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FPGA Implementation of LTE Downlink Transceiver with Synchronization and Equalization

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ABSTRACT

Long Term Evolution (LTE) is an advanced standard of the mobile communication systems. LTE has been developed by the 3rd Generation Partnership Project (3GPP). The new features exhibited by LTE is a direct impact of applying new modulation and coding techniques such as the Orthogonal Frequency Division Multiplexing (OFDM) for the Downlink and the Single Carrier Frequency Division Multiple Access (SC-FDMA) for the Uplink as well as turbo coding. This paper presents a Field Programmable Gate Array (FPGA) design and implementation of the LTE downlink transmitter and receiver according to releases 8 and 9 on Virtex 6 XC6VLX240T FPGA kit using Xilinx® ISE® Design Suite version 12.1. It is found that the utilization of the look up tables and flip flops amounts to about 65 percent while the other logic devices utilization on the chip amount to only 5–13 percent. Such implementations can be considered as IPs for software defined radios. The information is also useful for the FPGA developers. The most important consequence is that the FPGA vendors may produce more appropriate counts of the resource blocks for better the utilization of the chips used in the LTE transceivers.

Keywords

LTE, 4G, 3GPP, OFDM, 2G ,3G, LTE downlink physical layer, release 8, release 9 *Xilinx Design Suite, virtex 6 XC6VLX240T FPGA.*

1. INTRODUCTION

The Long Term Evolution (LTE) is an advanced standard for wireless voice and data communication.. The 3GPP standards' body has completed definition of the first release of the LTE system. The main advantages of the LTE, also known as 4G, over the 2G and 3G systems are utilizing a higher peak data rates by providing for an uplink speed of up to 50 megabits per second (Mbps) and a downlink speed of up to 100 Mbps. LTE will bring many technical benefits to cellular networks. Bandwidth will be scalable from 1.25 MHz to 20 MHz. This will suit the needs of different network operators that have different bandwidth allocations, and also allow operators to provide different services based on spectrum. LTE also improved spectral efficiency up to 5 bps/Hz for Downlink and 2.5 bps/Hz for Uplink, allowing carriers to provide more data and voice services over a given bandwidth.

The LTE physical layer (PHY) is a highly efficient means of conveying both data and control information between an enhanced base station (eNodeB) and mobile user equipment (UE). The LTE PHY layer employs some advanced technologies that are new to cellular applications. These include Orthogonal Frequency Division Multiplexing (OFDM) and Multiple Input Multiple Output (MIMO) data transmission. In addition, the LTE PHY layer uses Orthogonal Frequency Division Multiple Access (OFDMA) on the downlink (DL) and Single Carrier – Frequency Division Multiple Access (SC-FDMA) on the uplink (UL). OFDMA allows data to be directed to or from multiple users on a subcarrier-by-subcarrier basis for a specified number of symbol periods. Due to the novelty of these technologies in cellular applications, they are described separately before delving into a description of the LTE PHY layer.

LTE uplink requirements differ from downlink requirements in several ways. Not surprisingly, power consumption is a key consideration for UE terminals. The high PAPR and related loss of efficiency associated with OFDM signaling are major concerns. As a result, an alternative to OFDM was sought for use in the LTE uplink.

Single Carrier – Frequency Domain Multiple Access (SC-FDMA) is well suited to the LTE uplink requirements. The basic transmitter and receiver architecture is very similar (nearly identical) to OFDMA, and it offers the same degree of multipath protection. Importantly, because the underlying waveform is essentially single-carrier, the PAPR is lower [1-5].

The continued increase in the number of users of mobile communications all over the world, motivated researchers to search for a unified wireless platform. This will enable the mobile users to conduct business and exchange data easily while moving elsewhere in the world. The new features of LTE made it the promising platform intended for the advancements in mobile communications [6].

In the last few years, technology evolution in mobile communications is mainly motivated by two relevant agents: (1) the market globalization and liberalization and the increasing competence among vendors and operators coming from this new framework, (2) the exponential increase in the demand for advanced telecommunication services and we note that the computational framework and the insights gained via the numerical studies can be extended to other orthogonal division frequency multiple access (OFDMA) technologies. For that the many researchers are concerned with the development of implementation methods and techniques for the building blocks of the LTE physical layer. So, an extensive research work is directed to the implementation of the building blocks of this system using different platforms [7-10].

This paper presents the simulation and the FPGA implementation of the LTE downlink physical layer (on Virtex 6 XC6VLX240T FPGA kit) according to release 9 using Xilinx package version 12.1. Every stage in both the transmitter and receiver are implemented, and verified. The paper is organized such that section 2 presents the full detailed description of the building blocks of the LTE transmitter and

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Cognitive Radio Oriented Wireless Networks Ingrid Moerman,Johann Marquez-Barja,Adnan Shahid,Wei Liu,Spilios Giannoulis,Xianjun Jiao,2019-01-08 This book constitutes the refereed proceedings of the 13th EAI International Conference on Cognitive Radio Oriented Wireless Networks CROWNCOM 2018 held in Ghent Belgium in September 2018 The 20 revised full papers were selected from 26 submissions The papers are organized thematically in tracks Experimental Licensed Shared Access and Dynamic Spectrum Access and PHX and Sensing **Signal Processing for 5G** Fa-Long Luo,Charlie Jianzhong Zhang,2016-08-04 A comprehensive and invaluable guide to 5G technology implementation and practice in one single volume For all things 5G this book is a must read Signal processing techniques have played the most important role in wireless communications since the second generation of cellular systems It is anticipated that new techniques employed in 5G wireless networks will not only improve peak service rates significantly but also enhance capacity coverage reliability low latency efficiency flexibility compatibility and convergence to meet the increasing demands imposed by applications such as big data cloud service machine to machine M2M and mission critical communications This book is a comprehensive and detailed guide to all signal processing techniques employed in 5G wireless networks Uniquely organized into four categories New Modulation and Coding New Spatial Processing New Spectrum Opportunities and New System level Enabling Technologies it covers everything from network architecture physical layer down link and up link protocols and air interface to cell acquisition scheduling and rate adaption access procedures and relaying to spectrum allocations All technology aspects and major roadmaps of global 5G standard development and deployments are included in the book Key Features Offers step by step guidance on bringing 5G technology into practice by applying algorithms and design methodology to real time circuit implementation taking into account rapidly growing applications that have multi standards and multi systems Addresses spatial signal processing for 5G in particular massive multiple input multiple output massive MIMO FD MIMO and 3D MIMO along with orbital angular momentum multiplexing 3D beamforming and diversity Provides detailed algorithms and implementations and compares all multicarrier modulation and multiple access schemes that offer superior data transmission performance including FBMC GFDM F OFDM UFMC SEFDM FTN MUSA SCMA and NOMA Demonstrates the translation of signal processing theories into practical solutions for new spectrum opportunities in terms of millimeter wave full duplex transmission and license assisted access Presents well designed implementation examples from individual function block to system level for effective and accurate learning Covers signal processing aspects of emerging system and network architectures including ultra dense networks UDN software defined networks SDN device to device D2D communications and cloud radio access network C RAN Proceedings of the Future Technologies Conference (FTC) 2018 Kohei Arai,Rahul Bhatia,Supriya Kapoor,2018-10-19 The book presenting the proceedings of the 2018 Future Technologies Conference FTC 2018 is a remarkable collection of chapters covering a wide range of topics including but not limited to

computing electronics artificial intelligence robotics security and communications and their real world applications The conference attracted a total of 503 submissions from pioneering researchers scientists industrial engineers and students from all over the world After a double blind peer review process 173 submissions including 6 poster papers have been selected to be included in these proceedings FTC 2018 successfully brought together technology geniuses in one venue to not only present breakthrough research in future technologies but to also promote practicality and applications and an intra and inter field exchange of ideas In the future computing technologies will play a very important role in the convergence of computing communication and all other computational sciences and applications And as a result it will also influence the future of science engineering industry business law politics culture and medicine Providing state of the art intelligent methods and techniques for solving real world problems as well as a vision of the future research this book is a valuable resource for all those interested in this area **Long Term Evolution** Borko Furht,Syed A. Ahson,2016-04-19 While 3G has been an outstanding success the ever growing demand for higher data rates and higher quality mobile communication services continues to fuel conflict between the rapidly growing number of users and limited bandwidth resources In the future a 100 fold increase in mobile data traffic is expected That will necessitate further improvem **Design and FPGA Implementation of an OFDM System Based on 3GPP LTE Standard Over Multipath Fading Channel** Ahmed Almajdoob,2016 *Performance Evaluation of Channel Estimation Techniques* Kahsay Kiross,2017-11-04 **LTE Downlink Physical Layer Processing Chain SDR Application Acceleration with GPUs** Xavier Arteaga Martínez,2012 The technology moves fast and the wireless systems tend to be software defined radio SDR The new wireless standards increase the efficiency of communications also its complexity which demand more processing The FlexNets is an open source project that explores the new possibilities of flexible radio communications It provides some tools to develop SDR In recent years graphical processors have evolved and expanded to the market of high performance computing These processors GPUs are cheaper and consume less power per floating point operation than classical CPUs It is therefore quite interesting to study wether these processors are suitable for application in the SDR This work is aimed at analyzing the feasibility of this technology to implement systems based on SDR radio **Implementation and Evaluation of a QoS-aware Downlink Scheduling Algorithm for LTE Networks** Chih-Hao Howard Chang,2014 Long Term Evolution LTE is becoming the mainstream of the fourth generation standard for high speed wireless communications for mobile devices Its radio access for downlink involves allocation of Physical Resource Blocks PRB In order to achieve optimal download performance for different applications to satisfy different QoS requirements the downlink scheduling algorithm in use plays an important role in determining which PRBs and how are they allocated to each flow of bits Several researches have exploited different scheduling strategies for flows however both the frequency and time domain allocations for PRBs should be taken into account In this project we implement and evaluate a QoS aware downlink packet scheduling algorithm for LTE networks

known as the Packet Prediction Mechanism PPM using the LTE Simulator LTE Sim The PPM consists of three phases It first utilizes the PRBs effectively in the frequency domain It then manages queues and predicts the behaviour of future incoming packets based on the current ones in the queue by the concept of virtual queuing Finally it incorporates a cut in process to rearrange the transmission order and discard overdue packets based on the predicted information from the previous phase The simulation results demonstrate the effectiveness of the PPM scheme in achieving better downlink transmission performance in terms of Throughput Delay Fairness Index Packet Loss Ratio PLR and Spectral Efficiency than other downlink schedulers such as Priority First PF Modified Largest Weighted Delay First MLWDF and Exponential Proportional Fair EXPPF **Channel Estimation for LTE Downlink** Ahmed Mohammed Mohammed Al-Samman,2013 **An Efficient FPGA-Based Frequency Shifter for LTE/LTE-A Systems** Felipe A.P. de Figueiredo,Fabbryccio A.C.M. Cardoso,2019 The Physical Random Access Channel plays an important role in LTE and LTE A systems Through this channel the user equipment aligns its uplink transmissions to the eNodeB s uplink and gains access to the network One of the initial operations executed by the receiver at eNodeB side is the translation of the channel s signal back to base band This operation is a necessary step for preamble detection and can be executed through a time domain frequency shift operation Therefore in this paper we present the hardware architecture and design details of an optimised and configurable FPGA based time domain frequency shifter The proposed architecture is based on a customised Numerically Controlled Oscillator that is employed for creating complex exponential samples using only plain logical resources The main advantage of the proposed architecture is that it completely removes the necessity of saving in memory a huge number of long complex exponentials by making use of a Look Up Table and exploiting the quarter wave symmetry of the basis waveform The results demonstrate that the proposed architecture provides high Spurious Free Dynamic Range signals employing only a minimal number of FPGA resources Additionally the proposed architecture presents spur suppression ranging from 62 13 to 153 58 dB without employing any correction New Time and Frequency Synchronization Scheme in 3GPP LTE Downlink Systems □□□,2011

Reviewing **Fpga Implementation Of Lte Downlink Transceiver With**: Unlocking the Spellbinding Force of Linguistics

In a fast-paced world fueled by information and interconnectivity, the spellbinding force of linguistics has acquired newfound prominence. Its capacity to evoke emotions, stimulate contemplation, and stimulate metamorphosis is really astonishing. Within the pages of "**Fpga Implementation Of Lte Downlink Transceiver With**," an enthralling opus penned by a highly acclaimed wordsmith, readers set about an immersive expedition to unravel the intricate significance of language and its indelible imprint on our lives. Throughout this assessment, we shall delve in to the book is central motifs, appraise its distinctive narrative style, and gauge its overarching influence on the minds of its readers.

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