



**PERFORMANCE ANALYSIS OF INTERFACE BONDING AND
CHANNEL BONDING AT POINT TO POINT WIRELESS 802.11N**

GURUH FAJAR SHIDIK

MCS in Internetworking Technology

2011

BORANG PENGESAHAN STATUS THESIS*

JUDUL : PERFORMANCE ANALYSIS OF INTERFACE BONDING AND CHANNEL BONDING AT POINT TO POINT WIRELESS 802.11N

SESI PENGAJIAN : 2010 - 2011

Saya : GURUH FAJAR SHIDIK

(HURUF BESAR)

Mengaku membenarkan tesis Sarjana ini disimpan di Perpustakaan Fakulti Teknologi Maklumat dan Komunikasi dengan syarat-syarat kegunaan seperti berikut:

1. Tesis dan peojek adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan Fakulti Teknologi Maklumat dan Komunikasi dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan Fakulti Teknologi Maklumat dan Komunikasi dibenarkan membuat salinan tesis 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

(TANDA TANGAN PENULIS)

(TANDA TANGAN PENYELIA)

Alamat Tetap: _____

Nama Penyelia

Tarikh: _____

Tarikh: _____

CATATAN: * Tesis dimaksudkan sebagai Laporan Akhir Projek Sarjana (PS).

** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa.

**PERFORMANCE ANALYSIS OF INTERFACE BONDING AND
CHANNEL BONDING AT POINT TO POINT WIRELESS 802.11N**



**This report is submitted in partial fulfillment of the requirements for the
Master of Computer Science (Internetworking Technology)**

FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2011

DECLARATION

I hereby declare that this project report entitled “PERFORMANCE ANALYSIS OF INTERFACE BONDING AND CHANNEL BONDING AT POINT TO POINT WIRELESS 802.11N” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degrees.



اونيورسيتي تیکنیکل ملیسیا ملاک
Signature :

UNIVERSITI TEKNIKAL MALAYSIA MELAKA
Name : Guruh Fajar Shidik

Date : 21 July 2011

APPROVAL

I hereby declare that I have read through this project report and in my opinion, this project report is sufficient in terms of scope and quality for the award of the degree of Master of Computer Science (Internetworking Technology).



Signature :
اونيور سيبي تيكنيكل مليسيا ملاك

Supervisor : Dr. Zul Azri Bin Muhamad Noh
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Date : 21 July 2011

DEDICATION

To Allah (swt) that always provides miracles and guidance in my life.

To my family, for their love, caring, sacrifice, and support during the process of achieving this milestone in my life.

To my teachers who never stop teach and directing to this achievement



ACKNOWLEDGMENT

Alhamdulillah, all praises to Allah, for the strengths and the blessing in completing this project entitled: *Performance Analysis of Interface Bonding and Channel Bonding at Point to Point wireless 802.11n*.

Special appreciation goes to my supervisor, Dr. Zul Azri Bin Muhamad Noh, for his supervision and constant support. His invaluable help of constructive comments and suggestions throughout the experimental and project works have contributed to the success of this research.


I would like to express my appreciation to the Dean, Faculty of Information and Communication Technology, Prof. Dr. Shahrin bin Sahib @ Sahibuddin and also to the Deputy Dean, Faculty of Information and Communication Technology, Prof. Madya Dr. Burairah Hussin and Director of International Office Prof. Dr. Nanna Suryana Herman, for their support and help towards my postgraduate affairs. I also would like to thank Dr. Mohd. Faizal Bin Abdollah, for his very important suggestions in the preparation of this thesis.

I am also indebted to Dian Nuswantoro University (UDINUS) for their kindness in giving financial aid, during my study here. Special thanks also go to Dr. Ir. Edi Noersasongko, Dr. Abdul Syukur, Dr. Kusni Ingsih, for their tremendous support.

Sincere thanks to all my friends and senior, especially Mr. Affandy, Abang Fahmi, Mas Ricardus, Mas Yusuf, Mas Catur, Ferda, Abang Habib, Rabeea, Sa'ad, Mahir, Chaidir, Erika, Ika, Aisyah, Adhitya, Agung, Erwin, Fajrian, Fahri, PPI UTeM, and others for their kindness and moral support during my study. Thanks for the friendship and memories.

Finally, the deepest gratitude goes to my beloved parents and also to sister for their endless love, prayers and encouragement. To those who had indirectly contributed to this research, my profound thanks for your kindness, which means a lot to me.

TABLE OF CONTENTS

TITLE	PAGE
DECLARATION	ii
APPROVAL	iii
DEDICATION	iv
ACKNOWLEDGEMENT	v
TABLE OF CONTENTS	vi
LIST OF TABLES	ix
LIST OF FIGURES	xvi
LIST OF ABBREVIATIONS	xix
LIST OF ATTACHMENT	xxii
ABSTRACT	xxiii
ABSTRAK	xxiv
	
CHAPTER	
1. INTRODUCTION	
1.1 Introduction	1
1.2 Background of Study	2
1.3 Problem Statement	6
1.4 Variable	6
1.5 Parameter	7
1.6 Hypothesis	7
1.7 Research Questions	8

1.8	Research Objectives	8
1.9	Research Contribution	9
1.10	Scope and Limitation	9
1.11	Research Methodology	11
1.12	Project Report Overview	12
1.13	Summary	13
2.	Literature Review	
2.1	Introduction	14
2.2	Related Study	15
2.3	Point to Pont Link	16
2.4	Wireless Bridge	18
2.5	802.11 Specification	19
2.6	Wireless 802.11n	21
2.7	Channel Bonding	28
2.8	Interface Bonding	31
2.9	Parameter Measurements	34
2.9.1	Delay	35
2.9.2	Jitter	36
2.9.3	Data Loss Rate	36
2.9.4	Throughput	37
2.10	Variable Study	37
2.10.1	Packet Size	37
2.10.2	Signal Strength	38
2.10.3	Directional Traffic Flows	40

2.10.3.1	Single Directional Traffic Flow	41
2.10.3.2	Bidirectional Traffic Flow	41
2.11	Measurement Parameter Tools	42
2.11.1	Iperf	42
2.11.2	Netperf	44
2.11.3	D-ITG	44
2.12	Mikrotik ROS	47
2.13	WinBox	48
2.14	inSSider	48
2.15	Summary	49
3. Research Methodology		
3.1	Introduction	51
3.2	Research Method	51
3.3	Methodology	52
3.3.1	Literature Review	53
3.3.2	Experiment Design	54
3.3.2.1	Experiment Process	54
3.3.2.2	Network Design	56
3.3.2.3	Testbed Experiment Requirement	58
3.3.2.3.1	Software Requirement	59
3.3.2.3.2	Hardware Requirement	59
3.3.2.4	Design Experiment Setting	60
3.3.2.4.1	Variable Setting	62

3.3.2.4.2	Duration and Packet Rate during Experiment	63
3.3.2.5	Parameter Measurement	64
3.3.2.6	Performance Network Measurement Tools	65
3.3.3	Data Collection	66
3.3.4	Analysis	67
3.3.5	Test Validation	68
3.3.6	Project Schedule and Milestone	69
3.3.7	Conclusion	70
3.4	Summary	70
4.	Implementation Testbed Experiment	
4.1	Introduction	72
4.2	Point to Point wireless 802.11n Environment Testbed	73
4.3	Hardware and Specification	74
4.4	TP-Link WN 851N Wireless Adapter	75
4.5	Installation Mikrotik RouterOS	76
4.6	Configuration Traffic Generator and Parameter Measurements Tools	78
4.6.1	D-ITG	79
4.6.2	Winbox	82
4.7	inSSIDer	83
4.8	Testbed Experiment	83
4.8.1	Normal Wireless Mode Configuration	85
4.8.1.1	Mikrotik Router 1 Configuration	86
4.8.1.2	Mikrotik Router 2 Configuration	87

4.8.2	Channel Bonding Configuration	88
	4.8.2.1 Mikrotik Router 1 Configuration	89
	4.8.2.2 Mikrotik Router 2 Configuration	90
4.8.3	Interface Bonding Configuration	92
	4.8.3.1 Mikrotik Router 1 Configuration	93
	4.8.3.2 Mikrotik Router 2 Configuration	94
4.8.4	Directional Traffic Flows Configuration	97
	4.8.4.1 Single Directional Traffic Flows Configuration	97
	4.8.4.2 Bidirectional Traffic Flows Configuration	98
4.8.5	Configuration Signal Strength	99
4.8.6	Packet Size Configuration	101
4.8.7	Run Experiment	102
4.8.8	Measures Testbed Experiment	104
4.8.9	Collecting Data	107
4.8.10	Summary	108

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

5. Implementation Testbed Experiment

5.1	Introduction	109
5.2	Data Analysis	110
	5.2.1 OWD Throughput Analysis	111
	5.2.1.1 OWD Single Directional TCP Throughput at Strong Signal	111
	5.2.1.2 OWD Single Directional UDP Throughput at Strong Signal	112

5.2.1.3	OWD Bidirectional TCP Throughput at Strong Signal	113
5.2.1.4	OWD Bidirectional UDP Throughput at Strong Signal	114
5.2.1.5	OWD Single Directional TCP Throughput at Weak Signal	116
5.2.1.6	OWD Single Directional UDP Throughput at Weak Signal	117
5.2.1.7	OWD Bidirectional TCP Throughput at Weak Signal	118
5.2.1.8	OWD Bidirectional UDP Throughput at Weak Signal	120
5.2.1.9	Throughput Conclusion	121
5.2.2	RTT Delay Analysis	122
5.2.2.1	RTT TCP Delay at Strong Signal	122
5.2.2.2	RTT UDP Delay at Strong Signal	124
5.2.2.3	RTT TCP Delay at Weak Signal	125
5.2.2.4	RTT UDP Delay at Weak Signal	127
5.2.2.5	Delay Conclusion	129
5.2.3	RTT Jitter Analysis	130
5.2.3.1	RTT TCP Jitter at Strong Signal	130
5.2.3.2	RTT UDP Jitter at Strong Signal	132
5.2.3.3	RTT TCP Jitter at Weak Signal	134
5.2.3.4	RTT UDP Jitter at Weak Signal	136
5.2.3.5	Jitter Conclusion	138

5.2.4	RTT Data Loss Rate Analysis	139
5.2.4.1	RTT UDP Data Loss Rate at Strong Signal	140
5.2.4.2	RTT UDP Data Loss Rate at Weak Signal	141
5.2.4.3	Data Loss Rate Conclusion	142
5.3	Discussion Analysis Result	142
5.3.1	Summary of Findings	143
5.3.1.1	Throughput Performance	143
5.3.1.2	Delay Performance	144
5.3.1.3	Jitter Performance	145
5.3.1.4	Data Loss Rate Performance	146
5.3.2	Relate Finding with Literature Review	147
5.3.2.1	TCP/UDP	147
5.3.2.2	Signal Strength Performance	148
5.3.2.3	Directional Traffic Flows Performance	149
5.3.2.4	Channel Bonding Performance	150
5.3.2.5	Interface Bonding Performance	153
5.4	Summary	159
6.	Testing Validation	
6.1	Introduction	162
6.2	Data Sample	163
6.3	Test Process	164
6.4	Testing Result and Validation	165
6.5	Summary	179

7. Summary and Conclusion

7.1	Introduction	180
7.2	Research Summary	181
7.3	Conclusion	186
7.4	Limitation Research	190
7.5	Future Works	191

Reference	192
------------------	------------



LIST OF TABLES

TITLE	PAGE
Table 2.1: IEEE specifications	21
Table 2.2: Modulation and Coding Scheme (MCS) index Value	27
Table 2.3: Available Channel Bonding Bandwidth Spectrum	29
Table 2.4: Linux Bonding Modes	32
Table 2.5: Variable Packet Size	38
Table 2.6: Threshold Variable Signal Strength	40
Table 2.7: Comparison of network performance tools	41
Table 3.2: Milestone for Master Project I and II	69
Table 4.1: Lab Environment Specification	73
Table 4.2: Experimental Hardware Specification	74
Table 4.3: Specification TP-Link WN851NAdapter	75
Table 4.4: Format Data Collection Of Testbed Experiment.	107
Table 5.1: Maximum Throughput	121
Table 5.2: Maximum Delay	130
Table 5.3: Maximum Jitter	139
Table 5.4: Maximum Data Loss Rate	142
Table 6.1: Testing and Results Validation UDP Throughput of Data VoIP at Strong Signal	166
Table 6.2: Testing and Results Validation UDP Throughput of Bulk Data at Strong Signal	167

Table 6.3: Testing and Results Validation TCP Throughput of Bulk Data at Strong Signal	168
Table 6.4: Testing and Results Validation UDP Throughput of Data VoIP at Weak Signal	169
Table 6.5: Testing and Results Validation UDP Throughput of Bulk Data at Weak Signal	170
Table 6.6: Testing and Results Validation TCP Throughput of Bulk Data at Weak Signal	171
Table 6.7: Testing and Results Validation UDP Delay of Data VoIP	172
Table 6.8: Testing and Results Validation UDP Delay of Bulk Data	173
Table 6.9: Testing and Results Validation TCP Delay of Bulk Data	174
Table 6.10: Testing and Results Validation UDP Jitter of Data VoIP	175
Table 6.11: Testing and Results Validation UDP Jitter of Bulk Data	176
Table 6.12: Testing and Results Validation TCP Jitter of Bulk Data	177
Table 6.8: Testing and Results Validation TCP Data Loss Rate of Bulk Data	178

LIST OF FIGURES

TITLE	PAGE
Figure 1.1: Research Methodology Scheme	11
Figure 2.1: 40 MHz and 20 MHz Bandwidth Spectrum	28
Figure 2.2: Overlapping 40 MHz and Non-overlapping 20 MHz on 2.4 GHz	29
Figure 2.3: Linux Kernel Libraries	31
Figure 2.6: Wired Interface Bonding	33
Figure 2.7: D-ITG Architecture	45
Figure 3.1: Research Methodology Scheme	52
Figure 3.2: Experiment Process	55
Figure 3.3: Normal Mode on 20 MHz Point to Point 802.11n	56
Figure 3.4: Channel Bonding Mode on 40 MHz Point to Point 802.11n	57
Figure 3.5: Interface Bonding Mode on 20 + 20 MHz Point to Point 802.11n	58
Figure 3.6: Detail of Design Experiment Setting	61
Figure 3.7: Validation Analysis Result	68
Figure 4.1: Lab Environment Architecture	73
Figure 4.2: Download and Installation process of Mikrotik ROS	76
Figure 4.3: Netinstall Mikrotik ROS v5.2	77
Figure 4.4: Process Installation Mikrotik ROS on Computer	77
Figure 4.5: Main Interface Mikrotik ROS v5.2	78
Figure 4.6: D-ITG GUI Configuration	79
Figure 4.7: Winbox Configuration Tool	82
Figure 4.8: Scan Wi-Fi around Lab experiment used inSSIDer	83

Figure 4.9: Testbed Experiment Flow	84
Figure 4.10: Mikrotik router Configuration at Normal Wireless Mode	85
Figure 4.10: Scan 20 Mhz Band Used inSSider	88
Figure 4.12: Mikrotik Configuration at Channel Bonding	89
Figure 4.13: Scan 40 Mhz Band Used inSSider	91
Figure 4.14: Mikrotik Configuration Interface Bonding	92
Figure 4.15: Scan 20 Mhz band used inSSider	96
Figure 4.16: Single Directional Flows configuration	97
Figure 4.17: Bidirectional Flows configuration	98
Figure 4.18: Signal Strength Indicator (a) Strong signal, (b) Weak Signal	101
Figure 4.19: Configuration Packet Size used GUI	102
Figure 4.20: Configuration Before Run Experiment Testbed	104
Figure 4.21: D-ITG Decoding Log	105
Figure 4.22: Traffic Monitoring	106
Figure 5.1: Flowchart Analysis Result	110
Figure 5.2: OWD Single Directional TCP Throughput at Strong Signal	111
Figure 5.3: OWD Single Directional UDP Throughput at Strong Signal	112
Figure 5.4: OWD Bidirectional TCP Throughput at Strong Signal	113
Figure 5.5: OWD Bidirectional UDP Throughput at Strong Signal	115
Figure 5.6: OWD Single Directional TCP Throughput at Weak Signal	116
Figure 5.7: OWD Single Directional UDP Throughput at Weak Signal	117
Figure 5.8: OWD Bidirectional TCP Throughput at Weak Signal	119
Figure 5.9: OWD Bidirectional UDP Throughput at Weak Signal	120
Figure 5.10: RTT TCP Delay at Strong Signal	122
Figure 5.11: RTT TCP Delay at Strong Signal	123

Figure 5.12: RTT UDP Delay at Strong Signal	124
Figure 5.13: RTT UDP Delay at Strong Signal	125
Figure 5.14: RTT TCP Delay at Weak Signal	126
Figure 5.15: RTT TCP Delay at Weak Signal	127
Figure 5.16: RTT UDP Delay at Weak Signal	128
Figure 5.17: RTT UDP Delay at Weak Signal	129
Figure 5.18: RTT TCP Jitter at Strong Signal	131
Figure 5.19: RTT TCP Jitter at Strong Signal	132
Figure 5.20: RTT UDP Jitter at Strong Signal	133
Figure 5.21: RTT UDP Jitter at Strong Signal	134
Figure 5.22: RTT TCP Jitter at Weak Signal	135
Figure 5.23: RTT TCP Jitter at Weak Signal	136
Figure 5.24: RTT UDP Jitter at Weak Signal	137
Figure 5.25: RTT UDP Jitter at Weak Signal	138
Figure 5.26: RTT UDP Data Loss Rate at Strong Signal	140
Figure 5.27: RTT UDP Data Loss Rate at Weak Signal	141
Figure 5.28: Channel Bonding Before Sent Packet is transmitted	151
Figure 5.29: Channel Bonding During Send is transmitted	152
Figure 5.30: Throughput Channel Bonding	153
Figure 5.31: Interface Bonding Before Packet is Transmitted	154
Figure 5.32: Interface Bonding During Packet is Transmitted	155
Figure 5.33: Throughput Interface Bonding	156
Figure 5.34: Kernel Mikrotik Linux	157
Figure 6.1: D-ITG Codec for VoIP Packet Generator	163
Figure 6.2: Testing Validation Process	165

LIST OF ABBREVIATION

ACK	Acknowledgement
AP	Access Point
BPSK	Binary Phase Shift Keying
CCK	Complementary Code Keying
CF	Compact Flash
CSI	Channel State Information
CSMA/CA	Carrier Sense Multiple Access / Collision Avoidance
dbm	decible milliwatts
D-ITG	Distributed Internet Traffic Generator
DNS	Domain Name Services
DSSS	Direct Sequence Spread Spectrum
FHSS	Frequency Hopping Spread Sprectrum
GUI	Graphic User Interface
HDD	Hard Drive
ICMP	Internet Control Message Protocol
IDT	Inter Departure Time
IP	Internet Protocol
IP v6	IP version 6
IP v4	IP version 4
LAN	Local Area Network
LOS	Line Of Sight

MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MIMO	Multi Input Multiple Output
ms	Millisecond
mW	Milliwatts
OFDM	Orthogonal Frequency Division Multiplexing
OWD	One Way Delay
PBCC	Packet Binary Code
PHY	Physical
PS	Packet Size
PtP	Point to Point
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
ROS	Router Operating System
RR	Round Robin
RSSI	Received Signal Strength Indicator
RTT	Round Trip Time
SATA	Serial Ata
SMP	Symmetric Multiprocessing
SSH	Secure Shell
STA	Station
TCP	Transport Control Protocol
UDP	User Datagram Protocol
USB	Universal Serial Bus
UteM	University Teknikal Malaysia Melaka

VoIP	Voice Over Internet Protocol
WBRs	Wireless Bridge and Routing
WDS	Wireless Distributed System
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WWAN	Wireless Wide Area Network
WwiSE	World Wide Spectrum Efficiency



LIST OF ATTACHMENT

Appendix	Title	Page
A	Wireless Configuration	205
B	Testbed Experiment Result	210
C	Testing Validation Result	219
D	Project Schedule	225

