Packet Scheduling for LTE-Advanced

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In accordance with the requirement for the Degree of Master of Engineering by Research

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Certificate of Originality

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.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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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).
Acknowledgement

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# Table of Contents

CHAPTER 1:  INTRODUCTION ................................................................. 14

1.1.  Evolution of mobile technologies to 4th 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 Planning & 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
<table>
<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>TFT</td>
<td>Time For Transmission</td>
</tr>
<tr>
<td>TTI</td>
<td>Transmit Time Interval</td>
</tr>
<tr>
<td>UDF</td>
<td>User Discrimination Factor</td>
</tr>
<tr>
<td>UE</td>
<td>User Equipment</td>
</tr>
<tr>
<td>UMB</td>
<td>Ultra Mobile Broadband</td>
</tr>
<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunications System</td>
</tr>
<tr>
<td>UTRAN</td>
<td>UMTS Terrestrial Radio Access Network</td>
</tr>
<tr>
<td>VoIP</td>
<td>Voice over IP</td>
</tr>
<tr>
<td>WCDMA</td>
<td>Wideband Code Division Multiple Access</td>
</tr>
<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
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