DESIGN AND DEVELOPMENT OF SCHEDULING ALGORITHMS FOR DOWNLINK TRANSMISSION SYSTEM OF LONG TERM EVOLUTION (LTE) NETWORK

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By

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LIST OF ABBREVIATIONS

1G	First Generation
2G	Second Generation
3G	Third Generation
3GPP	3rd Generation Partnership Project
4G	Fourth Generation
AIPN	All IP network
AMC	Adaptive Modulation and Coding
AMIs	Advanced Meter Infrastructures
BLER	Block Error Rate
BS	Base Station
CCE	Control Channel Elements
CCI-A	Co-Channel Interference Avoidance
CDMA	Code Division Multiple Access
CP	Cyclic Prefix
CQI	Channel Quality Indicator
DwPTS	Downlink Pilot Transmission Slot
EDGE	Enhanced Data Rates for Global Evolution
ENodeB	E-UTRAN Node B
EPC	Evolved Packet Core
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
EXP/PF	Exponential/Proportional Fair
FD RR	Frequency Domain Round Robin

FDD	Frequency Division Duplexing
FDS	Frequency Time Scheduling
FFT	Fast Fourier Transform
FTP	File Transfer Protocol
GBR	Guaranteed Bit Rate
GP	Guard Period
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HSPA	High Speed Packet Access
HSS	Home Subscriber Server
HSPDA	High Speed Downlink Packet Access
IFFT	Inverse Fast Fourier Transform
ILLA	Inner Loop Link Adaptation
IP	Internet Protocol
ITU	International Telecommunication Union
KM	Kilometer
LTE	Long Term Evolution
LTE-A	LTE-Advanced
MAC	Media Access Control
Max TP	Maximum Throughput
MC	Mobile Cloud Computing
MC-PF	Multi-Carrier Proportional Fairness
MCS	Modulation and Coding Scheme
MIMO	Multiple-Input-Multiple-Output
Min-AL	Minimum Aggregation Level Algorithm

M-LWDF	Modified Largest Weighted Delay First
MME	Mobility Management Entity
MMS	Messaging and Multimedia Message
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
OLLA	Outer Loop Link Adaptation
OmNET++	Objective Modular Network Testbed in C++
OT-MRC	Output-Threshold Maximum Ratio Combining
PB	Priority Boosting
PDCCH	Physical Downlink Control Channels
PDSN	Packet Data Serving Node
PF	Proportional Fair
PFPS	Proportional Fairness Packet Scheduling
P-GW	Packet Data Network Gateway
PCRF	Policy and Charging Rules Function
PLR	Packet Loss Ratio
PMUs	Power Measurement Units
PRB	Physical Resource Block
QAM	Quadrature Amplitude Modulation
QCI	Quality of Service Class Identifier
QoE	Quality of Experience
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RAN	Radio Access Network
RB	Resource Block

RE	Resource Element
RF	Resource Fairness
R-LDE	Revenue-Based Low-Delay and Efficient
ROI	Region of Interest
RR	Round Robin
RRM	Radio Resource Management
SAE	System Architecture Evolution
SBs	Scheduling Blocks
SC-FDMA	Single Carrier Frequency Division Multiple Access
SET	Switch and Examine Transmission
S-GW	Serving Gateway
SGSN	Service GPRS Support Node
SINR	Signal-to-Interference-plus-Noise Ratio
SISO	Single-Input-Single-Output
SMS	Short Message Services
SNR	Signal to Noise Ratio
TDRR	Time Domain Round Robin
TDD	Time Division Duplexing
TDS	Time Domain Scheduling
TF	Trade-Off Factor
TFDRR	Time and Frequency Domain Round Robin
TTI	Transmission Time Interval
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
UpPTS	Uplink Pilot Transmission Slot

VBR	Variable Bit rate
VoIP	Voice over Internet Protocol
VS	Video Streaming
WCDMA	Wideband Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
WSPMin	Weighted Sum Power Minimization
WSRMax	Weighted Sum Rate Maximization

LIST OF SYMBOLS

Δf	Sub carrier spacing
µs	Micro second
A_n t_n	Number of allocation unit scheduled to user n
b and c	fairness of the scheduler.
B	total amount of received bits
bit/cu	Bit per channel user
D	the historical average data rate of the station
dB	Decibel
F_A (t_1,t_2,….t_N)	Fairness Index
fs	Sampling Rate
GHz	Giga Hertz
interference	Interference Power
k*	Scheduled UEs set
Kbps	Kilobits per second
KHz	Kilo Hertz
km	Kilometer
km/h	Kilometer per hour
L	Latency
Mbps	Megabits per second
Mcps	Megachip per second
MHz	Mega Hertz
ms	Millisecond
n	1,2,N user index

N	number of considered users
Noise	Noise Power
N_u	Number of users admitted
P	Fixed packet size
Pi	Probability of specific SINR value
Pmax	Priority
R	Achievable data rate for the station in the current time slot
R_i	Average throughput based on SINR range
R_k (t)	Rate the k-th UE got
Sc	Spectral Efficiency
SF	Size of the frame
Signal	Signal Power
t_c	Length of sub frame and the current time
T_{cp}	Normal CP Time
T_{cp-e}	Extended CP Time
T_{frame}	Frame size
T_k (t+1)	Average UE Throughput
t_l^a (k)	Arrival time of kth packet in connection l
T_P	Fixed interval between packets
T_s	Total Symbol Length
t_{sim}	Total simulation time
T_{slot}	Slot Time
$T_{sub\ frame}$	Sub Frame size
T_u	Useful Symbol Time

Reka Bentuk dan Pembangunan Algoritma Penjadualan untuk Sistem Penghantaran Pindah Turun daripada Rangkaian Evolusi Jangka Panjang (LTE)

ABSTRAK

Dalam pembangunan teknologi kini, rakyat perlu melayari internet di mana sahaja mereka berada, jadi jalur lebar mudah alih akan berkembang secara aktif. Oleh itu, pembekal perkhidmatan bersaing untuk menghasilkan kelajuan internet yang maksimum untuk kegunaan awam. Bagi menyediakan perkhidmatan data berkelajuan tinggi kepada pengguna telefon mudah alih, teknik penjadualan merupakan isu yang sangat dititikberatkan dalam rangkaian tanpa wayar. Penjadual yang bagus adalah penjadual yang boleh memberi peningkatan kendalian, kependaman sistem yang rendah dan boleh memberikan keuntungan perlindungan terbaik. Untuk membangunkan penjadualan terbaik, penjadual mestilah mengetahui kualiti saluran dan penjadual harus mempunyai sekutu kualiti saluran pembawa setiap sub dan setiap pengguna. Untuk mengeksploitasi kepelbagaian pengguna dan di samping memberi pematuhan peruntukan sumber, suatu algoritma dicadangkan dalam tesis ini di mana kependaman sistem adalah dianggap sebagai keutamaan dalam penjadualan dan diikuti dengan susunan pengguna mengikut Penjadual penunjuk saluran kualiti (CQI) untuk struktur rangkaian evolusi jangka panjang (LTE). Analisis dan perbandingan algoritma penjadualan telah disediakan melalui simulasi yang dijalankan menggunakan perisian MATLAB yang dihasilkan dari Universiti Vienna. Sasaran utama dalam tesis ini adalah untuk menghasilkan penjadualan baru bagi peruntukan sumber-sumber yang boleh bertoleransi antara kendalian dan keadilan untuk mengelakkan ruang yang dibazirkan dalam Penjadual. Ruang tidak berguna boleh menyebabkan kependaman yang boleh menyebabkan kelewatan dalam penghantaran. Penjadual pusingan Robin dan best CQI dititikberat dalam projek ini. Terdapat dua (2) algoritma penjadualan dicadangkan dalam penyelidikan ini iaitu algoritma penjadualan Resource Fairness (RF) dan Maximum Throughput (Max TP). Algoritma penjadualan dipertingkatkan telah dicadangkan berdasarkan penjadualan algoritma proportional fair (PF). PF adalah salah satu algoritma penjadualan yang mempunyai kompromi antara pemprosesan dan keadilan. Dari pemerhatian, ia menunjukkan bahawa algoritma penjadualan RF telah mencapai kira-kira 19% peningkatan dari segi indeks keadilan berbanding algoritma penjadualan lain untuk semua jenis rangkaian. Walau bagaimanapun, algoritma penjadualan Max TP mempunyai kira-kira 25% peningkatan dari segi pemprosesan untuk semua rangkaian. Memandangkan algoritma penjadualan RF mempunyai nilai pemprosesan kedua tertinggi iaitu kira-kira 11% peningkatan berbanding algoritma penjadualan lain, ia boleh dianggap bahawa algoritma penjadualan RF telah mencapai kompromi tinggi antara keadilan dan pemprosesan berbanding algoritma penjadualan PF.

Design and Development of Scheduling Algorithms for Downlink Transmission System of Long Term Evolution (LTE) Network

ABSTRACT

In today's technology development, people need internet access wherever they are, mobile broadband will grow up actively. Therefore, service providers gradually compete to produce the maximum internet speed for public uses. To enable high-speed data services to mobile users, scheduling technique gained significant attention in wireless access networks. A feature of the wireless environment is that the quality of the different channels of the user population due to a conflict path loss and effect of the attenuation. The best scheduler should provide high throughput, low latency system and the best coverage gains. In order to develop the best scheduling, the scheduler must be aware of the channel quality and scheduler should have associate of the channel quality for each sub carrier and each user. In order to exploit the diversity of multiuser in addition to deliver further compliance in resource allocation, an algorithm is proposed in this work where system latency is considered as the first priority in scheduling steps and followed by arrangement of user equipments (UEs) according to the Channel Quality Indicator (CQI) scheduler for Long Term Evolution (LTE) structure. The analysis and the comparison of these scheduling algorithms were prepared over simulations done by a MATLAB-based downlink system level simulator from the Vienna University. The main target in this thesis is to propose a new scheduling for resources allocation that may be compromise between throughput and fairness to avoid useless space in a scheduler. Useless space may cause the latency that may cause of delay in transmission. The Round Robin (RR) scheduler and best CQI scheduler are considered in this research work. There are two (2) enhanced scheduling algorithms proposed in this research work which are Resource Fairness (RF) and Maximum Throughput (Max TP) scheduling algorithm. The enhanced scheduling algorithms have been proposed based on Proportional Fair (PF) scheduling algorithm. PF is one's of scheduling algorithm that have compromise between throughput and fairness. From the observation, it shows that RF scheduling algorithm has been achieved about 19% of improvement in term of fairness index compared to other scheduling algorithm for all type of network scenarios. While Max TP scheduling algorithm has provide about 25% of improvement in term of throughput for all network scenario. Since RF scheduling algorithm provide second highest throughput value which having about 11% of improvement compared to other scheduling algorithm, it may be considered that RF scheduling algorithm has achieved high compromise between fairness and throughput compared to PF scheduling algorithm.

CHAPTER 1

INTRODUCTION

1.0 Introduction

This chapter begins with background information and presented in Section 1.1. In Section 1.2, motivation is discussed. Section 1.3 discussed about the problem statement and section 1.4 stated the objectives of this research. Section 1.5 shows the flow of the project.

1.1 Background of Study

The idea of wireless technology known as First Generation (1G) is introduced in the 1980s which used analogue radio signal. A voice call gets transmitted among radio towers with the help of 1G and is modulated to a higher frequency which was at 150 MHz. The second generation (2G) wireless technologies was based on digital technologies which for voice communication only, except short message services (SMS) messaging, picture messaging and multimedia message (MMS). Global System for Mobile Communication (GSM) is 2G technologies which launched in 1991. GSM

allows users to do messaging to any mobile network at any time (Kaur, Birla, & Ahlawat, 2011).

International Telecommunication Union (ITU) defined Third Generation (3G) of wireless technology standard IMT- 2000 to enhance bandwidth, to assist evolution and support more varied application. 3G network allocate improved spectral efficiency packet switched data with high speed data rate. The 3rd Generation Partnership Project (3GPP) was established in 1998 to adopt improvement of the 3G network where 3GPP technologies developed as General Packet Radio Service (GPRS) organized in 2000 obtained 114 Kbps for data rate, followed by the Enhanced Data Rates for Global Evolution (EDGE) in 2003 with 384 Kbps of data rate, Universal Mobile Telecommunications System (UMTS) and Wideband Code Division Multiple Access (WCDMA) presented 1.92 Mbps of downlink data rate while High Speed Downlink Packet Access (HSPDA) provides 14 Mbps of the downlink data rate at the end of 2007 (Hadden, 2011).

Fourth Generation (4G) is new technology in the network system. 4G Systems provides Internet protocol (IP) based and comprehensive mobile wireless network for laptops, smart phones and other mobile devices. Figure 1.1 illustrates the evolutions of the wireless technology since 1980s (Erfanian, 2011). 4G technologies such as Worldwide Interoperability for Microwave Access (WiMAX) and Long Term Evolution (LTE) has grown respectively from 2006 and 2009. LTE and WiMAX are the new network system which is able to provide 4G services. In LTE, downlink peak rate is 100 Mbps, while uplink is 50 Mbps as well as round trip time of Radio Access Network (RAN) is fewer than 10millisecond (ms). LTE has scalable broadband carrier, from 1.4 MHz to 20 MHz

is also based on Time Division Duplexing (TDD) as well as Frequency Division Duplexing (FDD).

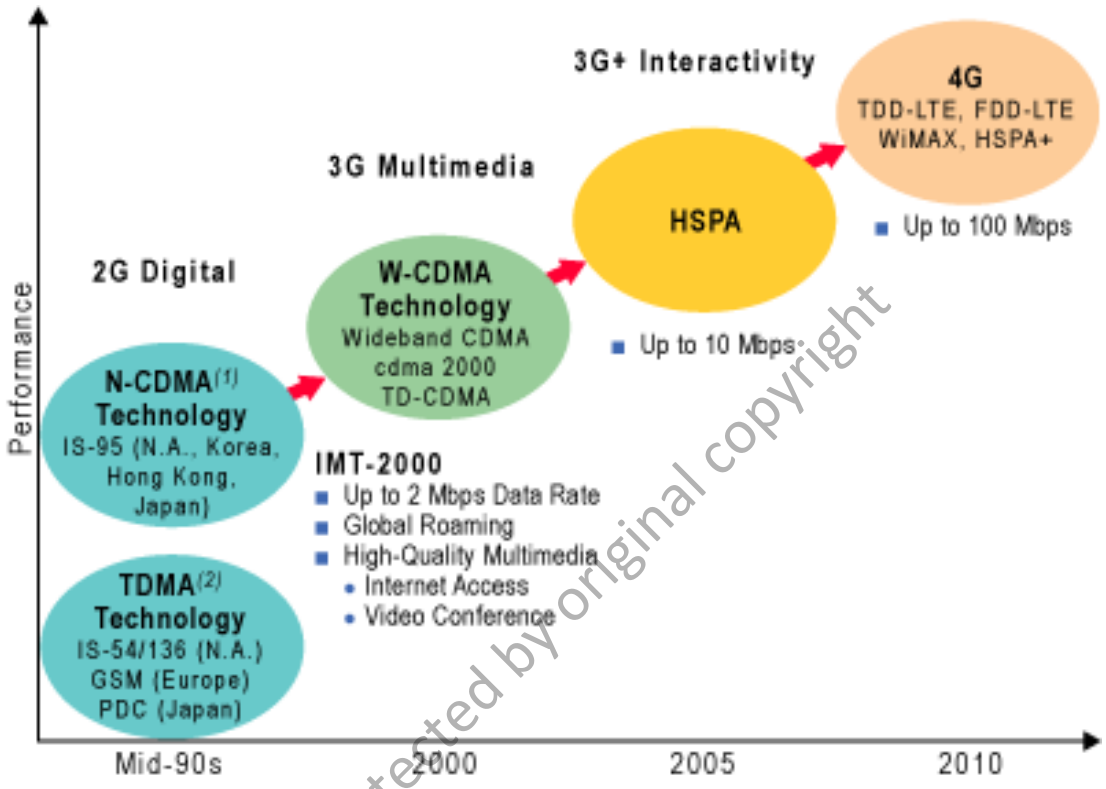

Figure 1.1: Evolution of Wireless Technology (Erfanian, 2011)

LTE is designed to provide better services for users, delivering new mobile services and remain as established system of wireless technology in the future. It is also designed to help service provider to deliver higher performance, ease of mass-market mobile communication, and provide high bit rate and throughput of the system with low latency for downlink and uplink transmission. LTE delivers high data rate and provide extending bandwidths from 1.4 MHz up to 20 MHz.

Scheduling is a significant element in network system which is intend to provide high speed data services to user equipments (UEs) (Izmailov & Wei, 2004). The channel

quality fluctuates through the user is an important characteristic in wireless configurations because of variances in fading, such as path loss. Every user's channel quality may be highly concern while choosing scheduling method. Channel dependent scheduling in the network system manages to serve among diverse radio resources and UEs in existing structures to obtain effective resource utilization (Erik Dahlman, Stefan Parkvall, 2008). In downlink transmission system, the packet transmission process is from E-UTRAN Node B (eNodeB) to UEs.

To achieve greater performance in the downlink scheduling of LTE, scheduler must concern on resource allocation of multi UEs (Kwan, Leung, & Zhang, 2008). In order to exploit the diversity of multiuser as well as to provide additional compliance in resource allocation, algorithms for scheduling are proposed in this research where system latency is considered as the first priority in new scheduling algorithms and trailed by allocation of UEs according to the Channel Quality Indicator (CQI). Round Robin (RR) scheduler and Best CQI scheduler are also considered in this project. The technique employs using an adaptive scheduling approach by designing the scheduler to allocate the packet to a UE with the highest CQI value and setting a fair allocation of remaining packet to the two others UE's in a fraction that's depends on a preset priority measurement.

1.2 Motivation

The motivation of this research work is from the statistic, it shows that in future LTE will serve more than 80% of all broadband user in the world since users start using internet application as their daily routine to communicate each other. Figure 1.2 shows

the user growth rate in network service from 2007 until 2014 (Beming et al., 2011). Packet data traffic having high demand compared than voice traffic (Halepovic, Williamson, & Ghaderi, 2009) starting from 2009 (see Figure 1.3). Introduction of HSPA network technology is the reason packet data traffic takes over voice traffic during May 2007 (Beming et al., 2011) in the networks. Performance, convenience, cost and security are driven as a motivation for introduction of LTE which can satisfy the high data rate user demand. Variation of network service is significantly improved with mobility. The motivation of LTE comprises particular principles for example shifting UMTS towards higher data rate, simple architecture, packet based system, several number of network elements and high quality of service (QoS) and reduced control plane latency significantly. Therefore, scheduling mechanism of radio resource in LTE system is one of the main performance indicators for suppliers.

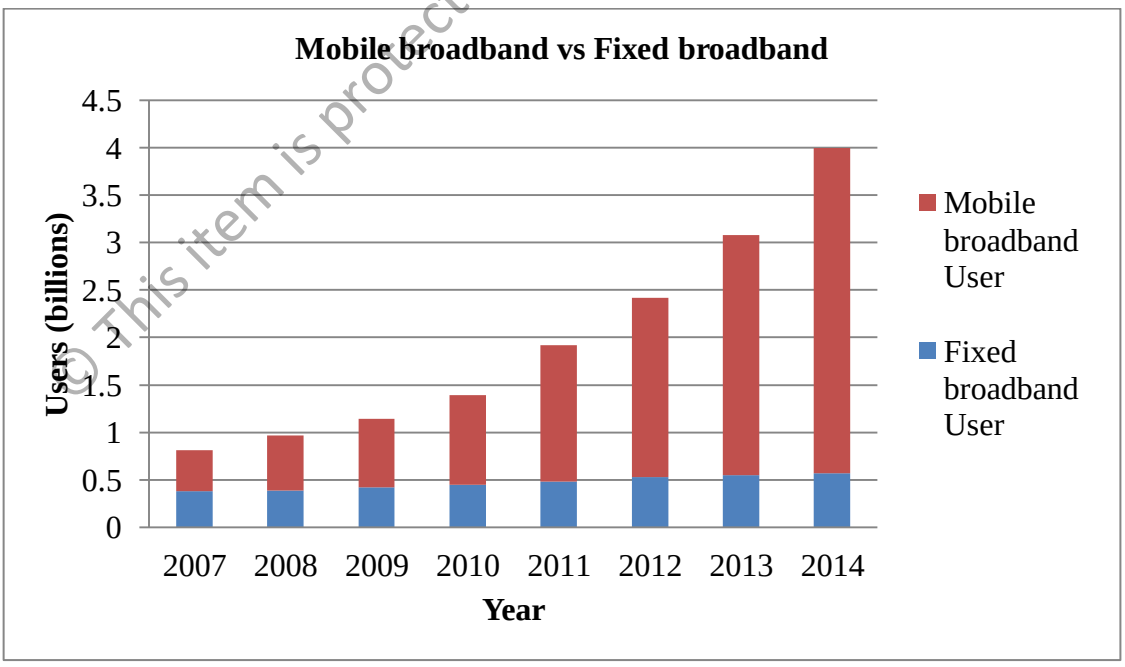

Figure 1.2: User Growth Rate in broadband service from 2007 until 2014 (Beming et al., 2011)