Simulation and Performance Analysis of Long Term Evolution (LTE) Cellular Networks for Downlink

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Abstract—In the development, standardization and implementation of LTE Networks based on Orthogonal Freq. Division Multiple Access (OFDMA), simulations are necessary to test as well as optimize algorithms and procedures before real time establishment. This can be done by both Physical Layer (Link-Level) and Network (System-Level) context. This paper proposes Network Simulator 3 (NS-3) which is capable of evaluating the performance of the Downlink Shared Channel of LTE networks and comparing it with available MatLab based LTE System Level Simulator performance.

Keywords: 3GPP, LTE, Downlink, NS-3, Simulator, MAC, PHY

I. INTRODUCTION

The Long Term Evolution (LTE) standard specified by the 3rd Generation Partnership Project (3GPP) is a new mobile communication technology, which is evolution of the Universal Mobile Telecommunications System (UMTS) and High-Speed Packet Access (HSPA) systems. LTE intends to deliver high speed data and multimedia services to next generation. LTE is also backward compatible with the CDMA family of technologies and thereby enables even CDMA operators to move to this technology. The main reasons for these changes in the Radio Access Network (RAN) system design are the need to provide higher spectral efficiency, lower delay, and more multi-user flexibility than the currently deployed networks. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time-division duplexing (TDD). The IP-based network architecture called the Evolved Packet Core (EPC) is designed to replace the GPRS Core Network. The LTE device has been conceived as a container of several entities: the IP classifier, the RRC entity, the MAC entity and the PHY layer. The core of the LTE module is composed by both MAC and PHY layers of an LTE device.

The Evolved Packet Core comprises the Mobility Management Entity (MME), the Serving Gateway (SGW), and the Packet Data Network Gateway (PGW). The MME is responsible for user mobility, intra-LTE handover, and tracking and paging procedures of User Equipments (UEs) upon connection establishment. The main purpose of the SGW is, instead, to route and forward user data packets among LTE nodes, and to manage handover among LTE and other 3GPP technologies. The PGW interconnects LTE network with the rest of the world, providing connectivity among UEs and external packet data networks. The LTE access network can host only two kinds of node: the UE (that is the end-user) and the eNB. Note that eNB nodes are directly connected to each other (this speeds up signaling procedures) and to the MME gateway. The eNB is the only device in charge of performing both radio resource management and control procedures on the radio interface. Figure 1 shows Service Architecture Evolution in LTE network [7].

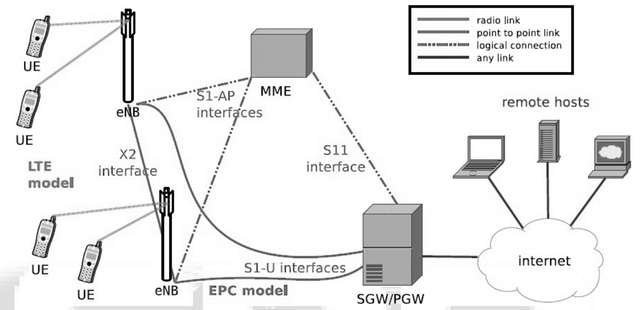

Fig. 1 Service Architecture Evolution in LTE network[1]

Multiple-Input Multiple-Output (MIMO) gains, Adaptive Modulation and Coding (AMC) feedback, modeling of channel encoding and decoding or physical layer modeling for system-level can be achieved by Link Level. Network-related issues such as scheduling, mobility handling or interference management can be achieved by System Level. Link-Level simulation tools are limited to consider the performance at the physical layer only. System level simulators (such as MatLab based) can go beyond the physical layer by introducing the MAC layer together with an abstract model of the higher layers. Due to this abstraction of the higher layers and evaluation of Radio Resource Management (RRM) algorithms, it cannot provide proper end-to-end performance and behavior of the network as a whole. Solution is Network Simulator and it can implement all the protocol layers from the MAC up to the application. LTE network simulator supports single and multi-cell environments, QoS management, multi user's environment, user mobility, handover procedures, scheduling, interference management and frequency reuse techniques.

In this proposed work, creation of LTE Network in NS-3 and its comparison with MatLab based System Level Simulator described. Require simulating LTE technology like scheduling or interference management using NS-3.

II. THE LTE MODULE FOR NS-3

Figure 2 shows schematic block diagram of LTE system level simulator [5].

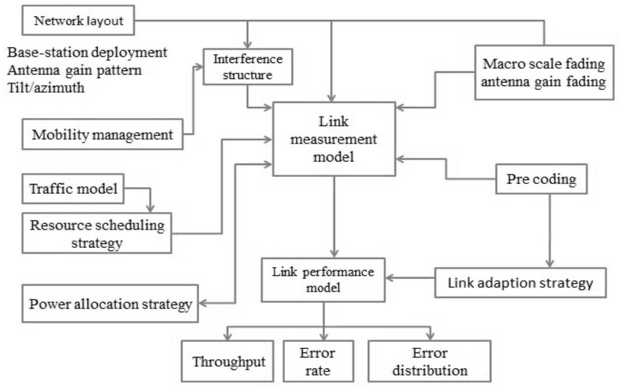

Fig. 2 LTE system level simulator

Similarly to other system-level simulators, the core part consists of (i) a link measurement model and (ii) a link performance model. The link measurement model abstracts the measured link quality used for link adaptation and resource allocation. On the other hand the link performance model determines the link Block Error Ratio (BLER) at reduced complexity.

The most important features provided by the proposed LTE NS-3 module are

1) A basic implementation of both the User Equipment (UE) and the enhanced NodeB (eNB) devices,
2) RRC entities for both the UE and the eNB,
3) A state-of-the-art Adaptive Modulation and Coding (AMC) scheme for the downlink,
4) The management of the data radio bearers (with their QoS parameters), the MAC queues and the RLC instances,
5) Channel Quality Indicator (CQI) management,
6) Support for downlink packet scheduling,
7) A channel model with propagation loss model,
8) Interference Management.

III. NETWORK DEVICES

NS-3 device contains and manages the main entities of the E-UTRAN protocol stack i.e. RRC, RLC, MAC and PHY. The UE stores information about which eNB it is registered to and using UE Manager, the eNB knows all the registered UEs. The most important task of the eNB is the Radio Resource Management (RRM).

A. Radio Resource Management Entity

In LTE, each traffic flows between the UE and the eNB are grouped into logical entities called End-to-End Bearers which are identified by their common end-to-endd QoS requirements and the corresponding accounting and billing policies. In detail: (i) the type of a radio bearer (Guaranteed Bit Rate (GBR) or Non-Guaranteed Bit Rate (Non-GBR)); (ii) The QoS Class Identifier which identifies the different treatment to be adopted for each bearer; (iii) The value of the guaranteed bit rate that represents the expected bit rate for a GBR bearer; (iv) The minimum bit rate to provide to the GBR bearer.

B. The RRC Entity

The Radio Resource Control (RRC) entity handles (i) connection establishment and management, (ii) broadcast of system information, (iii) radio bearer establishment and management, (iv) mobility management, and (v) paging. The interaction between the MAC and the Radio Bearer is provided by the RLC entity. In this simulation model, the RLC entity takes care of dequeueing the packets from the MAC queue and delivering them to the lower layer. RLC delivers all packets to the MAC layer without performing neither segmentation nor concatenation and without adding any RLC header.

C. The MAC Entity

The MAC Entity provides an interface between the device and the physical layer for both the UE and the eNB devices. It is responsible for the creation of the transport block to be sent to the PHY layer by composing packets and/or fragments provided by the RLC. Moreover, the MAC entity hosts the Adaptive Modulation and Coding (AMC) module.

D. The Adaptive Modulation and Coding module

It takes care of adapting the modulation and coding scheme used in the physical layer to the channel conditions faced by each user, in order to maximize the channel capacity and keep the residual bit error rate below a maximum acceptable threshold. The MAC scheduler needs to consider the behavior of AMC in order to take effective scheduling decisions. AMC module provides an unique mapping among the CQI, the MCS, the spectral efficiency, and the Transport Block (TB) Size.

E. CQI management

The eNB sends reference symbols every Transmission Time Interval (TTI), spreaded over the whole operative downlink bandwidth. In order to estimate the channel quality, the UE uses the data collected from these reference symbols to compute the SINR (Signal to Interference plus Noise Ratio) of the received signal. In particular, a SINR value is obtained for each downlink sub-channel. These values are then converted into CQI values that are sent to the target eNB using the uplink control channel.

IV. SIMULATION RESULT AND COMPARISON

The MATLAB based simulation result of this algorithm is shown in Fig. 3, Fig. 4 and Fig. 5 [5].

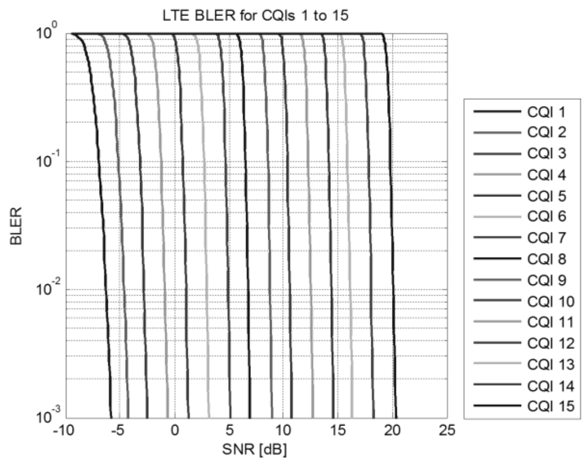

Fig. 3 BLER (Block Error Rate) for CQIs

A single CQI value is used to convey the channel quality over a large number of Scheduling Blocks (SBs), the scheduler may not be able to distinguish the quality variations within the reported range of subcarriers.

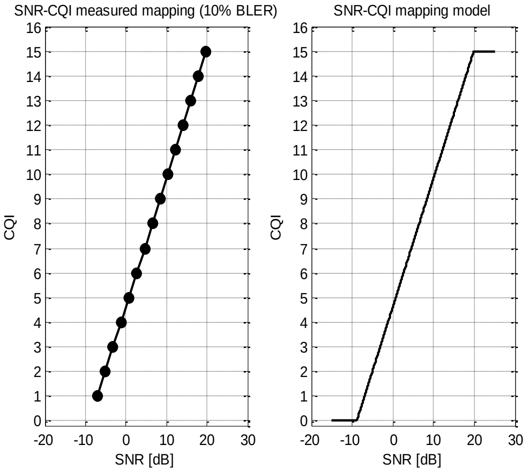

Fig. 4 SNR-CQI Mapping

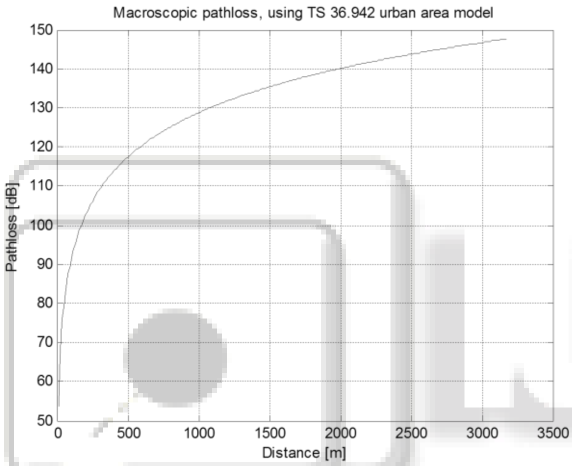

Fig. 5 Macroscopic Pathloss and Fading

The NS-3 based simulation result of network creation with 2 UE and 2 eNB is shown in Fig. 6

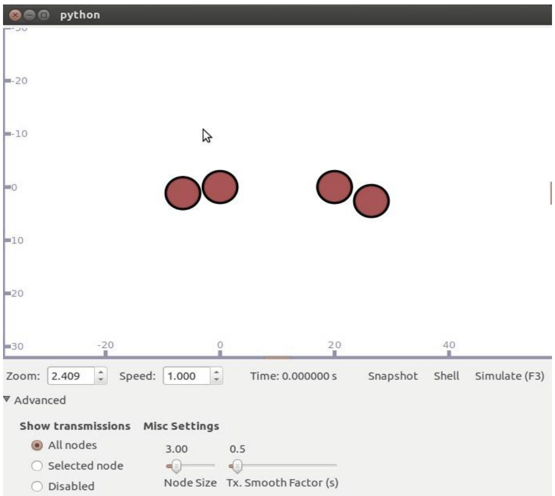

Fig. 6 Network created for CQI threshold, Pathloss and Fading

Time	Cell ID	IMSI (Unique UE ID)	Frame Number	Subframe Number	RNTI (Cell-specific UE ID)	MCS of TB 1	Size of TB 1
0.001	1	1	1	2	1	0 (Not Present)	81
0.001	2	3	1	2	1	0	81
0.002	1	2	1	3	2	0	81
0.002	2	4	1	3	2	0	81
0.003	1	1	1	4	1	0	81
0.003	2	3	1	4	1	0	81

Table. 1: Downlink MAC output (2 eNBs and 2 UEs)

Start time of Measurement	End time of Measurement	Cell ID	IMSI (Unique UE ID)	RNTI (Cell-specific UE ID)	Logical Channel ID	Number of Transmitted RLC PDUs	Total bytes Transmitted
0	0.25	1	1	1	1	2	162
0	0.25	1	2	2	1	1	81
0	0.25	2	3	1	1	2	162
0	0.25	2	4	2	1	1	81

Table. 2: Downlink RLC output (2 eNBs and 2 UEs)

V. CONCLUSION

Studied the basic concepts of Long Term Evolution, Orthogonal Frequency Division Multiple Access, LTE networks, MatLab based System Level Simulation, Ubuntu Operating system and Network Simulator 3. Simulated code of CQI, pathloss and fading modules for LTE downlink using MatLab and NS3. Using NS3, Implemented interface between User Equipment (UE) and the enhanced NodeB (eNB) devices.

Obtained the expected results and found that MatLab based System Level simulation can go up to Physical Layer simulation properly and require more computational time. Downlink MAC and Downlink RLC output shows quick response between interfaces UE-eNB, can try for more UEs.

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