UNIVERSITI PUTRA MALAYSIA

DETECTION OF BLACK HOLE NODES IN MOBILE AD HOC NETWORK USING HYBRID TRUSTWORTHINESS AND ENERGY CONSUMPTION TECHNIQUES

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By

AHMED SUDAD MUSTAFA

Thesis submitted to the School of Graduate Studies, Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

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DEDICATION

This thesis is dedicated to

All those I love

Especially

My dearest parents

My brothers and sister

For their endless encouragement, patience, and support and for being a great source of motivation and inspiration

And to all my friends

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science.

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March 2017

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Mobile ad-hoc network (MANET) is an evolving technology that is utilized in different applications (i.e. military surveillance, personal network, etc.) and developed in the recent years. Nodes in MANET are capable of functioning as a router for data communication. MANET devices do not require central management, capable of self-organizing/ healing through persistent reconfiguration. Any MANET node requires a protocol in order to communicate with its neighbor within its transmission range.

Ad hoc on-demand distance vector routing protocol (AODV) is a commonly used protocol in MANET. AODV is a reactive protocol that offers relatively low routing overhead since the nodes utilizing this protocol operates only when a route is requested. However, AODV suffers severely from the black hole attacks where the attacker node advertise itself as having the optimum path leading to the destination node by varying some essential parameters. Therefore, detecting the black hole in the network is substantial since MANET depends on the cooperation between adjacent nodes. In this thesis, a hybrid detection algorithm mechanism has been proposed which combines two detection algorithms based on nodes' trustworthiness and energy consumption in a parallel manner in order to detect the black hole nodes. An empirical testing approach was utilized here where several scenarios have been implemented and investigated in order to find the optimal settings. Network simulator (NS2) simulation findings demonstrate that the trust based algorithm achieves an average packet delivery ratio (PDR) of 87.3%, end to end delay (EED) of 7.47 ms and black hole detection accuracy of 90%. On the other hand, the detection algorithm based on the energy consumption achieves PDR of 91.6%, EED of 14.03 ms and detection rate accuracy of 93%. The hybrid technique offers decent average PDR of 94.7, EED of 8.62 ms and improved black hole detection rate

accuracy of 96%. Furthermore, the hybrid technique offers reduced end to end delay with relatively high PDR when compared with two recent works.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENGESANAN BLACK HOLE NOD DI MOBILE AD HOC NETEORK MENGGUNAKAN AMANAH DAN TENAGA TEKNIK PENGGUNAAN HIBRID

Oleh

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Rangkaian ad-hoc mudah alih (MANET) merupakan sesuatu teknologi yang berkembang yang digunakan dalam pelbagai aplikasi (seperti pengawasan tentera, rangkaian peribadi, dan lain-lain) dan telah dibangunkan sejak kebelakangan ini. Nod di dalam MANET berkemampuan untuk berfungsi sebagai penghala bagi komunikasi data. Peralatan MANET tidak memerlukan pengurusan pusat dan berkemampuan untuk menguruskan / penyembuhan diri melalui konfigurasi yang berterusan. Sebarang nod MANET memerlukan protokol untuk berkomunikasi dengan jirannya dalam jarak penghantaran tersebut.

Protokol penghalaan ad-hoc atas permintaan jarak vektor (AODV) adalah protokol yag sering digunakan dalam MANET. AODV merupakan protokol reaktif yang menawarkan overhead penghalaan yang rendah kerana nod-nod tyang menggunakan protokol ini beroperasi hanya apabila laluan diminta. Walau bagaimanapun, AODV terjejas teruk akibat dari serangan lubang hitam dimana nod penyerang mengiklankan dirinya sebagai mempunyai laluan yang optimum untuk ke nod destinasi dengan mengubah beberapa parameter yang penting. Oleh itu, pengesanan lubang hitam di dalam rangkaian adalah penting kerana MANET bergantung kepada kerjasama di antara nod-nod bersebelahan. Dalam tesis ini, sebuah algoritma pengesanan hibrid telah dicadangkan yang menggabungkan dua algoritma pengesanan berdasarkan kebolehpercayaan nod dan penggunaan tenaga dengan cara yang selarian untuk mengesab nod-nod lubang hitam. Sebuah pendekatan ujian empirikal telah digunakan di sini di mana beberapa senario telah dilaksanakan dan disiasat untuk mendapatkan tetapan-tetapan yang optimum. Hasil simulasi rangkaian simulator (NS2) menunjukkan bahawa algoritma berdasarkan kebolehpercayaan telah mencapai nisbah purata penghantaran paket (PDR) sebanyak 87.3%, tempoh kelewatan hujung ke hujung (EED) sebanyak 7.47 mili saat dan ketepatan pengesanan nod lubang hitam sebanyak 90%. Pada masa yang sama, algoritma

bersadarkan menggunaan tenaga telah mencapai PDR sebanyak 91.6%, EER sebanyak 14.03 mili saaat dan ketepatan pengesanan nod lubang hitam sebanyak 93%. Tambahan pula, teknik hibrid menawarkan pengurangan tempoh kelewatan hujung ke hujung dengan PDR yang agak tinggi sedikit apabila dibandingkan dengan dua kerja penyelidikan yang terkini.

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Most importantly, I want to say thanks to my dearest parents and my brothers and sister. They helped me out during the difficulties in life and provided me with warm encouragement.

This thesis was submitted to the senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the supervisory committee were as follows:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

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LIST OF ABBREVIATIONS

ACO	Ant Colony Optimization
AODV	Ad hoc On-Demand Distance Vector
ARA	Ant Colony Based Routing Algorithm
ARQ	automatic repeat request
AUC	Area under the curve
BH	Black hole
CBR	constant bit rate
CMT	cable mode transition
DoS	Denial of Service
DSDV	Destination-Sequenced Distance Vector
DSR	Dynamic Source Routing Protocol
E	Energy
EED	End-to-end Delay
FEC	forward error correction
FN	false negative
FPR	False positive ratio
GPS	Global positioning system
IN	Intermediate node
LN	Leader node
MAC	media access control
MANET	Mobile ad hoc network
MID	Multiple Interface Declaration
MPR	Multi-Point Distribution Relays
NS	Network Simulator
OLSR	Optimized Link State Routing Protocol
OSI	Open Systems Interconnection
PD	Processing Delay
PDR	Packet Delivery Ratio
PT	Propagation Time
QT	Queuing Time
RERR	Route Error
ROC	Receiver Operating Characteristic

RREP	Route Reply
RREQ	Route Request
SAODV	Secured Ad Hoc On-Demand Distance Vector
T	Threshold
TC	Topology Control
THe	Energy Threshold
THw	Trust Threshold
TI	Timer
TN	True Negative
TPR	True Positive Rate
TR	Transmission Range
TT	Transmission Time
TTL	Time to Live
TW	Trust Weight
ZRP	Zone Routing Protocol

CHAPTER 1

INTRODUCTION

1.1 Background

Mobile ad hoc network (MANET) is a combination of nodes that are moveable and has a dynamic topology in nature. It basically represents a sophisticated distributed system that is formed by a group of wireless mobile nodes, which communicate using wireless medium. The MANET nodes capable of operating as router for data communication within the grid. Due to the unique characteristics of MANET such as low cost as well as mobility, MANET is adequate for wide variety of applications such as monitoring and detecting specific events, battlefield surveillance, flood detection, health care, and home applications [1-6].

Routing is the main concern in MANET, since it is susceptible to error due to the mobility of the nodes as well as its dynamic topology. Earlier researchers focused on the efficiency of route establishment, so they considered all of the nodes are trustworthy [7, 8]. However, this scenario has been challenged recently as more attacks emerged to threaten MANET security [9].

Fundamentally, any MANET topology utilizes a communication protocol in order to operate such as Ad hoc On-Demand Distance Vector (AODV) and Destination-Sequenced Distance Vector (DSDV) and Dynamic Source Routing (DSR). Each one of these protocols has its own advantages and flaws [10]. However, AODV offers less packet loss and decent average delay as compared to the other protocols [11]. Thus, it is one of the most common routing protocols within MANET. AODV is a power efficient protocol since it does not rely on active links neither preserve any routing information. Furthermore, nodes do not have to discover or preserve a path to another node unless the two nodes require data transformation [12].

Whenever a specific node needs to send data to a destination node, a route discovery procedure is initiated by broadcasting a packet called route request (RREQ) to all its neighbors. Whenever an intermediate node has a fresh path to the destination, it immediately sends back a packet called route reply (RREP) to the source. In case a disconnect occurs between the two nodes, a route error (RERR) message is being sent indicating a disconnect in the route. Despite the advantages of AODV [7], it is vulnerable to the black hole attack, since it does not feature any defensive mechanism [8]. AODV protocol uses the sequence number as well as hop-count in order to determine the best route for data transmission. The higher sequence number means a better route for communication. The black hole node uses this property in order to lure the source to send the actual data to it by sending a bogus reply message carrying very high sequence number and low hop-count.

Basically, the black hole attack has two phases. The first one, the black hole node exploits the AODV routing protocol to declare itself as having a proper path to the destination node by increasing the sequence number as well as decreasing the hop count field. The second phase is when the black hole node drop every single packet it receives from the source node [13]. Eventually, the whole network will collapse.

1.2 Problem Statement

Black hole attacks in MANET have been a major issue for the past few years [10]. Any MANET network utilizes a specific routing protocol in order to send/ receive data packets, whether it is a reactive or a proactive protocol. Black hole attacks normally exploit the AODV protocol in order to perform its malicious activities. Since, ADOV does not have a concrete mechanism to fight the black hole attacks. Thus, researchers have proposed different types of approaches to remedy this issue. One of which includes a trust-based approach, by initiating a trust weight for all the nodes and keep monitoring the nodes using leader nodes with higher privilege (i.e. nodes capable of insolating specific nodes if necessary), or a cooperative approach by enabling the nodes to listen to each other. This involves detecting the node which its trust weight falls below the predefined threshold value [12]. Such approaches are decent with regards to the malicious detection rate. However, it offers relatively high average delay.

Other researchers used anomaly-based intrusion detection system (IDS) in order to isolate the black hole nodes in AODV [13]. This approach operates by implementing a baseline procedure for the network to operate. This procedure will include all the genuine activities that can be done in the normal circumstances and isolate any activity that falls outside the procedure. This approach offers a decent average delay. However, it suffers from the high false positive.

Our approach involves combining two fundamental algorithms. The first algorithm is based on trust technique that offers decent detection accuracy with minimal delay. Our hypothesis is that the detection accuracy can be further improved if another algorithm is added as a second layer of protection. The assumption is that, the second algorithm will not incur a heavy computational process that could burden the system. The second algorithm is based on the initial energy consumption of the nodes to locate the black hole node and detect it. The main aim of this research is to further improve the detection rate accuracy of malicious nodes and achieving higher packet delivery ratio (PDR) as well via the hybrid algorithm.

1.3 Research Aim and Objectives

1. To design and develop detection algorithm based on the trustworthiness among the AODV nodes in order to detect the black hole nodes.
2. To design and develop detection algorithm based on the initial energy consumption of the nodes in order to detect the black hole nodes within the AODV.
3. To combine the two approaches in order to enhance the PDR and black hole detection rate.

1.4 Thesis Scope

The scope of this research focuses solely on the internal-passive black hole attacks that can be launched against the AODV routing protocol by intruders. The internal black hole attack is difficult to detect since the attacker impersonates an existing node within the network to perform any malicious activity. This research considers the scenario where all the nodes in the topology are movable. This research also features receiver operating characteristic (ROC) curves that provide a comprehensive analysis in terms of malicious node detection rate. Furthermore, this research also seeks to offer an investigation of optimal scenario where minimal end to end delay is being produced as well as improved PDR. The proposed algorithms will assume the following:

The proposed algorithms are based on the following assumptions:

1. All leader nodes are trustworthy.
2. The two implemented black hole nodes are internal and passive type.
3. The black hole nodes are in a strategic position that allows them to participate in most network traffics.
4. The proposed algorithms are applied after the route discovery phase
5. The leader nodes are able to sniff all routing packets within their transmission range even if the packets are not intended for them using the promiscuous mode.
6. The black hole nodes ID are broadcasted successfully.
7. The leader nodes do not participate in the data transmission.
8. All node IDs are unique.

1.5 Motivation

Security of mobile ad hoc network (MANET) is one of the most difficult challenges. This is mainly because of the natural behavior of MANET such as open wireless medium, node mobility, bounded processing power, shortage of central monitoring, lack of obvious defensive technique and availability of the consumable resources such as bandwidth and battery power.

In order to assure a secure transmission over MANET, a comprehensive overview of different types of security threats and their effects is required. Black hole attack, wormhole attack, Sybil attack, routing table overflow attack, flooding attack, selfish node misbehavior, Denial of Service attack (DoS) and impersonating attack are the types of attacks that can be triggered against MANETs. A detailed explanation of possible hostile attack on MANET is discussed in [14] literature.

Generally, MANET is more susceptible to these kinds of attacks since one node in the MANET will assume all the nodes in the neighborhood are trustworthy [7]. MANET suffers not only from same types of threats like DoS and message distortion, IP spoofing as the infrastructure network. However, it also suffers from new threats caused by the exclusive characteristics of MANET like wormhole attack and black hole attack. For instance, black hole attack occurs when one node in the network advertise itself as having the best route from the source to the destination. This gives the malicious node the capability to insert itself in between the communicating nodes. Consequently, the malicious node drops all the packets it receives. MANET is more vulnerable to such unique attacks since the transmission is based on the common trust among participating nodes. In addition, there is no centralized monitoring of any misbehavior node.

The outcome of the research on securing the MANET against black hole attacks are the methods that either needs promiscuous monitoring to MANET nodes or incur considerable computational sophistication in individual nodes which eventually depletes their confined resources such as bandwidth, memory and power. Therefore, the main objective of this dissertation is to detect the black hole nodes that exist in MANET by proposing a new hybrid technique that can detect the black hole attacks efficiently with high PDR and better detection rate of black hole nodes.

1.6 Thesis Organization

This dissertation shows how the black hole attacks in MANET can be detected efficiently. The organization of this thesis is as follows. Chapter 2 introduces the literature review. We first provide a broad overview regarding mobile ad hoc network. Then we describe in detail MANET architecture and its corresponding layers. Then we talk about the structure of MANET and its different possible applications. Next, we introduce MANET routing tables and their classifications. Next, we describe the security threats in MANET and its flaws. Then, we explain the black hole attack in details and how it is devastating against AODV protocol. Last but not least in chapter 2, we introduce the related work models, and show how our work is distinguished from the others. Chapter 3 introduce our methodology to detect the black hole attack nodes. Here, we design a trust based intrusion detection system and test it. Then, we design another intrusion detection system based on the initial energy consumption and test it. Next, we combine both algorithms in order to enhance the malicious nodes detection rate and PDR. In chapter 4 we include our results and analysis with the proper diagrams. Chapter 5 presents our conclusion as well as proposed future work.

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