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Prevention of Information Leakage Detection in Wireless Adhoc Networks

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Abstract: A network is nothing but multiple nodes are connected with each other in some manner. The communication between each node and the topology of the network are important to make the environment more efficient. The communications between systems are broadly categorized into two; that are wired and wireless communication. In wired network, each node will be connected through physical wires and follows a topology. But in wireless network the communication between each node will be happen a centralized node called Access Point. In ireless environment a special wireless network is called MANET, in which there will be no centralized Access Points. MANET is nothing but Mobile Ad-hoc NETwork. In MANET each node acts as a sender and receiver. And there is no fixed route between nodes. Based on the nodes reachable, node will change the routing table dynamically. So the mobility and scalability of the nodes will not impact the MANET. The self-configuring ability of the MANET made it popular in military applications and emergency recovery. So the communication between each node should be more secure and trustable. And it's important to identify the malicious nodes in MANET too. The malicious nodes are nodes which are not able to sends packets further or the nodes which are sends false report to the sender. To identify these malicious nodes and sends the messages with more secure with authorization need to implement new Intrusion Identification System called Digital Signature with Acknowledgement name as Enhanced Adaptive Acknowledgement. The objective of MANET is fast communication. So its need to analyze the network throughput also once the new Intrusion Identification System introduced.

Keywords: MANET, Intrusion Detection System, Digital Signature, Malicious nodes, (AACK) (EAACK), Acknowledgement.

I. INTRODUCTION

Due to their natural mobility and scalability, wireless networks are always preferred since the first day of their invention. Owing to the improved technology and reduced costs, wireless networks have gained much more preferences over wired networks in the past few decades. By definition, Mobile Ad hoc Network (MANET) is a collection of mobile nodes equipped with both a wireless transmitter and a receiver that communicate with each other via bidirectional wireless links either directly or indirectly. Industrial remote access and control via wireless networks are becoming more and more popular these days. One of the major advantages of wireless networks is its ability to allow data communication between different parties and still maintain their mobility. However, this communication is limited to the range of transmitters. This means that two nodes cannot communicate with each other when the distance between the two nodes is beyond the communication range of their own. MANET solves this problem by allowing intermediate parties to relay data transmissions.

This is achieved by dividing MANET into two types of networks, namely, single-hop and Multi-hop. In a single-hop network, all nodes within the same radio range communicate directly with each other. On the other hand, in a multi-hop network, nodes rely on other intermediate nodes to transmit if the destination node is out of their radio range. In contrary to the traditional wireless network, MANET has a decentralized network infrastructure. MANET does not require a fixed infrastructure; thus, all nodes are free to move randomly [11]. MANET is capable of creating a self-configuring and self-maintaining network without the help of a centralized infrastructure, which is often infeasible in critical mission applications like military conflict or emergency recovery. Minimal configuration and quick deployment make MANET ready to be used in emergency circumstances where an infrastructure is unavailable or unfeasible to install in scenarios like natural or human-induced disasters, military conflicts, and medical emergency situations. Owing to these unique characteristics, MANET is becoming more and more widely implemented in the industry.

However, considering the fact that MANET is popular among critical mission applications, network security is of vital importance. Unfortunately, the open medium and remote distribution of MANET make it vulnerable to various types of attacks. For example, due to the nodes' lack of physical protection, malicious attackers can easily capture and compromise nodes to achieve attacks. In particular, considering the fact that most routing protocols in MANETs assume that every node in the network behaves cooperatively

with other nodes and presumably not malicious [6], attackers can easily compromise MANETs by inserting malicious or non-cooperative nodes into the network. Furthermore, because of MANET's distributed architecture and changing topology, a traditional centralized monitoring technique is no longer feasible in MANETs. In such case, it is crucial to develop an intrusion-detection system (IDS) specially designed for MANETs. Many research efforts have been devoted to such research topic [2]–[4], [7]–[10]. In the next section, we mainly concentrate on discussing the background information required for understanding this research topic.

II. MOBILE ADHOC WIRELESS NETWORK

The Mobile Ad hoc Wireless Network is more vulnerable to be attacked than wired network. These vulnerabilities are nature of the MANET structure that cannot be removed. As a result, attacks with malicious intent have been and will be devised to exploit these vulnerabilities and to cripple the MANET operation. Attack prevention measures, such as authentication and encryption, can be used as the first line of defense for reducing the possibilities of attacks. However, these techniques have a limitation on the effects of prevention techniques in general and they are designed for a set of known attacks. They are unlikely to prevent newer attacks that are designed for circumventing the existing security measures. The rest of this chapter is organized as follows – initially a classification of wireless networks in use today is described followed by the background and origins of ad hoc wireless networks. The general issues in ad hoc wireless networks are then discussed, followed by a few interesting applications. The final section gives an outline of the chapters to follow.

A. Taxonomy of Wireless Networks

A wireless network in general consists of a set of mobile hosts which communicate to other mobile hosts either directly or via an access point (base station).The following is a broad classification of wireless networks.

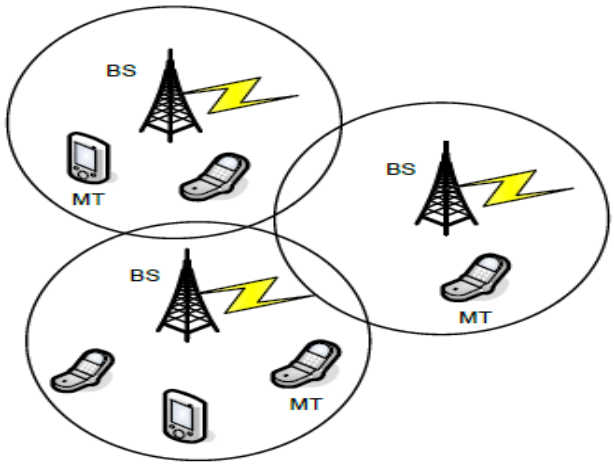

Fig.1. A Cellular network.

B. Wireless LANs and PANs

A Wireless Local Area Network (WLAN) consists of a set of mobile users communicating via a fixed base station or an access point. The mobile node can be any device such as a palmtop, PDA, laptop etc. A Wireless Personal Area Network (WPAN) consists of personal devices which communicate without any established infrastructure. The IEEE 802.15.1 standard for Wireless Personal Area Networks, also called popularly as the Bluetooth is currently being used for short range communication such as in digital cameras, PDAs, laptops, etc. Nowadays, the trend is towards a wireless internet consisting of mobile nodes accessing the internet without the help of any backbone network. This type of network is based on the cellular architecture in which a large area to be covered is divided in to several cells, each having a fixed base station. Each cell consists of several mobile terminals (MT) which communicate to other mobile terminals in a same cell through the base station as shown in Fig.1. Mobile Ad hoc networks or MANETs are the category of wireless networks which do not require any fixed infrastructure or base stations. They can be easily deployed in places where it is difficult to setup any wired infrastructure. As shown in Fig.2, there are no base stations and every node must co-operate in forwarding packets in the network.

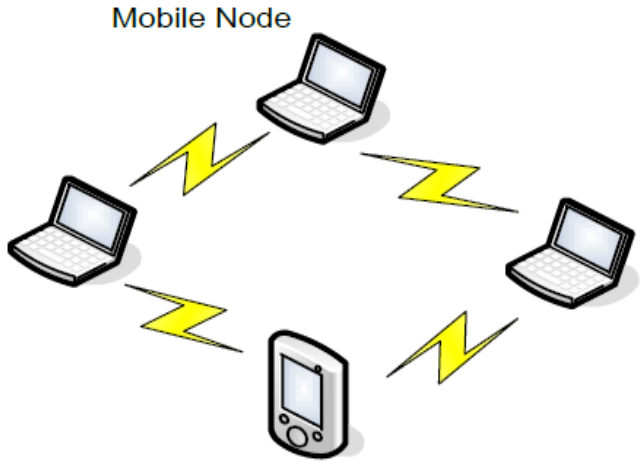

Fig.2. MANET.

Thus, each node acts as a router which makes routing complex when compared to Wireless LANs, where the central access point acts as the router between the nodes. A sensor network is a special category of ad hoc wireless networks which consists of several sensors deployed without any fixed infrastructure. The difference between sensor networks and ordinary ad hoc wireless is that the sensor nodes may not be necessarily mobile. Further, the number of nodes is much higher than in ordinary ad hoc networks. The nodes have more stringent power requirements since they operate in harsh environmental conditions. An example of a sensor network is a set of nodes monitoring the temperature of boilers in a thermal plant. Other application domains include military, homeland security and medical care.

C. Advantages of Mobile Ad Hoc Networks

Having discussed the general issues in MANETs, the reason behind their popularity and their benefits will now be discussed.

1. Low cost of deployment: As the name suggests, ad hoc networks can be deployed on the fly, thus requiring no

expensive infrastructure such as copper wires, data cables, etc.

2. Fast deployment: When compared to WLANs, ad hoc networks are very convenient and easy to deploy requiring less manual intervention since there are no cables involved.

3. Dynamic Configuration: Ad hoc network configuration can change dynamically with time. For the many scenarios such as data sharing in classrooms, etc., this is a useful feature. When compared to configurability of LANs, it is very easy to change the network topology.

III. INTRUSION DETECTION SYSTEM IN MANETS

As discussed before, due to the limitations of most MANET routing protocols, nodes in MANETs assume that other nodes always cooperate with each other to relay data. This assumption leaves the attackers with the opportunities to achieve significant impact on the network with just one or two compromised nodes. To address this problem, Intrusion Detection System (IDS) should be added to enhance the security level of MANETs. If MANET can detect the attackers as soon as they enter the network, we will be able to completely eliminate the potential damages caused by compromised nodes at first time. IDSs usually act as the second layer in MANETs, and it is a great complement to existing proactive approaches and presented a very thorough survey on contemporary IDSs in MANETs. In this section, we mainly describe three existing approaches, namely, Watchdog, TWOACK and AACK.

A. Watchdog

Watchdog that aims to improve throughput of network with the presence of malicious nodes. In fact, the watchdog scheme is consisted of two parts, namely Watchdog and Path rater. Watchdog serves as an intrusion detection system for MANETs. It is responsible for detecting malicious nodes misbehaviors in the network. Watchdog detects malicious misbehaviors by promiscuously listens to its next hop's transmission. If Watchdog node overhears that its next node fails to forward the packet within a certain period of time, it increases its failure counter. Whenever a node's failure counter exceeds a predefined threshold, the Watchdog node reports it as misbehaving. In this case, the Path rater cooperates with the routing protocols to avoid the reported nodes in future transmission. Many following researches and implementations have proved that the Watchdog scheme to be efficient. Furthermore, compared to some other schemes, Watchdog is capable of detecting malicious nodes rather than links. These advantages have made Watchdog scheme a popular choice in the field. Many MANET IDSs are either based on or developed as an improvement to the Watchdog scheme. Watchdog scheme fails to detect malicious misbehaviors with the presence of

- Ambiguous Collisions,
- Receiver Collisions,
- Limited Transmission Power,
- False Misbehavior Report,
- Collusion,
- Partial Dropping.

B. TWOACK

TWOACK is neither an enhancement nor a Watchdog based scheme. Aiming to resolve the receiver collision and limited transmission power problems of Watchdog, TWOACK detects misbehaving links by acknowledging every data packets transmitted over each three consecutive nodes along the path from the source to the destination. Upon retrieval of a packet, each node along the route is required to send back an acknowledgement packet to the node that is two hops away from it down the route. TWOACK is required to work on routing protocols such as Dynamic Source Routing (DSR).

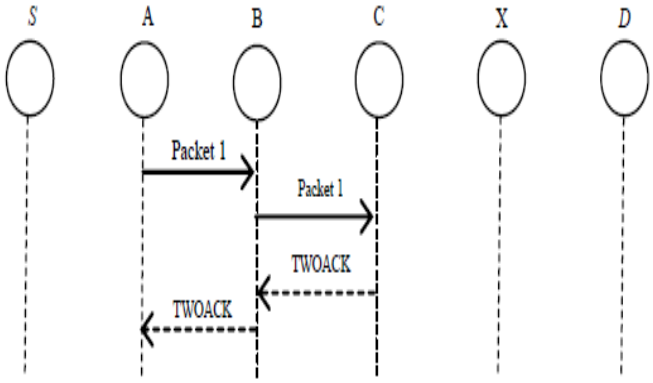

Fig.3. TWOACK.

The working process of TWOACK is demonstrated in Fig.3, node A first forwards packet 1 to node B, and then node B forwards Packet 1 to node C. When node C receives Packet 1, as it is two hops away from node A, node C is obliged to generate a TWOACK packet, which contains reverse route from node A to node C, and sends it back to node A. The retrieval of this TWOACK packet at node A indicates the transmission of Packet 1 from node A to node C is successful. Otherwise, if this TWOACK packet is not received in a predefined time period, both nodes B and C are reported malicious. TWOACK scheme successfully solves the receiver collision and limited transmission power problems posed by Watchdog. However, the acknowledgement process required in every packet transmission process added a significant amount of unwanted network overhead. Due to the limited battery power nature of MANETs, such redundant transmission process can easily degrade the life span of the entire network.

C. AACK

It is based on TWOACK Acknowledgement (AACK) similar to TWOACK,AACK is an acknowledgement based network layer scheme which can be considered as a combination of a scheme call ACK (identical to TWOACK) and an end-to-end acknowledgement scheme called ACK. Compared to TWOACK, AACK significantly reduced network overhead while still capable of maintaining or even surpassing the same network throughput. Source node S will

switch to TACK scheme by sending out a TACK packet. The concept of adopting a hybrid scheme in AACK greatly reduces the network overhead, but both TWOACK and AACK still suffer from the problem that they fail to detect malicious nodes with the presence of false misbehavior report and forged acknowledgement packets. In fact, many of the existing IDSs in MANETs adopt acknowledgement based scheme, including TWOACK and AACK. The function of such detection schemes all largely depend on the acknowledgement packets. Hence, it is crucial to guarantee the acknowledgement packets are valid authentic to address this concern, to adopt digital signature in proposed scheme EAACK.

IV. PERFORMANCE EVALUATION

In this section, we concentrate on describing our simulation environment and methodology as well as comparing performances through simulation result comparison with Watchdog, TWOACK, and EAACK schemes.

A. Simulation Methodologies

To better investigate the performance of EAACK under different types of attacks, we propose three scenario settings to simulate different types of misbehaviors or attacks.

Scenario1: In this scenario, we simulated a basic packet dropping attack. Malicious nodes simply drop all the packets that they receive. The purpose of this scenario is to test the performance of IDSs against two weaknesses of Watchdog namely, receiver collision and limited transmission power.

Scenario2: This scenario is designed to test IDSs' performances against false misbehavior report. In this case, malicious nodes always drop the packets that they receive and send back a false misbehavior report whenever it is possible.

Scenario3: This scenario is used to test the IDSs' performances when the attackers are smart enough to forge acknowledgment packets and claiming positive result while, in fact, it is negative. As Watchdog is not an acknowledgment-based scheme, it is not eligible for this scenario setting.

B. Simulation Configurations

Our simulation is conducted within the Network Simulator (NS) 2.34 environments on a platform with GCC 4.3 and Ubuntu 9.10. The system is running on a laptop with Core 2 Duo T7250 CPU and 3-GB RAM. In order to better compare our simulation results with other research works, we adopted the default scenario settings in NS 2.34. The intention is to provide more general results and make it easier for us to compare the results. In NS 2.34, the default configuration specifies 50 nodes in a flat space with a size of 670×670 m. The maximum hops allowed in this configuration setting are four. Both the physical layer and the 802.11 MAC layer are included in the wireless extension of NS2. The moving speed of mobile node is limited to 20 m/s and a pause time of 1000 s. User Datagram Protocol traffic with constant bit rate is implemented with a packet size of 512 B. For each scheme, we ran every network scenario three times and calculated the average performance. In order to measure and compare the performances of our proposed scheme, we continue to adopt the following two performance metrics.

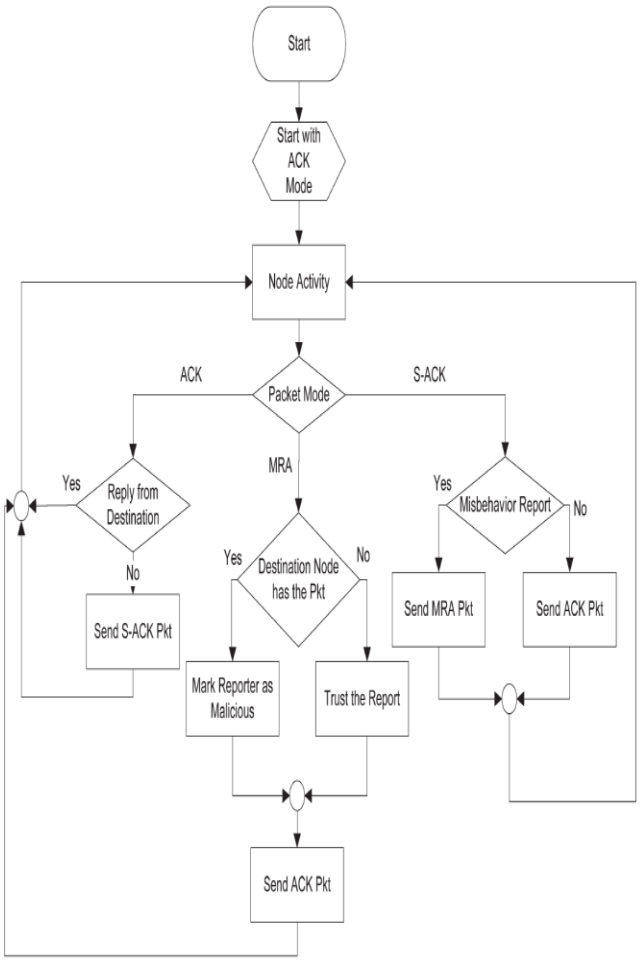

Fig.4. S-ACK scheme: Node C is required to send back an acknowledgment packet to node A.

1. Packet delivery ratio (PDR): PDR defines the ratio of the number of packets received by the destination node to the number of packets sent by the source node.

2. Routing overhead (RO): RO defines the ratio of the amount of routing-related transmissions [Route Request (RREQ), Route Reply (RREP), Route Error (RERR), ACK, S-ACK, and MRA].

During the simulation, the source route broadcasts an RREQ message to all the neighbors within its communication range. Upon receiving this RREQ message, each neighbor appends their addresses to the message and broadcasts this new message to their neighbors. If any node receives the same RREQ message more than once, it ignores it. If a failed node is detected, which generally indicates a broken link in flat routing protocols like DSR, a RERR message is sent to the source node. When the RREQ message arrives to its final destination node, the destination node initiates an RREP message and sends this message back to the source node by

reversing the route in the RREQ message. Regarding the digital signature schemes, we adopted an open source library named. This cryptography library is locally compiled with GCC 4.3. To compare performances between DSA and RSA schemes, we generated a 1024-b DSA key and a 1024-b RSA key for every node in the network. We assumed that both a public key and a private key are generated for each node and they were all distributed in advance.

The typical sizes of public- and private-key files are 654 and 509 B with a 1024-b DSA key, respectively. On the other hand, the sizes of public- and private-key files for 1024-b RSA are 272 and 916 B, respectively. The signature file sizes for DSA and RSA are 89 and 131 B, respectively. In terms of computational complexity and memory consumption, we did research on popular mobile sensors. According to our research, one of the most popular sensor nodes in the market. This type of sensor is equipped with a TI MSP430F1611 8-MHz CPU and 1070 KB of memory space. We believe that this is enough for handling our simulation settings in terms of both computational power and memory space.

C. Performance Evaluation

To provide readers with a better insight on our simulation results, detailed simulation data are presented in Table I.

TABLE I: Simulation Data

Scenario 1: Packet Delivery Ratio					
	Malicious Nodes: 0%	Malicious Nodes: 10%	Malicious Nodes: 20%	Malicious Nodes: 30%	Malicious Nodes: 40%
DSR	1	0.82	0.73	0.68	0.66
Watchdog	1	0.83	0.77	0.7	0.67
TWOACK	1	0.97	0.96	0.92	0.92
AACK	1	0.96	0.96	0.93	0.92
EAACK(DSA)	1	0.96	0.97	0.93	0.91
EAACK(RSA)	1	0.96	0.97	0.92	0.92
Scenario 1: Routing Overhead					
	Malicious Nodes: 0%	Malicious Nodes: 10%	Malicious Nodes: 20%	Malicious Nodes: 30%	Malicious Nodes: 40%
DSR	0.02	0.023	0.023	0.022	0.02
Watchdog	0.02	0.025	0.025	0.023	0.023
TWOACK	0.18	0.4	0.43	0.42	0.51
AACK	0.03	0.23	0.32	0.33	0.39
EAACK(DSA)	0.15	0.28	0.35	0.44	0.58
EAACK(RSA)	0.16	0.3	0.37	0.47	0.61
Scenario 2: Packet Delivery Ratio					
	Malicious Nodes: 0%	Malicious Nodes: 10%	Malicious Nodes: 20%	Malicious Nodes: 30%	Malicious Nodes: 40%
DSR	1	0.82	0.73	0.68	0.66
Watchdog	1	0.83	0.75	0.69	0.68
TWOACK	1	0.93	0.84	0.82	0.79
AACK	1	0.93	0.85	0.82	0.8
EAACK(DSA)	1	0.95	0.92	0.87	0.79
EAACK(RSA)	1	0.95	0.92	0.86	0.79
Scenario 2: Routing Overhead					
	Malicious Nodes: 0%	Malicious Nodes: 10%	Malicious Nodes: 20%	Malicious Nodes: 30%	Malicious Nodes: 40%
DSR	0.02	0.023	0.023	0.022	0.02
Watchdog	0.02	0.025	0.025	0.023	0.023
TWOACK	0.18	0.2	0.38	0.4	0.52
AACK	0.18	0.19	0.24	0.22	0.51
EAACK(DSA)	0.22	0.25	0.33	0.32	0.64
EAACK(RSA)	0.23	0.265	0.35	0.34	0.68
Scenario 3: Packet Delivery Ratio					
	Malicious Nodes: 0%	Malicious Nodes: 10%	Malicious Nodes: 20%	Malicious Nodes: 30%	Malicious Nodes: 40%
TWOACK	1	0.91	0.79	0.65	0.61
AACK	1	0.91	0.79	0.64	0.62
EAACK(DSA)	1	0.95	0.84	0.75	0.75
EAACK(RSA)	1	0.95	0.85	0.75	0.75
Scenario 3: Routing Overhead					
	Malicious Nodes: 0%	Malicious Nodes: 10%	Malicious Nodes: 20%	Malicious Nodes: 30%	Malicious Nodes: 40%
TWOACK	0.18	0.2	0.37	0.37	0.51
AACK	0.03	0.2	0.3	0.26	0.37
EAACK(DSA)	0.08	0.22	0.35	0.4	0.58
EAACK(RSA)	0.09	0.23	0.37	0.41	0.68

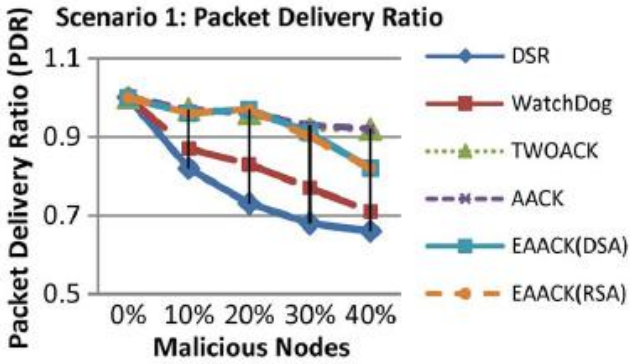

Fig.5. Simulation results for scenario 1—PDR.

1. Simulation Results—Scenario 1: In scenario 1, malicious nodes drop all the packets that pass through it. Fig. 5 shows the simulation results that are based on PDR. In Fig. 5, we observe that all acknowledgment-based IDSs perform better than the Watchdog scheme. Our proposed scheme EAACK surpassed Watchdog's performance by 21%. When there are 20% of malicious nodes in the network. From the results, we conclude that acknowledgment-based schemes, including TWOACK, AACK, and EAACK, are able to detect misbehaviors with the presence of receiver collision and limited transmission power. However, when the number of malicious nodes reaches 40%, our proposed scheme EAACK's performance is lower than those of TWOACK and AACK. We generalize it as a result of the introduction of

MRA scheme, when it takes too long to receive an MRA acknowledgment from the destination node that the waiting time exceeds the predefined threshold.

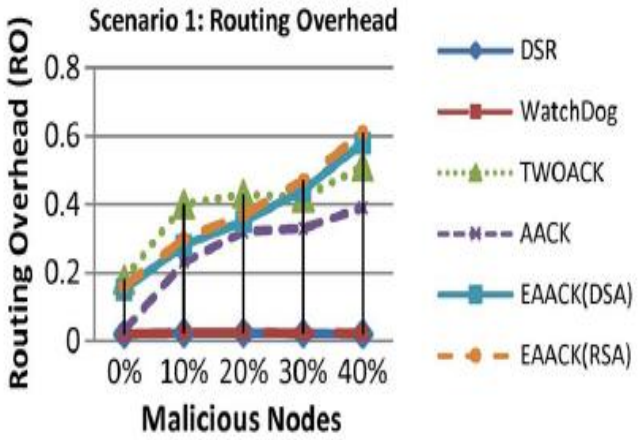

Fig.6. Simulation results for scenario 1—RO.

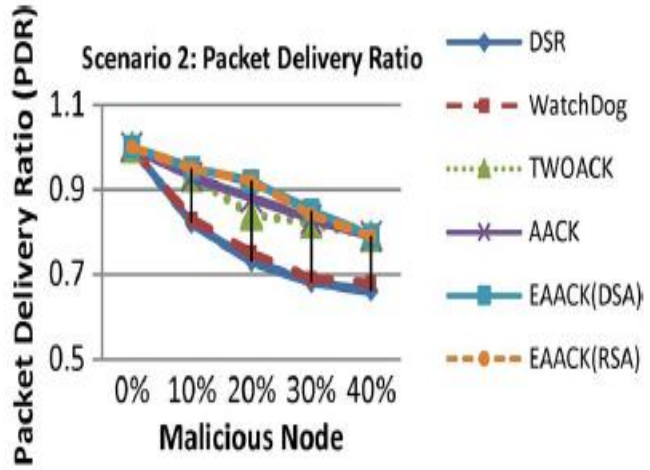

Fig.7. Simulation results for scenario 2—PDR.

The simulation results of RO in scenario 1 are shown in Fig.6. We observe that DSR and Watchdog scheme achieve the best performance, as they do not require acknowledgment scheme to detect misbehaviors. For the rest of the IDSs, AACK has the lowest overhead. This is largely due to its hybrid architecture, which significantly reduces network overhead. Although EAACK requires digital signature at all acknowledgment process, it still manages to maintain lower network overhead in most cases. We conclude that this happens as a result of the introduction of our hybrid scheme.

2. Simulation Results—Scenario 2*:* In the second scenario, we set all malicious nodes to send out false misbehavior report to the source node whenever it is possible. This scenario setting is designed to test the IDS's performance under the false misbehavior report. Fig.7 shows the achieved simulation results based on PDR. When malicious nodes are 10%, EAACK performs 2% better than AACK and TWOACK. When the malicious nodes are at 20% and 30%, EAACK outperforms all the other schemes and maintains the PDR to over 90%. We believe that the introduction of MRA scheme mainly contributes to this performance. EAACK is the only scheme that is capable of detecting false misbehavior report. In terms of RO, owing to the hybrid scheme, EAACK maintains a lower network overhead compared to TWOACK in most cases, as shown in Fig. 8. However, RO rises rapidly with the increase of malicious nodes. It is due to the fact that more malicious nodes require a lot more acknowledgment packets and digital signatures.

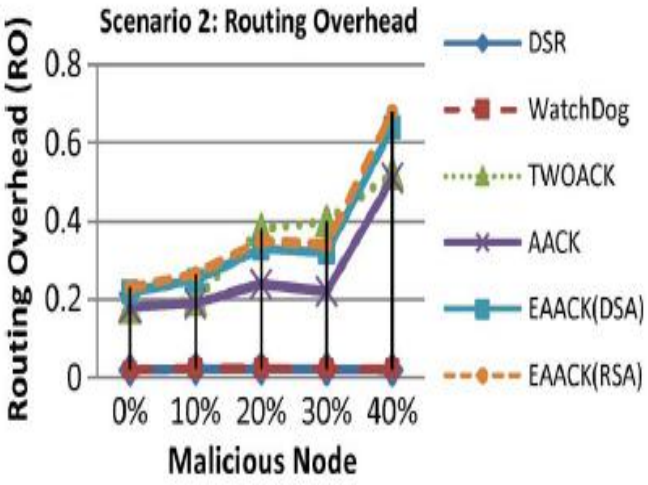

Fig.8. Simulation results for scenario 2—RO.

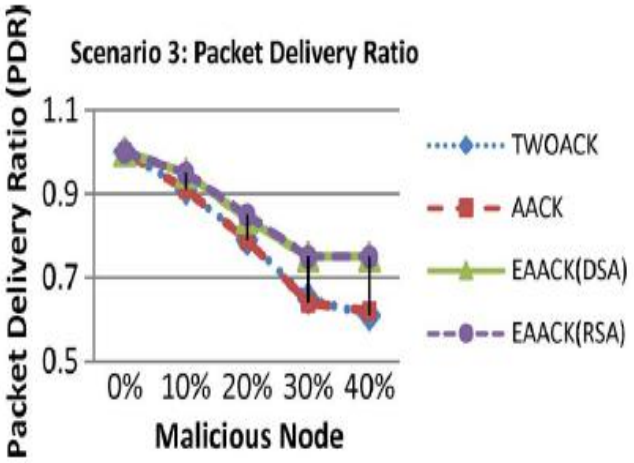

Fig.9. Simulation results for scenario 3—PDR.

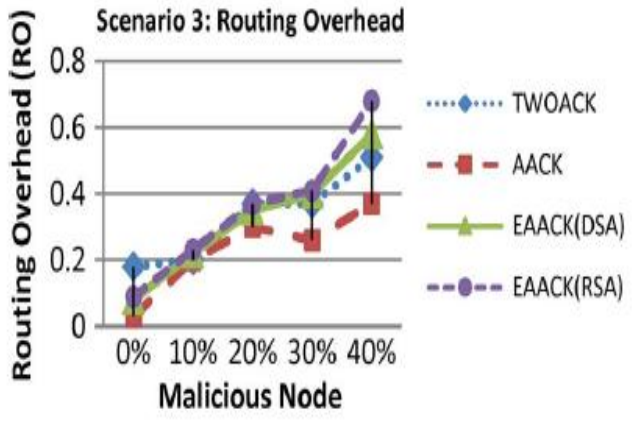

Fig.10. Simulation results for scenario 3—RO.

3. Simulation Results—Scenario 3: In scenario 3, we provide the malicious nodes the ability to forge acknowledgment packets. This way, malicious nodes simply drop all the packets that they receive and send back forged positive acknowledgment packets to its previous node whenever necessary. This is a common method for attackers to degrade network performance while still maintaining its reputation. The PDR performance comparison in scenario 3 is shown in Fig.9. We can observe that our proposed scheme EAACK outperforms TWOACK and AACK in all test scenarios. We believe that this is because EAACK is the only scheme which is capable of detecting forged acknowledgment packets. Fig.10 shows the achieved RO performance results for each IDS in scenario 3. Regardless of different digital signature schemes adopted in EAACK, it produces more network overhead than AACK and TWOACK when malicious nodes are more than 10%. We conclude that the reason is that digital signature scheme brings in more overhead than the other two schemes.

4. DSA and RSA: In all of the three scenarios, we witness that the DSA scheme always produces slightly less network overhead than RSA does. This is easy to understand because the signature size of DSA is much smaller than the signature size of RSA. However, it is interesting to observe that the RO differences between RSA and DSA schemes vary with different numbers of malicious nodes. The more malicious nodes there are, the more ROs the RSA scheme produces. We assume that this is due to the fact that more malicious nodes require more acknowledgment packets, thus increasing the ratio of digital signature in the whole network overhead. With respect to this result, we find DSA as a more desirable digital signature scheme in MANETs. The reason is that data transmission in MANETs consumes the most battery power. Although the DSA scheme requires more computational power to verify than RSA, considering the tradeoff between battery power and performance, DSA is still preferable.

V. CONCLUSION AND FUTURE WORK

Packet-dropping attack has always been a major threat to the security in MANETs. In this research paper, we have proposed a novel IDS named EAACK protocol specially designed for MANETs and compared it against other popular mechanisms in different scenarios through simulations. The results demonstrated positive performances against Watchdog, TWOACK, and AACK in the cases of receiver collision, limited transmission power, and false misbehavior report. Furthermore, in an effort to prevent the attackers from initiating forged acknowledgment attacks, we extended our research to incorporate digital signature in our proposed scheme. Although it generates more ROs in some cases, as demonstrated in our experiment, it can vastly improve the network's PDR when the attackers are smart enough to forge acknowledgment packets. We think that this tradeoff is worthwhile when network security is the top priority. In order to seek the optimal DSAs in MANETs, we implemented both DSA and RSA schemes in our simulation. Eventually, we arrived to the conclusion that the DSA scheme is more suitable to be implemented in MANETs. To increase the merits of our research work, we plan to investigate the following issues in our future research:

- Possibilities of adopting hybrid cryptography techniques to further reduce the network overhead caused by digital signature;
- Examine the possibilities of adopting a key exchange mechanism to eliminate the requirement of pre-distributed keys;
- Testing the performance of EAACK in real network environment instead of software simulation.

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