

**PERFORMANCE ANALYSIS OF NETWORK TRAFFIC FOR
LTE WIRELESS COMMUNICATION LINKS INTERFERED BY
LIGHTNING**

MUHAMMAD A'MMAR BIN JAMAL AKBAR



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**PERFORMANCE ANALYSIS OF NETWORK TRAFFIC FOR
LTE WIRELESS COMMUNICATION LINKS INTERFERED BY
LIGHTNING**

MUHAMMAD A'MMAR BIN JAMAL AKBAR

**This report is submitted in partial fulfilment of the requirements
for the degree of Bachelor of Electronic Engineering with Honours**



اونفوسيتي تكنولوجيكا مليسيا ملاك
Faculty of Electronic and Computer Engineering
Universiti Teknikal Malaysia Melaka

2022

BORANG PENGESAHAN STATUS LAPORAN
PROJEK SARJANA MUDA II

Tajuk Projek : PERFORMANCE ANALYSIS OF NETWORK TRAFFIC FOR LTE WIRELESS COMMUNICATION LINKS INTERFERED BY LIGHTNING
Sesi Pengajian : 2021/2022

Saya MUHAMMAD A'MMAR BIN JAMAL AKBAR mengaku membenarkan laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (✓):

SULIT*

(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)

TERHAD*

(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan.

TIDAK TERHAD



(TANDATANGAN PENULIS)

Disahkan oleh:



DR. MOHD RIDUAN BIN AHMAD
Profesor Madya
Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka (UTeM)
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

(COP DAN TANDATANGAN PENYELIA)

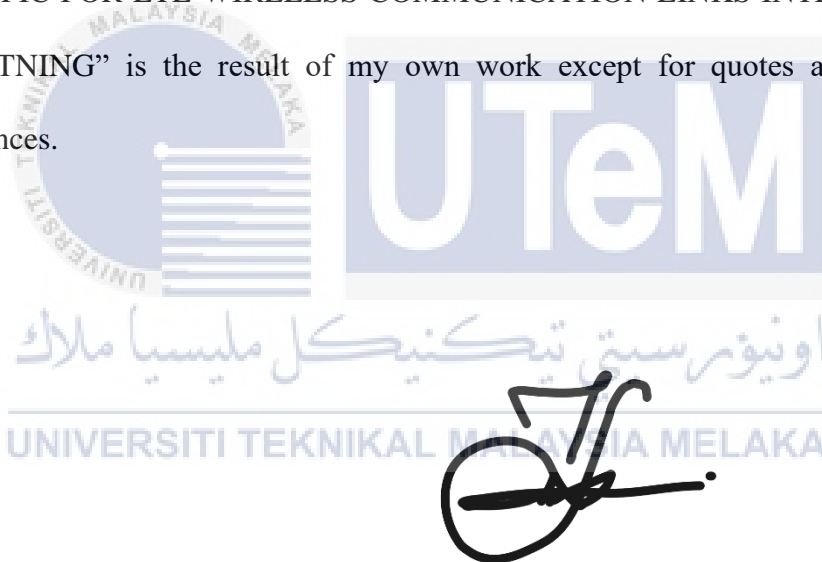
Alamat Tetap: A-276.....KAMPUNG WAKAF MEMPELAM,20050, KUALA TERENGGANU, TERENGGANU
JABATAN KEJURUTERAAN KOMPUTER, FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER (FKEKK), UTeM

Tarikh : 13 Jun 2022

Tarikh : 13 Jun 2022

D ECLARATION

I declare that this report entitled “PERFORMANCE ANALYSIS OF NETWORK TRAFFIC FOR LTE WIRELESS COMMUNICATION LINKS INTERFERED BY LIGHTNING” is the result of my own work except for quotes as cited in the references.



Signature :

Author : MUHAMMAD A'MMAR BIN
JAMAL AKBAR

Date : 13/6/2022
.....

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.



اونيور تیکنیکل ملیسیا ملاک

Signature :

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DR. MOHD RIDUAN BIN AHMAD
Profesor Madya
Fakulti Kejuruteraan Elektronik Dan Kejuruteraan Komputer
Universiti Teknikal Malaysia Melaka (UTeM)
Hang Tuah Jaya
76100 Durian Tunggal, Melaka

Supervisor Name :

Date : 13 June 2022

DEDICATION

To my beloved parents and siblings, who has been my source of strength and encouragement.

To my lecturers and colleagues for guidance and shared knowledge throughout those sleepless night.

Thank you

اونيورسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

ABSTRACT

Lightning is a natural event occurs in nature due to electrical discharges in the air. These electrical discharges emit a wide spectrum of electromagnetic (EM) fields. This EM spectrum includes the frequency of mobile communication networks particularly 4G frequency band at 2.3 GHz which is the interest of this study. In this thesis, experiments have been conducted to measure 4G network performances during lightning and thunderstorm events. A measurement system has been designed and developed to measure lightning interference effects toward 4G data transmissions. The measurement includes protocol that is commonly used by the end-user which is User Datagram Protocol (UDP). The measurement results were evaluated in terms of packet loss, jitter, throughput, and consecutive loss datagrams (CLDs). The significant finding is that, during heavy storm events, there were significant drop in throughput and significant increase in packet loss, jitter, and CLDs. Therefore, it can be concluded that EM radiation emitted by lightning interfered with 4G data transmission to the extent of reducing the overall performance of the 4G network.

ABSTRAK

Kilat adalah kejadian alam semula jadi yang berlaku disebabkan oleh penyahcasan elektrik di udara. Penyahcasan elektrik ini mengeluarkan medan elektromagnet (EM) yang merangkumi spektrum yang luas. Spektrum ini juga merangkumi frekuensi yang diguna pakai oleh rangkaian mudah alih termasuklah frekuensi 4G iaitu 2.3 GHz iaitu salah satu kepentingan kajian ini. Dalam tesis ini, eksperimentasi telah dijalankan bagi mengukur prestasi rangkaian 4G dalam keadaan fenomena kilat dan ribut. Satu sistem pengukuran yang telah direka bentuk dan dibangunkan bagi mengukur kesan gangguan kilat terhadap transmisi data 4G. pengukuran tersebut termasuklah protocol yang kebiasaannya digunakan oleh pengguna awam iaitu User Datagram Protokol (UDP). Keputusan pengukuran telah dinilai dalam terma, Kehilangan Paket, Jitter, Daya Pengeluaran dan Kehilangan Datagram Berterusan (CLD). Penemuan yang penting dari kajian ini adalah, Ketika ribut yang teruk, terdapat penurunan ketara dalam Daya Pengeluaran dan peningkatan ketara dalam Kehilangan Paket, Jitter dan CLD. Oleh itu dapat dikonklusikan bahawa radiasi EM yang dikeluarkan oleh kilat memberi kesan gangguan kepada transmisi data 4G yang membawa kepada penurunan prestasi keseluruhan rangkaian 4G

ACKNOWLEDGEMENTS

In the name of Allah SWT, the Most Gracious, the Ever Merciful. Praise is to Allah, Lord of the Universe. Peace and Prayers be upon His final Prophet and Messenger Muhammad SAW.

First and foremost, I would like to offer my highest appreciation to my supervisor, Dr. Mohd Riduan bin Ahmad for his fathomless and irreplaceable guidance. His supervision and endless support truly guide me on progression and smoothness of my work until I succeed to complete this project. His kindness and leadership will always be remembered closely to my heart all the time. Not to forget his willingness to share his time and energy to help guide me in every path that I take since day 1.

Nothing has been more important to me in the pursuit of this project other than the members of my family. I would like to thank my parents, Mr Jamal Akbar and Mrs Khamsiah; whose love and guidance are with me in whatever I pursue. They have been the ultimate role models. This accomplishment would not have been possible without them. I would also like to spare my gratitude to my grandparents,

Late Hajjah Hatmah and Hj, Mansor for always giving tremendous support and for believing in me when no one else did.

Also, not to forget thanks to all the BBNET lab members, Shamsul Ammar, Sulaiman, Azim, and Hj Yusri. Thank you for all the guidance and cooperation provided throughout the journey. Not forgetting my brothers in arms, my housemates whose, together we support each other and push ourselves in completing our degree journey. thank

Thank you, Assalamualaikum.



TABLE OF CONTENTS

Declaration	
Approval	i
Dedication	i
Abstract	i
Abstrak	ii
Acknowledgements	iii
Table of Contents	v
List of Figures	ix
List of Tables	xii
List of Symbols and Abbreviations	xiii
CHAPTER 1 INTRODUCTION	1
1.1 Project introduction	1
1.2 Problem statement	2
1.2.1 Data measurement and analysis on UDP packet	2

1.2.2	Additional performance parameter	3
1.2.3	A different set of network connection (Mobile connection).	4
1.3	Objectives	5
1.4	Scope of work	5
1.4.1	Experimental work	5
1.4.2	Point-to-point topology	5
1.4.3	Limited area of setup	6
1.4.4	U mobile network	6
1.4.5	UDP protocols	6
1.4.6	Software for analysis	6
1.5	Thesis Structure	7
CHAPTER 2 LITERATURE REVIEW		9
2.1	LTE and 4G	9
2.1.1	Introduction to 4G	10
2.1.2	Introduction to LTE	11
2.1.3	4G LTE Services by U Mobile	11
2.2	Network Traffic Models	12
2.2.1	Characteristics of Traffic Models	13
2.2.2	Application of Traffic Model	13
2.3	Network Protocol	14

2.3.1	UDP Protocol	17
2.3.2	Traffic generator and data packet transmission verifier	17
2.4	Lightning	18
2.4.1	Types of lightning	18
2.4.2	Lightning breakdown process	19
2.4.3	Electromagnetic Fields Emitted by Lightning Flashes	20
2.4.4	Microwave emission by Lightning Flash	21
2.4.5	Interference of lightning to wireless network	22
CHAPTER 3 METHODOLOGY		24
3.1	Introduction	24
3.2	Flow of Research and overall project	25
3.3	Design and Development of Lightning Measurement System	26
3.3.1	Buffer circuit configuration	29
3.3.2	Microwave antenna configuration	34
3.3.3	CAPPI Radar	35
3.4	Design and Development Data transfer system	37
3.4.1	Iperf3	37
3.4.1.1	Iperf3 installation guide	40
3.4.2	SoftEther VPN configuration	40
3.4.2.1	SoftEther VPN installation	41

3.4.2.2 Using UTeM VPN server	45
3.4.3 Wireshark	47
3.4.3.1 Wireshark installation and usage	47
3.5 Integration of hardware and software for data transfer system	49
CHAPTER 4 RESULTS AND DISCUSSION	55
4.1 Introduction	55
4.2 Electric field data measurement result	56
4.3 Network Performance measurement results	57
4.4 Method of analysis	60
4.5 Result analysis	67
4.5.1 Single data analysis (Preliminary analysis)	67
4.5.2 Correlation analysis (In-depth analysis)	69
CHAPTER 5 CONCLUSION AND FUTURE WORKS	75
5.1 Conclusion	75
5.2 Future work	77
5.3 Sustainable Development Goals (SDG)	77
REFERENCES	80
LIST OF PUBLICATIONS AND PAPERS PRESENTED	84

LIST OF FIGURES

Figure 2.1: Coverage network for U Mobile at Melaka [10]	12
Figure 2.2: Client and Server OSI model	15
Figure 2.3: UDP operations	17
Figure 2.4: Different types of lightning flash. (a) Cloud flash. (b) Negative ground flash. (c) Positive ground flash. (d) Air discharge. [19]	19
Figure 3.1: Block diagram for the project	26
Figure 3.2: Electrical field measurement system	26
Figure 3.3: Visual diagram for connection of lightning measurement	27
Figure 3.4: PicoScope 6404C	28
Figure 3.5: Example of fast antenna and microwave waveforms.	29
Figure 3.6: Circuit diagram of high-speed buffer amplifier circuit	30
Figure 3.7: IC OPA 633	31
Figure 3.8: Final buffer circuit model in proteus	32
Figure 3.9: Flow chart of the designing lightning measurement system for fast electric field sensor	33
Figure 3.10: Visual diagram of fast field system	34
Figure 3.11: ANT-GROD8-NSMA omnidirectional antenna.	35

Figure 3.12: Example of CAPPI radar data from MET Malaysia on 12 November 2019	36
Figure 3.13: Flowchart of Data transfer system	37
Figure 3.14: Iperf3 interface in window command prompt.	39
Figure 3.15: Iperf3 interface in Window PowerShell	39
Figure 3.16: Working principle for VPN	41
Figure 3.17: User 1 ping to User 2.	45
Figure 3.18: User 2 ping to User 1.	45
Figure 3.19: User 1 sending data packets to User 2 (receiver).	46
Figure 3.20: User 1 results of data sent.	46
Figure 3.21: User 2 receiving data packets from User 1 (sender).	46
Figure 3.22: User 2 results of data received.	46
Figure 3.23: Wireshark download option	48
Figure 3.24: Measurement sequence flowchart	49
Figure 3.25: The telecommunication tower hosted U Mobile 4G equipment located less than 1 km from the lightning sensors.	50
Figure 3.26: Measurement system monitoring and maintenance room	50
Figure 3.27: Client(left) and server(right) laptops	51
Figure 3.28: An example of how Wireshark was used to monitor UDP datagrams transmission.	52
Figure 3.29: GPS receiver and GPS module	52
Figure 3.30: NMEA Time Panel interface [22]	53
Figure 3.31: Command line in Window PowerShell for UDP	53
Figure 3.32: Command line in Window PowerShell	54
Figure 3.34: Server is created and listening to client.	54

Figure 4.1: Noise data captured by the fast field antenna and microwave antenna on 1 May 2022 at 2:07:42 AM	56
Figure 4.2: Lightning strike data captured by fast field antenna and microwave antenna on 16 November 2021 at 4:36:15 PM	57
Figure 4.3: Logfiles from iPerf3 using Window PowerShell. (A) Client logfile (B) server logfile	58
Figure 4.4: Sample of Throughput (A) and Datagram (B) from iPerf3 client logfile on 29 th October 2021, R2.	59
Figure 4.5: Sample of Packet Loss (A), Jitter (B), and Throughput (C) from iPerf3 server logfile on 29 th October 2021, R2.	59
Figure 4.6: Flowchart for method of analysis. The flowchart is used to organize and interpret the raw data that can lead to a conclusion from the results.	60
Figure 4.7: Readings of (A) low frequency and microwave electric field radiations and (B) CAPPI radar image showing intensity of rainfall rates.	67
Figure 4.8: Throughput measured at Client side for Storm 6 happened on 29th October 2021 between 17:32 to 19:26 local time (UTC+8). At 17:51:20, the throughput has dropped drastically and consequently 4G connection lost for around 4 minutes before it can be restored at 17:55:23.	68
Figure 4.9: Total datagram transmitted measured at Client side for Storm 6 happened on 29th October 2021 between 17:32 to 19:26 local time (UTC+8). At 17:51:20, the total transmitted datagram has dropped drastically to zero and consequently 4G connection lost for around 4 minutes before it can be restored at 17:55:23.	69
Figure 4.10: Minimum Throughput of Fair-Weather and Lightning events	71
Figure 4.11: Maximum Throughput of Fair-Weather and Lightning events	72
Figure 4.12: Maximum Jitter of Fair-Weather and Lightning events	73
Figure 4.13: Maximum Packet Loss of Fair-Weather and Lightning events	74
Figure 4.14: United Nation Sustainable Development goals [23]	77
Figure 4.15: SDG goal 9, Innovation and Infrastructure [23]	78
Figure 4.16: SDG goal 13, Climate action [23]	78

LIST OF TABLES

Table 2.1: 4G LTE services by U Mobile.....	12
Table 4.1: Combined reading from electric field measurement and network performance measurement. The timestamps in the cells are from the PicoScope lightning readings, and the green coloured cell are referring to network performance measurement logfile duration and time	61
Table 4.2: 27-set of storm data between 21 st October and 23 rd November 2021.....	62
Table 4.3: 9-set data of fair weather between 27 th October and 14 th November 2021.	64
Table 4.4: Selected storm data for analysis.....	65
Table 4.5: Selected Fair-Weather data for analysis	65
Table 4.6: Fair Weather and Storm data with 3 main parameters.....	66

LIST OF SYMBOLS AND ABBREVIATIONS

MCMC	:	Malaysian Communication and Multimedia Commissioner
ISP	:	Internet Service Provider
UDP	:	User Datagram Protocols
PTP	:	Point to point
RWT	:	Round way trip
OWT	:	One way trip
WWW	:	World Wide Web
ITU-R	:	International Telecommunications Union Radiocommunications Sector
NA	:	Not available
LAN	:	Local Area Network
Wi-Fi	:	Wireless Fidelity
OFDM	:	Orthogonal Frequency Division Multiplexing
OSI	:	Open Systems Interface
NBE	:	narrow bipolar event
IC	:	Intra-Cloud

CG	:	Cloud-to-Ground
BLR	:	Bit Loss rate
UHF	:	Ultra-High Frequency
PMR	:	Private mobile radio
IVG	:	Impulse Voltage Generator
RCT	:	Recloser Test-Set
LOS	:	Line Of Sight
FSK	:	Frequency Shift Keying
DO	:	Digital Oscilloscope
MET	:	Malaysian Meteorological Department



CHAPTER 1

INTRODUCTION



In this chapter, the general information of the project which consists of the project introduction, problem statement, objectives, scope of work, and expected outcome are explained. Project introduction explains the main idea of the project. The problem statement and the objective explain the purpose of this project and the scope of work outlines the process that is needed for the completion of the project.

1.1 Project introduction

The Fourth Generation Long Term Evolution (4G LTE) network has become an essential element for mankind today. With the fast connectivity, humans can be connected across the globe just at the tip of the finger. This mobile network traffic travels to and from cell towers on radio waves. Even in a fair-weather condition the wireless communication system experiences interference and noise but it is

negligible as the level is low. However, in a harsher condition, like lightning and thunderstorm, it has a more significance effect to the 4G network connection.

This project is a collaborative project with U Mobile SDN BHD and Malaysian Communication and Multimedia Commissioner (MCMC) to model lightning interference on LTE wireless communication links. This project involves extensive measurement campaign and network traffic data analysis from the interference of lightning.

The packet data generated for measurement campaign is User Datagram Protocol (UDP). The parameters that are monitored using the iPerf3 software are the bandwidth, latency, speed of data transfer, datagram, and data loss during the lightning interference events.

1.2 Problem statement

Based on the finding in [1], a wireless communication system in microwave band at 2.4 GHz [2][3] experienced noise and interferences even under fair weather condition. However, the study was done with only 2.4 GHz Wireless Fidelity (Wi-Fi) connection with one protocol which is UDP and with only one parameter of packet loss. The findings from the studies are the baseline for this project. Several aspects from the research paper can be further improvised to the next level. Some further improvements applied for this project are:

1.2.1 Data measurement and analysis on UDP packet

The UDP is a connectionless internet protocol which unlike Transmission Control Protocol (TCP), it doesn't have error checking and recovery service. In UDP packet transmission, data is continuously sent to the receiver, whether they receive it

or not. Common usage for UDP is for real-time communication such as steaming, broadcasting, online games, and Voice over IP. The main difference between TPC and UDP is the speed of data transfer. The UDP is much faster compared to TCP due to is simple and efficient protocols. Referring to the studies conducted in [1], [4-8], the studies only focus on UDP protocol, the additional TCP data will provide a variety of result for the result analysis in the MATLAB. Comparing TCP protocol with UDP, the protocol has a slower speed compared to UDP due to the 'Handshake' protocol that ensures a connection is established and it is maintained until the exchange between sending and receiving message is completed [9].

1.2.2 Additional performance parameter

According to [1] the research was done with only the measurement of bit error rate and packet loss. The performance parameter then is added for the data analysis of effect of the lightning interference to the network performance. The parameter that are measured are bandwidth, jitter, datagram, and packet loss. These parameters are measured using iPerf which can be seen in the logfile recorded.

i. Throughput at Client and Server (Round-way trip (RWT) and one-way Trip (OWT))

The maximum amount of data transmitted over an internet connection within a specific time. A larger bandwidth allows more data to be transmitted at the same time.

ii. Jitter

Jitter occurs when data packets are sent over your network connection with a temporal delay. It is commonly due to congestion on the

network, as well as data route changes. Jitter can cause negative impact on the video and audio quality, causing a glitchy output.

iii. Total number of Transmitted Datagram

A datagram is a fundamental transfer unit of a packet-switched network. The header and payload components of a datagram are normally separated. In a packet-switched network, datagrams provide a connectionless communication service. The delivery, arrival time, and order of arrival of datagrams need not be guaranteed by the network. This can be seen in the UDP protocol data.

iv. Packet loss

packet loss is the failure of small unit of data (packet) to reach its intended destination during transmission. It is a causes network disruption, slow service, and loss of network connectivity. It mainly occurred in protocols that has real-time processing such as UDP that are used in video, audio, and streaming.

1.2.3 A different set of network connection (Mobile connection).

The result from [1] was obtained only by using a Dual-band Linksys WRT610N router with multiple antennas. It was connected through local area network (LAN) cables to a laptop acting as a server and another laptop acted as a client and was connected to the router wirelessly. Thus, it only limits the network connection to a Wi-Fi network.

In comparison, a wi-fi network has a faster speed connection than a cellular network. However, a cellular network has a wider range of connection that is limited by its cellular tower coverage. According to [10], the mean speed of 4G in Malaysia