

## **ACKNOWLEDGMENT**

I would like to express my sincere gratitude to **Dr. Ashraf GasimElsid Abdallah**, for being the guiding force behind the research necessary for the completion of this dissertation. Without his guidance, encouragement, support, ideas, and scientific enlightenment this work would not have been possible.

My great appreciation goes also to **Center for Engineering & Technical Studies (CETS)** for their continuous support, and guidance for the work done in this thesis.

I am indebted to my Father and my small family for all their encouragement and support throughout my academic career, no words can express my gratitude to them. I therefore dedicate my work to them and also to my children Aseel, Noam and little Ali.

## **ABSTRACT**

Ad Hoc Network is a multihop wireless network where all nodes cooperatively maintain network connectivity without a centralized infrastructure. The nodes participating in Ad Hoc Network operate both as hosts and as routers. The success of TCP in wired networks motivates its extension to wireless network.

In Ad Hoc network the standard TCP faces server performance degradation over multihop networks given the noise nature of wireless media as well as unstable connectivity conditions in place. This research presents a study for a modified TCP protocol in order to enhance the behavior of the protocol in Ad-hoc wireless networks.

Proposed two modification of the standard TCP by adjusting TCP's behavior during slow start and congestion avoidance phase's. The throughput of the proposed protocols has increased over the throughput of the standard TCP protocol. Glomosim simulator was used, which is one of known simulators for Ad-hoc wireless networks.

## ملخص الرسالة

في مجال شبكات الحاسب تعرف الشبكات اللاسلكية ذاتية التنظيم بأنها عبارة عن شبكات مؤقتة تستخدم لربط عدة مستخدمين دون الحاجة إلى تحكم مركزي فكل حاسب بالشبكة يكون له القدرة على العمل كمضيف ومحدد مسار كما يكون عنده الاستعداد لتمثيل الرسائل الأخرى. ويعد بروتوكول نقل البيانات TCP من أهم البروتوكولات المستخدمة حاليا في الشبكات السلكية ونظرا للكفاءة العالية لهذا البروتوكول فإن العديد من الأبحاث تهتم بتحسين أداء هذا البروتوكول للعمل على الشبكات اللاسلكية ذاتية التنظيم.

ولقد تم تقديم مقترحين في هذه الرسالة لتحسين أداء بروتوكول نقل البيانات TCP للعمل على الشبكات اللاسلكية ذاتية التنظيم وخاصة تحسين عامل النفاذية Throughput وتم التأكد من الفاعلية من خلال المحاكى Glomosim الذي أعد خصيصا لمحاكاة الشبكات اللاسلكية ذاتية التنظيم. وتم اختبار النتائج باستخدام بروتوكولين من أشهر بروتوكولات تحديد المسار وهما

١. Dynamic Source Routing (DSR)

٢. Ad Hoc on-demand Distance vector (AODV)

وقد أثبتت الدراسة أن أداء بروتوكول نقل البيانات TCP قد تحسن تحسنا ملحوظا نتيجة التعديلات المقترحين في أداء البروتوكول، مما يسهم في دفع كفاءة عمل البروتوكول على الشبكات اللاسلكية ذاتية التنظيم.

# Contents

<b>Acknowledgement</b>	<b>I</b>
<b>Abstract</b>	<b>II</b>
<b>Contents</b>	<b>IV</b>
<b>List of Tables</b>	<b>VII</b>
<b>List of Figures</b>	<b>VIII</b>
<b>List of Abbreviations and Acronyms</b>	<b>IX</b>
<b>Chapter 1. Introduction</b>	<b>1</b>
1.1 Ad Hoc Networks Overview:	1
1.2 TCP Introduction and wireless Challenges.	1
1.3 Problem Definition.	3
1.4 Thesis Objective	4
1.5 Thesis Methodology	5
1.6 Expected results	5
1.7 Thesis Layout	5
<b>Chapter 2. Transmission Control Protocol</b>	<b>7</b>
2.1 Introduction	7
2.2 TCP Mechanisms	7
2.2.1 Connection Setup	8
2.2.2 Flow and Congestion Control	10
2.3 Congestion Control Mechanisms	12
2.3.1 Slow Start and Congestion Avoidance	12
2.3.2 Equation-Based Congestion Control	14
<b>Chapter 3. Ad Hoc Networks and TCP Challenges</b>	<b>16</b>
3.1 Characteristics of Ad Hoc Networks	16
3.1.1 Dynamic Topologies	16

3.1.2 Bandwidth-constrained and variable capacity links	16
3.1.3 Energy-constrained operation	16
3.1.4 Limited Physical security	16
3.2 Applications of Ad hoc Networks	17
3.2.1 Military Applications	17
3.2.2 Virtual Navigation	19
3.2.3 Crisis-management applications	19
3.3 Ad Hoc Protocol Stack	19
3.3.1 Internetworking	21
3.4 Proactive, Reactive and Hybrid Routing Protocols	23
3.4.1 Ad hoc On-Demand Distance Vector (AODV)	24
3.4.2 Dynamic Source Routing (DSR)	27
3.5 TCP Challenges in AD HOC Networks	29
3.5.1 Lossy channels	30
3.5.2 Hidden and Exposed stations	31
3.5.3 Path asymmetry	33
3.5.4 Network partition	35
3.5.5 Routing failures	36
3.5.6 Power constraints	37
3.5.7 Misinterpretation of packet loss	37
3.6 Misinterpretation of congestion window	38
3.7 The use of sliding-window-based transmission	38
<b>Chapter 4. Simulation Environments</b>	<b>40</b>
4.1 Introduction	40
4.2 OPNET Simulator	40
4.3 NS2 Simulator	41

4.4 QualNet simulator	41
4.5 Glomosim simulator	42
4.6 Choice of simulator	43
<b>Chapter 5. Methodology &amp; Experimental procedure</b>	<b>44</b>
5.1 Introduction	44
5.2 Simulation Setup	44
5.3 Experimental Configuration and Parameters	44
<b>Chapter 6. Simulation Results and Discussion</b>	<b>47</b>
6.1 Introduction	47
6.2 Experiment 1:Slow start modification (Slow Start TCP)	47
6.2.1 Objective	47
6.3 Experiment 2:Congestion avoidance modification (SCA TCP)	49
6.3.1 Objective	49
6.4 Simulation Results	52
6.5 TCP enhancement using Optimal Window Size	55
<b>Chapter 7.Conclusion and future work</b>	<b>58</b>
7.1 Conclusion	58
7.2 Recommendation and future work.	58
<b>References</b>	<b>59</b>
<b>Appendix A</b>	<b>A-1</b>
<b>Appendix B</b>	<b>B-1</b>
<b>Appendix C</b>	<b>C-1</b>
<b>Appendix D</b>	<b>D-1</b>

## **List of Tables**

5.1	Common TCP Parameters	47
6.1	Default throughput and after slow start modification	53
6.2	Default throughput and after congestion avoidance modification	55
6.3	Default throughput and after optimal window modification	58

## List of Figures

2.1	TCP three-way handshake	9
2.2	TCP congestion window evolution	13
3.1	The OSI model, TCP/IP suite and MANET protocol stack	21
3.2	The protocol stacks used by mobile nodes, gateways and Internet nodes	22
3.3	The ad hoc Family Tree	23
3.4	Hidden terminal problem	32
3.5	Exposed terminal problem	33
3.6	Network partition scenario	36
5.1	Simulation model	54
6.1	Default throughput and after slow start modification	55
6.2	Default throughput and after congestion avoidance modification	55
6.3	Ad hoc model of $h$ hops	57
6.4	Default throughput and after optimal window modification	58



## **List of Abbreviations, Acronyms and Symbols**

AP	Access Point
ACK	Acknowledgment
AODV	Ad-hoc On-demand Distributed Vector
AQM	Active Queue Management
ARQ	Automatic Repeat Request
ATCP	Ad hoc TCP
BER	Bit Error Rate
CF	Contention-Free
CFP	Contention-Free Period
CP	Contention Period
CRC	Cyclic Redundancy Check
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
CTS	Clear to Send
CW	Contention Window
CWR	Congestion Window Reduced (CWR)
CWND	Congestion Window
DAA	Dynamic Adaptive Acknowledgment
DAAP	Dynamic Adaptive Acknowledgment plus
DCF	Distributed Coordination Function
DNS	Domain Name Server
DS	Distributed System
DSR	Dynamic Source Routing
ECN	Explicit Congestion Notification
ELFN	Explicit Link Failure Notification
FCS	Frame Check Sequences
FEC	Forward Error correction
FEDM	Fuzzy-based Error Detection Mechanism
FILO	First In Last Out
FTP	File Transfer Protocol
HMM	Hidden Markov Model
HTTP	HyperText Transfer Protocol
ICMP	Internet Control Message Protocol
IDD	Inter-packet Delay Difference
IED	Improved Error Detection
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IFS	Interframe Space
IP	Internet Protocol
ISN	Initial Sequence Number
LAN	Local Area Network
LDA	Large Delayed Acknowledgment

LRED	Link RED
MAC	Medium Access Control
MANET	Mobile Ad hoc Networks
MSS	Maximum Segment Size
NDUP	Number of duplicate ACKs (threshold)
NH	Number of Hops
OSI	Open Systems Interconnect
PC	Point Coordinator
PCF	Point Coordination Function
PER	Packet Error Rate
PLR	Packet Loss Rate
POR	Packet Out-of-order delivery Ratio
RED	Random Early Detection
RFC	Request For Comments
RFN	Route Failure Notification
RR	RTT increase Rate
RRN	Route Re-establishment Notification
RREP	Route Reply
RREQ	Route Request
RTO	Retransmit Timeout
RTS	Request to Send
RTT	Round Trip Time
RTTVAR	Round Trip Time Variation
RWIN	Receiver Window
SANET	Static Ad hoc Networks
SMTP	Mail Transfer Protocol
SRTT	Smoothed Round Trip Time
STT	Short Term Throughput
SWS	Silly Window Syndrome
TCP	Transport Control Protocol
TTL	Time to Live
WI-FI	Wireless Fidelity
WLAN	Wireless Local Area Network
WWW	World Wide Web
r	Transmit rate in Bytes/second
s	Packet Size in bytes
R	round-trip time in seconds
P	the loss event rate
tRTO	TCP retransmission timeout value in seconds
b	number of packets acknowledged by a single TCP acknowledgment