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# **Packet Scheduling for LTE-Advanced**

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I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

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# Abstract

LTE-Advanced has been approved by the International Telecommunication Union (ITU) as a 4G mobile communication system. It is also called IMT-Advanced or true 4G technology. LTE-Advanced is an evolution of LTE (Release-8) and backward compatible with LTE because they both use the same air-interface technologies such as OFDMA, MIMO, and the same core network.

Since radio spectrum is the most valuable resource in mobile technology, radio resource management (RRM) mechanisms are critical for the operation of a cellular network. One of the key RRM mechanisms is packet scheduling and it allocates suitable radio resources to each user for transmission of the downlink from the base station through the air interface to each mobile station.

The overall objectives of this project are to study packet scheduling mechanism for LTE-Advanced and find an optimized packet scheduling algorithm(s) to fully utilize new features and challenges of LTE-Advanced. This project is an extension of previous work done in packet scheduling in LTE at Centre for Real-time Information Networks (CRIN), UTS.

This thesis begins by explaining the design considerations used to create a computer simulation tool to model packet scheduling as well as other RRM mechanisms for LTE-Advanced. Thereafter, it will model, simulate, validate, and evaluate the performance of current well-known and new packet scheduling algorithms for LTE-Advanced. In this thesis, two new algorithms called optimized cross-CC proportional fair (OCPF) and optimized cross-CC M-LWDF (OCM) are proposed. (CC: component carrier)

The OCPF algorithm can overcome the weaknesses of current algorithms and improve system throughput. The OCM can provide a more effective solution for realistic traffic with strict requirement on the quality of services (QoS).

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## Table of Contents

CHAPTER 1: INTRODUCTION .....	14
1.1. Evolution of mobile technologies to 4 <sup>th</sup> Generation (4G).....	14
1.2. 4G Technology and its technical requirements.....	16
1.3. Development in 3GPP from 2G to 4G.....	18
1.4. LTE-Advanced.....	22
1.5. Radio Resource Management .....	23
1.6. Research question and objectives.....	24
1.7. Research signification .....	25
1.8. Research Methodology and Plan.....	26
1.9. Publications.....	27
CHAPTER 2: LITERATURE REVIEW .....	29
2.1. LTE Technology Review .....	29
2.2. Major characteristics of LTE-Advanced.....	33
2.3. Packet Scheduling.....	38
2.3.1. Packet Scheduling Algorithms.....	39
A. Round Robin (RR).....	40
B. First-in-First-out (FIFO).....	40
C. Maximum Rate (Max Rate) .....	40
D. Proportional Fair (PF).....	41
E. Modified-Largest Weighted Delay First (M-LWDF) .....	41
F. Exponential/Proportional Fair (EXP/PF) .....	42
2.4. Theoretical Throughput Analysis of Packet Scheduling Algorithms.....	42
2.4.1. Theoretical Throughput Analysis of PF Algorithm .....	43
2.4.2. Theoretical Throughput Analysis of M-LWDF Algorithm .....	47
2.5. Packet Scheduling in LTE-Advanced .....	51

2.5.1. New proposed Packet Scheduling Algorithms for LTE-Advanced .....	51
2.5.2. Challenges Faced to Implement Scheduling.....	59
2.6. Summary.....	60
CHAPTER 3: SYSTEM MODELLING & SIMULATION .....	62
3.1. New model in LTE-A network.....	62
3.2. Packet Scheduling Simulation Tool .....	63
3.2.1. Pre-processing block .....	64
3.2.2. Main processing block .....	67
3.2.3. Post processing block .....	71
i. System throughput:.....	71
ii. Packet delay: .....	72
iii. Packet loss ratio .....	72
iv. Fairness.....	72
3.3. Summary.....	73
CHAPTER 4: PACKET SCHEDULING ALGORITHMS FOR LTE-ADVANCED	
74	
4.1. Cross-CC vs. In-CC scheduler with PF algorithm .....	74
4.1.1. Theory discussion .....	74
4.1.2. Simulation results .....	76
4.2. Cross-CC vs. In-CC scheduler with other algorithms.....	78
4.2.1. Theory discussion .....	78
4.2.2. Simulation results .....	79
4.3. Proposed PS algorithm for LTE-Advanced .....	83
4.3.1. Theory discussion .....	83
A. Optimized Cross-CC PF algorithm.....	83
B. Optimized Cross-CC M-LWDF algorithm .....	84
4.3.2. Simulation results .....	85

A.	Optimized Cross-CC PF Algorithm.....	85
B.	Optimized Cross-CC M-LWDF algorithm .....	91
4.4.	Summary.....	94
CHAPTER 5: CONCLUSION.....		95
APPENDIX.....		97
LIST OF SYMBOLS.....		101
GLOSSARY .....		106
REFERENCES.....		114

## List of Figures

Figure 1-1: The evolution paths to 4G .....	15
Figure 1-2: The transition from 2G to 4G in 3GPP family, adapted from [10] .....	19
Figure 1-3: 3PPP standardization & its key evolutionary features, adapted from [11] ...	20
Figure 1-4: The spectrum of three radio interfaces with its technologies, adapted from [12] .....	21
Figure 1-5: Radio Network Planing & Radio Resources Management [14] .....	24
Figure 2-1: The evolution in the Radio Access Network from 3G to LTE .....	29
Figure 2-2: Radio interfaces in the downlink and uplink of LTE [18] .....	30
Figure 2-3: Maintaining the Subcarriers' Orthogonality [18] .....	30
Figure 2-4: Radio Resource Block (RB) component [19] .....	31
Figure 2-5: The LTE scalable bandwidths .....	31
Figure 2-6: Modulation scheme & Link adaptation .....	32
Figure 2-7: Reference signals mapping [20] .....	32
Figure 2-8: FDD & TDD in LTE .....	32
Figure 2-9: MIMO technology [21] .....	33
Figure 2-10: Wider bandwidth [11] .....	34
Figure 2-11: Supporting wider bandwidth with multiple component carriers feature ....	34
Figure 2-12: Asymmetric bandwidth of uplink and downlink [25] .....	35
Figure 2-13: Advanced MIMO techniques [25] .....	35
Figure 2-14: Cooperative MultiPoint techniques [26] .....	36
Figure 2-15: Relaying function [25] .....	37
Figure 2-16: Packet scheduling operation [29] .....	39
Figure 2-17: Independent-Component Carrier scheduling [45] .....	51
Figure 2-18: Cross-Component Carriers scheduling [45] .....	52
Figure 2-19: Simple cross-CC Scheduling framework [44] .....	52
Figure 2-20: Throughput of cross-CC vs. In-CC [24] .....	54



Figure 2-21: Cell-edge user throughput [48] .....	54
Figure 2-22: Latency of cross-CC vs. In-CC [24] .....	54
Figure 2-23: Coverage of difference frequency bands [47].....	55
Figure 2-24: User throughput CDF .....	56
Figure 2-25: Average sector throughput.....	56
Figure 2-26: Throughput.....	57
Figure 3-1: New model of LTE-Advanced with many kinds of user co-existence .....	63
Figure 3-2: LTE-Advanced Simulation Tool Block Diagram.....	64
Figure 3-3: Sample picture of users' location and movement in new simulation .....	65
Figure 3-4: Model of Multi-path Fading [55] .....	66
Figure 4-1: System throughput, in-CC vs. cross-CC .....	77
Figure 4-2: Cell edge users throughput, in-CC vs. cross-CC.....	77
Figure 4-3: System throughput .....	78
Figure 4-4: System throughput, algorithms comparison .....	80
Figure 4-5: System fairness .....	81
Figure 4-6: System fairness, new algorithms of fairness .....	81
Figure 4-7: System delay .....	82
Figure 4-8: Packet Loss Ratio .....	82
Figure 4-9: System throughput .....	86
Figure 4-10: LTE-A users' throughput.....	86
Figure 4-11: Cell-edge users' throughput .....	87
Figure 4-12: 5% best users' throughput .....	88
Figure 4-13: System throughput with 50% LTE-A users.....	89
Figure 4-14: System throughput in scenario of different CC bands (800MHz + 2GHz) 90	
Figure 4-15: System fairness.....	91
Figure 4-16: System throughput with M-LWDF .....	93
Figure 4-17: Packet loss ratio .....	93

## List of Table

Table 1-1: Cell spectral efficiency .....	16
Table 1-2: Cell edge user spectral efficiency .....	17
Table 1-3: Mobility classes .....	17
Table 1-4: Handover interrupt time .....	18
Table 1-5: Voice capacity .....	18
Table 1-6: LTE-Advanced performance.....	22
Table 2-1: LTE Characteristics [22] .....	33
Table 2-2: LTE vs. LTE-Advanced [25].....	37
Table 2-3: Packet scheduling in wireless technologies [14] .....	40
Table 2-4: Throughput of new algorithm .....	57
Table 2-5: Average user throughput in Mbps, 30 Users/cell .....	58
Table 2-6: Fairness index .....	58
Table 2-7: Average cell-edge user throughput in Mbps .....	58
Table 3-1: Traffic pattern [59, 60] .....	67
Table 3-2. CQI Mapping table.....	70
Table 4-1: System simulation configuration .....	76
Table 4-2: LTE-A users' throughput.....	87
Table 4-3: 5% best users' throughput .....	88
Table 4-4: The system throughput of 3 algorithms .....	89
Table 4-5: System throughput in scenario of 2 different CC bands (800MHz & 2GHz) .....	90
Table 4-6: Standardized QCI characteristics [72] .....	92
Table 4-7: System throughput with M-LWDF .....	92
Table 4-8: Packet loss ratio data .....	93

## List of Acronyms

3G	3rd Generation Wireless Network
3GPP	3rd Generation Partnership Project
3GPP2	3rd Generation Partnership Project 2
4G	4th Generation Wireless Network
ACK	Acknowledgement
BLER	Block Error Rate
BS	Base Station
BSC	Base Stations Controller
CA	Carriers Aggregation
CC	Component Carrier
CDMA	Code Division Multiple Access
CoMP	Coordinated MultiPoint transmission and reception
CP	Cyclic Prefix
CQI	Channel Quality Indicator
CRIN	Centre of Real-Time Information Networks
Cross-CC	Cross-Component Carriers
CS/CB	Coordinated Scheduling/Beam-forming.
CSI	Channel State Information
EDGE	Enhanced Data rates for GSM Evolution
eNodeB	evolved NodeB
EPC	Evolved Packet Core
E-UTRAN	Evolved UTRAN
EXP/PF	Exponential/Proportional Fair
EVRC	Enhanced Variable Rate Coder
FDD	Frequency Division Duplex
FDMA	Frequency Division Multiple Access
FIFO	First-in-First-out
GSM	Global System for Mobile communications
HARQ	Hybrid-Automatic Repeat Request
HOL	Head of Line
HOM	Higher Order Modulations
HSDPA	High-Speed Downlink Packet Access
IEEE	Institute of Electrical and Electronics Engineers
IMT-2000	International Mobile Telecommunications-2000
In-CC	Independent-Component Carriers
IP	Internet Protocol
ITU	International Telecommunication Union
JP	Joint Processing
LTE	Long Term Evolution

LTE-A	Long Term Evolution Advanced
Max-Rate	Maximum-Rate
MCS	Modulation and Coding Scheme
MIMO	Multiple Input Multiple Output
M-LWDF	Modified-Largest Weighted Delay First
MME	Mobile Management Entity
NACK	Negative Acknowledgement
NRT	Non-Real Time
OCM	Optimized Cross-Component Carrier M-LWDF
OCPF	Optimized Cross-Component Carrier Proportional Fair
OFDM	Orthogonal Frequency Division Multiplex
OFDMA	Orthogonal Frequency Division Multiple Access
PCU	Packet Control Unit
PDF	Probability Density Function
PDN	Packet Data Network
PF	Proportional Fair
P-GW	PDN Gateway
PLR	Packet Loss Ratio
PS	Packet Scheduling
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
QSI	Queue State Information
RAN	Radio Access Network
RB	Resource Block
RMS	Root Mean Square
RN	Relay Node
RNC	Radio Network Controller
RNP	Radio Network Planning
RR	Round Robin
RRM	Radio Resource Management
RT	Real Time
RTT	Round-Trip Time
SA	Spectrum Aggregation
SC-FDMA	Single Carrier Frequency Division Multiple Access
SDF	Sub-band Discrimination Factor
S-GW	Serving Gateway
SINR	Signal to Interference-plus-Noise Ratio
SISO	Single-Input-Single-Output
SNR	Signal-to-Noise-Ratio
TB	Transport Block
TDD	Time Division Duplex
TDMA	Time Division Multiple Access

TFT	Time For Transmission
TTI	Transmit Time Interval
UDF	User Discrimination Factor
UE	User Equipment
UMB	Ultra Mobile Broadband
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
VoIP	Voice over IP
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access