ADAPTIVE OFDM-BASED RESOURCE ALLOCATION METHOD USING MACHINE LEARNING AND GENETIC ALGORITHM

By

Wafaa Sami Abdelhamed Taie

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Electronics and Electrical Communications Engineering

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Title of Thesis: **ADAPTIVE OFDM-BASED RESOURCE ALLOCATION METHOD USING MACHINE LEARNING AND GENETIC ALGORITHM**

Key Words: OFDMA Scheduler; Machine Learning; Genetic Algorithm

Summary: In this research, the concept of Machine Learning (ML) is utilized to adaptively provide the scheduler with some information about the User Equipment (UE), such as traffic patterns, demands, quality of service (QoS) requirements, and other network conditions. The proposed adaptive scheduler targets multiple objective scheduling strategies, where the different objectives' weights are adjusted based on the UEs' demand pattern to optimize the radio resources allocation per transmission. In addition, it overcomes the trade-off problem of the traditional scheduling methods. This technique can be used as a generic solution with any scheduling strategy. In this thesis, Genetic Algorithm (GA)-based multi-objective scheduler is adopted in order to illustrate the efficiency of the proposed technique. Moreover, the time complexity issue of the GA is addressed. Results show that using the combination of clustering and classification algorithms along with the GA optimizes the GA-based scheduler functionality and reduces its computational complexity by a multiplier factor.

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To *Amr & Lyla*

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List of Abbreviations

3GPP	3rd Generation Partnership Project
AC	Admission Control
AI	Artificial Intelligence
A/D	Analog to Digital
BSR	Buffer Status Report
CDMA	Code Division Multiple Access
CLSM	Closed Loop Spatial Multiplexing
CQI	Channel Quality Indicator
C/I	Carrier to Interference Ratio
CEU	Cell Edge Users
CP	Cyclic Prefix
DL	Downlink
EA	Evolutionary Algorithms
eNB	Evolved NodeB
EDGE	Enhanced Data rates for GSM Evolution
EXP-PF	Proportional Fair Exponential
FDD	Frequency Division Duplex
FFR	Fractional Frequency Reuse
GBR	Guaranteed Bit Rate
Non-GBR	Non-Guaranteed Bit Rate
GSM	Global System for Mobile communications
GPRS	General Packet Radio Service
GA	Genetic Algorithm
HSPA	High Speed Packet Access
HSDPA	High Speed Downlink Packet Access
HSUPA	High Speed Uplink Packet Access
HOL	Head of Line
ICI	Inter-Carrier Interference

ISI	Inter-Symbol Inference
IP	Internet Protocol
LTE	Long Term Evolution
MLT	Machine Learning Techniques
MUE	Mobile User Equipment
MCS	Modulation and Coding Scheme
MIESM	Mutual Information Effective Signal to Interference and Noise Ratio Mapping
MIMO	Multiple-Input Multiple-Output
MU-MIMO	Multi-User MIMO
MAC	Media Access Control
M-LWDF	Modified Largest Weight Delay First
OFDMA	Orthogonal Frequency Division Multiple Access
OFDM	Orthogonal Frequency Division Multiplex
PS	Packet Scheduling
PF	Proportional Fair
PAPR	Peak-to- Average Power Ratio
PDN-GW	Packet Data Network Gateway
QoS	Quality Of Service
QP	Quadratic Programming
QPSK	Quadrature Phase Shift Keying
QAM	Quadrature Amplitude Modulation
RB	Resource Block
RE	Resource Element
RR	Round Robin
RRM	Radio Resource Management
RRS	Residual Sum of the Square
SINR	Signal to Interference and Noise Ratio

SB	Scheduling Block
SVM	Support Vector Machine
SLS	System Level Simulator
SISO	Single-Input Single-Output
TDD	Time Division Duplex
TDMA	Time Division Multiple Access
TTI	Transmission Time Interval
UL	Uplink
UMTS	Universal Mobile Terrestrial System
UE	User Equipment
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access

Abstract

The various form factors of mobile devices accompanied with new broadband services, caused a huge demand on wireless networks resources. Moreover, introducing the user Quality of Experience (QoE) term as a criterion for the service quality level in services such as video streaming, online gaming and video conferencing, highly influenced the specifications of the future Radio Access Technologies (RAT). LTE is a vital example for RAT evolution to meet the users' as well as the network operators' demands.

The Third-generation Partnership Project (3GPP) has adopted OFDMA technology along with the Multiple Input Multiple Output (MIMO) techniques in order to achieve the specified LTE design goals (which involves, peak data rates: 100 Mbps DL/50 Mbps UL for 20 MHz bandwidth, Bandwidth Scalability, high mobility and extended coverage).

Multi-user diversity gain and the user channel feedback provided by the LTE physical layer, highly impacted the radio resources allocation schemes. Where the LTE schedulers managed to achieve the highest possible data rates for LTE users according to their channel conditions. However, the LTE scheduling system may have various objectives (one may target "fairness", another "Maximum throughput", a third "Minimum latency"…etc.). In order to compromise between the different objectives and overcome the tradeoff problem, and achieve optimum resource allocation, the scheduling function tends to be a complex constrained multi-objective optimization problem.

Therefore, recently, some heuristic techniques such as Genetic Algorithm (GA) are adopted in LTE schedulers. Heuristics can solve problems that are mathematically complicated and their solution require high computational power.

In this thesis, Machine Learning (ML) is utilized to adaptively provide the scheduler with some information about the UE, such as traffic patterns, demands, quality of service (QoS) requirements, and other network conditions. A clustering technique is used to process the data that the enhanced NodeB (eNB) collects from the UEs attached to it over time. In addition, a classification technique teaches the eNB how to deal with the different users' traffic demands. The proposed adaptive scheduler targets multiple objective scheduling strategies, where the different objectives' weights are adjusted based on the UEs' demand pattern to optimize the radio resources allocation per transmission. In addition, it overcomes the trade-off problem of the traditional scheduling methods. This technique can be used as a generic solution with any scheduling strategy. In this thesis, GA-based multi-objective scheduler is developed, performance analysis and simulation results that highlight the main advantages and challenges of using GA in LTE scheduling system are provided. In our work, GA- based scheduler is implemented in order to illustrate the efficiency of the proposed technique. Moreover, the time complexity issue of the GA is addressed.

This research is carried out using MATLAB based system level simulations, Simulation results show that using the combination of clustering and classification algorithms along with the GA manages in one hand to adapt the scheduler objective according to the UEs' demand pattern per sub-frame, and on the other hand, to reduce the GA-based scheduler computational complexity by a multiplier factor.

Chapter 1. **Introduction**

The demand of high data rates along with the data traffic nature is considered main reasons for the evolution of the wireless communication networks. Starting in 1991, when the world witnessed the first commercial network for the Global System for Mobile communications (GSM) [1]. GSM aimed to handle real time services with low data rates (voice traffic). Then, General Packet Radio Service (GPRS), which is known as by 2G or 2.5G, was developed to meet the need for mobile data services in addition to the voice services. GPRS paved the way to the internet connectivity, by integrating IP-based packet switching to GSM networks managed by Time Division Multiple Access (TDMA) technology in 2000 [2]. Targeting higher data rates and network capacity, the Enhanced GPRS or Enhanced Data rates for GSM Evolution (EDGE) was introduced. EDGE was considered as a transition between GSM and Universal Mobile Terrestrial System (UMTS) and was known as 2.9G or pre- 3G. UMTS adopted Wideband Code Division Multiple Access (WCDMA) technology to achieve the 3G data rates specifications in 2001 [3].

The Third Generation Partnership Project (3GPP) was created by various telecommunications standard development organizations, in order to set the specifications and develop the next generations of wireless networks and ensure the stability and compatibility with the previously existing wireless networks.

Due to the mobile broadband requirements and the massive demand for high data rates despite the spectrum radio resources scarcity, 3 GPP has provided the High Speed Packet Access (HSPA). HSPA and HSPA+ have already succeeded to fill this gap and dominated in the market in the 3G phones or what's called smart phone. Multimedia, internet and online gaming applications are working efficiently on 3G phones. However, the requirements of online and interactive gaming and TV applications on mobile devices in addition to the wireless networks capacity issues, was behind the evolution of the 3G and the existence of the Long Term Evolution (LTE), which was defined by 3GPP [3] [4].

LTE was expected to propose a new radio-access technology that would achieve higher spectral efficiency and data rates (100 Mbps DL/50 Mbps UL), decrease complexity and cost in addition to minimizing the latency. The new radio access workshop began its work in 2004. While, the LTE specifications were announced in 2008 (as Release 8) and 2009 was expected to witness the initial implementation of LTE [5].

The LTE physical layer is directly impacted by the huge need for high data rates. Therefore, Orthogonal Frequency Division Multiplex (OFDM) has been chosen to fulfil these challenges. OFDM was first considered in the 3G networks, but at that time (mid-1990s) it was difficult to be implemented. Thanks to the progress in electronics and signal processing, the OFDM technology became mature enough to be adopted in many wireless technologies such as IEEE 802.16 Worldwide Interoperability for Microwave Access (WiMAX) [6] and many other systems besides LTE downlink transmission [7].

Multiple Input Multiple Output (MIMO) has played an effective role in LTE in achieving the high peak data rates. Last but not least, LTE works in both Time Division Duplexing (TDD) Frequency Division Duplexing (FDD) and supports scalable bandwidths (1.25-20 MHz).