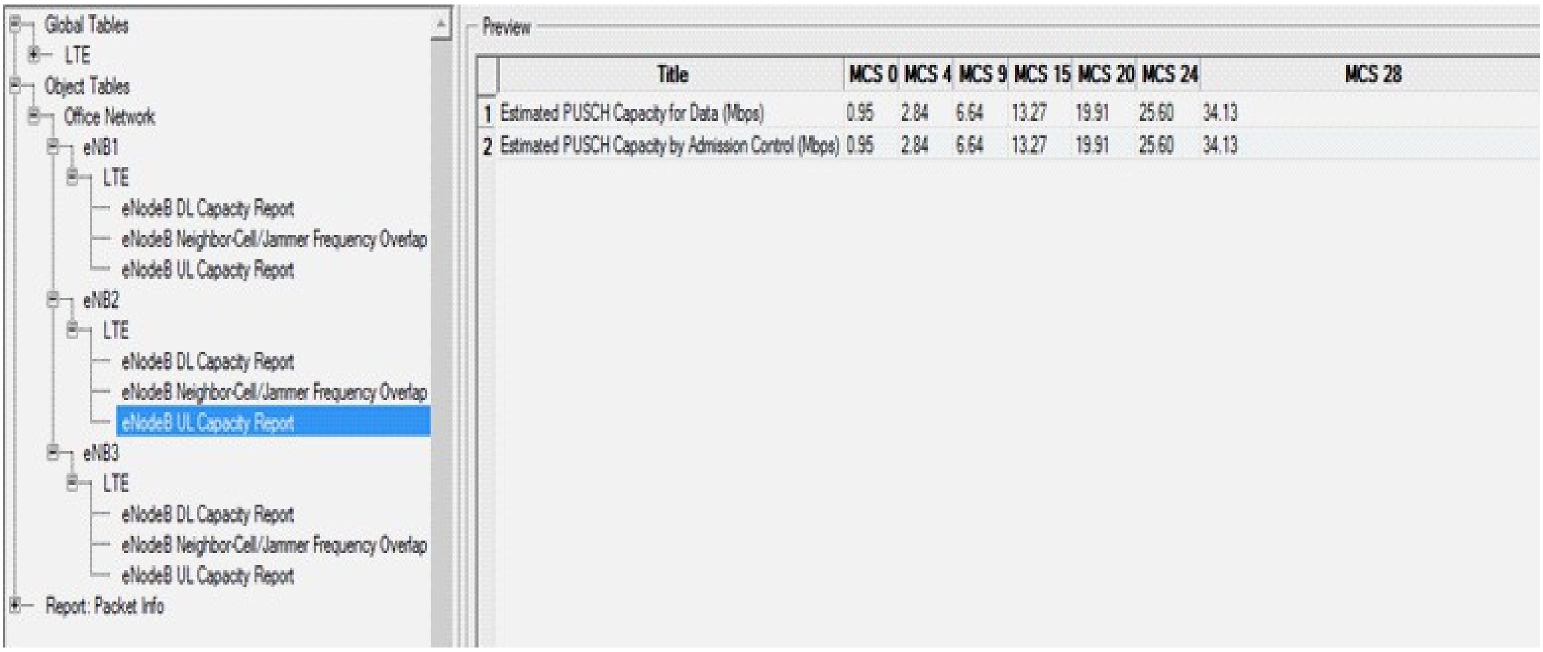
	Title	MCS 0	MCS 4	MCS 9	MCS 15	MCS 20	MCS 24	MCS 28
1	Estimated Total Downlink Capacity for Data (Mbps)	4.14	10.68	23.69	42.37	59.26	81.18	90.53 - 108.50
2	Estimated PDSCH Capacity for Data (Mbps)	3.31	8.54	18.95	33.89	47.40	64.94	72.42 - 86.80
3	Estimated PDSCH Capacity by Admission Control (Mbps)	3.31	8.54	18.95	33.89	47.40	64.94	86.80
4	Estimated PMCH Capacity for Data in MBSFN (Mbps)	0.83	2.14	4.74	8.47	11.85	16.24	18.11 - 21.70

The second result shows that there is no overlap between eNB2 and any other eNBs, and that means the network succeeded to avoid the interference between the eNBs.



	Neighbor eNodeB/Cell	PHY Profile Name	UL Overlap (MHz)	UL Overlap (%)	DL Overlap (MHz)	DL Overlap (%)
1						

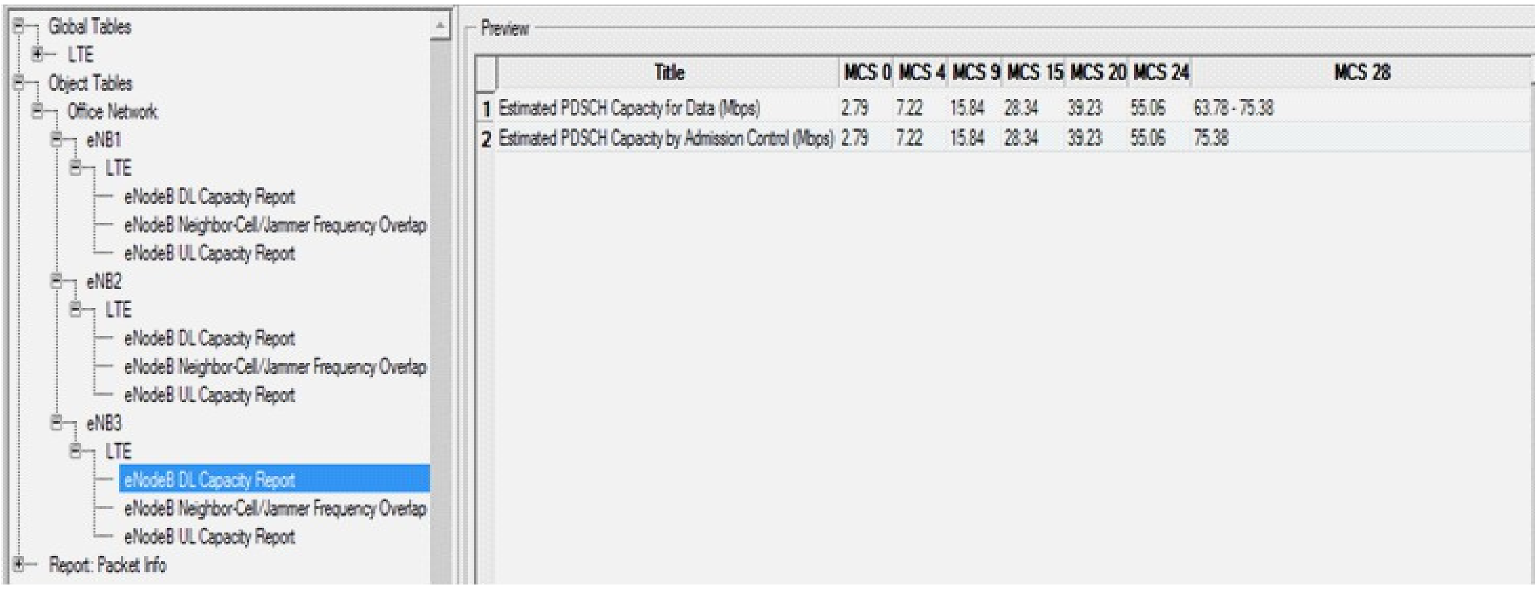
The last result, show the PUSCH and how it works in eNB2.



	Title	MCS 0	MCS 4	MCS 9	MCS 15	MCS 20	MCS 24	MCS 28
1	Estimated PUSCH Capacity for Data (Mbps)	0.95	2.84	6.64	13.27	19.91	25.60	34.13
2	Estimated PUSCH Capacity by Admission Control (Mbps)	0.95	2.84	6.64	13.27	19.91	25.60	34.13

Appendix C: Modulations result in eNB3

The result shows the modulations in eNB3, how the PDSCH works. There is no result for MBSFN here because is not used.



The second result shows that there is no overlap between eNB3 and any other eNBs, and that means the network succeeded to avoid the interference between the eNBs.

The last result, show the PUSCH and how it works in eNB3.