A PROPOSED PACKET SCHEDULING SCHEME FOR REAL-TIME MULTIMEDIA APPLICATIONS IN LONG TERM EVOLUTION – ADVANCED (LTE-A)

BY

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ABSTRACT

Real time applications with strict Quality of services (QoS) are quite popular among cellular users, whereas delay sensitive applications require an advanced technology to adopt them. This is where Long Term Evolution-Advanced (LTE-A) comes and fulfil this requirement. LTE-A is the top leading Fourth Generation (4G) technology. It provides a speed of 3Gbps and 1.5 Gbps in downlink and uplink respectively. With this ever evolving technology the need for improvements is required. Packet scheduling is one of the important key features of LTE-A, where it dictates user selection and transmission of those user's packets based on the priority of the users to reach the receiver end correctly. Packet scheduling is one mean to achieve those QoS requirements that real-time applications require. Example of these algorithms are HARQ Aware Scheduling Algorithm (HAS), Retransmission Aware Proportional Fair Algorithm (RAPF), Chase Combining Based Max C/I Scheduling and Maximum-Largest Weighted First algorithm (M-LWDF). Although this algorithms are efficient, their performance needs to improved for real-time multimedia applications be M-LWDF is one of the best algorithm in LTE-A which was chosen to be further investigated to support QoS in high mobility environment. Packet Loss Ratio (PLR), Mean User Throughout and Fairness performance measures were used to validate the performance of M-LWDF algorithm against other algorithms using similar mobile environment. Simulation results indicate the capability of M-LWDF algorithm within the threshold of the performance measures against other benchmarks where it has demonstrated more efficiency to support and improve the performance of real-time multimedia traffic.

ملخص البحث

التطبيقات الآنية ذات المتطلبات الصارمة لجودة الخدمات لها شعبية بين مستخدمي الهاتف الخلوي، بينما تتطلب التطبيقات الحساسة للتأخير تكنولوجيا متقدمة لاعتمادها. هنا تأتي تكنولوجيا التطور طويل الأمد المتقدمة (Long Term Evolution-Advanced, LTE-A) لتحقيق هذا المطلب. LTE-A هي التكنولوجيا الرائدة في الجيل الرابع (4G) لشبكات الهاتف الخليوي. وهي توفر سرعة 3 جيجابايت في الثانية و1.5 جيجابايت في الثانية في التنزيل والتحميل على التوالي. جدولة الرزم هي واحدة من السمات الرئيسية الهامة لLTE-A ، حيث يحدد اختيار المستخدم وإرسال الرزم لهؤلاء المستخدمين على أساس الأولوية للمستخدمين للوصول إلى الطرف الاخر (المتلقي) بشكل صحيح. خوارزميات جدولة الرزم واحدة من الطرق لتحقيق متطلبات جودة الخدمة التي تحتاجها التطبيقات الآنية. أمثلة هذه الخوارزميات هي خوارزمية الجدولة المدركة لل HARQ (HARQ Aware Scheduling Algorithm, HAS)، وخوارزمية جدولة إدراك إعادة الإرسال والعدل النسبي (Retransmission Aware Proportional Fair Algorithm, RAPF)، وخوارزمية جدولة قائمة على الدمج الملاحق ل أقصى C / I (Chase Combining Based Max C/I) واول خوارزمية كبرى وقصوى متناسبة (Maximum-Largest Weighted Delay First Algorithm, M-LWDF). بالرغم من ان أداء هذه الالخوارزميات بصورة عامة جيد, الا انه يحتاج الى تحسين في ما يخص تطبيقات الوسائط المتعددة الآنية. M-LWDF هي واحدة من أفضل الخوارزميات في LTE-A وبالتالي تم اختيارها ليتم التحقيق من دعمها لجودة الخدمة في بيئة التجوال عالي السرعة. معدل فقدان الرزم (Packet Loss Ratio, PLR)، متوسط تراسل المستخدم(Mean User Throughput) والعدالة بين المستخدمين (User Fairness) استخدمت للتحقق من فعالية أداء خوارزمية M-LWDF بمقارنتها مع خوارزميات أخرى تحت نفس ظروف التنقل عالي السرعة. نتائج المحاكاة تشير إلى قدرة خوارزمية M-LWDF ضمن حدود مقاييس الأداء المذكورة سابقا مقارنة بخوارزميات اخرى، حيث أثبتت أن عندها كفاءة لدعم وتحسين الأداء للتطبيقات الوسائط المتعددة الآنية.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a thesis for the degree of Master of Science (Communication Engineering)

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

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DECELRATION

The dissertation is particularly dedicated for my loved persons, my father Hani Arafa, my mother Nahla Karaki, my beloved brothers and sister, my beloved friends and anyone who has helped me in completing this thesis.

Thanks so much for the endless encouragement

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LIST OF ABBREVIATIONS

3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
ACK	Positive Acknowledgment
AMC	Adaptive Modulation and Coding
CA	Carrier Aggregation
CC	Component Carrier
CQI	Channel Quality Information
eNB	Evolved NodeB
EPC	Evolved Packet Core
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FD	Frequency Domain
GBR	Guaranteed Bit Rate
HARQ	Hybrid Automatic Repeat Request
HAS	HARQ Aware Scheduling
HeNB	Home eNB
HOL	Head of Line

ISI	Inter-Symbol Interferences
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union Radio Sector
LTE	Long Term Evolution
LTE-A	Long Term Evolution-Advanced
M-LWDF	Maximum Largest Weighted Delay First
MME	Mobility Management Entity
NACK	Negative Acknowledgment
NRT	Non Real Time
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PCRF	Policy and Charging Rules Function
PDN	Packet Data Network
PDN GW	Packet Data Network Gateway
PLR	Packet Loss Ratio
PS	Packet Scheduler
QoS	Quality of Services
RAPF	Retransmission Aware Proportional Fair
RNC	Radio Network Controller
RB	Resource Block

RRM	Radio Resource Management
RT	Real Time
SC-FDMA	Single Carrier Frequency Division Multiple Access
S-GW	Serving Gateway
TB	Transmission Block
TD	Time Domain
TSN	Transmission Sequence Number
TTI	Transmit Time Interval
UE	User Equipment

LIST OF SYMBOLS

μ_i (t)	the priority of user i
α_i	the QoS requirement for user i
W(t)	the delay of Head-of-line(HOL)
r_i (t)	the instantaneous data rate of user i
B_i (t)	the total bit size of all packets in the buffer
R_i (t)	the average throughput of user i
T_i (t)	the buffer delay threshold of user i
α	a constant parameter
$r_i(t)$	the instantaneous data rate for user i
δ_i	maximum probability for HOL to exceed delay threshold
η	data rate scaling factor
rni(t)	the normalised data rate of user i
k	a variable of the summation to compute across all users
N	the total number of users
M_r	the total transmission attempts for user i
$SNR_{inst(Mr)}(i)$	instantaneous SNR of Mr^{th} transmission of the same packet of user i
T_i	the application dependent buffer delay threshold of user *i*
$I_i(t)$	indicator function of event that packets user's selected for transmission
t_c	a time constant
SNR	signal to noise ratio

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Wireless communication is one of the most active areas of technology development of present time. This development is being driven primarily by the transformation of what has been largely a medium for supporting voice telephony into a medium for supporting other services, such as the transmission of video, images, text, and data. Thus, the demand for new wireless capacity is growing at a very rapid pace. Few years back, Third Generation (3G) technology was dominating over the other communication technologies, however, a constant demand for development and better performance led to creating a new Fourth Generation (4G). Long Term Evolution (LTE) was considered to be the greatest of 4G technology. However, a more developed release of the technology emerged, namely Long Term Evolution – Advanced (LTE-A), it became the leading 4G technology. This was due to some limitations in LTE such as not having a high data rate and its vulnerability to interference and scrambling in the physical layer. LTE-A (which is known as release 10) was developed by the Third Generation Partnership Project (3GPP) in order to meet the demands of higher data rate (i.e. 3/1.5 Gbs for downlink and uplink respectively) within the quality of service (QoS) required by the International Telecommunication Union - Radio communication (ITU-R). The LTE-A has high peak data rate and improved capacity and coverage as compared to LTE. This is achieved through the usage of improved packet scheduling algorithms, such as the Carrier Aggregation (CA) technique, the enhanced usage of multi-antenna techniques and support for relay nodes (Ghosh, 2010).

1.1.1 Long Term Evolution-Advanced (LTE-A)

In LTE-A system, the core network is divided into several parts as shown in figure 1-1. Enhanced NodeB (eNB) is a combination of NodeB and Radio Network Controller (RNC) which interconnects the User Equipment (UE) and is able to serve more than one cell at a time while home eNB serves a femtocell. Furthermore, Enhanced Packet Core (EPC) consists of serving gateway (S-GW) for routing packets between UE and Packet Data Network (PDN), whilst Mobility Management Entity (MME) copes UE access and mobility, and PDN Gateway (PDN GW) is a gateway to PDN (Yuan, 2010).

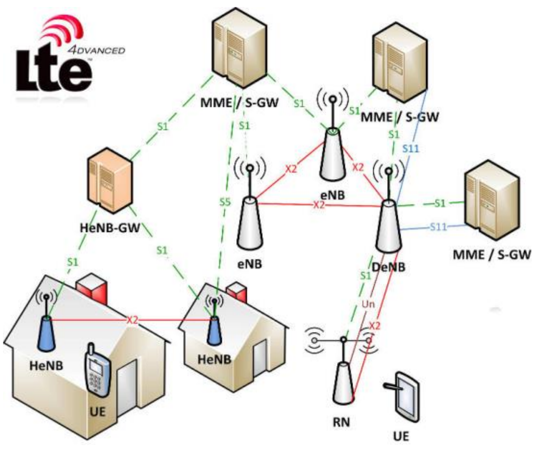

Figure 1.1 LTE-A Network architecture

In LTE-A, Orthogonal Frequency Division Multiple Access (OFDMA) is used for downlink transmission and Single Carrier Frequency Division Multiple Access (SC-FDMA) is used for uplink transmissions. The OFDMA symbols are grouped into Resources Blocks (RB), the RBs have a total size of 180 kHz in the frequency domain and 1 ms in the time domain. Each user is allocated a number of RB and each CC contains a number of RB available for usage. However, each RB can merely be assigned to one used only during each 1ms Transmission Time Interval (TTI) (Ramli, 2009).

The LTE-A employs a simplified Evolved Universal Terrestrial Radio Access Network (E-UTRAN) architecture that only consists of eNBs'. The eNB node links users to the core network and performs all Radio Resource Management (RRM) functions. Packet scheduling is one of the key RRM functions and its uses become vital as the LTE-A delivers both delay-sensitive Guaranteed Bit Rate (GBR) and loss-sensitive Non-GBR multimedia applications using packet switching technology (Ghosh, 2010).

Packet scheduling algorithm signifies an approach on the methods used to transmit packets efficiently by using applicable scheduling criteria such that specified performance metrics are fulfilled. In a non-real time (NRT) service environment, channel condition is the most common scheduling criterion, but in real-time (RT) service environment, mean user throughput, Packet Loss Ratio (PLR) and fairness are the common scheduling criterion. (Ramli,2014)

1.1.2 Packet scheduling

Packet scheduling is the process of assigning user's packets to suitable shared resource in order to achieve maximum performance. There are various forms of packet scheduling and some are explained later in the literature review. Packet scheduling improves the system capacity via the resources channels and additionally it also provides high utilization in multiplexed packets. If the network overloads with packets, the scheduling algorithms plan the order of the packet transmission under various QoS requirements from different users and allocates them to different resources so that it offers larger capacity and higher data. (Tsai, 2011)

1.2 STATEMENT OF THE PROBLEM

Packet scheduling is one of the key features in LTE-A for the reason that real-time application uses packet switching technology. Although there are some packet scheduling algorithms that have been created to withstand real-time multimedia applications, there are some challenges that need to be overcome such as imperfect channel quality information (CQI) reports, radio propagation environments that is subject to error, and the different QoS requirements of multimedia applications. Therefore, a novel design of packet scheduling algorithm for LTE-A is needed to provide an enriched performance of the real-time multimedia applications in downlink LTE-A, this enhancement is showed in terms of metrics such as Packet Loss Ratio(PLR), Mean User Throughput and Fairness.

1.3 PURPOSE OF THE STUDY

The purpose of this study is to come up with the following:

i. A novel packet scheduling algorithm for real-time applications.
ii. A C++ computer simulation tool that supports packet scheduling in the downlink LTE-A.

1.4 RESEARCH OBJECTIVES

The research objectives are stated as follow:

i. To modify packet scheduling algorithm to enhance the performance of real-time multimedia applications.
ii. To evaluate and benchmark the performance of the proposed algorithm over conventional algorithms via simulation.

1.5 RESEARCH QUESTIONS

i. How to create a new computer simulation tool to model and simulate the LTE-A?

ii. How to design a new packet scheduling algorithm that can efficiently utilize all packets while guaranteeing fairness and QoS requirements of every user in the downlink LTE-A?

1.6 SIGNIFICANCE OF THE STUDY

Demand for greater real-time multimedia applications in future wireless network will be very expensive and competitive. Future mobile technologies such as LTE-A will also undergo an essential role in every aspect of our life, in our governments, businesses, entertainment, and personal communication. Advanced techniques such as packet scheduling can significantly improve the usage of real time multimedia applications. The models, tools and algorithms which were developed in this research project will lead to improvements in the performance of LTE-A network. The outcome of this will be a novel packet scheduling algorithm that will enhance the handling of transmitted and retransmitted packets in the system to improve the real time multimedia application performance.

1.7 LIMITATIONS OF THE STUDY

The limitations of this study is in the range of objectives. They are stated as following:

i. This research is limited to the downlink in LTE-A

ii. The main focus will be the real-time multimedia applications where real-time data transmission is crucial

iii. The performance will be evaluated via computer simulation

1.8 DEFINITION OF TERMS

Packet Scheduling: The process of assigning user's packets to appropriate shared resources to achieve maximum performance.

Real-Time Multimedia Applications: Applications in which multimedia data has to be delivered and rendered in real time; it can be broadly classified into interactive multimedia and streaming media.

Long Term Evolution-Advanced: A mobile communication standard and major enhancement from LTE that is proposed by 3GPP to meet the requirements of International Mobile Telecommunication-Advanced (IMT-Advanced) on the ITU-R WP 5D Third workshop on IMT-Advanced which incorporates an all IP network architecture.

1.9 REPORT ORGANISATION

This thesis consists of five chapters and the first chapter is the Introduction chapter which presents a conceptual layout of the whole thesis. Chapter two is the Literature Review which briefly discusses on communication technologies and compares the LTE-A to packet scheduling, in addition to a short elaboration on the known algorithms. Furthermore, chapter three is the Methodology which consists of the system setup, performance measures, system objective and the proposed algorithm design. Chapter four is the Results and Discussion which contains the results of the simulation for the proposed algorithm with respect to the different performance measures discussed in methodology and the results of the bench mark algorithms used. It also contains the discussion of all the performance measures, how to interrupt them and how they were achieved. The final chapter is the Conclusion which concludes the report and whilst also stating the future work that could be done.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter is elaborated on 3G technology, its architecture, network and design and specification in a review form to initiate the topic of communication technology. Following this is the Long Term Evolution (LTE) which will also come in the form of a review of the same things in 3G but a more detailed version. 3G and LTE are compared to show the difference between the two technologies and then Long Term Evolution-Advanced (LTE-A) is explained in more details and how it's different from LTE. Succeeding this is a comparison of the two technologies in the form of a table and then packet scheduling is discussed. Next, some known algorithms in LTE and LTE-A along with their advantages and disadvantages are elaborated. Finally, the chapter ends with a discussion on the packet scheduling algorithms used in the simulation.

2.2 3G REVIEW

3G, or third generation, as it is just that in terms of the evolutionary path of the mobile phone industry was named as such for the reason that it is the third generation of the standards of telecommunication hardware. It is also the general technology for mobile networking, succeeding the recent 2.5G. The technology is founded on the ITU or International Telecommunication Union group of standards which belongs to the IMT-2000.

3G technology is an innovative service that uses a high network capacity, through an amplified spectral efficiency, to deliver the latest range of mobile-phone