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LTE Performance Measurement In Trial Network & Validation Of LTE Performance Estimation Models

A thesis submitted in partial fulfillment of

Master of Science

By

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Abstract

After GSM(2G) and UMTS(3G), 'Long Term Evolution' (4G) networks are gaining popularity as the latest mobile telecommunication standard. The prospective roll out plans for LTE in The Netherlands emphasize the need for accuracy in the LTE performance optimization and prediction models. The drawback of theoretically based modeling approaches are that they lack knowledge about the performance and practicalities of the LTE radio interface features observed in realistic deployments.

In this thesis, the problem is addressed by first measuring the LTE radio performance from a small scale trial network and by later comparing the results with simulations performed for similar usage scenarios. The main features chosen for investigation are the performance impact of activating the MIMO (Multiple Input Multiple Output) antenna technology in the downlink and the closed loop and open loop power control schemes in the uplink.

The measurements were performed on a 10 MHz spectrum with the available two operational frequency bands (800 MHz and 1800 MHz). On each measurement day the settings are configured at the base stations. The indoor tests are done inside the office building and for the outdoor tests, we drive around in a car along the pre-defined drive routes with the user equipment. Various tools are used to log data at the network side and for each user in the test environment. The simulations are performed on a centralized server with ten replications for each test case with settings the same as that of the measurement plan. Results are averaged at the end to increase the statistical reliability. After post processing measured and simulated performance results, based on the analysis, we draw conclusions and give recommendations are given to improve the existing LTE models/simulators.

Preface

As a child, I have always wondered at the tremendous innovations in the telecom sector, the advent of smartphones and tablets carrying information and entertainment at our finger tips. Past 9 months of my work at TNO was a great learning opportunity to gain practical knowledge of the LTE networks which boosts high speed connectivity and instant video on demand.

I am excited of having successfully completed my thesis. At this juncture, I would like to express my sincere gratitude to my supervisor Dr. Ljupco Jorguseski who patiently took me into the research team and provided me with valuable ideas and approaches for my work.

I want to extend special thanks to Prof. Rob Kooij who supervised me from TU Delft by listening to my research updates and by giving advices for improvement.

Many thanks to my friends Yohan Toh, Kostas Trichias and Hans Schmidt with whom I worked in close association while gathering data from the LTE trial network set up across the TNO offices in Zuidflank, Brassersplein and Van Mourik Broekmanweg. They are very cheerful, always willing to help and I have fond memories of the time spent at the control room in the Zuidflank office.

Thanks to Dr. Remco Litjens for providing the LTE simulator, a key tool for theoretical simulation performance.

Thanks to Peter and Jaap for assistance in the car while doing drive tests.

Last but not the least, I want to thank God Almighty; my parents and my brother Varghese who are very proud of me, they are my source of inspiration and sound health.

Susan Mathew

Delft, The Netherlands
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List of Abbreviations

3GPP - 3rd Generation Partnership Project

CLPC – Closed Loop Power control

CP – Cyclic Prefix

EPC - Evolved Packet Core

E-UTRAN - Evolved UMTS Terrestrial Radio Access Network

FFR - Fractional Frequency Reuse

GPS – Global Positioning System

ICIC - Inter Cell Interference Coordination

IMS - IP Multimedia Subsystem

MIMO - Multiple Input Multiple Output, an antenna technology

OFDM - Orthogonal Frequency Division Multiplexing

OLPC – Open Loop Power control

PDN - Packet Data Network

PDSCH - Physical Downlink Shared Channel

P-GW - PDN Gateway

PRB - Physical Resource Block

PUSCH- Physical Uplink Shared CHannel

QoS - Quality of Service

RRU - Remote Radio Unit

RSRP - Reference Signal Received Power

RS SNR - Reference Signal's Signal to Noise Ratio

SINR - Signal to Interference and Noise Ratio

S-GW - Serving Gateway

SON – Self Optimizing Networks

TPC - Transmit Power Control

UE - User Equipment

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Chapter 1

Introduction

In the recent years, there are manifold increases in the mobile data services as more and more people enjoy emailing, video streaming, web browsing, social networking and interactive game play on the move. Latest studies from Cisco VNI [1] revealed a 2.3-fold increase for global mobile data traffic in 2011, doubling for the fourth year in a row and predicts an 18-fold increase for the next five years in this field. The trend is facilitated by 3G services with easy accessibility from handsets and USB dongles, but these networks tend to be capacity constrained with exhaustive data usage. The latest 3GPP standard Long Term Evolution (LTE) [2] as a follow-up of UMTS is designed to make significant contributions in this direction by providing increased peak data rates (up to 50 Mbps uplink and 100 Mbps downlink for 20 MHz bandwidth) and spectral efficiency (up to 2.5 bps/Hz uplink and 5 bps/Hz downlink), reduction in network latency, scalable bandwidth capacity (ranging from 1.25 up to 20 MHz), better cell edge performance and more importantly it is backward compatible with both 2G and 3G standards.

From a world-wide perspective, many operators have already deployed and operate on commercial LTE networks [3]. At this juncture, there is substantial LTE theoretical and simulation modeling knowledge available at TNO. However, what is lacking is a practical hands on experience with LTE systems to compare the LTE performance measurement results to improve the accuracy of the theoretically based simulation performance analysis. Being an emerging new technology, the potential market success of LTE will depend on the satisfactory level of performance it offers to the end users.

1.1 Problem Statement

This thesis is motivated to broaden the scope of expertise in the LTE network technology. The main aim of the research is to narrow down the gap between the observations in a deployed LTE network and the TNO's LTE performance optimization and prediction models. This study intends to find out how the LTE simulator predictions relate to a realistic LTE deployment and what improvements they require with regard to their current implementation based on literature.

The chosen area of focus is to understand the working of LTE radio network interface including uplink and downlink performance for the available dual frequency bands – 800 MHz and 1800 MHz, the impact of system and channel conditions on uplink specific features like open and closed loop power control schemes and downlink specific features like multi antenna technologies using Multiple Input Multiple Output (MIMO).

1.2 Thesis Contributions

Being part of the first few users of LTE network in the Netherlands, the thesis gave the opportunity to :

- To evaluate the ability of the TNO theoretical models to predict LTE radio performance achievable in practice.
- Propose adjustments to improve the theory based prediction models using results from LTE measurement in the field trial.

1.3 Thesis Outline

The remaining parts of this thesis are structured as follows:

Chapter 2 provides the background obtained by reading literature materials related to our work.

Considerable portion of this report is devoted to the measurements on the radio interface. Chapter 3 provides an understanding of tools and performance metrics used. Overview of the measurements plan is given in chapter 4. The measurement results are discussed in detail and summarized in chapter 5.

Chapter 6 explains the simulator in brief and the approach used in performing simulations. The simulation results, its comparison with field trial results are given in chapter 7.

Chapter 8 presents the conclusions drawn and recommendations for future modeling updates.

Chapter 2

Background

This section presents the theoretical knowledge required for understanding the concepts discussed in this thesis. It is intended as a background reading in order to comprehend the chapters to come.

Description Of Investigated LTE Radio Interface Features

The LTE physical layer is used in two scenarios, first when the users perform download, in this case the data is directed from eNodeB towards UE and second when users perform upload directing data towards eNodeB from UE. Physical Shared Channels are explicitly present for Downlink and Uplink known as PDSCH and PUSCH respectively. They work with QPSK, 16QAM and 64QAM modulation schemes. PDSCH supports spatial multiplexing giving a chance to investigate the working of MIMO modes. A generic frame structure is common to both UL and DL consisting of frames having 10 msec duration. A frame is divided into 20 slots with 0.5 msec time period. Two slots together form a sub-frame that has 1 msec duration. Slots contain OFDM symbols separated by cyclic prefixes (CP) which are the ending portion of previous symbol repeated before the starting of a new symbol as guard intervals to reduce Inter Symbol Interference (ISI).

The OFDM symbols are 6 (long CP) or 7 (short CP) in number. The smallest element allocated as resource to a user is obtained by combining 12 consecutive subcarriers (with 15 KHz sub-carrier spacing) in each slot, this is called a Physical Resource Block (PRB) in LTE. As our operational bandwidth is 10 MHz, the maximum number of PRBs is 50 based on specifications [16].

This sub-section aims to provide readers the underlying principles behind downlink and uplink specific LTE radio interface measurements performed in chapter 4 of this report.

Multiple Input Multiple Output (MIMO) Downlink Transmission

MIMO aims to provide increase in data throughputs and link range by making use of the multi-path characteristics of the wireless channels. The concept of spatial multiplexing improves spectral efficiency by permitting transmission of multiple streams of data simultaneously on the same downlink resource blocks. The data streams can be of single or multi users. The transmit antennas transmit different data streams and receive antennas can receive all of the transmitted data streams. The channel consists of channel matrix H , see Figure 2-1, with dimension $N_t \times N_r$, where N_t is the number of transmit antennas and N_r the number of receive antennas. The coefficients H_{ij} of this matrix represent all possible paths between transmitter and receiver side.

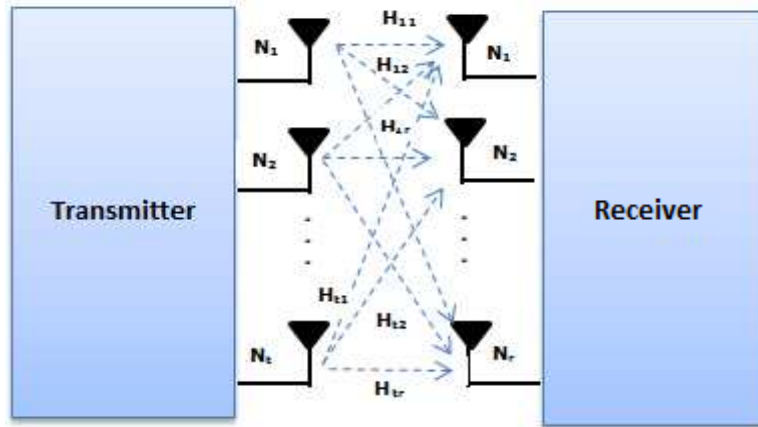


Figure 2-1: Block Diagram of MIMO transmission system

2.2.1 Uplink Power Control Schemes - Closed Loop and Open Loop

The power control scheme is setting up the output power levels for LTE transmitters e.g. at eNodeBs during downlink transmission and at UEs during uplink transmission.

The uplink TPC for the Physical Uplink Shared Channel (PUSCH) used for uplink data transmission is defined in 3GPP Specification TS 36.213 [6] by the following equation :

$$P_{PUSCH}(i) = \min\{P_{CMAX}, 10\log_{10}(M_{PUSCH}(i)) + P_{0_PUSCH}(j) + \alpha(j) \cdot PL + \Delta_{TF}(i) + f(i)\}$$

Chapter 3

LTE Radio Interface Measurement - Tools and Performance Metrics

This chapter describes the measurement tools and the data processing approach used for the analysis of the collected measurements during the LTE trial at TNO. Section 3.1 presents the processing approach based on the measurement data logged at the measurement terminal while section 3.2 presents the processing approach of the measurement data logged at the network side via the measurement traces. To ensure fair comparison of the results specific performance metrics are used to process the logged measurement data and graphs are plotted based on them.

Chapter 4

LTE Radio Interface Measurement Plan

This chapter describes the various operation and measurement tests conducted on the LTE trial network set up for getting a greater insight about the performance, overall system capacity, observed latency and spectral efficiency, the cell-edge performance etc. The tests were focused on investigating LTE radio performance from an end user perspective, to give definite answers to whether this technology guarantees all the data services to the operators as defined in the LTE specifications.

These measurements sheds light on actual data obtained from an up and running LTE network, it plays a strong influencing role on the design decisions to aid in the successful LTE deployment. An optimal performance vs. cost effective radio planning evolves from good design decisions resulting from a thorough understanding of the existing system behaviour.

Chapter 5

LTE Radio Interface Measurement Results

This section presents the measurement results for the plan listed in Chapter 4. Graphs are plotted as per post processing approach described in Chapter 3. Section 5.1 presents the results of downlink performance tests for MIMO algorithms and section 5.2 presents results of uplink performance test for closed and open loop power control schemes.

Chapter 6

Simulation Approach Overview

The goal of the simulation approach is to replicate the test case scenarios of the performed measurements via TNO's Delphi-based LTE downlink and uplink simulators in order to validate the consistency of their performance evaluation and prediction. A brief description of LTE downlink and uplink simulators along with input and output parameters and the simulation procedure is presented in this chapter.

Chapter 7

Simulation Results

This section presents the results of the performed simulations similar to field trial measurement plan. Section 7.1 gives downlink test results for MIMO and section 7.2 gives uplink test results for open and closed loop power control schemes. The summary and main differences is given in section 7.3.

Chapter 8

Conclusions and Recommendations

In light with the ambitious roll out plans for LTE in The Netherlands, an attempt is undertaken in this thesis to evaluate and refine the performance prediction capability of TNO's LTE downlink and uplink simulators. As part of our work we stitch together the results of TNO's LTE field trial which measures the radio performance from an end user perspective as close as possible to the real world with the simulation performance analysis results of the existing TNO LTE models.

In this investigation a 10 MHz spectrum LTE system is measured, with 800 MHz and 1800 MHz frequency bands and the usage scenarios were specific to estimating the peak data rate, capacity and coverage in combination with modeling of link budget for MIMO activation in the downlink and spectral efficiency for power control schemes in the uplink.

Recommendations

After a qualitative and quantitative analysis of the field trial measurements and simulation performance results, the possible causes for observed differences between them are identified and recommendations are derived for future studies.

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