LTE SIMULATION ON OPEN SOURCE FRAMEWORK

OMNET++

Capstone Project Report

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Abstract

Long term Evolution is the recent telecommunication technology proposed by 3GPP. It is boasts to have low latency, high data rates and higher spectral efficiency which occurs by having Packet switched architecture for both voice and data.

For this altered architecture, testing LTE in real network would be too expensive. OMNET++ provides a cheapest and effective way of testing LTE network before implementing it in real network. OMNET++ is open source simulation platform. It implements the user plane of LTE-network.

The main objective behind this work is to test how well LTE-network is implemented and what further changes can be made in it. The effectiveness of current LTE package (Sim-LTE) is tested by performing several simulations.

Content

CHAPTER-1

Introduction

Driving the evolution of wireless broadband technology is customer's increasing demand for higher speed and global access. Customer wants more application with high speed on their mobile devices. For service providers to achieve higher data rates with mobility, wireless network need to behave like wired network so that emerging need for higher data rates and increase of new application (like mobile TV) can be served. This leads to the change in network infrastructure as whole, changing the way data was transferred over radio network and way packets were handled inside the core network. LTE is completely packet based technology. To provide Quality service for different type of data at low price is one of the challenges which almost every service provider is facing today. Therefore, there is need to test LTE network before implementing in real world.

LTE also known as Long term Evolution is a fourth generation (4G) wireless broadband technology that has evolved from the third generation (3G) technology. Unlike earlier generation of network, LTE is based on TCP/IP protocol, which is a whole new way voice and data are delivered to users in telecommunication. TCP/IP enables wireless network to provide higher data rate and provide support for voice to be delivered as VOIP (voice over IP) and provide better integration with other application like video traffic, downloading etc. LTE provide increase in end user throughput, low latency, higher data rate, low user plane latency, support new applications and more mobility to the user. To support new requirements of network, changes are made in core as well as radio part of the network. Physical layer of the network is changed to have higher bandwidth efficiency. In 3G network TDD was used, to use radio network more efficiently OFDMA (orthogonal frequency division multiplexing) and MIMO (multiple input multiple output) technologies are used in LTE. To have low latency in user plane of the network, base station is changed, less number of network devices are used so that latency due to network devices can be minimized. Core of Lte is called EPC (Evolved Packet core) and radio network is known as EUTRAN (Evolved UTRAN). The radio access network manages radio connections to the UE (user equipment), and the core network manages overall services.

LTE network is supposed to handle different type of services and at same time migration should be cost effective and backward compatible. Bandwidth capability of user is expected to be 20 MHz for both uplink (with peak data rate of 100Mbps) and downlink (peak data rate of 50mbps). Expected latency for link establishment and for packet delivery is expected to be less than 100ms and 5ms respectively. Another performance metric of LTE is high capacity i.e. support more number of voice calls with same amount of radio resources as in UMTS, thus radio resources should not be allocated to particular user for lifetime of call rather resources are assigned dynamically as per the requirements of the user. To make LTE backward compatible with 3G, UMTS and service providers (using different spectrum), LTE is designed to work in different spectrum bandwidths ranging from 1.25 to 20 MHZ.

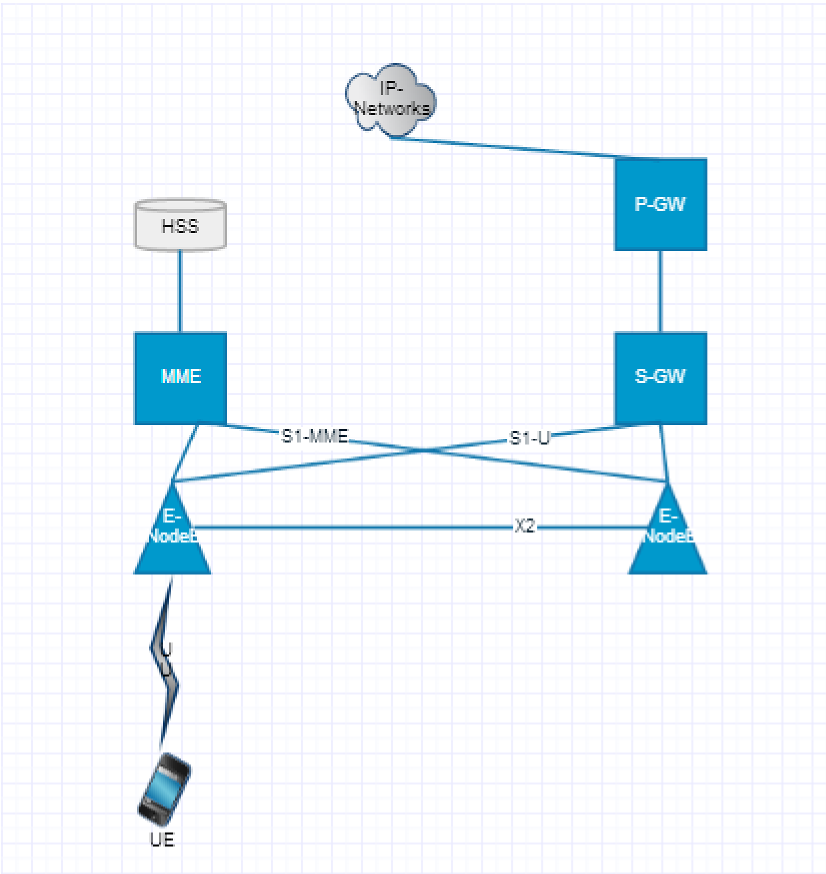

Figure 1: *Network architecture of LTE*

Packet based lte network can be divided into evolved UTRAN (E-UTRAN) and the Evolved packet core (EPC). EUTRAN consist of one node called Evolved nodeB (EnodeB) that interact with UE (user equipment). The EPC contains the PDN Gateway (P-GW), the Serving Gateway (S-GW), the Home Subscriber Server (HSS), the Policy Control and Charging Rules Function (PCRF) and the Mobility Management Entity (MME).

1.1 Core Network

The P-GW (packet gateway) is the outer most node of LTE which connects internal nodes of EPC to the external networks like internet or other radio access networks (RAN). Its main function is to assign IP addresses to UE. It also performs filtering of packets according to various rules applied by PCRF and then sends filtered packets into different radio bearer. These bearers provide required Qos to the traffic. Filtering of packets is performed by traffic flow filter in P-GW. In Lte ipv4, ipv6 as well as ipv4v6 packets are supported.

The S-GW (Serving Gateway) act as a mobility anchor when user moves between different EnodeB's. It connects EUTRAN to the EPC of the LTE network. It also facilitates handover. S-GW buffer data when user is in idle mode and packet is received from external source until connection is established with user.

The HSS stores and handles information like subscription information, authentication information, and security information.

The MME is a central node of the core network. It exchanges signalling with UE. MME manages the establishment, modification, and release of radio bearers. It checks the authenticity if user to validate user. It provides security keys to the Enb (PDCP layer) so that it can perform ciphering and Integrity check. It also handles the overall Qos and radio carrier's management. When the user is in idle mode MME keeps track of user location at tracking area level.

1.2 E-UTRAN

The ***radio access part (User plane)*** of the network consists of EnodeB. By having just one network element in the user plane, data is delivered fast to the UE that increases efficiency of the system. Enb manages radio resources allocation and de-allocation. It takes care whether new connections should be accepted or not, according to the availability of the radio resources. When UE is in RRC_CONNECTED mode (i.e. when the user is active), mobility of the UE is controlled by the eNB. ENB decides which cell should be used for the connection to the UE and also makes an appropriate handover decision if signal strength from user is below some specific level. It performs coordination among neighbouring Enodes so that there is minimum interference among different cells in Enb. Enb manages the Qos at cell level. To optimize radio resource usage and network configuration, the eNB performs several measurements and delivers outcomes to operators or control entities. It also handles handover from one EnodeB to another.

Enodes are connected to each other by interface called “X2” and to EPC by S1 interface. The interface between UE and Enb is called Uu interface.

1.3 Protocol architecture

The protocol architecture of EnodeB consists of PDCP Layer (Packet Data Convergence Protocol), RLC Layer (Radio link control), MAC Layer (Medium access layer) and PHY Layer (Physical layer) under user plane. It also includes RRC Layer (Radio Resource Control) under control plane. Functions of these layers are explained below:

RRC Layer**:** It controls communications between user and Enb and it also control communication of users crossing cell. Ue can be in two RRC states i.e. RRC connected (if there is RRC connection i.e. user is active) and RRC idle (if there is no RRC connection between user and enb). RRC layer deliver system information such as cell selection and reselection, radio resource configuration etc. to the user in both RRC states. RRC layer also perform paging if the user is in idle mode to inform about the incoming calls and then provide require resources to the user so that call can be established. Another important feature of RLC is handover.

***PDCP Layer*:** Packet data convergence layer is located below the RRC layer and above RLC layer. It handles security functions by providing data integrity and ciphering. It performs header compression of IP packets thus transferring fewer amounts of bytes on the network and increasing efficiency of network. After receiving security indications from RRC layer PDCP layer perform data integration and then ciphering is performed to maintain the confidentiality of the message, then PDCP PDU is transferred to the lower layer. At receiver de-ciphering is performed with same ciphering key, integrity is verified and then decompression of data unit is done.

***RLC Layer*:** RLC layer receives packets from PDCP layer and perform resizing of these packets to size specified by the MAC layer. RLC functions are performed by RLC entity and it is established when radio resource is assigned to the user and removed as soon as that resources are released. It eliminates duplicate SDU to be delivered to upper layer.

RLC entity can be established in three modes:

- AM Mode (Acknowledged Mode)
- UM Mode (Unacknowledged Mode)
- TM Mode (Transparent Mode)

Transparent Mode RLC: It is a Null entity which doesn't perform any function. Messages from RRC layer which don't need any data protection such as paging messages use TM Mode RLC. These messages bypass PDCP layer thus layer above TM mode RLC is RRC layer. It is unidirectional entity (i.e. either transmitting side RLC or receiving side RLC). It is used when packet size is already know such as packets for broadcast information

Unacknowledged Mode RLC: Packets which are sensitive to delay such as real time traffic (voice) use unacknowledged mode RLC. In this mode of operation there is no retransmission of lost or corrupted packet. UM RLC perform segmentation of packet data units received from PDCP layer as per size indicated by MAC layer, a sequence number is assigned to each RLC PDU so that if these packets are received out of order they can be rearrange at receiver side. It supports unidirectional radio bearers. To support bidirectional radio bearers, two UM-RLC are created one for transmission and one for reception.

Acknowledge Mode RLC: It affords lossless transmission of packets by facilitating retransmission of lost packets. Services such as Video streaming, file transfer that are not delay sensitive rather there should be no loss of packets use AM mode RLC. It supports bidirectional radio bearers. ARQ is used to provide lossless transmission.

Medium Access Layer: MAC layer connect RLC layer to the PHY layer, it provide connectivity between logical channels of RLC layer to the transport channels of PHY layer. Mac layer consist of following Entities:

- Multiplexing and Demultiplexing Entity
- HARQ Entity
- Control Entity
- Logical Channel Prioritization Entity

Logical Channel Prioritizing entity: Some information can be delayed where as some packets is delay sensitive such as VOIP, these packets are given priority as compare to other which are not sensitive to delay, logical channel entity prioritizes packets received from logical channels and trigger multiplexing and demultiplexing entity.

Multiplexing and Demultiplexing Entity: when MAC SDU are received from logical channels it performs multiplexing according to the available resources and create MAC PDU, then send PDU on the transport channels assigned by the physical layer. At receiver side reverse action is performed.

Hybrid Automatic Repeat Request: This entity performs Harq operation at receiver and transmitter side. HARQ at receiver side request for retransmission if packets received are corrupted, HARQ at transmitter side respond to ARQ request sent by the receiver and resend that packet.

Control Entity: This entity performs resource request and Discontinuous reception (to extend the battery life of UE), Power headroom reporting etc.

***Physical Layer*:** After data is being processed by all above layer it is passed to physical layer. The smallest time unit of 1ms is assigned for transmission. Physical layer of LTE perform RF processing (modulation and demodulation) and handles time and frequency synchronization. It provides detection against channel errors by using adaptive modulation and coding techniques. It process CQI reports from user and inform upper layers to provide better services.

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Chapter 2

LTE presents a new way telecommunication network should be established, which can provide high data rates and internet access anywhere on mobile devices. It is worthwhile checking the workability of LTE on simulation software before changes are made in real network. Various companies invested in different LTE simulation software's. LTE-Sim is omnet++ based open source framework which provide performance verification of lte network. Various features of Lte such as user mobility, frequency reuse, scheduling policies etc. are modelled in this framework. Before talking more about LTE-Sim, a brief introduction about OMNET++ is explained below.

OMNET

OMNET++ is a C++ based discrete event simulator for modelling wired or wireless networks, multiprocessors, protocol modelling and other distributed systems. It is a tool in which we can create simulation environment. Simulations are written in form of models. An Omnet++ model consists of reusable modules. There are two types of modules, simple modules and compound module (simple modules combine to form compound module). Simple modules are the active modules in the network, they are written in C++, using the simulation class library. Simple modules communicate by passing messages; messages can be sent to destination module directly, via gates or connections. Input and output interfaces of modules are called In gates and Out gates respectively. An input and output gates of simple modules can be linked with a connection.

Modules can have parameters. Parameters are mainly used to pass configuration data to simple modules, and to help define model topology. Compound modules may pass parameters or expressions of parameters to their submodules.

Structure of model can be defined in high-level language called NED. NED description defines simple module, compound module and network definitions. Simple module declarations describe the interface of the module i.e. gates and parameters. Compound module definitions consist of the declaration of the module’s external interface, and the definition of submodules and their interconnection. A network definition basically defines a model as an instance of a module type. OMNeT++ also includes a graphical editor which uses NED as its native file format.

Chapter 3

LTE-SIM

LTE-Sim is open source package to simulate Lte network on OMNET. It provides performance verification of LTE network. LTE-SIM is compatible with Inet framework. Several functions of both EUTRAN and EPS have been implemented in LTE-Sim. Under EUTRAN, eNBpp is implemented. In Evolved Core, Pgw and S-GW are implemented. UE is also modelled. If we look at protocol architecture of LTE, it can be viewed as user plane and Control Plane. Under user plane RLC, PDCP, MAC, PHY layers are modelled. Some functionality of control plane (RLC layer) is also modelled along with PDCP layer.

LTE is OFDM based technology i.e. user can be assigned resources by frequency division time multiplexing or frequency division time multiplexing. LTE-Sim provide radio resources to user in time-frequency plane, resources are allocated to user typically for 0.5 ms and over one sub-channel called resources block, which is the smallest radio resource that can be allocated to the user. It support single cell and multicell environment and provide Qos service, user mobility.

3.1 E-UTRAN of LTE in OMNET

EnodeB and UE, both of these nodes are implemented as protocol stack. There are four layers Pdcp_rrc, rlc, mac and phy. ***LtePdcpRrc.ned*** contain module for implementation of pdcp and rrc features for both Ue and Enb of lte network. It has a settrafficinformation class for setting rlc type that should be used for VOIP, Gaming, and Video application. Headercompress and headerdecompress classes to perform compression and decompression of packets received from upper layer. It has statics to record end to end delay and throughput. Ports (inout TM_Sap, inout AM_Sap, inout UM_Sap) to receive and deliver packets to different types of rlc units (am, um or tm mode). Relays are implemented to connect rrc layer to pdcp layer. When a packet is received from upper layer compression of packet is performed by headercompress class and then settrafficinformation class select the type of rlc entity required for transmission of packet down the link.

RLC layer is implemented under LteRlc.ned compound module. Different kind of applications require different type of rlc entity to support required quality of service, to support that feature TM mode, UM mode and AM mode rlc entity are required which are implemented as simple modules namely LteRlctm, LteRlcum and LteRlcam . For UM and AM mode packets received from upper layer need to be fragmented to the size defined by mac layer, to support this feature, transmission and receiving queue classes are implemented. In Am RLC mode reliable transmission is required to support that windowing and Ack features are implemented under simple AmRxQueue. Various performance parameters for uplink and downlink such as Rlc delay, Rlc throughput, packet loss, are also modelled. Data packets from different users or different applications need to share the radio resources, MUX entity (implemented as LteRlcmux simple module), multiplex RLC PDU and demultiplexing when packets are received from Mac layer.

Mac entity is designed for both user and EnodeB devices. Another important feature of LTE MAC layer is link adaption that means coding of packet being sent on link is changed according to the SNR ratio of the signal received on that link. If SINR is high, Higher-order modulation schemes with high spectral efficiency are used otherwise lower-order modulation with low spectral efficiency is used. To support this feature AMC (Adaptive modulation and coding techniques) entity is designed in which support for different types of coding techniques (auto, piloted, das and multi) are modelled. LTE is based on OFDMA technology, radio resources should be managed properly among various UE so that each user is given enough resources to transmit but there is no wastage of resources. LteMacEnb class has a parameter “rballocationtype” to support this feature. Power model for different type of frames (paging, syncro, normal etc.) are implemented in LteMacEnb class. To measure the performance of MAC layer parameters like throughput delay, HARQ error rate, buffer overflow and mac packet loss are implemented under the LteMacBase class.

Physical properties of EnodeB and UE are tailored under the phy entity. ***LtePhy.ned*** module implements the physical channel of the enb and Ue. LtePhy.ned has parameters such as eNodeBTxPower, relayTXPower, ueTXPower, microTXPower, userpropagationDelay, channel model. Channel features of Enb and UE can be changed to check the performance of LTE in several environments. LTERealisticChannelModel.cc class has different options to model the physical layer of LTE; height of antenna, height of building, correlation distance, Antenna gain, thermal loss, cable loss, noise figure, carrier frequency (default of 2GHz) and various other features are implemented to provide a realistic view of LTE simulation. Interference due to other cells and path loss is also measured.

Sim-LTE also support the mobility of user i.e. user can move. Doppler shift due to the mobility of user is measured. Various parameters of the channel (such as fading) are measured and signal transmitted to the user is changed accordingly.

3.2 Core of LTE in OMNET

To analyse the workability of user plane (EUTRAN), EPC (core) is required, so that packets can be sent outside network to other networks or to check transfer of packet from one service gateway to another. For that purpose two nodes are created namely packet gateway and service gateway. All functions of packet gateway and service gateway are not yet implemented, but the basic function to form tunnels and to send packets to outside network and LTE-to-LTE has been modelled. Two entities specifically ***Traffic Flow Filter and GTP-U*** (GPRS Tunnelling Protocol- user) are modelled.

TFT (traffic flow filter) is a classifier which matched the inner packet of GTP tunnel and provides different radio bearer performance. Packets can be matched according to source address, IP protocol type, Destination port range, type of service, Source port. Static or dynamic TFT can be used, in SIM-LTE, static TFT filtering is used. After filtering packets dedicated bearer is created and traffic is imposed on that bearer and required Qos is provided to the traffic. In SIM_LTE, TFT is designed for ipv4 addresses. Packets are filtered according to the source address and destination addresses. Filtering based on port is not yet implemented. After filtering TFT, IDs are assigned to the packets, which are used by the GTP-u to route packets in tunnels. At EnodeB filtering table is indexed by source address first so either source name or source address should be mentioned, whereas at P-GW filtering table is indexed by destination address. Traffic Flow Filter keeps a table for mapping traffic according to destination IP address.

GTP-U is used for carrying user data between the radio network and core. The user data transported can be any of IPv4, IPv6 or PPP format. GTP protocol header has 32 bit TEID (Tunnel endpoint identifier) field which is used to identify different connections in same tunnel. Each user can have multiple tunnels between same endpoints to have different Qos for different type of applications. An IP packet for a UE is encapsulated in a GTP-U packet and tunnelled between the P-GW and the EnodeB for transmission with respect to a UE over S1-U and S5/S8 interfaces. In SIM-LTE GTP-U keeps two tables one for mapping TFT to TEID id and other for TEID to TEID table, it receives packets from traffic flow filter and maps packet to specific bearers and then tunnel them tcp/ip stack or outside network.

Packet gateway and EnodeB has both traffic flow filter and GTP, whereas service gateway has only GTP-U. When packets are received by EnodeB or P-GW, they are filtered by TFT according to the Qos (In EnodeB on basis of source address and in P-GW based on Destination address) and then these packets are tunnelled by GTP-U from one service gateway to other or S-GW to Internet or vice-versa. S-GW swaps the label and forward packet in GTP-U tunnel.

3.3 Traffic models

Another important force driving the need for development of LTE is availability of various applications on one single device. Lte provide power to access different applications on mobile device of user. Sim-LTE has implemented two features to test the implementation of lte simulation namely ***VOIP, Gaming and VOD***. In LTE voice is delivered on IP packets, the analog voice is encoded and packetized and streamed over the ip network and reverse process is performed at receiving side. Similarly, Video on demand is another feature of lte which also implemented. Video and voice packets are treated differently by various layers and different Qos is provided.

3.4 Other models used in simulation

Configurator: IPv4NetworkConfigurator module assign IPv4 addresses to the various nodes of the network. It checks if there is duplication of addresses. User can pass parameters (in form of xml files) to this module and assign IP to the network.

LTE Binder: It stores table of ip address and corresponding node. This is used by sender to find the Id of the destination node.

LTE Deployer : This module has classes to change the radio parameters of the LTE network. Number of channels per band, number of OFDMA symbols per slot, number of signalling symbols per channel all these features can be modified, to test the various modified implementation of LTE networks in different environments.

Chapter 4

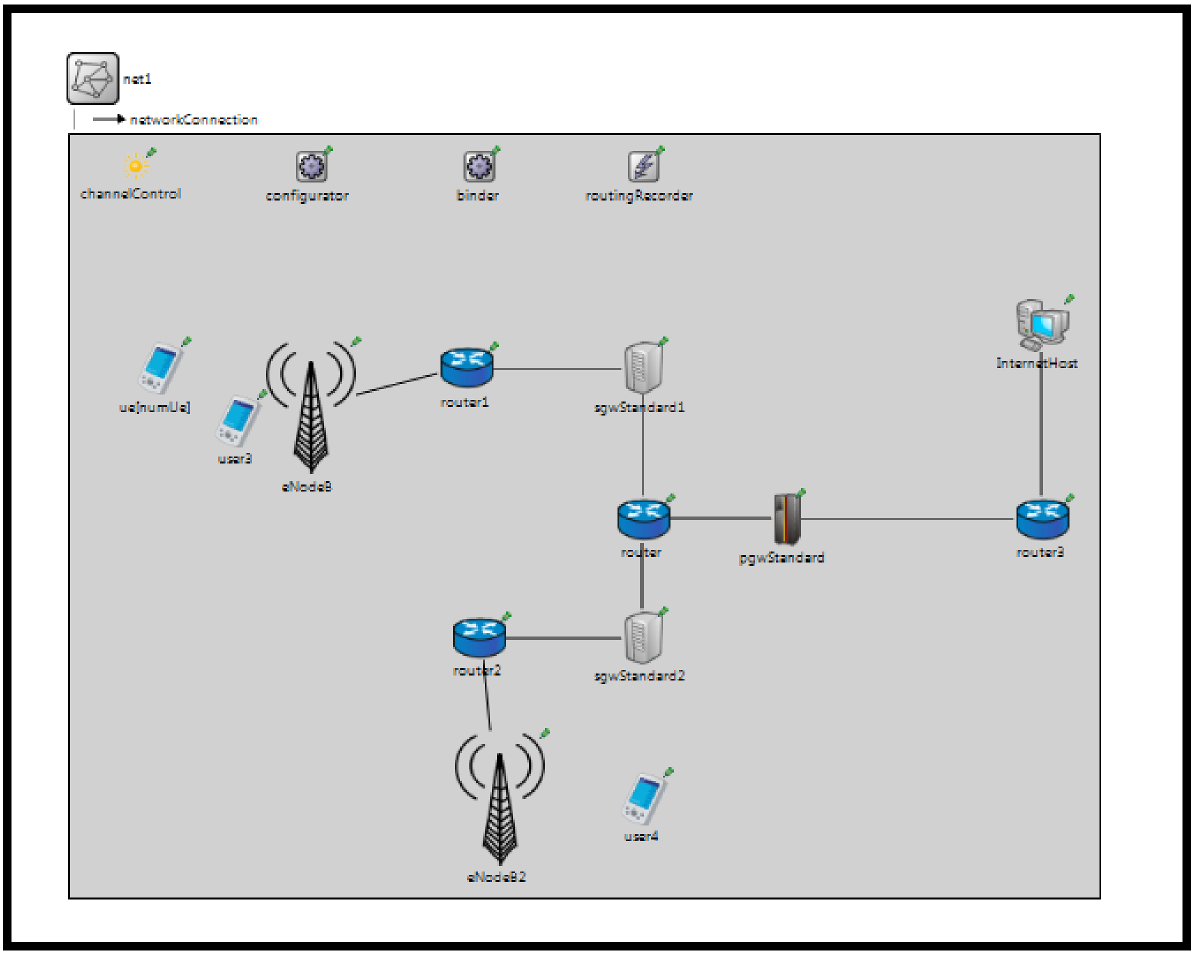
Simulation model and configurations

4.1 Objective

The main focus of this simulation is to check the effect of increasing number of users on performance of network and to validate the implementation of LTE network on OMNET++.

Simulation overview is shown in diagram below.

Figure 2: Simulation Diagram



4.2 Simulation Specifications

There are four routers in current simulation design. There can be several EnodeB's under one service gateway, to direct IP based traffic routers are required to connect S-GW to each EnodeB. In current simulation there is just one EnodeB in the network so there is no need for special routing in connecting routers.

There are 41 users under one EnodeB and 1 user under EnodeB2. Each user is configured with one service type. 40 users (ue[numUe]) under EnodeB are downloading video from server outside the Lte network and user3 under EnodeB is sending VOIP packets to user4 under EnodeB2. For user mobility, Imobility model is used in users and UE are moving linearly at different speed.

Mobility type of all UE = linear mobility

To look at the impact of increasing number of users in network on ue[0] VOD packets and user-4 VOIP packets. Simulation is executed with four different scenarios having different number of active users. Simulations run time in each case is 12 sec with warm-up period of 0.08s.

Scenario 1:

Ue[0] is active after 1sec

User 3 and user 4 are active after 0.08

Scenario 2:

Ue[0] is active after 1sec

ue[1] to ue[9] are active after 1.5sec

user3 and user 4 are active after 0.08sec

Scenario 3:

Ue[0] is active after 1sec

ue[1] to ue[9] are active after 1.5sec

ue[10] to ue[19] are active after 2sec

user3 and user 4 are active after 0.08sec

Scenario 4:

Ue[0] is active after 1sec

ue[1] to ue[9] are active after 1.5sec

ue[10] to ue[19] are active after 2sec

ue[20] to ue[29] are active after 2.5sec

user3 and user 4 are active after 0.08sec

Scenario 5:

Ue[0] is active after 1sec

ue[1] to ue[9] are active after 1.5sec

ue[10] to ue[19] are active after 2sec

ue[20] to ue[29] are active after 2sec

ue[30] to ue[39] are active after 0.02sec

user3 and user 4 are active after 0.08sec

Speed of UE

Ue[0..9] and ue[30..39] = 0mps

Ue[10..19]   = 4mps

Ue[20..29]   = 2mps

Common configuration in all scenarios are explained below

Channel:

Delay = 0.1micro sec

Data rate = 10Mbps

AMC module parameters:

Radio resource allocation type = localized

Max harq retransmission = 3

Transmitted power = 40

Scheduling = MAXCI

Physical layer specifications are passed through channel.xml file.

Encoding = UTF-8

Carrie frequency = 2 GHz

EnodeB noise figure = 5

UE noise figure = 7

Antenna Gain of EnodeB = 18

Antenna Gain of ue = 0

IP are passed through xml file to ipv4 network configurator. Lte and outside network (server) are given different IP networks.

To check the consequence of mobility of users, all scenarios discussed above are repeated with all ue under EnodeB having zero mobility.

4.3 Simulation result and Analysis

To measure the effect of increasing number of users on VOD packets received by particular user, End-to-end delay is measured for ue[0] with different number of users in network with and without mobility. Below figure show values recorded from simulation.

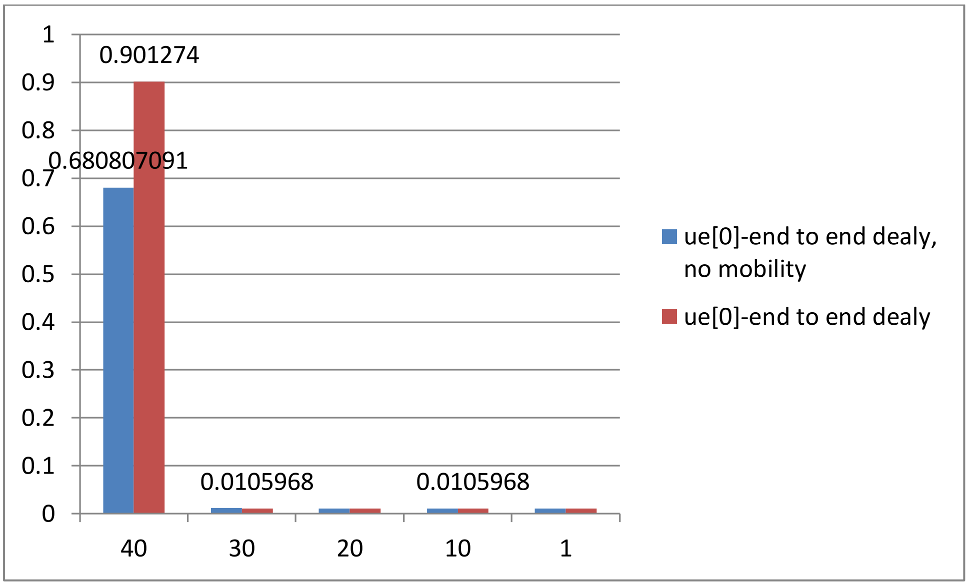


Figure 3: The effect of number of users on end to end delay of ue[0]. X-axis show the number of users and Y-axis show value of delay in sec.

When network has users in range 1 to 30 performance of system remains pretty good (value of delay remain same i.e. 0.0105968 sec) and then start degrading with more users in system. With 40 users in system end to end delay when users are mobile is more then with static users in system. In order to achieve satisfactory performance for VOD packets, more radio resources should be assigned to EnodeB, but statically assigning more resources is wastage as every network has limited amount of bandwidth. Thus dynamic resource allocation is needed, i*n Sim-LTE RRC layer is not implemented which handles the dynamic allocation of resources*.

Throughput is another important performance measure of LTE network. Omnet provide measurement of throughput at various layers. Throughput measurement provides how effectively channel is utilized and how effectively messages are delivered across the network without error. Mac throughput measurements for ue[0] show that system has good throughput up to 30 users and start decreasing with more users, which is basically due to the large queue at EnodeB and static resource allocation.

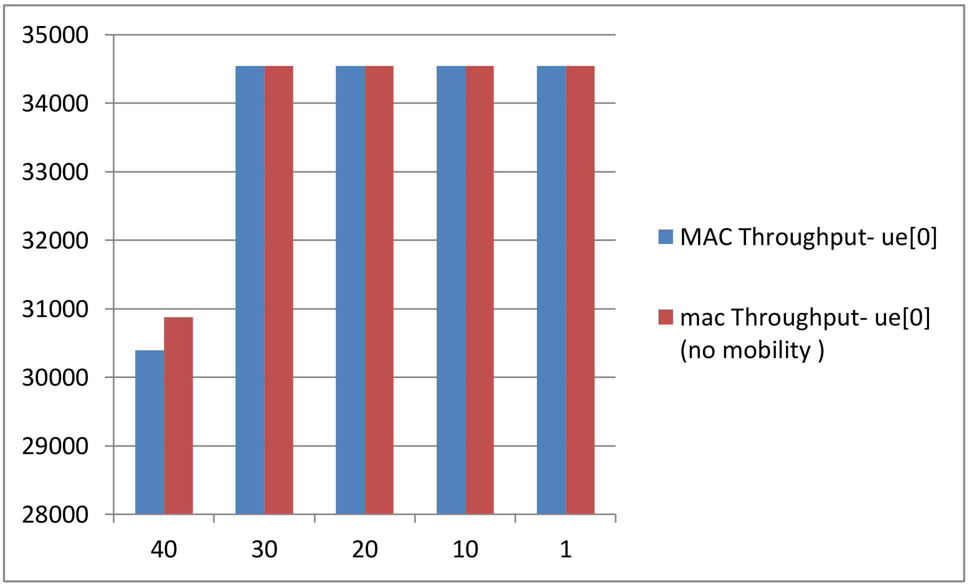


Figure 4: Show mac throughput downlink of ue[0] with different number of users in system

MOS (mean opinion score) measures subjective call quality for a call. It ranges from 1 (acceptable quality) to 5 (excellent quality). Measurements from simulations show how the MOS changed with changing number of users in the system. User-4 (which is under EnodeB2) is receiving VOIP packets from user-3 (which is under EnodeB). Figure 5 and Figure 6, shows MOS and frame delay for user4 respectively.

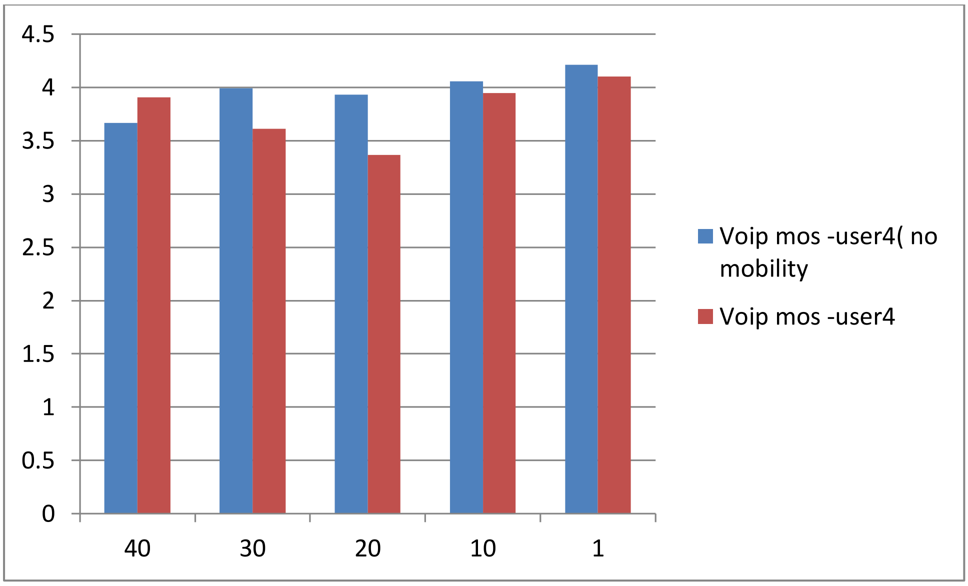


Figure 5: *Above figure show the mean opinion score of user-4 with change in the number of users under EnodeB with and without mobility*

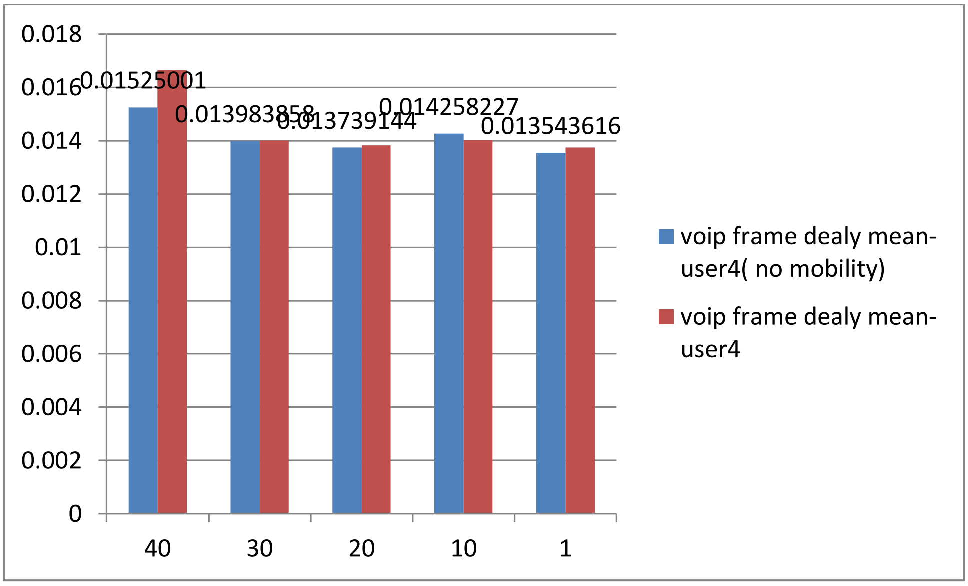


Figure 6: Show mean frame delay of user4 with different number of users with and without mobility

By looking at bar graphs we can see that how the services of user-4 are being affected by increased number of users in different cells.

Reason for increase in delay for user 4 might be the delay packets suffer while travelling from user3 to EnodeB and through network.

One more interesting point about Sim-LTE is that it provides Qos to voip and video packets. With variation in number of users in system voip frame delay does not change as much as video end to end delay. Min video delay is 0.01 sec and max is 0.68 sec whereas for voip packets it changed from 0.013 sec to 0.015 sec.

Chapter 5

Conclusion

LTE network simulator (Sim-LTE) is modelled and implemented in the OMNET simulator environment. The model includes detailed layered EUTRAN model, Mobility model, channel model. Voice and video traffic models are used to test and validate the performance of network. Benefit of modularized approach is that it provides flexibility to change configurations of various nodes in the network and to test different network conditions. End-to-end delay, VoIP, MOS mean, throughput are measured for different UE .modules.

From result analysis of simulation, it can be concluded that under given conditions, network work well up to certain number of users but performance degrades if more users are active. Preference is given to VOIP packets as compared to Video. There was no drop of VOIP packets with increased number of users, but delay increases. Reason for such a result might be that there was no dynamic allocation of radio resources by EnodeB. Bandwidth assigned to each EnodeB must be shared among all users which result in increased delay.

In real networks, radio resources are assigned dynamically to each EnodeB. When there are more users under EnodeB then it can serve, it can perform Intra-cell handover (to another cell under same EnodeB) or it can stop accepting new users or more bandwidth can be given to that EnodeB to handle load. RRC layer plays this role of managing dynamic resources and performing handover. In SIM-LTE, RRC layer is not yet implemented which limit the performance.

Moreover, current version of Sim-LTE doesn't contain model for Evolved core of LTE. Packet filtering feature of S-GW and P-GW are modelled but other features such as authenticating users, charging, services available are not yet modelled.

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