QUALITY OF SERVICE AND SCHEDULING PERFORMANCE OPTIMIZATION IN LTE NETWORKS

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Field of Study: **Mobile Wireless Network**

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ABSTRACT

Long Term Evolution (LTE) is a technology introduced by Third Generation Partnership Project (3GPP) specification to transmit high data rate and increases applications requirements with reliable and best connection. LTE is marketed as 4G cellular network technology. It is a packet switch network designed with features such as supporting high data rate in both downlink and uplink channel. It also supports user in higher mobility cell and allows multi-user scheduling of radio resource. Scheduling is a Radio Resource Management mechanism (RRM) used to allocate radio resources to the user's channel bandwidth. Scheduling plays a vital role to provide Quality of Service (QoS) over the LTE networks. However, daily usage of the current scheduling schemes have degrade the overall system performance, which resulted in reducing the QoS for LTE system. This research proposed an optimal downlink scheduling algorithm called Video Real-Time Scheduling Algorithm (VRTSA) to support real-time traffic of video in LTE network. The developed algorithm is simulated in LTE-Sim simulator released 5 in terms of three QoS metrics (1) Packet Loss Ratio (2) Delay (3) Throughput. The developed scheduling algorithm is accomplished in three methodological stages as follows: first, frequency domain was considered for efficient scheduling at Resource Blocks (RBs) to the users based on best Channel Quality Indicator (CQI) report send from mobile station called as User Equipment (UE) to the base station (eNodeB). Second, time domain is also considered for controlling queue and prediction delay of the late coming expired packet. Third, termination processing unit is created for termination late expired packets those did meet the delay requirements. The performance of the developed VRTSA is evaluated and compared with three well-known downlink scheduling algorithms in LTE such as Proportional Fair (PF), Modified Largest Weight Delay First (MLWDF),

Exponential Proportional Fair (EXP/PF) as well as recent algorithm called LTTI. The results have shown that the developed VRTSA has outperformed others in terms of QoS metrics with 1. low packet loss ratio 2. low packet delivery delay 3. maximized system throughput. The result demonstrated using LTE-Sim is achieved to satisfied the QoS requirements in terms of packet loss rate, delay and system throughput. This study simulated single cell scenario with interference, and covered the area with radius 1 Km having a speed of 3Km/h and consists the number of users up to 20 also moving in a random direction at pedestrian and vehicular (PED A and VEH B) channels. The future work will consider to simulate multi cell scenario and the system complexity evaluation.

ABSTRAK

Evolusi Jangka Panjang (LTE) adalah teknologi yang diperkenalkan oleh spesifikasi Projek Perkongsian Generasi Ketiga (3GPP) untuk menghantar kadar data yang tinggi dan meningkatkan keperluan permohonan dengan dipercayai dan sambungan terbaik. LTE dipasarkan sebagai rangkaian selular teknologi 4G. Ia adalah satu rangkaian suis paket direka dengan ciri-ciri seperti menyokong kadar data yang tinggi dalam kedua-dua pautan turun dan saluran memuat naik. Ia juga menyokong pengguna dalam sel mobiliti yang lebih tinggi dan membolehkan penjadualan bagi pengguna yang pelbagai bagi sumber radio. Mekanisma bagi proses penjadualan adalah Radio Pengurusan Sumber (RRM) yang digunakan untuk memperuntukkan sumber radio saluran jalur lebar pengguna. Penjadualan memainkan peranan penting untuk menyediakan Kualiti Perkhidmatan (QoS) bagi rangkaian LTE. Walau bagaimanapun, penggunaan harian skim penjadualan semasa menjejaskan prestasi keseluruhan sistem, yang menyebabkan pengurangan QoS untuk sistem LTE. Kajian ini mencadangkan satu algoritma penjadualan pautan turun optimum dipanggil Video Real-Time Penjadualan Algoritma (VRTSA) untuk menyokong trafik masa sebenar aliran video. Algoritma yang dicadangkan disimulasi menggunakan LTE-Sim simulator dan mengeluarkan 5 dari tiga QoS metrik (1) Nisbah Packet Loss (2) Kelewatan (3) Pemprosesan. Penjadulan algoritma yang dicadangkan berjaya mencapai tiga peringkat metodologi seperti berikut: pertama, domain frekuensi dianggap untuk penjadualan berkesan di Sumber Blok (RBS) kepada pengguna berdasarkan laporan Saluran Penunjuk Kualiti (CQI) yang dhantar oleh pengguna (UE) kepada stesen pangkalan (eNodeB). Kedua, domain masa juga dipertimbangkan untuk mengawal barisan dan meramal kelewatan bagi paket tamat tempoh. Ketiga, unit penamatan pemprosesan dicipta untuk menamatkan paket yang lewat yang tidak memenuhi keperluan kelewatan. Prestasi VRTSA yang dibangunkan dinilai dan dibandingkan dengan tiga algoritma yang terkenal untuk penjadualan pautan

turun di LTE seperti berkadar sama rata (PF), Pengubahsuaian Terbesar Berat Kelewatan Berat Pertama (MLWDF), Exponen berkadar sama rata (EXP / PF) serta algoritma baru dipanggil LTTI. Keputusan telah menunjukkan bahawa VRTSA yang dibina telah mengatasi orang lain dari segi metrik QoS dengan 1. nisbah kehilangan paket yang rendah 2. penghantaran kelewatan paket yang rendah 3. maksimumkan sistem pemprosesan. Hasil menunjukkan penggunaan LTE-Sim mencapai QoS yang berpuas hati bagi keperluan dari segi kadar kehilangan paket, kelewatan dan sistem pemprosesan. Kajian ini, simulasi senario sel tunggal dengan gangguan dalam kerja-kerja masa depan akan mempertimbangkan untuk mensimulasikan persekitaran sel yang pelbagai.

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DEDICATION

This dissertation is dedicated to my beloved parents, wife and son.

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LIST OF SYMBOLS AND ABBREVIATIONS

AMC	:	Adaptive Modulation and Coding
CQI	:	Channel Quality Indicator
eNodeB	:	evolved NodeB
EPC	:	Evolve Packet Core
E-UTRAN	:	Evolve Universal Terrestrial Radio Access Network
EXP/PF	:	Exponential Proportional Fair
FDD	:	Frequency Division Duplex
GBR	:	Guaranteed Bit Rate
HARQ	:	Hybrid Automatic Retransmission Request
IP	:	Internet Protocol
LTE	:	Long Term Evolution
MAC	:	Medium Access Control
MLWDF	:	Modified Largest Weighted Delay First
MME	:	Mobility Management Entity
Non-GBR	:	Non-Guaranteed Bit Rate
OFDMA	:	Orthogonal Frequency Division Multiple Access
PDCCH	:	Physical Downlink Control Channel
PDSCH	:	Physical Downlink Shared Channel
PF	:	Proportional Fair
PHY	:	Physical Layer
PLR	:	Packet Loss Ratio
QAM	:	Quad-lateral Amplitude Modulation
QCI	:	QoS Class Identifier
QoE	:	Quality of Experience

QoS	:	Quality of Service
QPSK	:	Quad-lateral Phase Shift Keying
RB	:	Resource Block
RE	:	Resource Element
RLC	:	Radio Link Control
RRC	:	Radio Resource Control
RR	:	Round Robin
RRM	:	Radio Resource Management
S-GW	:	Serving Gateway
SINR	:	Signal to Interference Noise Ratio
SC-OFDMA	:	Single carrier-Orthogonal Frequency Division Multiple Access
TDD	:	Time Division Duplex
TTI	:	Time Transmission Interval
UE	:	User Equipment
VoIP	:	Voice over Internet Protocol
VRTSA	:	Video Real-Time Scheduling Algorithm

CHAPTER 1: INTRODUCTION

This chapter includes background of the study, problem statement, research aims and objectives, research questions, significant of study, research motivation as well as dissertation outline.

1.1 Background of the Study

The emergence of mobile cellular networks services such as web browsing, Voice of Internet Protocol (VoIP) call, video call, video streaming and video conference require low delay, less packet loss and high throughput. This became one of the challenges facing in a future design cellular network. Third Generation Partnership Project (3GPP) introduced broadband wireless cellular network called Long Term Evolution (LTE) system (Astély et al., 2009; Chadchan & Akki, 2010; Ekstrom et al., 2006; Sesia et al., 2011). LTE is marketed as 4G cellular network technology. It manifested with features such as; it supports high data rate transmission for both downlink and uplink data transmission. The downlink channels can peak data rate up to 100 Mbps on the other hand, uplink can peak data rate up to 50 Mbps. It provides flexible bandwidth allocation range from 1.4 MHz to 20 MHz with high spectral efficiency two to four times better than the previous 3G networks. The 4G LTE supports users with higher mobility and allows multi-user scheduling of radio resources.

Furthermore, LTE is designed with other features like less packet delivery delay, low packet loss ratio, high spectral efficiency and throughput. This network leads to reduction in cost and system complexity. The communication system in LTE is a packet switch network which acquired all Internet Protocols (IP) architectures to access the radio service and Evolve Packet Core (EPC) networks. There are over twenty LTE cellular operators all over the world, and more than thirty-two million LTE subscribers are predicted by the year 2013 (Mcqueen, 2009). The effectiveness of the LTE necessities push reasons for academic and industries researchers to improve its features. They proposed new or enhancing solutions with intend to analyze and optimize system performance.

Scheduling plays a vital role in allocation radio resources to different users in LTE network. And it is a RRM mechanism responsible for radio resources allocation to cellular users.The packet scheduler is deployed at the base station, the base station is called evolve NodeB (eNodeB). In LTE packet scheduler transmits radio resources via downlink and uplink schedulers through their interfaces simultaneously. Each radio resource is allocating in time and frequency domain. In time domain the resources are allocated in each Time Transmission Interval (TTI) updated in every 1ms (Chadchan & Akki, 2010). Moreover, Each TTI contains two time slots each slot has 0.5 ms last. Every time domain corresponds to fourteen (14) Orthogonal Frequency Division Multiple Access (OFDMA) symbols by default configuration. In frequency domain the bandwidth is distributed into one hundred and eighty Kilo Hertz (180 KHz) sub-channels which correspond to the 12 consecutive and equal sub-carriers space. In wireless connection, channel quality is liable to change in frequency and time domains as a result of some issues such as multipath propagation and fading effect.

Downlink scheduling accesses the radio resources from eNodeB through OFDMA radio interface to the mobile devices (UE). Through OFDMA can access LTE network to support a vast internet and multimedia services with a high mobility. The downlink scheduling frame accessed resources based on frequency and time domain resource containing multiple Resource Blocks (RBs). The resource block is divided into multiple Resource Elements (REs) and the scheduler assigns frequency and time domains to various users in the cell. To accomplish these aims the Radio Resource Management (RRM) blocks at layer two is exploited to joint of Advanced Medium Access Control (MAC) and physical functions. The physical functions include Channel (CQI) report, resource allocation, Hybrid Automatic Retransmission Request (HARQ), link adaptation via Adaptive Modulation and Coding (AMC). The data exchanged at MAC layer is between the user and base station through sublayers using transmission transport blocks which send data through downlink and uplink transmission channels. In this case, designing an efficient resource allocation method is vital. In fact, effective usage of the radio resources is significant to achieve good system performance to satisfy the user's demands based on specific QoS requirements (Avocanh et al., 2013; ITU-T E.800 Annex B, Aug. 2008). Based on the previous reasons mentioned, channel-aware strategies solutions can be implemented in OFDMA system. Since they can achieve channel quality differentiations by giving high priority to the users having the best channel condition. Many issues emerge during the designing of this solution in LTE, covering from providing of good scheduling process and high cell capacity to satisfying QoS requirements. Similarly, a packet scheduler is also responsible for allocating portions in the spectrum to share among several users based on service policies.

QoS in LTE is influenced by significant factors such as availability of radio resources, optimizing scheduling performance, types of services and channel conditions. The improvements of RRM mechanism is lead to optimize the system performance and achieve the QoS requires. The real-time services are required a robust QoS in LTE. The QoS in LTE is an important issue need to be consider in a preparation to design a future broadband network or to improve the system capacity for different services. Many cellular subscribers are used LTE network for different services such as video calls, voice calls, online video gaming, bank transaction, web browsing, all these services are requiring different QoS in their traffic. LTE are designed particularly with a target to provides the QoS for successful packet transmission. Hence, to handle these issues a high QoS is required by design an optimal downlink scheduling algorithm in order to improve the system level performance in LTE.

1.2 Problem Statement

LTE system is a broadband network technology designed to transmit high data rate and increase applications requirements with reliable connection. The emergence of real-time multimedia services like video streaming, video call, online video gaming and voice call, requires QoS to satisfy the user's requirements. The daily usage of the existing scheduling schemes can degrade the system performance which can affect the QoS in the LTE network (Camarda, 2012). Whereas, LTE specification is not restricting the adoption of any specific scheduler, however the 3GPP have not provide real-time traffic of video scheduling algorithm, thus leaving freely to implement different solutions (Alfayly et al., 2012; B. Liu et al., 2013; Mahfoudi et al., 2015; Piro et al., 2011).

In the same vein, the real-time of video traffic required QoS for adequate resource allocation which is an issue to be considered to maintain the QoS in LTE network. In real-time traffic of video, it is not worthy of receiving late arrived and corrupted packet to the user. However, transmitting of packet loss is a wastage of bandwidth to downgrade the system throughput. This study proposed an optimal downlink scheduling algorithm called VRTSA to improve the overall system performance and QoS in LTE network to satisfy the users requirements for real-time traffic of video.

1.3 Research Aims and Objectives

The aims of this research is to optimized scheduling performance and quality of service in LTE network. To achieve this aim, the following objectives are required.

i. To investigate and analyze the performance of downlink scheduling algorithms in LTE network.

ii. This study developed downlink scheduling algorithm to support video traffic in LTE network.

iii. To evaluate and compare the performance of the developed downlink scheduling algorithm with the current algorithms.

1.4 Research Questions

i. Does the existing scheduling algorithms have the capability to cope with Quality of Service requirements in LTE network?

ii. Is the developed scheduling algorithm can achieve Quality of Service requirements?

iii. Does the validation of the Quality of Service metrics of the proposed scheduling algorithm satisfy the users' requirement?

1.5 Significant of Study

The significant of this study is highlighted as follows:

i. The developed algorithm is a useful solution to scheduling issue which provides guaranteed good system performance.

ii. The developed algorithm improved the QoS metrics for real-time traffic of video.

iii. The study provides reliable connection to access the video traffic effectively.

iv. The developed algorithm is significant for saving bandwidth based on frequency domain consideration during scheduling in a tried to avoid transmission corrupted packets.

v. The developed algorithm can efficiently be utilize in future study in which the simulation scenarios can be performed and validated in a multiple cell eNodeB and system complexity issue is also considering.

1.6 Research Motivation

Today the high emergence of cellular user's demand to subscribe LTE network for different services such as video streaming, video calls, VoIP calls, video conferencing and online video games. All these services are required different QoS especially the real-time traffic of video require low packet transmission delay, reduce packet loss ratio and higher throughput. Indeed, LTE is mainly designed to provide efficient QoS to satisfy users' requirements. However, due to the increasing of real-time data traffic and high applications emergences today need reliable connection. Nevertheless, to maintain the future challenges in LTE network, design an optimal downlink scheduling technique is significant to achieve good system performance and satisfy the user's QoS requirements in LTE (Wang & Lin, 2004; Avocanh et al., 2013; ITU-T E.800 Annex B, Aug. 2008). Hence, an optimal scheduling techniques need to be develop or improve to upgrade the system performance to achieve QoS in LTE.

1.7 Dissertation Outline

This study described an effective model which provide optimal scheduling technique. The proposed model considers scheduling issues. The dissertation is organized into chapters outlined below:

Chapter 1: focused on research work which includes the Background of Study, Problem Statement, Research Aims and Objectives, Research Questions, Significant of Study, Research Motivation as well as Dissertation Outline.

Chapter 2: contains review of the related works on downlink scheduling issues the methods to achieve QoS in LTE network. This chapter comprises; Introduction, Long Term Evolution, LTE System Architecture, Evolve Packet Core, Architecture of Evolve Packet Core, Mobility Management Entity, Evolved-Universal Terrestrial Radio Access Network, Base Station, User Equipment, Radio Bearer Management, Physical Layer, Orthogonal Frequency Division Frequency Multiplexing Access, Frame Structure, Frequency Division Duplex, Time Division Duplex, Radio Resource Management, Channel Quality indicator Reports, Physical Channel, Scheduling and Limitation of previous studies and Research Gap as well as Table of Summarized Related Works.

Chapter 3: comprises the comprehensive methodology of the proposed system for real-time scheduling traffic of video flow which encompassed sub title as follows; The

Proposed Video Real-Time Scheduling Algorithm, Methodological Stages of the Proposed VRTSA, Implementation Parameters, Efficient Scheduling for Resource Blocks Based on CQI Reports, Controlling Queue and Prediction of Delay of the Late Arriving Expired Packet, Termination Processing Unit of late Expired Packets as well as Summary of this chapter.

Chapter 4: Conducted a detail analysis on the results found of the issue of real-time traffic of video flow being solved and compared the efficiency of the proposed method with three existing downlink scheduling algorithms as well the recent algorithm. The proposed scheduling algorithm was met a better performance. Also this chapter contains outline as follows; Simulation Results and Summary.

Chapter 5: Presented a summary and conclusion of the research, as well as suggesting some recommendations for the future work.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

This chapter carried out a rigorous study and analysis of reviews of research related to the present study. Many researchers come up with different approaches to improving QoS in LTE system by optimizing scheduling performance. However, achieving a good scheduling performance in LTE networks will satisfy the user's requirements. The academic researchers and industries are giving enormous efforts to conduct more research on different areas over the LTE to design an optimal scheduling algorithm for QoS provisioning to the users. Therefore, we studied a lot of previous scholars works with detail references from different sources related to this work including journals articles, books, conference, and websites. However, this project mainly focused to proposed an optimal downlink scheduling algorithm which improves QoS metrics particularly delay, throughput, and packet loss.

The outline of this chapter as follows: Long Term Evolution, LTE System Architecture, Evolve Packet Core, Architecture Of Evolve Packet Core, Mobility Management Entity, Evolved-Universal Terrestrial Radio Access Network, Base Station, User Equipment, Radio Bearer Management, Physical Layer, Orthogonal Frequency Division Frequency Multiplexing Access, Frame Structure, Frequency Division Duplex, Time Division Duplex, Radio Resource Management, Channel Quality Indicator Reports, Physical Channel, Scheduling And Limitation Of Previous Studies And Research Gap.

2.2 Long Term Evolution (LTE)

LTE simply refer to as “Long Term Evolution” it is introduced by the Third Generation Partnership Project (3GPP) in December 2009 (Astély et al., 2009). It comprised two portions of the radio access networks, the Evolve-Universal Terrestrial Radio Access Network (E-UTRAN) and Evolve Packet Core (EPC). It aims to determine the new packet optimization method and all internet protocols (IPs) architecture. It can access the radio service and core network (Astély et al., 2009; Chadchan & Akki, 2010; Ekstrom et al., 2006; Piro et al., 2011; Sesia et al., 2011).

LTE is provided mainly to transmit high rate of data with a high mobility; it reduced the cost, delay and packet loss, maximize the system throughput and spectral efficiency better than previous Third Generation (3G) networks (ITU-T E.800 Annex B, Aug. 2008).

LTE network is usually access technique through Single Carrier-Frequency Division Multiple Access (SC-FDMA) for uplink direction and Orthogonal Frequency Division Multiple Access (OFDMA) for downlink direction of the radio interface. However, it supports two channels for radio resources transmission in downlink and uplink direction simultaneously. It is highly supporting multimedia applications and Internet services in a Radio Resource Management (RRM) unit blocks is accomplished which encompasses mixed of Medium Access Control (MAC), Channel Quality Indicator feedback (CQI), Channel link over Adaptive Modulation and Coding (AMC) scheme and Hybrid Automatic Retransmission Request (HARQ). The LTE performance improvements see Table 2.1 (Capozzi et al., 2013).

Table 2.1: LTE Performance (Capozzi, 2013)

Data rate	• Peak 100 Mbps at Downlink • Peak 50 Mbps at Uplink
Service support	• Web-browsing, FTP, Voice (VoIP), and Video streaming • VoIP supports QoS as voice flow over UMTS network.
Spectral efficiency	• 2 to 4 times improved than 3G network
Cell bit-rate	• Maximize at similar position expanding today
User plane delay	• Less than 5 ms for 5MHz bandwidths or above
Mobility	• Improved mobility up to 15 km/h • High speed up to 120 km/h • It retains connection up to 350 km/h

Table 2.1, Continued

Bandwidth Allocations	• range from1.4 MHz up to 20 MHz
RRM	• Improved packet delivery for end-to-end QoS • Effective transmission and function of the upper layer protocols

2.3 LTE System Architecture

LTE system is designed with flat architecture also known as Service Architecture Evolution (SAE) on previous 3G networks (Capozzi et al., 2013; Parkvall et al., 2009). It guarantees high mobility support with very fast data delivery to the destination and signaling. See in figure 2.1 below, it is designed the core networks composed of EPC and E-UTRAN.

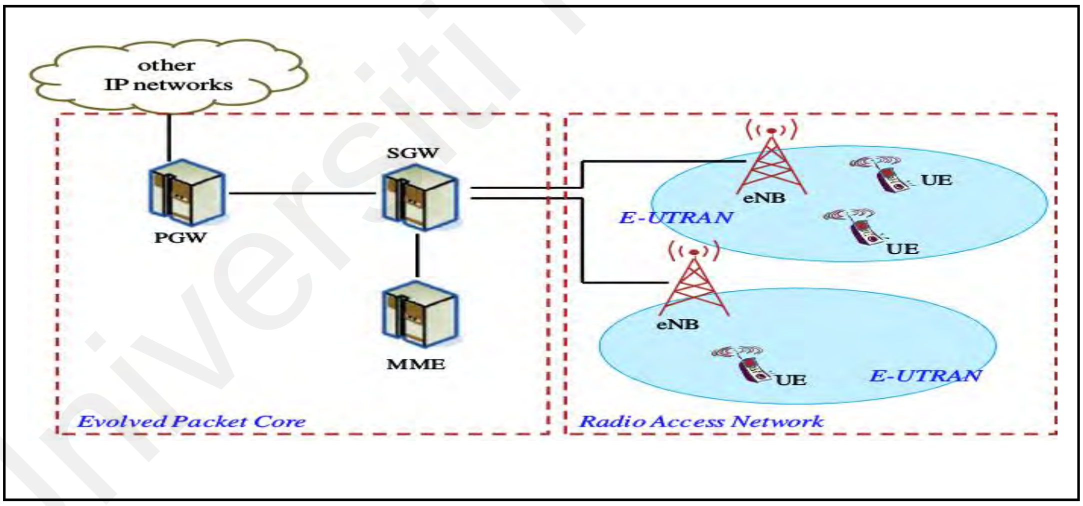

Figure 2.1: Service Architecture of LTE network (Capozzi, 2013)

The EPC is the newest architecture of 3GPP network, in GSM the architecture depends on circuit switching. The EPC contains Mobility Management Entity (MME), Serving Gateway (SGW), and Packet Data Network Gateway (PDN). The MME handle user mobility, handover, tracking and contacting procedures to provide the cellular users' connection set up. Handover is in charge to manage and select a suitable cell eNodeB service connection to maintain the user to have QoS in the multi-cell environment. SGW is used to route and forwards packet between the LTE system and control handover between LTE and the remaining 3GPP networks. The Packet Gate Way (PGW) provides connections between EPC and other outside IP global networks and routes the packets from sender to the receiver of the PDNs. It performs several functions such as IP addresses prefix assigning, charging and policy control. It provides a connection between the users and the external packet networks (Myung, 2008).

Also EPC are initiated by 3GPP Release 8, to handle data traffic efficiently based on the system performance. Thus, a trivial network node is elaborated to carrying the traffic and protocol change is avoided. It can separate user data which known as user plane, and the signal is known as a control plane to form a scale-independent (Sesia et al., 2011).

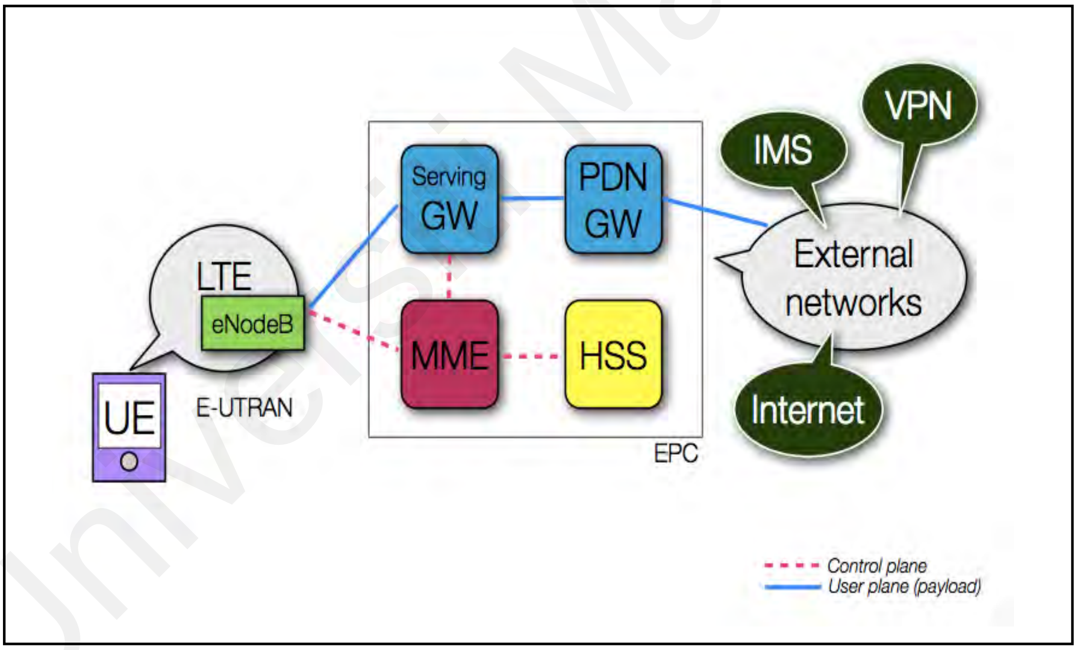

Figure 2.2: Architecture of EPC with E-UTRAN Access (Firmin)

The MME is compromised with control-plane its cares with a signaling which associated with mobility and protected from E-UTRAN network access (Prasad et al., 2007).

2.4 Evolved-Universal Terrestrial Radio Access Network

The E-UTRAN composed of two essentials devices; the base stations (eNodeB) and mobile station (UE). It provide evolve universal terrestrial radio access user plane (PDCP/RLC/MAC/PHY) and control plane of Radio Resource Control (RRC) protocol abort with the approach of the user. The eNodeB is connected to each other and MME via the interfaces X2 and S2 to the EPC, and MME-S-GW (Access, 2008).

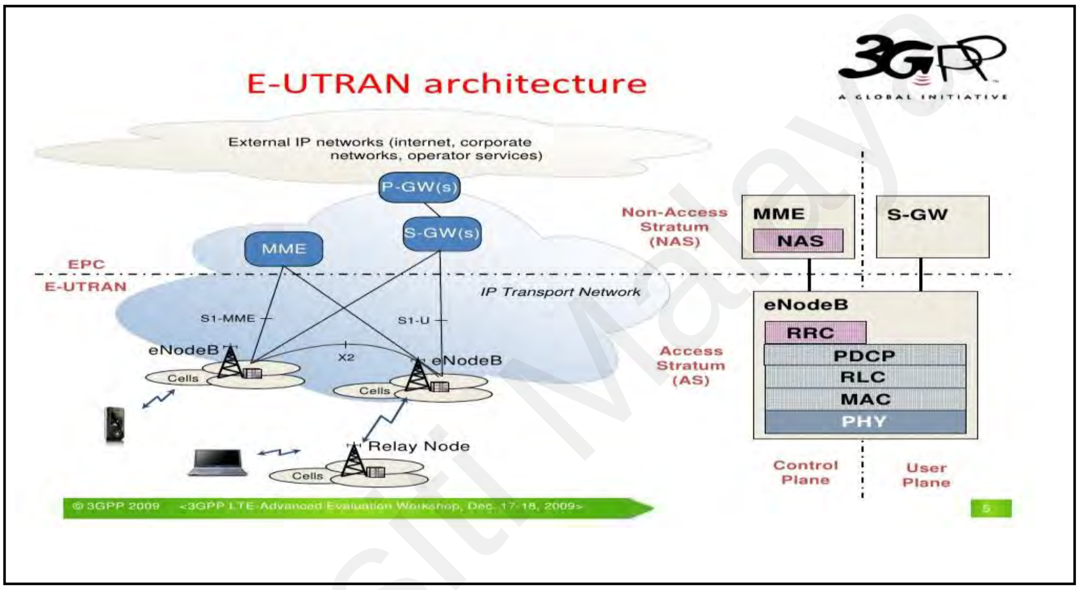

Figure 2.3: E-UTRAN Architecture (Lindstrom,2009)

(a) **Base Station**

The base station (eNodeB) which controls the entire radio access service such as compression of IP header, radio resources control, encrypted user's data, scheduling, and transmission. Choosing Mobility Management Entity (MME) of the user attached, routing user-plane data to S-GW and receiving Channel Quality Indicator (CQI) feedback from the UE for making scheduling decision to allocate radio resources in Resource Blocks (RBs). The eNodeB has two interfaces S1 and X2; The **S1** is an interface connect the eNodeB with EPC system which communicates between UE and radio access networks. EPC and **X2** is an interface which provides connections among various eNodeB and supports high mobility cells interference control (Sesia et al., 2011).

(b) **User Equipment (UE)**

User Equipment (UE) is a mobile station or any device used by end user which enable to communicate with the base station (eNodeB) system. Each UE is receives a reference signals to process the CQI and send it back to eNodeB to select the channel with quality to allocate the RBs for scheduling active users on the network (Sesia et al., 2011).

2.5 Radio Bearer Management and Protocol Stalk

The radio bearer is a channel connection made between eNodeB and UE. It has the responsibility to control the QoS on E-UTRAN interfaces. However, during the UE connect the network, the default bearer established the main connection and communication to control messages. The Default bearer keeps existing during the whole period of connection. The dedicated bearer is set up each time have a new specific service is a connection. The radio bearer depended on QoS requirements and classified as Guaranteed Bit Rate (GBR) and non-Guaranteed Bit-Rate (non-GBR) bearers (Ekstrom, 2009). The QoS requirements are interpreted in a variable that describes the performance experienced from the UE (B. Liu et al., 2013). The conventional QoS metrics is related to individual radio bearer, though it depends on the application carries, also the capability of distinguishing among different flows. Based on this fair during LTE standard state several classes of QoS has been proposed through Quality of Service Identifiers (QCIs) (3GPP TS 23.203; Capozzi et al., 2013). In table 2.2 as follows each class of QoS is characterized based on its type of resources either GBR or non-GBR, maximum delivery delay, acceptable packet loss and priority level.

Table 2.2: The QoS Class Identifiers in LTE (Capozzi et al., 2013)

CQI	**Type of Resource**	**Priority**	**Packet Delay budget (ms)**	**Packet Loss Rate**	**Services**
1	GBR	2	100	0.01	Conversational voice
2	GBR	4	150	0.001	Video live streaming

Table 2.2, Continued

CQI	Type of Resource	Priority	Packet Delay budget (ms)	Packet Loss Rate	Services
3	GBR	5	300	10^{-2}	Non-live streaming (buffered streaming)
4	GBR	3	50	0.001	Real-time game
5	Non-GBR	1	100	10^{-6}	IMS
6	Non-GBR	7	100	0.001	Voice, live video streaming, and interacting game
7	Non-GBR	6	300	10^{-6}	Video (buffered streaming)
8	Non-GBR	8	300	10^{-6}	TCP e.g. web browsing, email, chat, FTP and P2P file sharing.
9	Non-GBR	9	300	10^{-6}	

Radio Resource Control (RRC) is to handle of making and control connection, transmission system information, paging processing, mobility and established reconfiguring and manage the radio bearers (Capozzi et al., 2013).

2.6 Physical Layer

LTE system designed with highly dynamic wireless access technology which supports a high bandwidth allocation from 1.4 MHz up to 20 MHz in the spectrum. The radio in the spectrum is accessed through Orthogonal Division Multiplexing (OFDM) layer. The OFDMA radio interface is used to access downlink channel. OFDM is allowed multi-access by allocation set of sub-carriers to the individual user. Similarly, OFDMA can achieve sub-carriers allocating in the spectrum. Also, OFDMA can provide high robustness against frequency and time selection fading of the radio channel. The radio resources is allocated in time-frequency domain described in Figure 2.4 below (Channels, 2007).

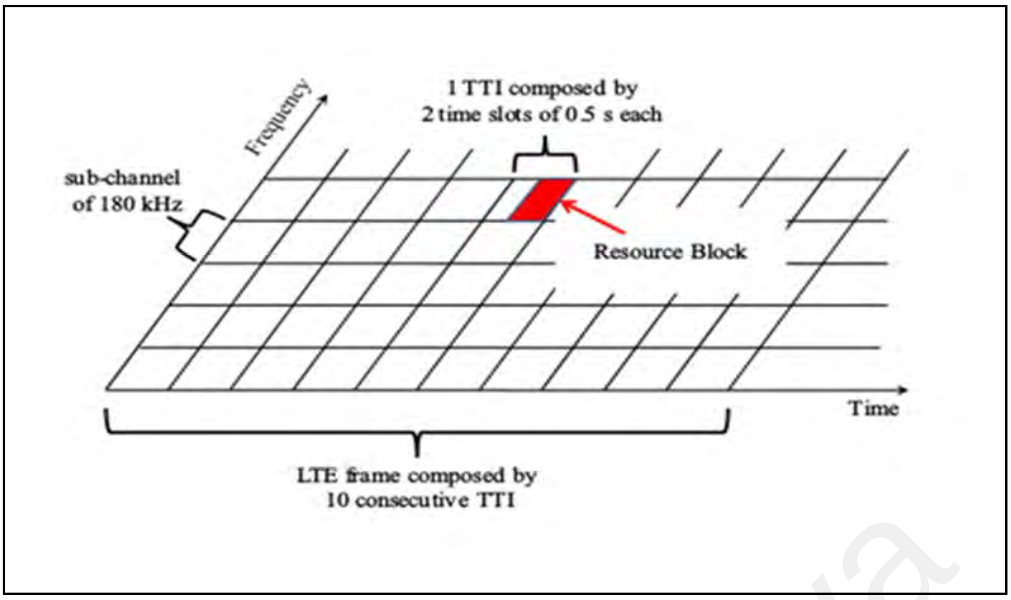

Figure 2.4: Time and Frequency Resource Grid (F.Capozzi,2013)

The radio resources are assigned to frequency or time domain (Channels, 2007), in time the radio resources is distributed after every update of Time Transmission Interval (TTI) at 1 ms. The time been divided into frames each frame consists ten (10) consecutive TTIs. Moreover, each TTIs are created with two time slots each half is 0.5 ms, consistent to 7 symbols of OFDMA by default configuration having a low cycle prefix. But in Frequency domain, instead a whole bandwidth is split into sub channels as180 KHz, each has 12 successive and equal spaced of OFDMA sub-carriers. Moreover, the time or frequency resources is covered two times slots in time domain and above one sub channel in a frequency domain called as Resource Block (RB) and linkage to lower wireless resource component that can be allocated to UE for transmission data. The sub-channel magnitude is not yet changed, a number of the RBs differentiate based on system bandwidth allocation (Capozzi et al., 2013).

2.7 Orthogonal Frequency Division Multiplexing Access

The OFDMA allow multiple accesses via allocating subcarriers to individual users. It also accomplishes sub-carriers allocated in the spectrum (Piro et al., 2010).

(a) **Frame Structure**

LTE interface supports two different types of frames proposed for E-UTRAN which work in duplexing mode. It is operated via Frequency Division Duplex (FDD), and the bandwidth is shared into two equal parts to permit downlink and uplink data transmission simultaneously. Frame contains 10 ms corresponding sub-frames each one is last for 5 ms time TYPE 1: support FDD Transmission and TYPE 2: support TDD Transmission (Channels, 2007).

(b) **Frequency Division Duplex**

In FDD frame the bandwidth are allocated into two different channel allowing downlink and uplink to transmit data simultaneously. LTE frame contained 10 consecutive similar sub frames (Capozzi et al., 2013).

(c) **Time Division Duplex**

Time Division Duplex (TDD) is split into two successive parts, and each half frame will be lasting for 5 ms duration. Different frames configuration allows the various balance of the resource provided for downlink and uplink data transmission. The frame can be high of the downlink is in configuration column (5) while the uplink is a configuration in column (0) as described in Table 2.3 as follows:

Table 2.3: TDD Frame Configuration (Capozzi et al., 2013)

Configuration Number	**1st Half-frame**					**2nd Half-frame**				
	0	1	2	3	4	5	6	7	8	9
0	D	S	U	U	U	D	S	U	U	U
1	D	S	U	U	D	D	S	U	U	D
2	D	S	U	D	D	D	S	U	D	D
3	D	S	U	U	U	D	D	D	D	D
4	D	S	U	U	D	D	D	D	D	D
5	D	S	U	D	D	D	D	D	D	D
6	D	S	U	U	U	D	S	U	U	D

Key Elements

D: Downlink sub-frame U: Uplink sub-frame S: Special sub-frame

2.8 Radio Resource Management

LTE perform extensive use of Radio Resource Management (RRM) scheme such as radio power control; bearer control, admission control, mobility control, channel link adaptation, scheduling resources, HARQ, and CQI report. It is deployed at layer 2 which integrated MAC and Physical layers to access the radio resources effectively (Capozzi et al., 2013; Sesia et al., 2011).

2.9 Channel Quality Indicator Report

The process of CQI report is an essential feature of the LTE system it able to estimate the channel quality at the downlink channel of eNodeB. The CQI is computed as a scale by measuring channel has experiencing interference of SINR. The issue related to CQI feedback system is to discover a good compromise between the exact channel quality estimated also lower the signal (Kolehmainen et al., 2008).

2.10 Physical Channel

The eNodeB is transmitting data on downlink channel through Physical Downlink Shared Channel (PDSCH). It is distributed among all terminals in a cell, completely no resource is reserving is made over the LTE system. The transmission PDSCH large message is permitted within a specificied allocated portion of spectrum and in certain interval of time based on the system. In figure 2.5 as follow is a structure of downlink frame in LTE (Capozzi et al., 2013).

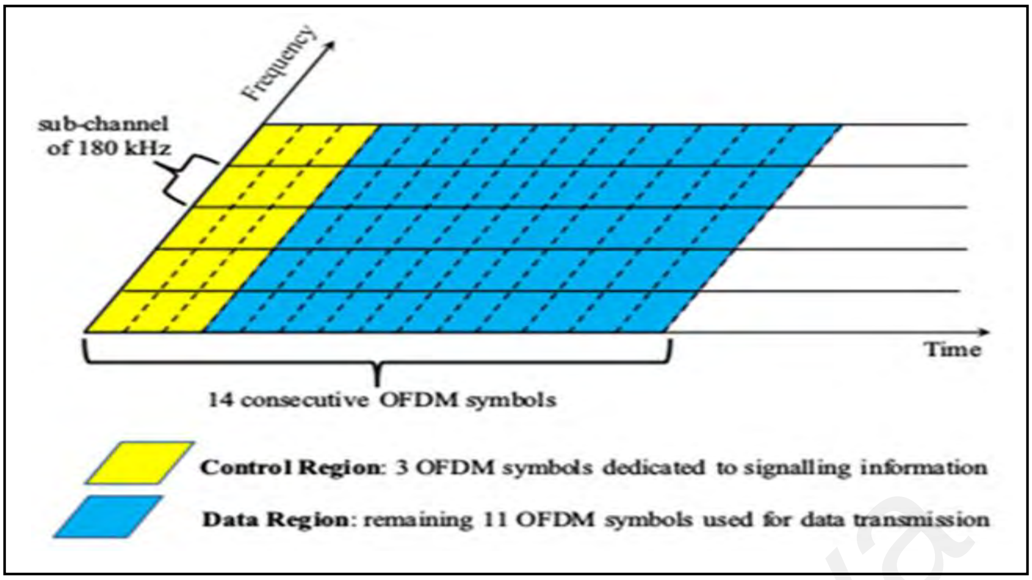

Figure 2.5: Time/Frequency LTE Downlink Sub frame (F.Capozzi,2013)

The data and the signal at downlink channel are in multiplex forms at sub-frame, the channels control may occupy at each TTI update and the first selection of one to three (1-3) symbols in OFDM from the whole of 14 symbols. Thus, the data is permitted to transmit through the remaining time. The downlink signal control is conducted by three channels (Love et al., 2008).

2.11 Scheduling

Schedule is a crucial issue in LTE network, a good scheduling performance improves the system performance. Radio resources is allocated to users after each TTI (Chadchan & Akki, 2010). Scheduling flows have been studied extensively (Kwan & Leung, 2010; Piro et al., 2011; Sadiq et al., 2011).

Related researches has been conducted on downlink scheduling algorithms**,** in their work Alfayly et al. (2012) investigated and evaluated the performance of three well-known downlink scheduling algorithms these are PF, EXP/PF and MLWDF in terms of Quality of Experience (QoE) and Quality of Service (QoS) metrics of; packet loss ratio and delay for VoIP flow. The result simulated in LTE-Sim, showed that the Modified Largest Weight Delay First (MLWDF) outperformed others with low end-to-end delay of less than 50 ms, and permitting high number of user's access more than 50 users at standard MOS score above 3.5 of QoE. PF algorithm has higher end-to-end delay with more than 200ms as the number of user's access above 30. This research is simulated single cell scenario without interference and there is handover issue.

Another research has been conducted by AlQahtani et al. (2013). The researchers performed comparison of six different downlink scheduling algorithms in LTE. The researchers analyzed the performance of the following algorithms; BCQI, PF, MaxMin, Kwan Maximum Throughput (KMT), Resource Fair (RF) and RR. The authors evaluated the performance in terms of throughput and fairness. The result revealed that PF and MaxMin algorithms provided a cleared compromise between throughput and fairness. Also, they found that, it is not good selecting of channel without considering allocation resources, as like the way RR scheduler behaving. Because it has neither high throughput nor fairness is achieved. This study detected algorithms having weakness in terms of maximizing throughput and fairness at OFDMA channel. In another research presented by Sulthana and Nakkeeran, (2014) performed analysis on well-known existing downlink scheduling algorithms over the LTE network. The study attempted to identify the weakness and strength of downlink scheduling algorithms; PF, MLWDF, LOG-rule and EXP-rule and their singnificant features for future consideration in designing new robust network. The result showed that MLWDF, LOG-rule and EXP -rule algorithms have lowest delay resulting to better performance for real time applications. The algorithms are simulated single cell scenario without interference.

Several researches has been conducted to proposed fairness in allocating radio resources in LTE network. Liu et al., (2003) worked on fairness presented a method named as opportunistic scheduling. In their work investigated different scheduling problems composed two fairness. Firstly, the utilitarian and temporal fairness then secondly, the least performance constraint. They brought optimal solutions of these two scheduling problems. The result revealed that opportunistic scheduling technique has significant improved as compared to non-oppoturnistic method. The limitation of this study is considered fairness while did not consider other scheduling problems particularly delay and short term requirements. Another research proved that the greedy scheduling algorithm could be half ½ as best improved offline algorithm. The research showed that there is no online algorithm is improved. This algorithm is serving offline there need to serve at wireless channel with improved metrics (Agarwal & Puri, 2002).

Dikamba (2011) attempted to overcome the compromised between system throughput and fairness for downlink scheduling resources over the LTE. The researcher proposed downlink scheduling algorithm called (new scheduling). The proposed algorithm and two other downlink scheduling algorithms RR and Best CQI is simulated in MATLAB simulator in two different channels pedestrian B and vehicular A. This study evaluated the performance of the proposed algorithm and compared with others in terms of fairness and throughputs metrics. The result revealed that the Best CQI algorithm has highest a throughput and then followed by proposed algorithm has higher throughput better than RR algorithm. Furthermore, the proposed new algorithm has achieved to obtained the high fairness in sharing radio resources. The proposed algorithm is simulated in a single cell scenario while it can only serve the users on fairness metrics.

The research conducted by Kausar et al., (2011) designed a cross-layer packet scheduling algorithm called as (CLPSA) with new two functions over the previous downlink transmission in LTE. The research retained system throughput and fairness among users. The first, function, specifies the service queue sorting algorithms for the service performance improvement. The second, adapted time domain priority algorithm for network performance improvement. The performance of the proposed CLPSA algorithm is evaluated and compared with other scheduling algorithms in terms of QoS metrics includes; delay, throughput and packets drops. The result discovered that the proposed CLPSA algorithm is improved in terms of reducing packet delay and lowest packet drops in real-time and improved throughput needs for non-real-time. The proposed algorithm is simulated in a single cell scenario. Another study proposed by Gavrilovska and Talevski (2011) developed two downlink scheduling algorithms in LTE namely; MY_SCH_not_Fair & MY_SCH_Fair. The performance of developed algorithms evaluated and compared with Max C/I scheduling algorithm. The result revealed that the proposed algorithms presented fairness in sharing the network resources. The limitation of this study, the proposed algorithms can only handle traffic with fairness metric otherwise in future work the other QoS metrics should be consider.

Wu et al., (2015) developed downlink scheduling algorithm with the aim to trunking multimedia applications in LTE. The research give effort to overcome the problem of previous DTLCP scheduling algorithm for giving high priority in assign radio resources to users have high QoS channel. However, the others have low priority will be kept in starvation especially when the network is congested. Consequently, the research offered optimal downlink scheduling algorithm named as Intelligent Priority PF (IP/PF). The proposed algorithm evaluated its performance and compared with other two existing downlink scheduling algorithms namely; FLS and DTLCP schedulers. The research found that, the proposed algorithm optimized the scheduling performance better than the others with fairness to all users. This solution is improved fairness for real-time traffic while the non-real-time and other QoS metrics should be consider in the traffic.

Kumar et al., (2015) in their research proposed downlink scheduling algorithm called Three Level Scheduler (TLS) in LTE. The proposed TLS is designed in three stages; The higher level of proposed method is called (super-frame) it is responsible for scheduling frame for estimation of total incoming packets for individual active Real-Time (RT) flow and determined the expectation at all the cell in the subsequent super-frame. Based on estimation made to calculate the total data to transmit in each flow at individual frame in super-frame. It has less overhead mechanism found to assign the entire RBs of the subsequent frame to transmit in three rounds. Firstly, the RT can be flow, Secondly, arriving RT data blow out and non-RT is flow and Thirdly, in each TTI turn the RBs is allocated to transmit data by considering assign RBs metric found at Flame Level Scheduler (FLS). The performance of the proposed TLS algorithm for both RT and non-RT flows is evaluated and compared with LOG-Rule, EXP-Rule, EXP-VT-SH, New Two Level Scheduler and FLS scheduling algorithms. The proposed TLS has 5 ms frame size of PLR and Goodput with 95% confidence interval of PLR experienced by TLS. The proposed algorithm is simulated in LTE-Sim. The result showed that the proposed TLS has outperformed other scheduling algorithms in terms of spectral efficiency and Goodput. The proposed algorithm can process real-time and non-real-times flows at OFDMA channel in terms of spectral efficiency and Goodput metric.

Throughput is another significant metric to improve QoS in LTE. Sadiq et al, (2011) carried out research proposed an optimal delay for opportunistic scheduling and approximation. They described that maximum current system throughput is opportunistic rather than balance a queue such as Ex-rule, MaxWeight, and the Log-rule algorithms namely as (RSM). A wireless channel time is liable to change to share by several users. The study showed that designed scheduling algorithm improved the overall system level performance expected for adapt statistical traffic than other scheduling method designed have worse case scheduling decision making. In another study conducted by Zhou (2011) modified RR downlink scheduling algorithms based on Coordinated Multi-Point (CoMP) technique. The result revealed that the modified RR algorithm is achieve to alliavated the inter-cell interferences and also lower the system complexity which increased the system performance and QoS in LTE-A network. The algorithm is able to performed scheduling in a cluster eNodeB, otherwise, cannot do in multiple eNodeB in LTE-A. Moreover, another study presented by Abrahão et al., (2015) proposed a new resources allocation at OFDMA called (Proposed) over the LTE network. The research applied βMWM model and adaptive bandwidth estimation are used to designed the two approaches these are; Max-Min approach and low computational complexity approach. The result disclosed that the performance of proposed scheduling algorithm is evaluated and compared with two other scheduling algorithms PSO and QoS-guaranteed. The effectiveness of the proposed algorithm is clearly improved the system performance as compared to others in terms of throughput and fairness. The proposed algorithm is limited to fairness and throughput for both two types of packets flows at OFDMA channels. Further, research conducted by Pokhariyal et al., (2007) investigated the Frequency Domain of Packet Scheduler (FDPS) under Fractional Load (FL) strategy. The proposed downlink scheduling algorithm used system level simulator to simulate the scenario. The performance of the proposed algorithm is evaluated and compared with other scheduling algorithms. The result showed that, the PF scheduling algorithm optimized the resource allocation by ensuring that there is no transmission on any channel's frequency experiencing much cell interference. The proposed algorithm limited to serve at OFDMA channel while considering SINR.

In another research work carried out on Multiple Input and Multiple Output (MIMO), the authors presented their work on MIMO at downlink channel with frequency domain packet scheduling over LTE 3GPP specification. The study used a partial channel report to schedule on MIMO over LTE. The result proved that the frequency domain of scheduling packet for single user MIMO system is NP-hard under LTE. Also, all the RBs allocated to users can be transmitted in one MIMO processing in a TTI at 1ms, as the spatial or transmission diversity. Likewise, for time domain the PF algorithm was slightly modified then frequency domain is also used in this research (Lee et al., 2009). Moreover, in MIMO configuration of downlink scheduling has called attention of various researchers Kwan et al., (2008) and Wei et al.,(2007) In a single user MIMO each RB able to allocated to one user only, or multi-user MIMO and is a flexible. Hence, MIMO can allocate various spatial flows to several users within the same RB. The authors approached another problem whereas they integrated two frequency domain resource allocation and Spatial Division Multiplex (SDM). The outcome showed that, the significant of precoding to system throughput.

The research conducted by Zaki et al., (2011) developed new downlink scheduling algorithm in LTE. The developed algorithm varies among QoS classes and its requirements. Two classes of QoS is considered, GBR and non-GBR. The proposed scheduling method is considering various users channel condition and attempted to balance between QoS guarantee and multiple user diversity in PF scheduling method. The bearers are need various QoS requirements for GBR and non-GBR and their performance is evaluated. Three different scenarios are investigated to simulate the scenario, which represented different service separation within the MAC scheduler. The results show that VoIP bearers remain constant even if they are mixed with non-GBR bearers within the same MAC QoS class. The study contributed by Seeling and Reisslein (2012) on trace-based, described the evaluation technique of allocating H.264 encoded video.

In another research, Hsieh (2015) developed a new algorithm called S-DFS. In their work they considered different service traffic at downlink scheduling channel to satisfy QoS of GBR traffic to ensure that data is transmitted to the non-GBR. The research proposed S-DFS algorithm, it is design in two methodological stages. Firstly, treat the RBs based on channel conditions and secondly, the QoS class identifier is also taking into account. The performance of the proposed algorithm is evaluated and compared with others; MLWDF, EXP/PF, EX-RULE, LOG-RULE, MT and PPM scheduling algorithms in LTE-Sim simulator. The result revealed that the developed S-DFS algorithm is improved transmission efficiency in LTE, over the others in terms of lowest packet delay and high dropping packet of GBR flows and also improved the throughput of non-GBR. The proposed algorithm has a drawback which is only control data traffic at OFDMA channel for QoS in LTE.

The research work conducted by T.-C et al., (2016) proposed downlink scheduling algorithm based on QoS-aware strategy for reporting multimedia applications traffic in LTE-A called as (QoS-MTRS). The proposed algorithm is scheduling the resources based on different level of data traffic. The proposed algorithm is considering channel availability to ensure feasibility of transmission. The performance of the proposed QoS-MTRS is evaluated and compared with others algorithms such as BQA, FCFS and Greedy algorithm in terms of occurrence probability of receiving over one type of traffic data, duplication ratio, end-to-end delay, overall traffic data value, types per location block, location coverage, flow rejection rate and throughput. The result showed that the proposed QoS-MTRS is achieved good scheduling performance. The limitation of the proposed algorithm is stick on reporting data traffic to multimedia services.

Related work contributed by Gotsis et al., (2012) proposed evolution of packet scheduling for machine type communications over LTE. The research provided signal scheduling policies and low complexity, the research solved the problem by applied three methodological stages. Firstly, based on efficient bandwidth allocation analyzed QoS performance from time to time of scheduling. Secondly, they used analytical model to forecast QoS performance of M2M process static scheduling algorithm and proposed queue-aware enhanced the state-of-the-art algorithm. Thirdly, the authors also considered M2M devices clustering methods. The result showed an improvement on M2M system in scheduling traffic. This study has weakness while did not consider the packet drop rate as a result of the channel impairment.

Another research carried out on downlink scheduling techniques proposed two admission control techniques. The researchers used Markov chain to designed the system model. The study evaluated the system performance in terms of; the probability of loss possession QoS for Non real-Time (NRT) calls, the likelihood of blocking new Real-Time (RT) calls in migration state and the total throughput. The researchers designed the techniques by considering call admission control based on two of categories of mobility situation includes; firstly, mobility within the cell and second, mobility between the cell). The author used AMC scheme to divided geographical area into different regions. They proposed two admission control techniques namely Real-Time (RT) and Non-Real-Time (NRT) by used Markov chain in analysis to designed the system model. The performance of the proposed algorithms is evaluated in terms of probability of blocking a new call, loss of call, residence time and throughput. The result is achieved guaranteed QoS of two admission control sessions and accomplished to maintained the same QoS for RT calls and fairness in allocating radio resources for NTR. The limitation of this techniques has network mobility in regional area for RT and NTR, in another circumstance can be extend their mobility to global service to both RT and NRT services (Rejeb et al., 2014).

Pande (2014) conducted a research and developed an optimal downlink resource allocation algorithm for LTE-A using carrier aggregation technique. The research proposed 3-Dimensional scheduler (3D), which designed in three different layers. The accomplishment of the proposed approach evaluated its performance in LTE-Sim simulator, and compared its performance with two scheduling algorithms; MLWDF and EXP-rule. The result revealed that the proposed algorithm optimized the system performance better than well-known scheduling algorithms. Hence, the proposed approach is maximized throughput, lower packet loss ratio, reduced delay and improved MOS for QoE. The limitation of this study, it can make scheduling decision in a simple scenario and can handle the QoE metric despite the fact future study need to improve QoS metrics.

Another study was performed to improve the QoS based on energy efficient scheme is presented. The research is proposed new downlink scheduling algorithm called (Q-DRX) in LTE. The performance of the proposed algorithm is evaluated and compared with other popular scheduling algorithms such as PF, Round Robin and Best CQI algorithms. The proposed algorithm is simulated in LTE-Sim in power mode in terms of QoS metrics as follows: packet loss ratio, delay and throughput and fairness. The proposed algorithm has reduced the packet loss ratio and improve fairness among users. Hence, the proposed algorithm satisfied the QoS requirements of the users for multimedia services. The proposed algorithm has optimized the QoS metrics in power. In future study, there is need to simulate the proposed Q-DRX in normal QoS metrics for optimal scheduling performance (Mushtaq et al., 2015).

Furthermore, the Channel Quality Indicator (CQI) report is an issue to be considered in an attempted to improve scheduling performance in the LTE network. Some scholars attempt to solve the problem of CQI reporting delay which send from user (UE) to the base station (eNodeB) during scheduling process. This delay is occurred before physical layer complete processing information and handle to packet scheduler for scheduling decision. Any CQI report came late this will be considered as not reported and it will not include in allocation resources during scheduling. This also affects the system throughput performance (Holma & Toskala, 2009). In another study, Kwan et al (2010) conducted research on downlink scheduling in LTE. It is obtained a partial number of response. The performance of the proposed scheduling algorithm in comparison with others has improved, and also optimized scheduling technique for multiple user scheduling on frequency domain by considering MCS. This study has limitation by only measuring delay of CQI feedback while other traffics reports is not consider.

Moreover, some researchers conducted without considering CQI report delay. Authors decided to enhance the PF scheduling scheme by using Karush Kuhn–Tucker (KKT) condition. The scheduling method is greedy PF scheduler, the algorithm is used and placed in advanced, although there are authors attempted to resolve the CQI report delay issues. Basukala et al., (2010) in their work analyzed the influence of CQI delay and the its aperiodic reporting frequently about the performance of the existing downlink scheduling algorithm of the real-time allocating video flows to users at various speeds. The study compared with system having a complete and delay information during each scheduling. The study minimized the rate of requesting aperiodic CQI report to sustain QoS of the user's requirements.

Djouama and Lim (2015) proposed new method for requesting CQI report via modified cost function method in two phases. The first phase proposed a method to make a regression model to observe CQI report. Second, to predict the channel condition. The research is evaluated the performance of the proposed algorithm and compared with PF algorithm through linear prediction and RR scheduling algorithm. The result showed that the proposed algorithm has performed better than others in terms of reducing signaling for feedback, which permit a virtuous data to be transmitted. Furthermore, Avocanh et al., (2013) in their work proposed a new downlink scheduling algorithm which optimized the resource allocation scheme based on considering the overbooking scheduling. During the number of requested users is become higher than the available resources on the network. The research evaluated the performance of the proposed algorithm and compared with PF and RR algorithms. The result revealed that the proposed algorithm has better performance for serving users with resources efficiently during overbooking. This research can only handle the overbooking issue at OFDMA channel.

Related research conducted for real-time flows over the LTE network, Piro et al, (2011) in compare were developed two-level downlink scheduling algorithm called Frame Level Scheduler (FLS) for multimedia real-time services traffic over the LTE network. The authors used QoS-aware strategy to designed packet scheduling algorithm for real-time flows at downlink OFDMA air interface. The proposed scheduling algorithm is designed with two levels, first, is the upper level are achieved by the used of linear control theory and second, is the lower level is accomplished by modified the PF scheduler. The performance of the proposed FLS evaluated and compared with two well-known scheduling algorithms EXP-rule and LOG-rule in terms of packet loss ratio and inter cell interference on QoE of real-time traffics. The comparative algorithms are simulated in LTE-Sim; the result is visibly showed that the proposed scheduler outperformed others in terms of QoE particularly the real-time video flows. The proposed algorithm can be handling QoE metric while other QoS metrics cannot be processed.

Another research carried out by Liu et al, (2013) developed new downlink scheduling algorithm called (M-EDF-PF). The proposed scheduling algorithm has been designed with low complexity for the real-time services which exploit the existing PF and EDF scheduling algorithms. The performance of the proposed M-EDF-PF algorithm is evaluated and compared to other well-known scheduling algorithms in terms of metrics such as PLR, delay, spectral efficiency, fairness and throughput. The proposed algorithm is simulated in a system level simulator. The result found that the proposed M-EDF-PF algorithm and EXP-RULE algorithms has good scheduling performance for real-time flows compared to other scheduling algorithms includes; MLWDF, EXP/PF and LOG-RULE. In addition, the EXP-RULE algorithm is experienced low complexity when the network is containing a high traffics. The proposed M-EDF-PF algorithm outperformed others in achieving lowest complexity. The proposed algorithm has limitation while concentrated on processing complexity.

Sun and Wu (2014) designed and implemented downlink packet scheduling algorithm for real time services. The research is accomplished based on Discrete Time Linear Control Theory (DTLC) approach to determine scheduling users based on their priority level. The performance of the proposed DTLC algorithm is evaluated and compared with recent scheduling algorithms. The algorithm is scheduling users having good channel condition will take high priority, and users experiencing bad channel condition should be kept in starvation. The proposed algorithm has limited on fairness index metric flow.

Asheralieva et al., (2016) attempted to improve QoS of end-to-end packet transmission. The research developed a new downlink scheduling technique to assigned the radio resources at integrated microcell or Pico cell area. The researchers argue about the performance of end-to-end transmission could be optimized significantly by considering individual traffic need different users which can track in LTE over the user. The research is attempted to reduce difficulty of this problem by introducing two methods namely; Exact Branch and Bound (B&B) and applying modified heuristics Generic Algorithm called (MGA). The OPNET-based is a simulator used to conducted simulation. The result revealed that, the proposed scheduler achieved low complexity also the solution time is faster and outperformed as compared to other three scheduling methods namely as; Resource Allocation 1 (RA1), Resource Allocation 2 (RA2) and Exact Branch & Bound (EB&B). The proposed technique has limitation, can allocate wireless resources at integrated microcell or Pico cell at downlink channel but for uplink is not achieve.

In addition, another research worked on real-time proposed new downlink scheduling algorithm based on QoS-aware strategy in LTE for video flow via downlink transmission.

The proposed algorithm was exploited based on integrated cross-layer design. It is allocate the radio resources to multiple users dynamically and efficiently. The study selects the best improved parameters which includes: modulation coding scheme (MCS) and video encoding parameters. It is obtained in view of adjusting to various channel quality of each RBs. The results showed that the proposed algorithm is achieved good scheduling performance of perceiving user of video quality with limited application delay and significantly improved the system performance while satisfied the users requirements based on QoS demand. The proposed scheduling algorithm treated QoE metrics while in future study the other normal QoS metrics to be improve for real-time traffic (Luo et al, 2010).

Related research conducted on downlink scheduling real-time flows. The authors proposed two-level scheduling algorithm (FLS-M-EXP), they studied scheduling algorithms of real-time applications flows and later developed a new downlink scheduling algorithm. The performance of proposed algorithm is evaluated and compared with other well-known downlink schedulers PF, M-LWDF, FLS of real-time flow. The result found that the proposed (FLS-M-EXP) packet scheduler has improved the system performance by improved packet delivery delay metric. The proposed algorithm can handle the packets delivery delay, however the other QoS metrics will be consider (Ang et al., 2014).

Hence, in research work conducted proposed new downlink scheduling algorithm for real-time flow over LTE networks. The research proposed downlink scheduling algorithm called LTTI. The proposed scenario is simulated in LTE-Sim Simulator, the performance of the proposed algorithm is evaluated and compared with other three well-known downlink scheduling algorithms such as PF, MLWDF and EXP/PF. The effectiveness of the proposed algorithm improved the QoS metrics in terms of packet loss ratio, delay and throughput. The proposed algorithm outperformed others comparative scheduling algorithms. The proposed algorithm is treated VoIP and video flows while the video flow metrics need efficient QoS to handle real-time traffic (Mahfoudi et al., 2015).

2.12 Limitations of Previous Studies and Research Gap

Based on the rigorous literature review conducted, it was revealed that the existing scheduling algorithms have the limitation regarding the QoS requirements in LTE network, particularly in real-time traffic. The present researchers analyzed the performance of state-of-art downlink scheduling algorithms. It was realized that the previous scheduling schemes in LTE network proposed by the several researchers have different solutions proposed to scheduling problems most of the researcher give attention on fairness, QoE and improving transmission efficiency which can affect real-time services and cannot provide efficient QoS for video flows. But yet the researchers did not provide an optimal downlink scheduling algorithm specifically for video flow. Therefore, continue using the previous schemes would not achieve good performance, this is because it does not serve the real-time traffic efficiently of video flows. To achieve a good performance, there is need to develop an optimal downlink scheduling algorithm for real-time traffic.

Table 2.4: The Summarized Related Works

Author and year	Method	Findings	Limitation
Alfayly et al. (2012)	The research investigated and evaluated the performance of the three well-known downlink scheduling algorithms includes PF, EXP/PF and MLWDF in terms of Quality of Experience (QoE) and Quality of Service (QoS) metrics of; packet	The output showed that the MLWDF algorithm outperformed others with low end-to-end delay with less than 50 ms, and permitting high number of user's access more than 50 users at standard MOS score above 3.5 of QoE. Also, the PF algorithm has	This research is simulated single cell scenario without consider interference and handover.

Author and year	Method	Findings	Limitation
	loss ratio and delay for VoIP flow.	higher end-to-end delay with more than 200ms as the number of user's access above 30.	
AlQahtani et al., (2013).	The research has performed comparison of six different downlink scheduling algorithms in LTE. The authors were analyzed the performance of the following algorithms; BCQI, PF, MaxMin, Kwan Maximum Throughput (KMT), Resource Fair (RF) and RR, and also evaluated their performance in terms of throughput and fairness.	The findings revealed that PF and MaxMin algorithms provided a cleared compromise between throughput and fairness. Also, it proved that, it is not good of selecting channel without considering allocation resources, as like the way RR scheduler is behaving. Because it has neither high throughput nor fairness is achieved.	This study has a weakness in terms of maximizing throughput and fairness at OFDMA channel.
Sulthana and Nakkeeran, (2014)	The authors conducted analysis on the popular existing downlink scheduling algorithms over the LTE network. The study attempted to identified the weakness and strength of downlink scheduling algorithms; PF, MLWDF, LOG-rule and EXP-rule and their singnificant features for future consideration in designing new robust network.	The result showed that MLWDF, LOG-rule and EXP -rule algorithms have lower delay for real-time applications.	The study simulated a single cell scenario without considering interference.
Kausar et al., (2011)	The study designed a cross-layer packet	The result discovered that the	The proposed algorithm is

Author and year	Method	Findings	Limitation
	scheduling algorithm called (CLPSA) with new two functions over the previous downlink scheduling methods in LTE. The performance of the proposed CLPSA is evaluated and compared with other scheduling algorithms in terms of QoS metrics like delay, throughput and packets drops.	proposed CLPSA are improved in terms of reducing packet delay and lowest packet drops in real-time traffic and improved the throughput demand for non-real-time.	simulated in a single cell scenario without considering interference.
Gavrilovska and Talevski (2011)	The authors developed two downlink scheduling algorithms namely; MY_SCH_not_Fair & MY_SCH_Fair. The performance of developed algorithms evaluated and compared with Max C/I scheduling algorithm.	The result revealed that the proposed algorithms offered fairness in sharing the network resources.	This study is simulated fairness metric only, but in future work others QoS metrics can be consider.
Wu et al., (2015)	The research developed a downlink scheduling algorithm with aim of trunking multimedia applications over the LTE. This research offered an optimal downlink scheduling algorithm called Intelligent Priority PF (IP/PF) and evaluated its performance by compared with two downlink scheduling	This solution is improved fairness only for real-time traffic.	This study did not considered non-real-time and other QoS metrics in their traffic.

Author and year	Method	Findings	Limitation
	algorithms as follows; FLS and DTLCP.		
Kumar et al., (2015)	The authors proposed downlink scheduling algorithm named as Three Level Scheduler (TLS) in LTE. It is designed based on three stages. The performance of the proposed TLS algorithm for both RT and non-RT flow is evaluated and compared with LOG-Rule, EXP-Rule, EXP-VT-SH, New Two Level Scheduler and FLS downlink algorithms.	The outcome showed that the proposed TLS has outperformed other scheduling algorithms in terms of spectral efficiency and goodput.	The proposed algorithm is processed real-time and non-real-time flow at OFDMA channel and simulated spectral efficiency and goodput metrics only. Future study will consider other QoS metrics.
Sadiq et al, (2011)	The research proposed (RSM) downlink scheduling algorithm for optimal delay for opportunistic scheduling and approximation. The authors described that maximum current system throughput is opportunistic rather than balance a queue such as Ex-rule, MaxWeight, and the Log-rule algorithms named as (RSM).	The algorithm is improved the system performance expected for adapt statistical traffic than other scheduling methods have worse case scheduling decision making.	This study alleviated the issue of the system throughput only.
Zhou (2011)	The author modified RR downlink scheduling algorithms based on Coordinated Multi-Point (CoMP) technique.	The result revealed that the modified RR algorithm is achieved to alliavated the inter-cell interferences and	This study can performed scheduling in a cluster eNodeB, otherwise, cannot in multiple eNodeB in LTE-A.

Author and year	Method	Findings	Limitation
		lowered the system complexity.	
Abrahão et al., (2015)	The study proposed new resources allocation scheme on OFDMA interface called (Proposed) over LTE network. The authors are applied βMWM model and adaptive bandwidth estimation are used to designed the two approaches as follows:(1) Max-Min approach (2) low computational complexity approach. The proposed method is evaluated and compared with two other scheduling algorithms PSO and QoS-guaranteed.	The effectiveness of the proposed scheme is improved the system performance in terms of throughput and fairness.	The proposed scheme is bounded to fairness and throughput for both the two types of traffics on OFDMA.
Pokhariyal et al., (2007)	This research investigated the Frequency Domain of Packet Scheduler (FDPS) under Fractional Load (FL) approach. The study proposed downlink scheduling algorithm and evaluated its performance also compared with other scheduling algorithms.	The result showed that, the PF scheduling algorithm improved resource allocation technique by ensuring that there is no transmission on any frequency channel which experiencing much cell interference.	The proposed algorithm can allocating network resources only at OFDMA air interface.
Zaki et al., (2011)	Developed new downlink scheduling algorithm in LTE. The authors are designed the scheme by considered two	The result disclosed that the VoIP bearers remain constant even if they are mixed with non-GBR bearers	This study is resolved the VoIP bearer's problem.

Author and year	Method	Findings	Limitation
	classes of QoS as follows: GBR and non-GBR. However, the developed algorithm is considering different users channel condition in attempted to balance between QoS guarantee and multiple user diversity with PF scheduling algorithm. The bearers are needed different QoS requirements for GBR and non-GBR. And their performance is evaluated.	within the same MAC QoS class.	
Hsieh (2015)	Proposed S-DFS algorithm is designed based on two stages. Firstly, treat the RBs based on channel conditions and secondly, the QoS class identifier is also taking into account. The performance of the proposed algorithm is evaluated and compared with others such as; MLWDF, EXP/PF, EX-RULE, LOG-RULE, MT and PPM scheduling algorithms.	The result revealed that the proposed S-DFS is improved transmission efficiency in LTE, over the others in terms of lowered packet transmission delay and lowered dropping packet of GBR traffic and improved the throughput of non-GBR.	This algorithm can only controlling data traffic on OFDMA channel. However, cannot on SC-FDMA.
T.-C et al., (2016)	The study proposed downlink scheduling algorithm based on QoS-aware strategy for reporting multimedia traffic	The result presented that the proposed QoS-MTRS is achieved good scheduling performance than others.	The proposed algorithm is fixed on reporting data traffic to multimedia services.

Author and year	Method	Findings	Limitation
	in LTE-A called as (QoS-MTRS). The proposed algorithm is scheduling the resources based on different level of data traffic, and considering channel availability to ensure feasibility of transmission. The performance of QoS-MTRS is evaluated and compared with other algorithms includes; BQA, FCFS and Greedy algorithms in terms of occurrence probability of receiving over one type of traffic data, duplication ratio, end-to-end delay, overall traffic data value, types per location block, location coverage, flow rejection rate and throughput.		
Gotsis et al., (2012)	The research proposed evolution of packet scheduling for machine type communications in LTE. The study provided signal scheduling policies and low complexity, and solved the problem by applied three methodological stages. Firstly, based on efficient bandwidth allocation analyzed QoS performance from time to time of	The result exhibited an improvement on M2M system in a scheduling traffic.	This study has a weakness because it is not considering the packet drop rate as a result of the channel impairment.

Author and year	Method	Findings	Limitation
	scheduling. Secondly, they used analytical model to forecast QoS performance of M2M process static scheduling algorithm and proposed queue-aware enhanced the state-of-the-art algorithm. Thirdly, the authors also considered M2M devices clustering methods.		
Rejeb et al., (2014).	The study is carried out on downlink scheduling algorithm and Markov chain are used to designed the system model. The authors proposed two admission control techniques namely; Real-Time (RT) and Non-Real-Time (NRT). Also, the performance of the proposed algorithms is evaluated in terms of probability of blocking a new call, loss of call, residence time and throughput.	The result revealed that the proposed techniques accomplished to maintained the same QoS for RT calls and achieved fairness in allocating network resources for NTR.	This study is considered network mobility in a regional area for RT and NTR. However, in another circumstance there is need to extend its mobility to global services for both RT and NRT.
Pande (2014)	Developed an optimal downlink resource allocation algorithm for LTE-A using carrier aggregation technique. The research proposed 3-Dimensional scheduler (3D), which designed in three different layers. The	The proposed approach is maximized throughput, lower packet loss ratio, reduced delay and improved MOS for QoE.	This study can make scheduling decision in a single scenario and handle QoE metric despite the fact future study need to improve QoS metrics.

Author and year	Method	Findings	Limitation
	proposed approach is evaluated its performance and compared with two other scheduling algorithms as follows; MLWDF and EXP-rule.		
Mushtaq et al., (2015).	The research proposed new downlink scheduling algorithm called (Q-DRX) in LTE. The performance of the proposed algorithm is evaluated and compared with other scheduling algorithms such as PF, Round Robin and Best CQI algorithms in power mode in terms of QoS metrics including, packet loss ratio, delay and throughput and fairness.	The proposed algorithm has reduced the packet loss ratio and improve fairness among users. Hence, the proposed algorithm satisfied the QoS requirements of users for multimedia services.	The proposed algorithm optimized the QoS metrics in power mode. In future QoS metrics can be consider.
Kwan et al., (2010)	The authors conducted a research on downlink scheduling in LTE. The study proposed scheduling algorithm by obtained the partial number of response. The performance of the proposed algorithm is compared with others.	The research was improved the scheduling performance of multiple user on frequency domain by considering MCS.	This algorithm is measuring delay of CQI feedback while other traffics reports is not consider.
Basukala et al., (2010).	The study analyzed the influence of CQI delay and its aperiodic reporting frequently about the performance of the existing downlink	The study minimized the rate of requesting aperiodic CQI report to sustain QoS of the user's requirements.	The study is processing CQI report during real-time scheduling of video flow.

Author and year	Method	Findings	Limitation
	scheduling algorithm of real-time allocating video to users at various speeds. The study compared system having complete and delay information during each scheduling.		
Djouama and Lim (2015)	Proposed new method for requesting CQI report via modified cost function method in two phases. The first phase proposed a method applied regression model to observe CQI report. The second, is predicting the channel condition. The research evaluated the performance of the proposed algorithm and compared with PF and RR scheduling algorithms.	The research is achieved that the proposed algorithm has performed better than others in reducing signaling of CQI feedback, which permit a virtuous data to be transmitted.	The study is handling CQI report during packet scheduling on downlink channel.
Avocanh et al., (2013)	The work proposed new downlink scheduling algorithm which optimized the resource allocation scheme based on considering the overbooking scheduling. The research evaluated the performance of the proposed algorithm and compared with PF and RR algorithms.	The result revealed that the proposed algorithm has a better performance for serving users having efficient resources during overbooking.	This research is handling the overbooking during scheduling at OFDMA channel.
Piro et al, (2011)	Developed two-level downlink scheduling	The result is clearly showed that the proposed	This algorithm is handling QoE metric. In future

Author and year	Method	Findings	Limitation
	algorithm called Frame Level Scheduler (FLS) for multimedia real-time services traffic over the LTE network. The study applied QoS-aware strategy to designed packet scheduling algorithm for real-time flow on OFDMA interface. The algorithm is designed in two levels, the first level is used linear control theory and the second is accomplished by modified the PF scheduler. The performance of the proposed FLS is evaluated and compared with famous scheduling algorithms as follows: EXP-rule and LOG-rule in terms of packet loss ratio and inter cell interference on QoE for real-time traffics.	scheduler outperformed others in terms of QoE for real-time traffic.	other QoS metrics will be consider.
Liu et al, (2013)	The authors developed new downlink scheduling algorithm called M-EDF-PF. The authors are considered low complexity in their effort to designed the M-EDF-PF algorithm for the real-time services which exploit the existing PF and EDF scheduling	The finding showed that the proposed algorithm outperformed others in achieving lowest complexity.	The proposed algorithm is fixed the issue of system complexity.

Author and year	Method	Findings	Limitation
	algorithms. The performance of the proposed algorithm is evaluated and compared with other scheduling algorithms MLWDF, EXP/PF and LOG-RULE in terms of QoS metrics as follows; PLR, delay, spectral efficiency, fairness and throughput.		
Asheralieva et al., (2016)	The research developed new downlink scheduling technique to assigned radio resources at integrated microcell or Pico cell. The study introduced two methods and by modified heuristics Generic Algorithm called (MGA). The developed algorithm is evaluated and compared with other scheduling methods as follows; Resource Allocation 1 (RA1), Resource Allocation 2 (RA2) and Exact Branch & Bound (EB&B).	The result revealed that the developed algorithm is outperformed others in achieving low complexity.	The proposed algorithm can allocate the radio resources only at integrated microcell or Pico cell on downlink channel.
Luo et al, (2010).	The research proposed new downlink scheduling algorithm based on QoS-aware strategy in LTE network for video flow. The proposed algorithm was exploited based on integrated cross-layer design. It is	The research outcome showed that the proposed algorithm is achieved good scheduling performance of perceiving user having a video quality with limited application delay and	The proposed algorithm is simulated QoE metrics while in future study other QoS metrics can be consider.

Author and year	Method	Findings	Limitation
	allocate the radio resources to multiple users dynamically and efficiently. The study selected the best improved parameters such as: modulation coding scheme (MCS) and video encoding parameters.	significantly improved the system performance also satisfied the users requirements based on QoS demand.	
Ang et al., (2014).	The authors are studied downlink scheduling algorithms for real-time services and later developed new downlink scheduling algorithm called (FLS-M-EXP). The performance of developed algorithm is evaluated and compared with other downlink schedulers as follows: PF, M-LWDF, FLS.	The research is revealed that the developed (FLS-M-EXP) has improved the system performance in terms of delay.	This study is overcome the issue of the packets delivering delay metric.
Mahfoudi et al., (2015).	The scholars proposed downlink scheduling algorithm for real-time traffic in LTE system called LTTI. The performance of proposed algorithm is evaluated and compared with others includes PF, MLWDF and EXP/PF algorithms.	The effectiveness of the proposed algorithm improved the QoS metrics in terms of packet loss ratio, delay and throughput. Hence, the proposed algorithm outperformed other comparative scheduling algorithms.	The proposed algorithm is simulated in a single cell.

CHAPTER 3: RESEARCH METHODOLOGY

As were revealed in chapter two, the downlink scheduling issue of real-time traffic of video are found and there is need to be solve the problem. Hence, the study proposed a new downlink scheduling algorithm VRTSA are suggested to solve this issue. The study investigated the previous downlink scheduling algorithms which found their weakness. And later we proposed the system model which composed of three stages as follows: The first stage, frequency domain is considered for efficient scheduling resources in RBs based on CQI reports obtained from the network users to allocate radio resources to the users having a good channel quality. The second stage, time domain is also considered for controlling queue and prediction delay of the late coming packet in the queue. Lastly, at the third stage, termination processing unit is provided for terminating the late arriving (expired) packets in the queue when the delay exceeds the maximum threshold (time) of 0.1s. The system complexity is increasing as the number of stages increases. Hence, after combined all these three stages stated above then we developed the VRTSA which improved the overall system performance and provided the QoS requirements to the users.

The outline of this chapter composed as follow: The proposed (VRTSA), Methodological Stages of the Proposed VRTSA, Implementation Parameters, Efficient Scheduling for Resource Blocks Based on CQI Reports from users, Controlling Queue and Prediction of Delay of the Late Arriving Packet, Termination Processing Unit of Expired Packets as well as Summary of this chapter.

3.1 The Proposed Video Real-Time Scheduling Algorithm

Scheduling is one of the significant issues need to be consider while to improve the QoS in LTE network. The system can improve by designing efficient scheduling algorithm to optimize the system level performance and QoS metrics such as; low delay, low packet loss rate, and maximize the system Throughput (ITU-T E.800 Annex B, Aug.

2008). The proposed scheduling algorithm is designed based on QoS-aware strategy in (Capozzi et al., 2013). The proposed algorithm is supporting real-time traffic of video flow. The designed is achieved and implemented in three methodological stages as follows:

3.2 Methodological Stages of the Proposed VRTSA

i. Efficient scheduling in Resource Blocks (RBs) based on CQI report

ii. Controlling queue and prediction delay of the late arriving packet in the queue

iii. Termination Unit of the Expired Packet.

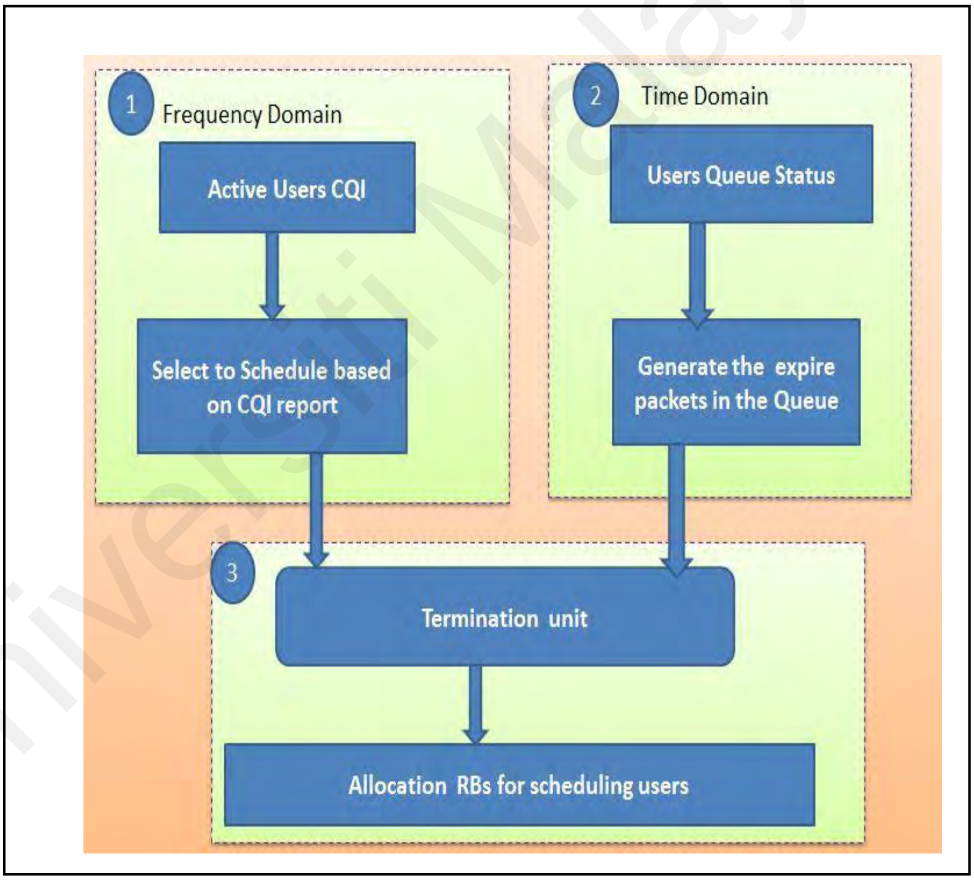

Figure 3.1: The Propose System Model

The proposed system model is depicted in figure 3.1 above which composed of three stages for downlink scheduling packets. The first stage is considering frequency domain, were the RB's is allocates to the users only having a good CQI report. However, in each Transmission Time interval (TTI) there is update of CQI report of various users will be compared before allocating RB's to the users. The main goal of designed the first stage, is to yield a good system throughput. Second Stage, the time domain is also considering to the users Those experiencing their CQI report is not good. Therefore, their packets cannot be transmitting to their destination in a right time. Hence, all expired packets are generating at stage two whereas handle it to the third stage, the termination unit to terminate all the packets cannot satisfy the maximum delay requirement at the threshold.

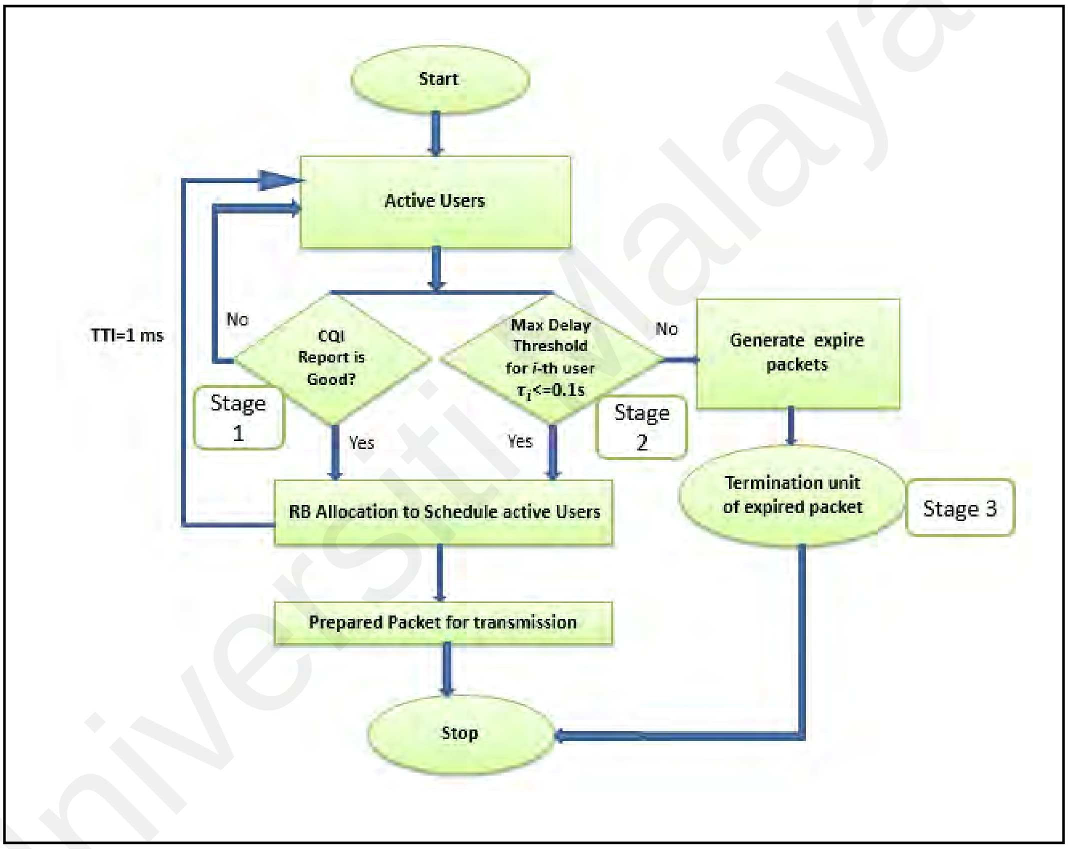

Figure 3.2: The Proposed System Flow Chart

Figure 3.2 above is a proposed system flow chart, initially the system will start were all active users are available on the network. At the first stage a decision will be taking based on frequency domain are considered to allocate the RB's to active users if their CQI report is good, else the system will be back to active users again and search for another good CQI report. The second stage is another decision phase were the maximum delay requirement at the threshold is 0.1s is monitoring for each incoming packet into the queue. However, any packet exceeded the maximum time delay setting at threshold will be generated as expired packet, hence these packet will be handled and terminated at third stage (termination unit) to avoid transmission expired packet to improve the system performance and QoS to the users.

3.3 Implementation Parameters

$\mathrm{CQI}_{i,j}$: The $\mathrm{CQI}_{i,j}$ referred as if RB *j* assigned to user *i* flow,

where $0 \le i \le n-1$ and $0 \le j \le m-1$, as $i,j \in N$.

$M_{i,j}$: $\mathrm{CQI}_{i,j}$ values of RBs *j* is high if RBs *j* assigned to user *i*.

EU_i: Is the average throughput for user *i* packet, in the queue (q), $0 \le i \le n$, where *n* values are referring to number of users.

Therefore, we can measured throughput of the user *i* by the CQI of the channel condition and also control their modulation and coding scheme (MCS). Similarly, the user *i* will not get a chance to send the packets in each time, yet we should count the user's throughput in any TTI.

$$1TTI = 0.001\text{ms} \tag{3.1}$$

$DB_{q,x}$: Is a delay bound of packet *x* in the queue (q). while delay bound is based on the types of the packets.

n_q : Is the number of packets in a queue (q), packets range as 0 to j-1.

$t_{q,x}$: Is a time of *x*th packet arrived into the queue (q).

$t_{sq,x}$: Is a time stamp for *x*th packet in the queue (q).

$t_{p,x}$: Is a propagation delay at physical queue (q) of *x* packet.

$t_{o,q}$: Is an observation time which calculates the packets those cannot reach its destination before delay settings time.

$R_{q,x}$: xth packet in queue (q) can be schedule to transmit at $R_{q,x}$ as interval of:

$0 \le x \le y - 1$

$R_{q,i}=\left(\frac{x+1}{EU_{i\ T_I}}\right)$ (3.2)

f_q: Is a first packet identified at the queue (q), during scheduling time to send the packet also the packet can be late, this packet will not able to reach its destination in a specified time of: $0 \leq f_q \leq y-1$.

l_q : Is the last packet identified in a queue (q), also the packet can be late during schedule to send packet as result the packet cannot reach its destination in a specified time $0 \leq f_q \leq l_q \leq y-1$.

L_q: Is an estimated packet loss rate in a queue (q).

N_q: Is a number of successfully packets transmitted in queue (q) before the observation time $t_{o,q}$: Observation time after lost the last packet $t_{o,q}$, when the packet is drop or lost it is N_q signify as 0. When there are more burst packets between the first and last time were observing these packets, the last burst will begin count before the first observation time.

T_q : Is a threshold that monitoring the packet loss rate in a queue (q).

ΔT_q: Mean of inter-arrival packet time in queue (q).

$\Delta T_{s,q}$: Is a time-stamp of a packet in queue (q)

ef_q: Is a first predictable number of packets in virtual (q) which schedule time for transmission is late and consequently the packet cannot reach to the destination in a specified time, at the interval of $0 \leq f_q \leq y-1$.

el_q : Is a last predictable number of a packet in virtual (q) which schedule time for transmission is late and consequently the packet cannot reach to the destination in a specified time, at interval of $0 \leq f_q \leq l_q \leq y-1$.

$ER_{q,n}$: The estimation of n_{th} packet which can be schedule and transmit in ER_n with transmission interval of $0 \leq n \leq y-1$

$et_{q,n}$: Is an estimation of arrive time for nth number of packet in virtual (q).

$et_{sq,n}$: Is a time stamp estimation of the nth packet in virtual (q).

ev_{nq} : Estimate of new packet arrive time in virtual (q) when there is time interval of transmission which all $n_q$recent packets in queue (q) are sent.

T_{nq} : mean time required to send n_q packets in a queue (q).

eL_q: estimated packet loss rate received in a queue (q).

$ET_{i,j}$: This referred as expected throughput when resource block j is allocated to user i, 0≤i≤n_u and 0≤j≤n_b whereas n_b is available number of the RBs.

3.4 Efficient Scheduling for Resource Block Based on CQI Report

First, we consider frequency domain to control this stage to choose the channel with high quality to allocate the radio resource into RBs as to avoid bandwidth wastage to achieve the high system throughput. Because transmission packet in a poor channel quality condition will lead to cause a packet loss. Likewise, transmission packet loss is a waste of bandwidth which leads to downgrade system throughputs. Therefore, once the system succeeds to reduce wasted packets transmission the system throughput will be improved. This stage is mainly designed to achieve high throughput for packets transmission expressed in equation (3.3):

$$M_{i,j} = \arg\max_{i}\left(CQI_{i,j}\right) \quad (3.3)$$

It is implemented as follows:

DL_Proposed_VRTSA_PacketScheduler::AllocateUseriHasMaxCqiToRbJ(),

created the CQI values of user *i* in RB *j*, this process is achieved by calling this method *PackectScheduler::FlowToSchedule::GetCqiReport()***.** Moreover, another method was added *PackectScheduler::FlowToSchedule::SetBestCqiReports().* It mark a user which have best $M_{i,j}$ is the one having the best CQI. Finally, we created access method called

PackectScheduler::FlowToSchedule::GetBestCqiReports(), to allow stage 2 to query whether a user has best channel quality to schedule.

3.5 Controlling Queue and Prediction Delay of the Late Arriving Packet

In contrary to previous stage, this stage deal with users experiencing poor CQI condition may be they are deployed at cell edges which relate to eNodeB. These packet cannot be transmitted to its destination in time. If the only throughput is considering there is tendency to have many expired packets that get terminated at the destination. Instead of that, delay, packet types, and timestamp will be considered to satisfied the user QoS requirements. The timestamp is an instance that packet created at application layer. The continuous packets in the similar MAC layer queue have the same type, and the same timestamp and delay bound. The packet x in queue (q) cannot be transmitted in time if $DB_{q,x} - (t_{oq} - t_{q,x}) < R_{q,x} \times T_I + t_{px}$,

Moreover, many expired packets can be rejected for transmission to the destination due to the high delay found at MAC layer however, as we solve this issue it is significant to save more bandwidth. Also, to achieve the QoS we shall consider the types of packets traffic which have a timestamp and delay time. Real-time in a wireless network is transmitting the packets in a continuous system instead to transmit one after the other while compressed the packets in a frame structure. The continuous packets are required to be the same type of packet and QoS requirement, likewise having the same delay bound and time stamp.

The two scenarios are used if there is a continuous expired packet in a queue (q) as follows:

a) There are some continuous expire packets are enqueueing, but the packet at last position in physical queue q will sent within a specified time which depicted in figure 3.3. The buffer space filled with green color is a packet who's expected to transmit in time, the spaces filled with dark ash color is the expired packets which cannot transmit in time, and white space is an empty buffer storage.

b) There are some continuous expired packets are enqueueing, but the packet at the end of the queue will be sent out without delay, it is depicted in Figure 3.4.

Scenario 1: once if we have packets in a queue (q) which is not able to send in time but it it is also within the queue (q) as shown in figure 3.3 below.

The *x* packet cannot be transmitted in time if: $DB_{q,x} - (t_{oq} - t_{q,x}) < R_{q,x} \times T_I + t_{px}$

The first late packet is identified in queue (q) as expressed in equation (3.4):

$$f_q = \text{arg min}(x | DB_{q,x} - (t_{oq} - t_{q,x}) < R_{q,x} \times T_I + t_{px}) \quad (3.4)$$

The last late packet is identified in queue (q) as expressed in equation (3.5):

$$l_q = \text{arg max}(x | DB_{q,x} - (t_{oq} - t_{q,x}) < R_{q,x} \times T_I + t_{px}) \quad (3.5)$$

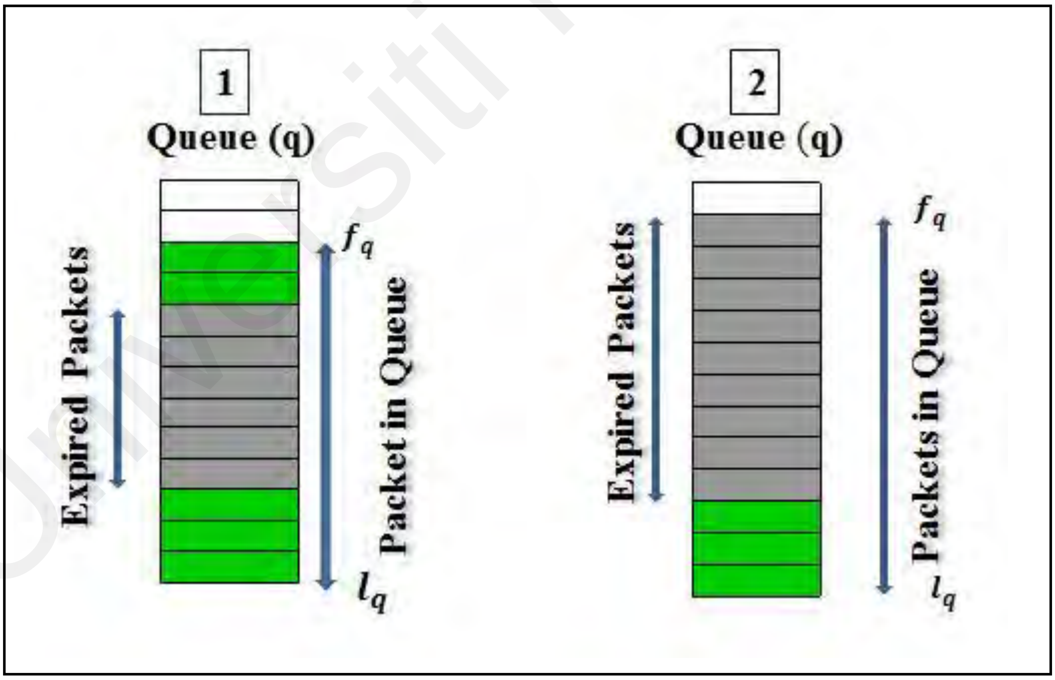

Figure 3.3: Two Scenarios States for Continuous Expired Packet.

The two states of the queue (q) [1] and [2] is collectively formed scenario 1, and it is handle the function of *DL_Proposed_VRTSA_PacketScheduler::HandleScenario1()* for user *x*.

The estimation of packets loss rate is computed by equation (3.6):

$$L_q = \frac{l_{q-f_q+1}}{N_{q+l_q}} \quad (3.6)$$

If the computed L_q is greater or equal to defined threshold, T_q then QoS of the packets cannot be achieving. The termination unit will be called and if the computed L_q is less than threshold T_q the termination unit will not be called. To support deleting the range of packets from f_q to l_q within a queue, by created new method *MacQueue::TerminatePackets()*. Also, the expired packets in a queue (q) will be terminated. The current queue (q) is accepting higher packet loss rate, the late packets in the queue (q) are terminated while their bandwidth is allocated to another user in time to avoid late in the next coming packet transmission.

Based on the two conditions stated, if the last packet cannot be sent in time while is not in the queue so that the other scenario in figure 3.4 will be handle function of *DL_Proposed_VRTSA_PacketScheduler::HandleScenario2()*.
the last packet of the late packets is not in the queue (q).

Scenario 2: The packets within the queue which cannot be sent in a specified time. Likewise the last packets being arrived late cannot be sent in time in the queue. At this scenario, we are required to call estimate process in Figure 3.4 as following. Moreover, as described in figure 3.4, we provided a virtual queue (q) to evaluate the behaviour of the next incoming packets in a virtual (q) based on performance and update of the recent incoming packets in a virtual (q).

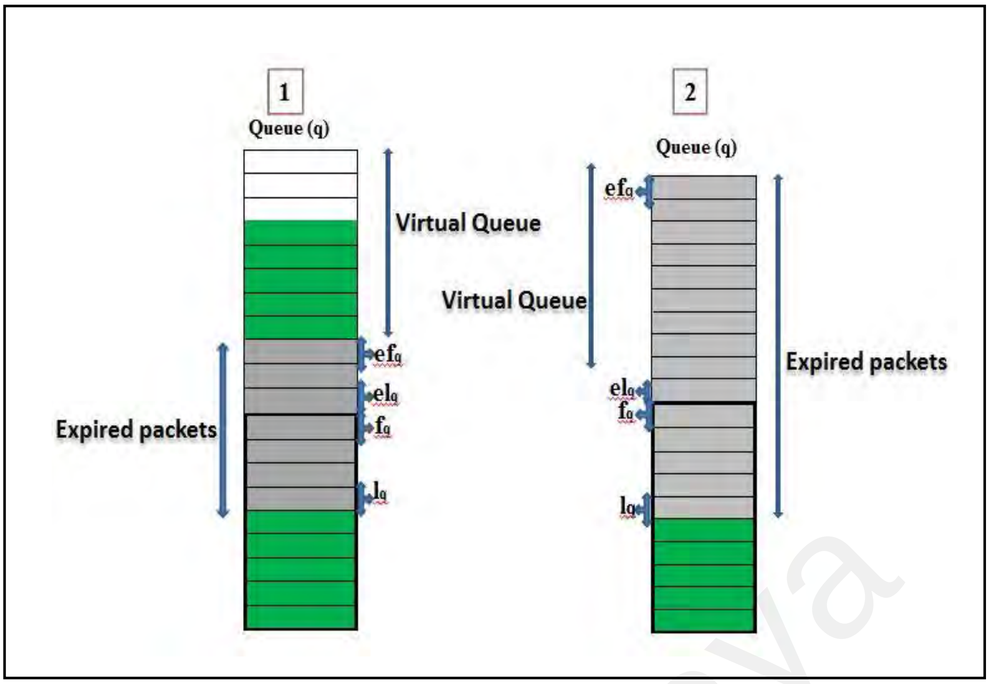

Figure 3.4: Virtual Queue for Prediction Packet Loss.

Figure 3.4, the virtual queue (q) concept are created, the reason is to estimate the behavior of the next incoming packets into the virtual queue according to the behavior of the current packet in a real queue (q). Consequently, we provided a scheme that can predict the next incoming packet by the current packet in a real queue (q), as to provide the most updated packet information. We used the time-stamp and arrival time of the current packet in a queue (q). It is used for prediction of the arrived time and stamped time of the current incoming packets into the real queue (q) or virtual (q). Therefore, base on this prediction can decide if there is a possibility of the next coming packet (new) is able to transmit in time.

First, we calculate the mean of the arrival time of the ongoing packet in a queue (q), ΔT_q as formulated in equation (3.7) below:

$$\Delta T_q = \frac{1}{n_q}\sum_{i=0}^{n_{q-1}}\left(t_{q,i+1} - t_{q,i}\right) = \frac{t_{q,n_q-t_{q,0}}}{n} \quad (3.7)$$

Where n_q is a number of the packet in queue (q).

calculating the average of internal stamp time of the ongoing packet in a queue (q), ΔT_q also defined in equation (3.8):

$$\Delta T_{sq} = \frac{1}{n_q}\sum_{i=0}^{n_{q-1}}\left(t_{sq,i+1} - t_{sq,i}\right) = \frac{t_{sq,nq}-t_{sq,0}}{n} \quad (3.8)$$

Where n_q is a number of packets presently in queue (q).

(n_{q-1})th is represented last packet in the queue, whose packet can be transmitted in a $R_{q,n_{q-1}}$ in regular, and can be achieve to be compute in equation (3.9):

$$R_{q,n_q-1=}\left(\frac{n_q}{EU_i \times T_I}\right) \qquad (3.9)$$

The amount of time required to transmitting n_q packets in queue (q) is defined in equation (3.10):

$$T_{n_q} = R_{q,n_q-1} \times T_I \qquad (3.10)$$

The time defined in equation (3.10) and the average of inter-arrival time computed previously are used to estimate the number of new packet arrived into queue (q) during the interval of eq_{nq} packets which all current n_q packets in the queue (q) is transmitted. The current arrival packet are assessing at the queue (q) at the interval of time for all n_q packets which is presently in queue (q) is transmitted in $et_{n,q}$ in equation (3.11).

$$et_{nq=}\left(\frac{T_{nq}}{\Delta T_q}\right) \qquad (3.11)$$

The estimation of arrival time of the packet *n* within the virtual queue (q) of the real queue (q), $et_{q,n}$ is calculated in equation (3.12) as follows:

$$et_{q,n=}\, t_{q,nq-1} + (n+1)\Delta T_q \qquad (3.12)$$

The values of n were range as: $0 \leq n \leq y-1$

The estimated timestamp of packet n in virtual queue of the q and $et_{sq,n}\, is$ calculated as:

$$et_{sq,n} = t_{sq,nq-1} + (n+1)\Delta T_{sq,} \qquad (3.13)$$

Where $0 \leq n \leq y-1$

Similarly, to estimate nth packets in a virtual queue (q) of the packet queue (q) can also schedule to send the packet at $ER_{q,n}$ interval, also it is calculated as follow in equation (3.14) below:

$$ER_{q,n} = \left(\frac{n_{q+}n+1}{EU_i \times T_I}\right) \qquad (3.14)$$

In another condition, n packet cannot be transmitted in time if:

$$DB_{q,n} - \left(t_{oq} - et_{q,n}\right) < ER_{q,n} \times T_I + t_{pn}$$

The t_{oq} is an observation time. The estimated time of arrival of nth packet in queue (q), and $et_{q,n}$ can be later than t_{oq} observation time. In consequences the value $\left(t_{oq} - et_{q,n}\right)$ will be negative, means for nth packet have still remaining time $DB_{q,n} + (et_{q,n} - t_{oq})$ before the packet delay budget is being exhaust lead to expire.

First packet can be identify which can become late in the queue (q) computed in equation (3.15):

$$ef_q = \arg min\left(n \middle| DB_{q,n} - \left(t_{oq} - et_{q,n}\right) < ER_{q,n} \times T_I + t_{pi}\right) \quad (3.15)$$

Hence, to find the last packet in the queue (q) which is also late as used equation (3.16):

$$ef_q = \arg max\left(n \middle| DB_{q,n} - \left(t_{oq} - et_{q,n}\right) < ER_{q,n} \times T_I + t_{pi}\right) \quad (3.16)$$

estimated packet loss rate of eL_q is calculated in the formulae as follows:

$$eL_q = \begin{cases} \frac{(l_q - f_q + 1) + (el_q - ef_q + 1)}{N_q + l_q + el_q} & if\ 0 \le el_q - ef_q < tl_q \\ T_q + \varepsilon & if\ el_q - ef_q \ge tl_q \\ \frac{(l_q - f_q + 1)}{N_q + l_q} & \text{if } ef_q \text{cannot found} \end{cases} \quad (3.17)$$

if computed eL_q value is equal or greater than to our defined threshold T_q, the QoS of these packets in this queue cannot satisfy the users requirements. The termination processing unit in the third stage is called to handle this case. Otherwise the late packet is terminating by calling this method *MacQueue::TerminatePacket()*, since a current queue can accept greater packet loss rates. It allows the other packets in time to utilize the channel bandwidth. Else, If computed eL_q is less than threshold T_q the termination unit cannot be called to process.

At the last, if all packet in the queue (q) can transmit in time, the termination unit in stage 3 will not be called. This also represented as scenario 3.

In scenario 3 all packets contain in a queue (q) can be transmit in time and also does not involve in controlling queue and prediction delay of the late arrival packet.

Finally in we combined *DL_Proposed_VRTSA_PacketScheduler::HandleScenario1(),* and *DL_Proposed_VRTSA_PacketSheduler::HandleScenario2(),* from scenario 1 and 2 in a single function formed scenario 3 as follows: *DL_Proposed_VRTSA_PacketScheduler::ControlQueuesAndPredictionPcktDelay()*.

3.6 Termination Unit of the Expire Packet

In this stage three, this function are created as *AllocateTerminatedUserZForRbJ()*. It will find out terminated expired user z from the entirely contestant users based on this formular: $T_{z,j}$=min $(ET_{i,j} - ET_{z,j})$ (3.18)

It is iteratively searching the user's z have a low throughput until all terminated users are processed all over the RBs were assigned. If all terminated users are being handled the extra RBs is allocated to users have a least throughput. If all RBs are allocated these terminated users requires more RBs than available RBs. And, if the terminated users are not called RB j is allocate to user i having minimum throughput. In fact, the terminated users with high throughput will be selected to use the RBs.

3.7 Summary

In this chapter, the proposed approach has been introduced to overcome the scheduling issues of real-time traffic. The system is allocating radio resources to the user based on CQI report to user having good channel quality will be considering first since the real-time traffic does not need delay. Second, controlling the queue and prediction delay of the late incoming packet in the queue, that is to determine the late coming packet by setting the maximum delay required in the τ_i threshold in the queue. Third, created termination processing unit for each packet exceeded its maximum time of delay requirement to be terminated from the traffic. Finally, the VRTSA has been proposed. The scheduling decision of this approach has been focused to satisfy the QoS require for real-time traffic for video flow. It is also relay on exploiting QoS metrics these are: Packet Loss Ratio, Delay and Throughput.

CHAPTER 4: RESULT AND DISCUSSION

4.1 Simulation Result

To evaluate and compare the performance of the proposed Video Real-Time Scheduling Algorithm (VRTSA) with other three well-known existing downlink scheduling algorithms namely; PF, MLWDF, EXP/PF and as well as the recent work called LTTI respectively. The parameters values are shown in Table 4.1 is used to simulate single cell with interference scenario in LTE-Sim simulator. The Signal to Interference Noise Ratio (SINR) were generating from six neighboring cells. The scenario cell is at the center consists the number of users moving in a random direction ranges from [5 to 20] users at pedestrian and vehicular (PED A and VEH B) channels.

The outline of this chapter includes Simulation Result and Summary.

Table 4.1: Simulation Parameters

Parameters	Values
Number of Cell	1
RBs	25
Number of users (UE)	5, 10, 15, 20
Number of Users Interval	5
Radius	1 km
Types of flows	Video
Downlink Schedulers	PF, MLWDF, EXP/PF, LTTI, and Proposed_VRTSA
Speed	3 km/h
Maximum Delay	0.1s
MCS	QPSK, 16 QAM and 64 QAM
Video bit rate	242 kbps
Bandwidth	5 MHz
Simulation Time Duration	100s

The performance of proposed VRTSA is evaluated and compared with (Mahfoudi et al., 2015) in terms of QoS metrics; Packets Loss Ratio, Delay and Throughput. The proposed VRTSA has achieved better scheduling performance which improved the QoS and satisfied user's requirements of video flow in LTE network. The Figure 4.1, 4.2 and 4.3 respectively, presented simulation results of this research.

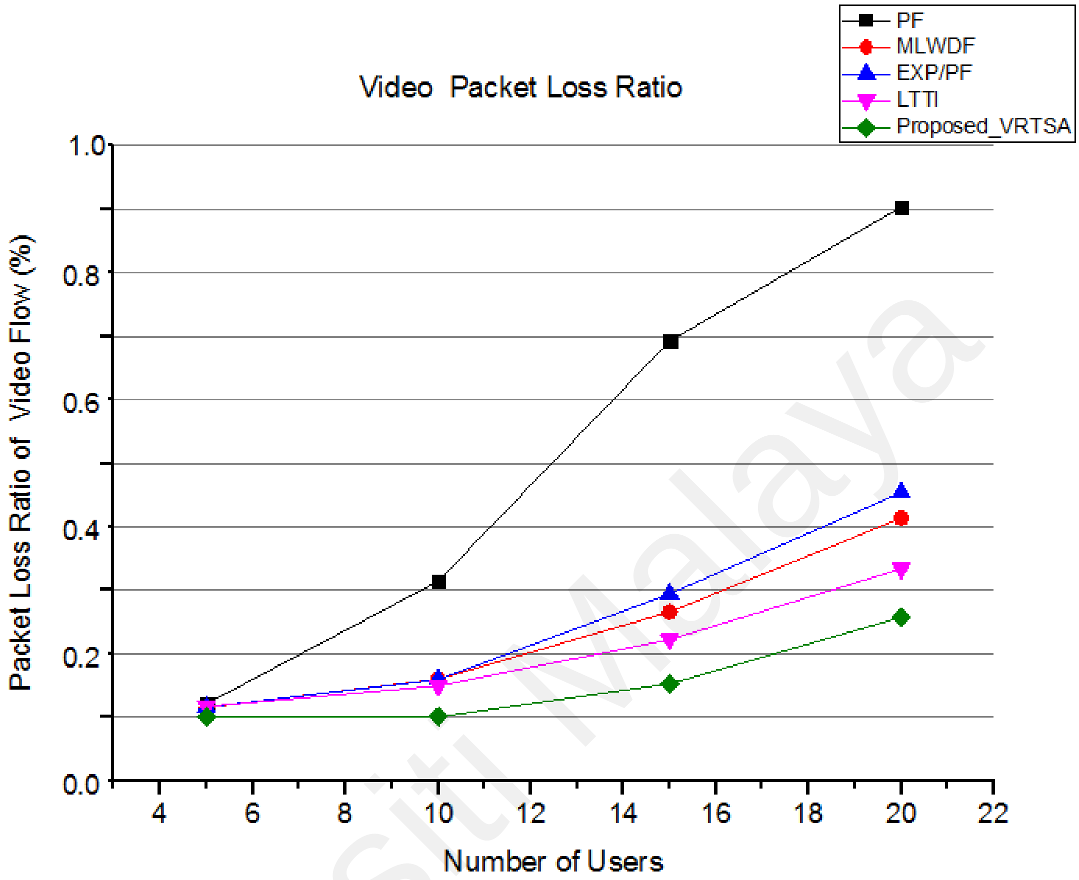

Figure 4.1: The Packet Loss Ratio of Video Traffic

Figure 4.1 shows that the proposed VRTSA is achieved in lowest Packet Loss Ratio (PLR), which showed that the new developed scheduling algorithm improved the QoS at downlink video flow to satisfy the user’s requirements. The ratio shows that there is relatively less PLR of the proposed VRTSA when compared to other scheduling algorithms. In addition, as the number of users increases in the network, the packet loss ratio is also increases. At the highest number of 20 users on the network, the packet loss ratio of the Proposed VRTSA shows an improved scheduling performance up to 0.26% as compared to LTTI=0.33%, MLWDF=0.40%, EXP/PF=0.45% and PF=0.90%, respectively. Therefore, the proposed VRTSA outperformed other algorithms in term of packet loss ratio, and PF scheduling algorithm has the weak scheduling performance for real-time traffic of video flow.

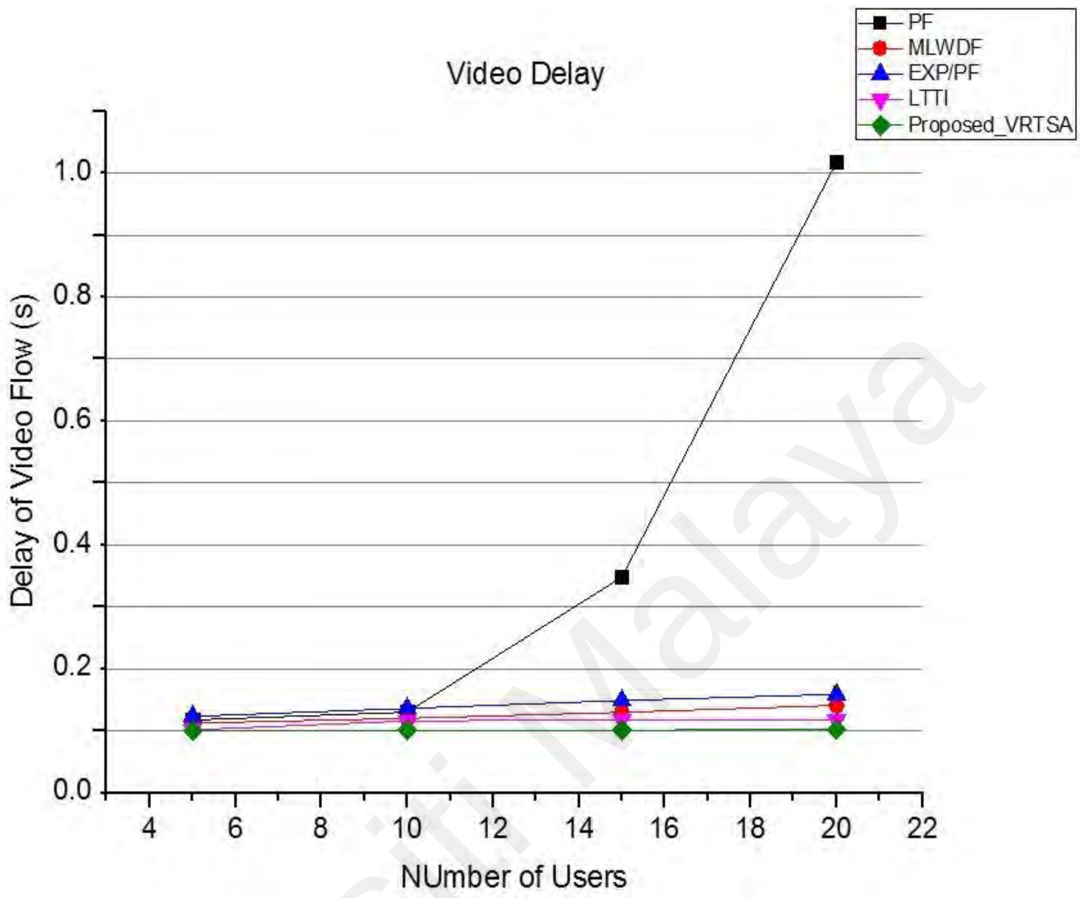

Figure 4.2: The Packet Delay of Video Traffic

Figure 4.2 depicted that, the proposed VRTSA has lowest packet delay in real-time traffic of video, which proved that the developed scheduling algorithm has the capability to optimize the QoS to satisfy the user's requirements. The ratio shows that there is an achievement in lowering packet delivery delay of the proposed VRTSA when compared to other scheduling algorithms. Thus, as the number of users increases in the network also the packet delivery delay increased due to the heavy load of packets increases on the network. As the network contains highest number of 20 users, the packet delivery delay of the proposed VRTSA shown that has been reduced to 0.1s as compared to LTTI, MLWDF, EXP/PF and PF algorithms which have 0.12s, 0.15s, 0.17s and 1.0s respectively. The proposed VRTSA is achieved better performance to reduce the packet delay than other scheduling algorithms. The PF algorithm has a poor scheduling performance for real-time traffic of video.

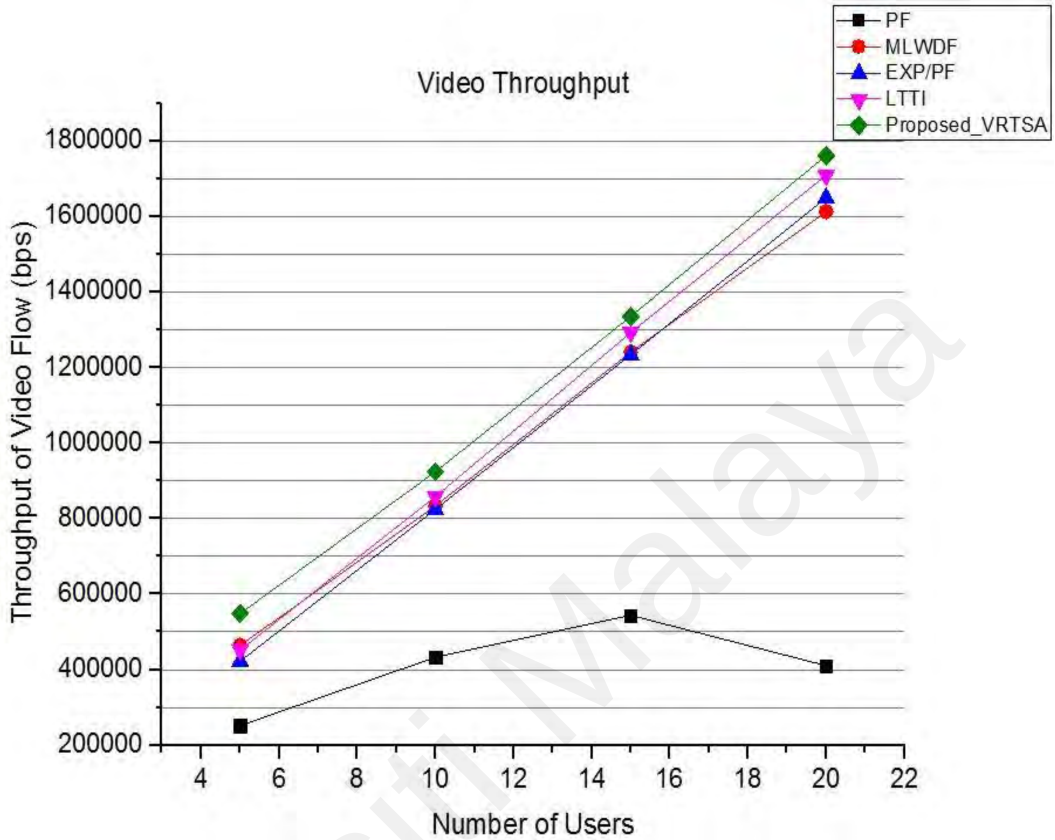

Figure 4.3: The Throughput of Video flow

In Figure 4.3 shows that the proposed VRTSA has achieved to maximized the system throughput and shows that the new developed algorithm has improved the QoS for real-time traffic of video flow in satisfying the user's requirements. The ratio shows that relatively there is higher growth of throughput from the proposed VRTSA when compared to other scheduling algorithms PF, MLWDF, EXP/PF as well as recent work LTTI algorithms. Moreover, as the number of users increases in the network, the system throughput is also increased. At high level number of 20 users on the network, the throughput of the proposed VRTS shows that has been maximized up to 1670000 bps, as compared to LTTI, EXP/PF, MLWDF, and PF which have 1600000 bps, 1520000 bps, 1500000 and 300000 bps respectively. The proposed VRTSA outperformed other algorithms in term of maximizing throughput. Finally, the PF scheduling algorithm has the least system throughput for real-time traffic of video flow.

4.2 Summary

In this chapter, the scheduling issue has been verified and simulated the scheduling of real-time traffic for video flow. It also justified by comparing the proposed algorithm with existing scheduling algorithms this mentioned as follows; PF, MLWDF and EXP/PF as well as the recent algorithm called LTTI respectively. It improved scheduling performance in term of QoS metric 1. packet loss ratio 2. delay 3. throughput. Also, achieved good scheduling performance which provides QoS to satisfied the user's requirements by lowered packet loss ratio, delay, maximized system throughput. Similarly, by quantitative analysis, the Proposed VRTSA reduced the packet loss rate to 0.26%, as compared to LTTI, MLWDF, EXP/PF and PF, which have 0.33%, 0.40%, 0.45% and 0.90% respectively. The delay has been lowest up to 0.1s, as compared to LTTI, MLWDF, EXP/PF, and PF, which have 0.12s, 0.15s, 0.17% and 1.0s respectively. Finally, the proposed algorithm has achieved high throughput which maximized up to 1670000 bps, as compared to LTTI, EXP/PF, MLWDF, and PF, which have 1600000 bps, 1520000 bps, 1500000 and 300000 bps respectively.

CHAPTER 5: CONCLUSION AND FUTURE WORK

The outline of this chapter is concealments Conclusion and Future Work.

Cellular mobile users are always in need of QoS especially in real-time traffic for reliable connection over the LTE networks. Indeed, the rigorous literature review performed revealed that the existing scheduling algorithms have the limitation regarding the QoS requirements in LTE network particularly in real-time traffic. The present research analyzed the performance of state-of-art downlink scheduling algorithms. It was realized that the previous scheduling schemes in LTE network proposed by the researchers unable to provide adequate performance. This is because it does not serve the real-time efficiently, especially in video streams. In order to achieve a good performance, there is a need to develop optimal downlink scheduling algorithm. Therefore, this research developed an optimal downlink scheduling algorithm called Video Real-Time Scheduling Algorithm (VRTSA) to support QoS of video traffic in LTE networks. The developed VRTSA was evaluated and compared with three well-known existing downlink scheduling algorithms in LTE network namely: PF, MLWDF and EXP/PF as well as a recent work named LTTI. Which validate its performance in satisfying the user's requirements of QoS. The developed algorithm is achieved better performance than its comparatives as a result of improvement in the QoS metrics. The result shows that the developed algorithm has a low packet loss ratio, less delay and maximized system throughput compared with PF, MLWDF and EXP/PF and LTTI algorithms. In addition, the developed algorithm is exploited low packet loss ratio at peak point as contains a higher number with 20 users at the cell. Precisely, the performance of the developed algorithm has been improved by 26% as compared to LTTI, MLWDF, EXP/PF and PF which have 33%, 40%, 45% and 90% respectively. Moreover, the developed algorithm has low packet delivery delay at a higher number of 20 users. Precisely when the network is overloaded the packet delay is improved as low as 10s compared with recent LTTI, MLWDF, EXP/PF, and PF which have 12s, 15s, 17s and 100s respectively. On the other hand, the developed algorithm at the highest number of users was exploited to maximized the throughput up to 167 bps, as compared with LTTI, EXP/PF, MLWDF and PF which have 1600000 bps, 1520000 bps, 1500000 and 300000 bps respectively. Due to, mentioned outstanding performance of the developed algorithm can be concluded that the developed scheduling algorithm is achieved to improved scheduling performance which improved the overall system efficiency of QoS and satisfies the user's requirements of real-time traffic for video flows over the LTE network.

5.1 Future Work

The developed VRTSA is simulated in a single cell scenario with interference. The users are moving in a random direction in a single cell environment (eNodeB) at pedestrian and vehicular channels. However, increasing the number of stages, it may increase the algorithm complexity. Therefore, in future work the developed VRTSA can be simulate in multi-cells (eNodeBs) and complexity metric can be evaluating.

REFERENCES

Abrahão, D. C., Vieira, F. H. T., & Ferreira, M. V. G. (2015). *Resource allocation algorithm for LTE networks using βMWM modeling and adaptive effective bandwidth estimation.* Paper presented at the Telecommunications (IWT), 2015 International Workshop on.

Access, E. U. T. R. (2008). and Evolved Universal Terrestrial Radio Access Network (E-UTRAN). *Overall description, 126*.

Agarwal, M., & Puri, A. (2002). *Base station scheduling of requests with fixed deadlines.* Paper presented at the INFOCOM 2002. Twenty-First Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE.

Alfayly, A., Mkwawa, I.-H., Sun, L., & Ifeachor, E. (2012). *QoE-based performance evaluation of scheduling algorithms over LTE.* Paper presented at the Globecom Workshops (GC Wkshps), 2012 IEEE.

AlQahtani, S. A., & Alhassany, M. (2013). *Comparing different LTE scheduling schemes.* Paper presented at the Wireless Communications and Mobile Computing Conference (IWCMC), 2013 9th International Conference.

Alsahag, A. M., Ali, B. M., Noordin, N. K., & Mohamad, H. (2016). Maximum rate resource allocation algorithms with multiuser diversity and QoS support for downlink OFDMA based WiMAX system. *Telecommunication Systems, 63*(1), 1-14.

Ang, E. M., Wee, K. K., Pang, Y. H., & Lau, S. H. (2014). *Two-level scheduling framework with frame level scheduling and exponential rule in wireless network.* Paper presented at the Information Science and Applications (ICISA), 2014 International Conference on.

Asheralieva, A., & Miyanaga, Y. (2016). Effective resource block allocation procedure for quality of service provisioning in a single-operator heterogeneous LTE-A network. *Computer networks, 108*, 1-14.

Astély, D., Dahlman, E., Furuskär, A., Jading, Y., Lindström, M., & Parkvall, S. (2009). LTE: the evolution of mobile broadband. *IEEE Communications Magazine, 47*(4).

Avocanh, J. T. S., Abdennebi, M., & Ben-Othman, J. (2013). *A new two-level scheduling algorithm for the downlink of LTE networks.* Paper presented at the Globecom

Workshops (GC Wkshps), 2013 IEEE.

Basukala, R., Ramli, H., Sandrasegaran, K., & Chen, L. (2010). *Impact of CQI feedback rate/delay on scheduling video streaming services in LTE downlink.* Paper presented at the Communication Technology (ICCT), 2010 12th IEEE International Conference on.

Camarda, P. (2012). *QoS provisioning in LTE-A networks with relay nodes.* Paper presented at the Proceedings of the IFIP Wireless Days Conference (WD'12). Dublin, Ireland.

Capozzi, F., Piro, G., Grieco, L. A., Boggia, G., & Camarda, P. (2013). Downlink packet scheduling in LTE cellular networks: Key design issues and a survey. *IEEE Communications Surveys & Tutorials, 15*(2), 678-700.

Chadchan, S., & Akki, C. (2010). 3gpp lte/sae: an overview. *International Journal of Computer and Electrical Engineering, 2*(5), 806.

Channels, P. (2007). modulation (Release 8), 3GPP TS 36.211. *V1. 0.0, Mar*.

Dikamba, T. (2011). Downlink scheduling in 3GPP long term evolution (LTE).

Djouama, A., & Lim, M.-S. (2015). Reduction of the feedback delay effect on a proportional fair scheduler in LTE downlink using nonlinear support vector machine prediction. *AEU-International Journal of Electronics and Communications, 69*(10), 1393-1402.

Ekstrom, H. (2009). QoS control in the 3GPP evolved packet system. *IEEE Communications Magazine, 47*(2), 76-83.

Ekstrom, H., Furuskar, A., Karlsson, J., Meyer, M., Parkvall, S., Torsner, J., & Wahlqvist, M. (2006). Technical solutions for the 3G long-term evolution. *IEEE Communications magazine, 44*(3), 38-45.

Gavrilovska, L., & Talevski, D. (2011). *Novel scheduling algorithms for LTE downlink transmission.* Paper presented at the Telecommunications Forum (TELFOR), 2011 19th.

Gotsis, A. G., Lioumpas, A. S., & Alexiou, A. (2012). *Evolution of packet scheduling for machine-type communications over LTE: Algorithmic design and performance analysis.* Paper presented at the Globecom Workshops (GC

Wkshps), 2012 IEEE.

Holma, H., & Toskala, A. (2009). *LTE for UMTS-OFDMA and SC-FDMA based radio access*: John Wiley & Sons.

Hsieh, S.-Y. (2015). Service-differentiated Downlink Flow Scheduling to Support QoS in Long Term Evolution.

Huang, J., Subramanian, V. G., Agrawal, R., & Berry, R. A. (2009). Downlink scheduling and resource allocation for OFDM systems. *IEEE Transactions on Wireless Communications, 8*(1), 288-296.

Kausar, R., Chen, Y., & Chai, K. (2011). *QoS aware packet scheduling with adaptive resource allocation for OFDMA based LTE-advanced networks.* Paper presented at the Communication Technology and Application (ICCTA 2011), IET International Conference on.

Kolehmainen, N., Puttonen, J., Kela, P., Ristaniemi, T., Henttonen, T., & Moisio, M. (2008). *Channel quality indication reporting schemes for UTRAN long term evolution downlink.* Paper presented at the Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE.

Kumar, S., Sarkar, A., Sriram, S., & Sur, A. (2015). A three level LTE downlink scheduling framework for RT VBR traffic. *Computer networks, 91*, 654-674.

Kwan, R., & Leung, C. (2010). A survey of scheduling and interference mitigation in LTE. *Journal of Electrical and Computer Engineering, 2010*, 1.

Kwan, R., Leung, C., & Zhang, J. (2008). Multiuser scheduling on the downlink of an LTE cellular system. *Research Letters in Communications, 2008*, 3.

Kwan, R., Leung, C., & Zhang, J. (2010). *Downlink resource scheduling in an LTE system*: INTECH Open Access Publisher.

Lee, S.-B., Choudhury, S., Khoshnevis, A., Xu, S., & Lu, S. (2009). *Downlink MIMO with frequency-domain packet scheduling for 3GPP LTE.* Paper presented at the INFOCOM 2009, IEEE.

Liu, B., Tian, H., & Xu, L. (2013). *An efficient downlink packet scheduling algorithm for real time traffics in LTE systems.* Paper presented at the Consumer communications and networking conference (CCNC), 2013 IEEE.

Liu, T.-C., Wang, K., Ku, C.-Y., & Hsu, Y.-H. (2016). QoS-aware resource management for multimedia traffic report systems over LTE-A. *Computer networks, 94*, 375-389.

Liu, X., Chong, E. K., & Shroff, N. B. (2003). A framework for opportunistic scheduling in wireless networks. *Computer networks, 41*(4), 451-474.

Love, R., Kuchibhotla, R., Ghosh, A., Ratasuk, R., Xiao, W., Classon, B., & Blankenship, Y. (2008). *Downlink control channel design for 3GPP LTE.* Paper presented at the Wireless Communications and Networking Conference, 2008. WCNC 2008. IEEE.

Luo, H., Ci, S., Wu, D., Wu, J., & Tang, H. (2010). Quality-driven cross-layer optimized video delivery over LTE. *IEEE Communications Magazine, 48*(2).

Mahfoudi, M., Bekkali, M. E., Najd, A., Ghazi, M. E., & Mazer, S. (2015). A New Downlink Scheduling Algorithm Proposed for Real Time Traffic in LTE System. *International Journal of Electronics and Telecommunications, 61*(4), 409-414.

Mcqueen, D. (2009). The momentum behind LTE adoption [sGPP LTE]. *IEEE Communications Magazine, 47*(2), 44-45.

Monghal, G., Pedersen, K. I., Kovacs, I. Z., & Mogensen, P. E. (2008). *QoS oriented time and frequency domain packet schedulers for the UTRAN long term evolution.* Paper presented at the Vehicular Technology Conference, 2008. VTC Spring 2008. IEEE.

Mushtaq, M. S., Fowler, S., Mellouk, A., & Augustin, B. (2015). QoE/QoS-aware LTE downlink scheduler for VoIP with power saving. *Journal of Network and Computer Applications, 51*, 29-46.

Myung, H. G. (2008). Technical overview of 3GPP LTE. *Polytechnic University of New York.*

Pande, M., & Piro, G. (2014). *Optimal resource allocation scheme for LTE-A systems with carrier aggregation.* Paper presented at the Advanced Networks and Telecommuncations Systems (ANTS), 2014 IEEE International Conference.

Parkvall, S., Dahlman, E., Sköld, J., & Beming, P. (2009). 3G Evolution–HSPA and LTE for Mobile Broadband. *Presentation at Chalmers University of Technology*.

Piro, G., Grieco, L. A., Boggia, G., Capozzi, F., & Camarda, P. (2011). Simulating LTE cellular systems: An open-source framework. *IEEE transactions on vehicular technology, 60*(2), 498-513.

Piro, G., Grieco, L. A., Boggia, G., Fortuna, R., & Camarda, P. (2011). Two-level downlink scheduling for real-time multimedia services in LTE networks. *IEEE Transactions on Multimedia, 13*(5), 1052-1065.

Pokhariyal, A., Monghal, G., Pedersen, K. I., Mogensen, P. E., Kovacs, I. Z., Rosa, C., & Kolding, T. E. (2007). *Frequency domain packet scheduling under fractional load for the UTRAN LTE downlink.* Paper presented at the Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th.

Prasad, A. R., Laganier, J., Zugenmaier, A., Bargh, M. S., Hulsebosch, B., Eertink, H., Idserda, J. (2007). *Mobility and key management in SAE/LTE.* Paper presented at the Wireless Communications 2007 CNIT Thyrrenian Symposium.

Rejeb, S. B., Nasser, N., & Tabbane, S. (2014). A novel resource allocation scheme for LTE network in the presence of mobility. *Journal of Network and Computer Applications, 46*, 352-361.

Sadiq, B., Baek, S. J., & De Veciana, G. (2011). Delay-optimal opportunistic scheduling and approximations: The log rule. *IEEE/ACM Transactions on Networking (TON), 19*(2), 405-418.

Seeling, P., & Reisslein, M. (2012). Video transport evaluation with H. 264 video traces. *IEEE Communications Surveys & Tutorials, 14*(4), 1142-1165.

Sesia, S., Baker, M., & Toufik, I. (2011). *LTE-the UMTS long term evolution: from theory to practice*: John Wiley & Sons.

Sulthana, S. F., & Nakkeeran, R. (2014). Study of Downlink Scheduling Algorithms in LTE Networks. *JNW, 9*(12), 3381-3391.

Sun, R. Q., & Wu, S. C. (2014). *A Downlink Scheduling Scheme for Trunking Multimedia Services in LTE Public Networks.* Paper presented at the Applied Mechanics and Materials.

Wang, L.-C., & Lin, W.-J. (2004). *Throughput and fairness enhancement for OFDMA broadband wireless access systems using the maximum C/I scheduling.* Paper presented at the Vehicular Technology Conference, 2004. VTC2004-Fall. 2004 IEEE 60th.

Wei, N., Pokhariyal, A., Sorensen, T. B., Kolding, T. E., & Mogensen, P. E. (2007). *Performance of MIMO with frequency domain packet scheduling in UTRAN LTE downlink.* Paper presented at the Vehicular Technology Conference, 2007. VTC2007-Spring. IEEE 65th.

Wu, S., Sun, R., Ma, K., & Liu, Y. (2015). *A downlink scheduling scheme for trunking multimedia services in TD-LTE public networks.* Paper presented at the Wireless Communications and Mobile Computing Conference (IWCMC), 2015 International.

Zaki, Y., Weerawardane, T., Gorg, C., & Timm-Giel, A. (2011). *Multi-QoS-aware fair scheduling for LTE.* Paper presented at the Vehicular technology conference (VTC spring), 2011 IEEE 73rd.