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# Decode and Forward Relay Technology for LTE-Advanced

A Research Submitted in Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honor) In Electronics Engineering

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## DEDICATION

*This thesis is dedicated to our beloved mothers and fathers for planting the magic inside us and uplifting our spirit by supporting us all the way along. Also, it isdedicated to our brothers, sisters, friends and our supervisor for spending his time and effort to make this project on its best way.*

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*All praise to Allah, today we fold the days' tiredness and the errand summing up between the cover of this humble work. To our mothers, to whom they strive to bless comfort and welfare and never stint what they own to push us in the success way who taught us to promote life stairs wisely and patiently, to our dearest fathers.*

*To our supervisor **Dr.Fath Elrahman Ismael Khalifa** who supervised, guided, encouraged and helped us wholeheartedly.*

*To those who taught us letters of gold and words of jewels of the utmost and sweetest sentences in the whole knowledge. Who reworded to us their knowledge simply and from their thoughts made a lighthouse guides us through the knowledge and success path, to our honored teachers, thanks very much.*

# ABSTRACT

One of the main challenges faced by the developing standard for mobile broadband access isproviding high throughput at the cell edge. The transmitted signal from the base station to the mobile station directly is often degraded by random fades, noise and other propagation losses. This resulting in low SNR, and high packet error rate (PER). Therefore, users on the cell edge will face relatively low performance of the services offered to them.One solutionto improve coverage is to use the relay stations to transmit data between the Base Stations and the Mobile Stations or User Equipment through multi hop communication.

This work focus on Decode and Forward Relay which is can be used by wireless nodes to take the benefits of broadcast nature and to relay messages for each user. The ARQ mechanism that used as an efficient error control technique with DF relay introduces an ARQ feedback message made by the RS for fast and efficient data transmission. Simulation results show that transmission delay is reduced by 4.43% and throughput is enhanced by 66.1%. Above that the SNR is increased and PER is also decreased by about 22.9% and 95.1% respectively.

# المستخلص

تم تطوير معايير جديدة لأنظمة الإتصال المتنقلة ذات النطاق الواسع التي من شأنها تلبية متطلبات الإنتاجية والتغطية الكافية بتكنولوجيا الجيل الرابع الخلوية . وزادت الأهداف الرئيسية لهذا التطور منها زيادة معدل البيانات، تحسين كفاءة الطيف، تحسين التغطية وتقليل التأخير. أحد التحديات الرئيسية التي تواجهها أنظمة الإتصال الخليوية هي توفير إنتاجية عالية عند أطراف منطقة التغطية. من أفضل الحلول المتوفرة لتحسين التغطية هو استخدام محطات إعادة الإرسال لنقل البيانات بين أبراج الإتصال و أجهزة المستخدمين .

هذا المشروع يركز بشكل أساسي على أنظمة إعادة الإرسال التي تعتمد علي آلية التشفير, فك التشفير, تكبير الإشارة و من ثم إعادة إرسالها إلى المستخدم . و باستخدام تقنية مناسبة لتصحيح الخطأ تقوم فيها محطة إعادة الإرسال بإرسال رسالة تأكيدية إلى برج الإتصال مما يزيد من كفاءة الإرسال و يقلل التأخير المحتمل. ونتيجة لإستخدام محطة إعادة الإرسال مع آلية تصحيح خطأ مناسبة فإن ذلك سيزيد من قوة الإشارة و بالأخص عند حافة الخلية بنسبة 22.9% كما أن معدل الخطأ سيقل بنسبة 95.1% تقريبا. كذلك سوف يقل التأخير بنسبة 4.43% و تزيد كفاءة الإرسال و معدل سرعة البيانات بنسبة 2.09% و7.1% بالتتابع. أخيرا يمكن القول أن محطات إعادة الإرسال تعتبر واحدة من أهم التحسينات التي أدخلت على تكنولوجيا الجيل الرابع الخليوية التي يمكن إستخدامها لتعزيز التغطية و تحسين الإنتاجية .

# TABLE OF CONTENTS

# LIST OF TABLES

# LIST OF FIGURES

# LIST OF SYMBOLES

| | |
|---|---|
| Pr | Received power |
| N | Noise |
| Pt | Transmitted power |
| Gt | Transmitted gain |
| Gr | Received gain |
| Pl | Pass loss |
| hb | Base station antenna height |
| hm | Receiver antenna height |
| hr | Relay station antenna height |
| a(hm) | Receiver antenna height correction factor |
| a(hr) | Relay station antenna height correction factor |
| do | Reference point |
| d | Transmitter- Receiver Separation in Km |
| d* | Separation Between eNB and RN in meter |
| r | Modulation factor |
| n | Packet size |
| BW | Channel Bandwidth |
| D | Delay |
| T | Frame duration |
| P | Packet Error Rate |
| η | Transmission Efficiency |

# ABBREVIATIONS

| | |
|---|---|
| 1G | First Generation |
| 2G | Second Generation |
| 3G | Third Generation |
| 3GPP | Third Generation Partnership Project |
| 4G | Forth Generation |
| AF | Amplify and Forward |
| AMC | Adaptive Modulation and Coding |
| ARQ | Automatic Repeat Request |
| BER | Bit Error Rate |
| BS | Base Station |
| CA | Carrier Aggregation |
| COW | Cell on Wheels |
| DF | Decode and Forward |
| eNB | eNode-B |
| GSM | Global System for Mobile |
| HARQ | Hybrid Automatic Repeat Request |
| HSPA | High Speed Packet Access |
| ITU | International Telecommunication Unions |

| | |
|---|---|
| IMT | International Mobile Telecommunications |
| LOS | Line of Sight |
| LTE | Long Term Evolution |
| MCS | Modulation Coding Scheme |
| MRBS | Multi-hop Relay Base Station |
| MS | Mobile Station |
| NLOS | Non Line of Sight |
| OFDM | Orthogonal Frequency Division Multiplexing |
| OFDMA | Orthogonal Frequency Division Multiple Access |
| PER | Packet Error Rate |
| RN | Relay Node |
| RS | Relay Station |
| RS ACK | Relay Station Acknowledgement |
| RS NAC | Relay Station Negative Acknowledgement |
| SNR | Signal to Noise Ratio |
| SINR | Signal-to-Interference-plus-Noise Ratio |
| TDMA | Time Division Multiple Access |
| UE | User Equipment |
| WCDMA | Wide CodeDivision Multiple Access |

# CHAPTER ONE

# INTRODUCTION

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# INTRODUCTION

In this chapter, a brief introduction about fourth generation and primary aspects of the project will be presented.

## 1.1 Preface

Wireless networks are becoming very popular at the present time because of the improvements in the new generation of wireless technology.New generation wireless standards like IEEE 802.16 (WiMAX) and LTE-Advanced offer more flexibility, mobility and high data rate. Also, they have improved the connectivity.

Still by deploying IMT-Advanced standard and enhancements in radio link technology will not solve the basic problem related to propagation loss, that is coverage and capacity at the cell border remain relatively small due to low Signal-to-Noise-Ratio (SNR). A very promising solution to overtake this problem and improve the cell-edge SNR, throughput and to extend the coverage of high data rates is to use Relay Nodes (RN) in the network [1] [2]. Alternatively, deploying RNs near the cell edge will help to increase the capacity [3].

For this, relay technologies have been actively studied and considered in the standardization process of next-generation mobile communication systems, such as 3GPP LTE-Advanced. Relay transmission can be seen as a kind of collaborative communications, in which a Relay Node (RN) helps to forward the data-information from a local eNode-B or Base Station (BS) to the neighboring user equipment (UE). As a result, a RN can effectively extend the signal and service coverage of an eNode-B and enhance the overall throughput performance of a wireless communication system and solve the above mentioned low SNR problem. A part from this, Relaying technology can also be integrated in normal base station platforms which is cost efficient and easy to deploy as it does not require additional back haul [1].

While conventional Amplify and Forward (AF) relays can be used to increase the coverage, the basic problem is that they amplify not only desired signal but also both interference and noise. Therefore AF relays provide best benefit in noise limited system deployment while the benefit from their usage in presence ofheavy interference is limited. On the other hand, Decode and Forward (DF) relays detect the desired signal and then encode and forward it. Therefore DF relays are applicable also in interference limited environments and thus, they can be used to improve system capacity [2].

This thesis considersand analyzes Decode-and-Forward (DF) relaying for LTE-Advanced network which is recommended as a candidate of 4G system

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## 1.2 Problem Statement

Current broadband wireless networks are characterized by large cell sizes. Yet, even in advanced networks that will be built using 3GPP Long Term Evolution (LTE), also referred to as 3GPP LTE-Advanced, users on the cell edge will face relatively low performance of the services offered to them [2].

The transmitted signal from the base station to the mobile station directly is often degraded by random fades, noise and other propagation losses.  Hence, the coverage and capacity at the cell edge became small due to the previous reasons which are resulting in low SNR, high packet error rate (PER) and low throughput.

## 1.3 Proposed Solution

An attractive solution for the mentioned problems is provided by multi-hop technologies.  The Decode-and-Forward relay (DF) technique is used to enhance the SNR for the cell edge users. In addition to that, an applying ofan error control mechanism such as an Automatic Repeat Request (ARQ) in the relay station will improve the reliability of data transmission for the end users.

## 1.4 Research Aims and Objectives

The aim of this research isimprove the quality of the services offered for the end users especially at the cell edge and shadowing places. The detailed objective of this research is achieved through simulation to show the effectiveness of using RS in:

-Enhance Signal-to-Noise-Ratio (SNR).

-Increase the throughput.

-Decrease packet error rate (PER).

-Improve the reliability of data transmission.

-Band Width Utilization.

-Decrease Recovery Time.

## 1.5 Methodology

The research methodology contains different stages, these are:

- Deep study of decode and forward relay technology.
- Performance metrics equations have been collected.
- Mathematical calculations have been done.
- MATLAB code has been written.
- DF Relay effectiveness on some parameters such as SNR, throughput, PER, delay, transmission efficiency, data rates and accumulated throughput have been discussed.
- Two mechanisms of ARQ, End-to-End ARQ (when RS makes no action) and ARQ relay have been studied and compared together depending on the previous parameters.

- The results of each parameter of the two mechanisms have been analyzed and presented in separated figure.

## 1.6 Research Outlines

In Chapter two, general overview of LTE and LTE-Advanced technology has been given. Also, relay technology types and deploying scenarios have been mentioned.

In chapter three, the methodology of this work has been illustrated in details with all equations and ARQ mechanisms that have been used in the project.

In Chapter four, main parameters and equations have been used. Then,two individual simulation scenarios have been applied and the results from each scenario have been presented.

In Chapter five, the conclusion has been obtained from all the results that have been drawn. Some recommendations for the future workrelated to this project are also proposed.