POWER ALLOCATION TECHNIQUES FOR NON ORTHOGONAL MULTIPLE ACCESS

By

Mohamed Magdy El-Sayed Ahmed

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

ELECTRONCIS AND COMMUNICATIONS ENGINEERING

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Under the Supervision of

Prof. Dr. Mohamed Mohamed Khairy
Professor of Communication Engineering
Electronics and Communication Engineering
Faculty of Engineering, Cairo University

Dr. Ahmed Salah Ibrahim
Assistant Professor
Electronics and Communication Engineering
Faculty of Engineering, Cairo University

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Approved by the

Examining Committee

Prof. Dr. Mohamed Mohamed Khairy, Thesis Main Advisor

Prof. Dr. Hebat Allah Mostafa Mourad, Internal Examiner

Prof. Dr. Abdel Hady Abdel Azim Ammar, External Examiner

Faculty of Engineering, Al-Azhar University

FACULTY OF ENGINEERING, CAIRO UNIVERSITY

GIZA, EGYPT

2017

Engineer's Name: Mohamed Magdy Elsayed Ahmed

Date of Birth: 29/04/1987

Nationality: Egyptian

E-mail: Magdy1987@gmail.com

Phone: +201018066655/+0201147745451

Address: 8 Mostafa Srour off Bakriya Street, Bab El-Shariya, Cairo, Egypt

Registration Date: September 2011

Awarding Date: 2017

Degree: Master of Science

Supervisors:

Prof. Dr. Mohamed Mohamed Khairy

Dr. Ahmed Salah

Examiners:

Prof. Dr. Abdel Hady Abdel Azim Ammar (External Examiner)

Prof. Dr. Hebat Allah Mostafa Mourad (Internal Examiner)

Prof. Dr. Mohamed Mohamed Khairy (Thesis Main Advisor)

Title of Thesis: **POWER ALLOCATION TECHNIQUES FOR NON ORTHOGONAL MULTIPLE ACCESS**

Key words: non-orthogonal multiple access, successive interference cancellation and power allocation

Summary:

Non-Orthogonal Multiple Access (NOMA) is considered as a promising downlink Multiple Access (MA) scheme for future radio access. (NOMA) has been recently proposed for 3GPP Long Term Evolution (LTE) and envisioned to be an essential component of 5th generation (5G) mobile networks. The key feature of tour proposed model of NOMA is to serve multiple users at the same time/frequency/code, but with different power levels, which yields a significant spectral efficiency gain over conventional orthogonal MA. In this thesis, we will start by providing mathematical modelling for. Also we will study how to improve NOMA performance. MIMO and Cooperative transmission will be applied to NOMA. The Simulation results showed that NOMA performance using the proposed techniques and techniques achieves superior performance compared to that for Orthogonal Multiple Access (OMA)

Acknowledgments

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Last but not the least, I would like to thank my family: my parents and my brother for supporting me spiritually throughout writing this thesis and my life in general.

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List of Abbreviations

3GPP	The 3rd Generation Partnership Project
5G	5th Generation
AWGN	Additive White Gaussian Noise
BS	Base Station
CAM	Channel Access Method
CDMA	Code Division Multiple Access
CSI	Channel State Information
FDM	Frequency-Division Multiplexing
FDMA	Frequency division Multiple-Access
FEC	Forward Error Control
GSM	Global System for Mobile Communications
HSUPA/HSDPA	High Speed Uplink/Downlink Packet Access
i.i.d	Independent Identically Distributed
iDEN	Integrated Digital Enhanced Network
IDMA	Interleave Division Multiple Access
ITU-R	International Telecommunications Union Radio
LLS	Link Level Simulation
LTE	Long Term Evolution
MA	Multiple Access
MIMO	Multiple Input Multiple Output
MRC	Maximum Ratio Combiner
MUD	Multiuser Detection
MUSA	Multi-user Shared Access
NOMA	Non Orthogonal Multiple Access
OFDMA	Orthogonal-Frequency division Multiple-Access
OMA	Orthogonal Multiple Access
OSI	Open Systems Interconnection
PDC	Personal Digital Cellular
PDMA	Pattern Division Multiple Access
SC	Superposition Coding
SCMA	Sparse Code Multiple Access
SIC	Successive Interference Cancellation
SLS	System Level Simulation
TDD	Time Division Duplex
TDMA	Time division Multiple-Access
TPA	Transmission Power Allocation
UTRA	Universal Terrestrial Radio Access
WCDMA	Wide Code Division Multiple Access
WLAN	Wireless Local Area Networks

List of Symbols

N	Number of users per Base station
B	Number of Frequency Blocks
W	Bandwidth of single Frequency Block
$\boldsymbol{m_B}$	Total number of users per Frequency Block
$\boldsymbol{P_{max}}$	Maximum transmitted power by Base Station per Frequency Block
$\boldsymbol{R_i}$	Achievable downlink rate achieved bu the i-th user per the k-th frequency block
$\boldsymbol{h_i}$	Fading channel's coefficients for i-th user per k-th Frequency Block
$\boldsymbol{s_i}$	Modulated signal for i-th user per k-th Frequency Block
$\boldsymbol{x_k}$	Composite NOMA signal per k-th Frequency Block
$\boldsymbol{P_i}$	Power per i-th user per k-th Frequency Block
$\boldsymbol{n_i}$	Additive White Gaussian Noise
$\boldsymbol{y_i}$	Received NOMA signal for i-th user per k-th Frequency
$\boldsymbol{P_e^{(i)}}$	The probability of decoding the i-th user incorrectly
$\boldsymbol{\rho}$	Transmit Signal to Noise Ratio
$\boldsymbol{\gamma_i}$	Signal to Interference and Noise Ratio for the i-th user per k-th frequency block
$\boldsymbol{y_i^{DT}}$	Received NOMA signal for i-th user per k-th Frequency during Direct Transmission
$\boldsymbol{y_i^{JT}}$	Received signal for i-th user per k-th Frequency during Cooperative Transmission

Abstract

The demand for increased data rates produces demand for increased bandwidth and increased spectrum occupancy so that spectrum capacity is under pressure from the rapid expansion of mobile data applications and the increasing volume of downloaded data. The demand for spectrum is influenced by growing affordability of mobile broadband, combined with the consumer trend of increased data transmission and or higher bandwidth applications

Non-Orthogonal Multiple Access (NOMA) is considered as a promising downlink Multiple Access (MA) scheme for future radio access. (NOMA) has been recently proposed for 3GPP Long Term Evolution (LTE) and envisioned to be an essential component of 5th generation (5G) mobile networks.

The key feature of the proposed NOMA model in this thesis is to serve multiple users at the same time/frequency/code, but with different power levels, which yields a significant spectral efficiency gain over conventional orthogonal MA.

In this thesis, we will start by providing mathematical modelling for NOMA. After System modelling, four power allocation techniques for NOMA are proposed. The first technique is based on channel state information experienced by NOMA users. The second technique is based on pre-defined QoS per NOMA user.

The Third and fourth power allocation techniques will be derived from detailed analysis for NOMA capacity maximization formula. As the problem is complex and not easily to be solved so we will try numerical solutions for the problem. One technique is derived based on Bisection search method while the other is derived based on SINR equality among cell users.

We will also discuss how to enhance NOMA performance using MIMO and Cooperative Transmission. Simulation results showed that NOMA performance using the proposed techniques and techniques achieves superior performance compared to that for Orthogonal Multiple Access (OMA).

Chapter 1 : Introduction

1.1 Introduction

The demand for increased data rates produces demand for increased bandwidth and increased spectrum occupancy so that spectrum capacity is under pressure from the rapid expansion of mobile data applications and the increasing volume of data that is downloaded. The demand for spectrum is influenced by growing affordability of mobile broadband, combined with the consumer trend of increased data transmission and or higher bandwidth applications.

As shown in **Figure 1.1**, the bar chart represents data demand based on industry assumptions to 2015 and trending to 2020. The curve is the anticipated level of spectrum demand to meet the needs of mobile broadband[1].

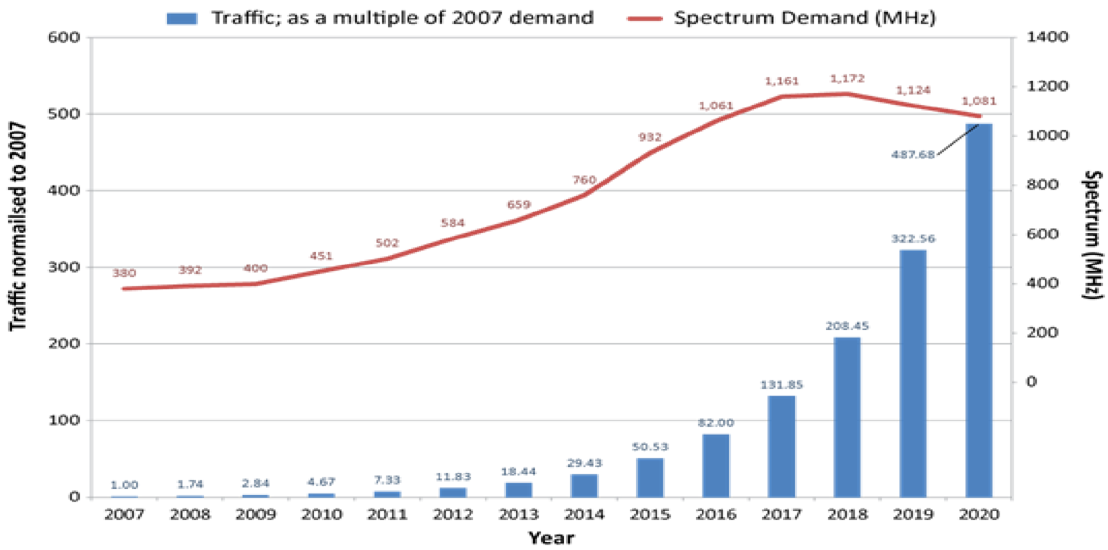

Figure 1.1: Expectations for data and spectrum demands

Forecasts also reveal that 90 percent of the world's population over six years old is predicted to have a mobile phone by 2020. Furthermore, by 2020 smartphone subscriptions are forecast to reach 6.1 billion which will be accompanied by enormous and fast growing segment of mobile data traffic. Which is shown in Error! Reference source not found.

Global mobile broadband subscriptions are predicted to reach 8.4 billion by 2020, accounting for a larger share of all broadband subscriptions in many markets. Mobile broadband will play a complementary role alongside fixed broadband in some segments, and replace it in others. Most mobile broadband devices are, and will continue to be, smartphones. Many consumers in developing markets first experience the internet on smartphones – usually because they have only limited access to fixed broadband.

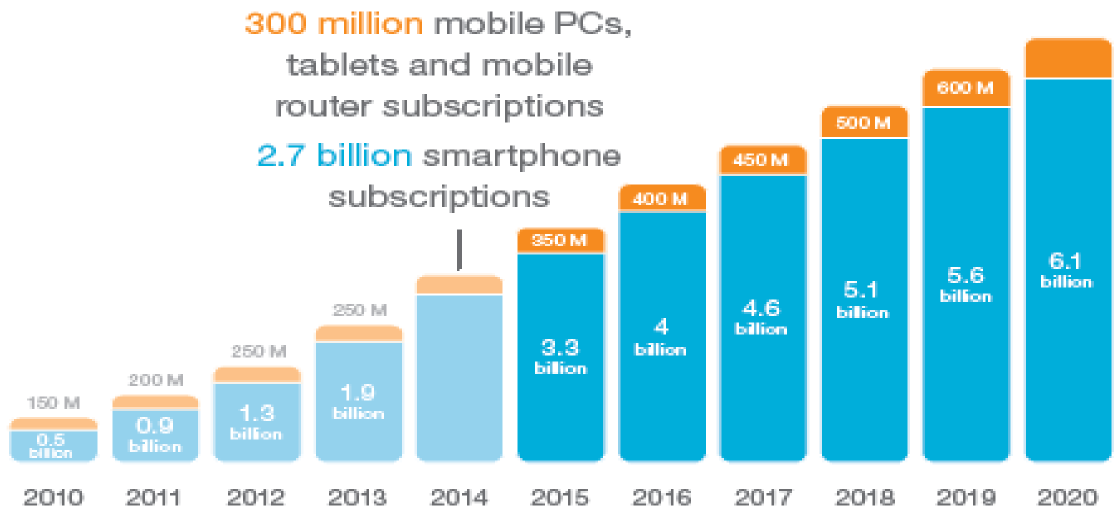

Figure 1.2: Smartphones, mobile PCs, tablets and mobile routers with a cellular connection

Figure 1.3 shows the rising number of smartphone subscriptions is the main driver of mobile data traffic growth. Increased consumption of mobile/cellular data per subscription – mainly driven by video – is also contributing to this growth.
Mobile data traffic is expected to rise by around 40 percent (2014–2020). This will result in an 8-fold increase in traffic by the end of 2020. Total mobile traffic generated by mobile phones is now around twice that of mobile PCs, tablets and mobile routers.

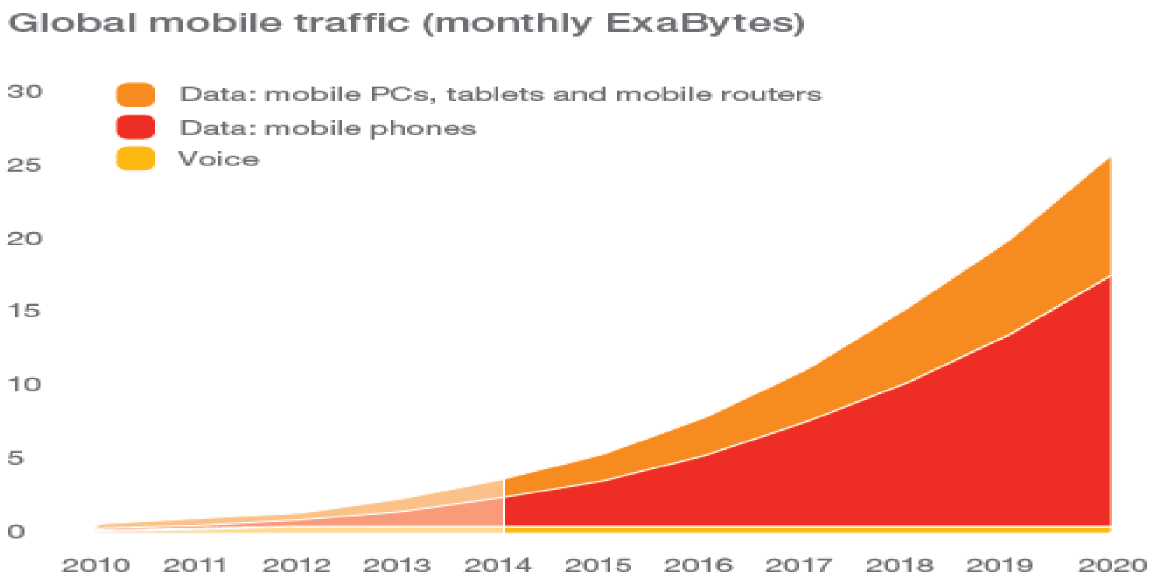

Figure 1.3: Mobile traffic generated by mobile phones, mobile PCs, tablets and router

All above mentioned forecasts show the importance of better bandwidth utilization and enhancing spectral efficiency. This will demand new technologies and novel technical solutions. The new techniques shall provide higher capacity and higher quality of user experience. The 3rd Generation Partnership Project (3GPP) started discussions on further steps in the evolution of Long Term Evolution (LTE) toward the future, i.e., Release 12 and onwards [2]. Furthermore, some initial discussions on the 5th Generation (5G) mobile communication systems are taking place in the radio communication sector of the International Telecommunications Union Radio (ITU-R) and are being led by multiple projects and companies [3], [4]. One of the topics under discussion is the MA techniques and how it can offer better user throughput and enhance overall system capacity.

Multiple major 5G technologies such as ultra-densification, millimetre wave, and massive Multiple-Input Multiple-Output (MIMO), have attracted considerable attention in both industry and academia[5].

The aim of Base Station (BS) densification is to improve the wireless transmission rate in partial regions and the most challenge of BSs densification is the interference coordination for cellular networks. The massive MIMO antennas will be integrated into BSs, where hundreds antennas are utilized for transmitting Gbits level wireless traffic. The millimeter wave communication technology is expected to provide hundreds MHz bandwidth for wireless transmissions. However, the transmission distance of millimeter wave communications has to be restricted into 100 meters considering the propagation degradation of millimeter wave in the atmosphere.

In addition to these technological implications, physical layer issues such as transmission waveforms and MA schemes should be reconsidered. A Promising downlink MA scheme which is NOMA is considered. NOMA is expected to achieve high spectral efficiencies over Orthogonal Multiple Access (OMA) by combining superposition coding at the transmitter with Successive Interference Cancellation (SIC) at the receivers which will be discussed in coming chapters [6][7]

1.2 NOMA

NOMA has been recently recognized as a promising MA technique to significantly improve the spectral efficiency of mobile communication networks. For example, Multiuser Superposition Transmission (MUST),is a downlink version of NOMA, which has been proposed for 3rd generation partnership project long-term evolution advanced (3GPP-LTE-A) networks. Furthermore, the use of NOMA has also been envisioned as a key component in 5th generation (5G) mobile systems [2].

NOMA has been discussed in several research works after being proposed as a potential candidate for next radio generation and LTE-A. The research started to propose system modelling for NOMA and how it will operate. Also the research focus on showing NOMA benefits over traditional MA techniques in terms of cell throughput, user throughput and spectrum efficiency. Beside proposing the system modelling for NOMA, step by step NOMA performance issues such as power allocation, scheduling techniques, achievable capacity, etc. started to be tackled with proposals for each performance issue. It started with simple proposals with no detailed analysis or verification. Later the proposals started to be modelled and verified and NOMA performance gains are benchmarked to traditional Orthogonal MA techniques [6-12].

Research also go for studying other accessibility techniques other than power domain to implement NOMA like Sparse Code Multiple Access (SCMA), Multi-user Shared Access (MUSA), and Pattern Division Multiple Access (PDMA) [13].

After having clear and mature system model for NOMA, research started to target NOMA performance enhancement and how to maximize capacity as much as possible. Advanced techniques like MIMO Beam-Forming, cooperative transmission, smart antennas …etc. was proposed and discussed for NOMA [14-19].