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EAACK— Intrusion-Detection-System for MANETs

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Abstract— Future wireless communication systems will be greatly dependent on the instantaneous deployment of independent mobile users. Some of the notable and interesting examples include creating sustainable, well organized, well planned, effective, and active communication systems for emergency/exigency/crises operations, catastrophe relief efforts, and military networks. Such networking situations depend on distributed, dispersed and disorganized connectivity, and can be designed as applications of Mobile Ad Hoc networks. A MANET is a self-governing and self-organizing collection of mobile nodes that communicate over relatively bandwidth constrained wireless links. The network is decentralized and disseminated, where all networking including discovering the topology and conveying the messages must be accomplished by the nodes themselves, i.e, routing capabilities are assimilated into mobile nodes. However, determining feasible routing paths and distributing messages in a decentralized environment where topology varies is a difficult job. Factors such as the open medium and vast distribution of nodes, topological changes, variable wireless link quality, and propagation path loss become pertinent issues and make MANET unprotected to intrusions. Thus it becomes pivotal to develop a systematic intrusion detection mechanisms to secure MANET from intruders. In this paper, we put forward and apply an efficient intrusion detection system named Enhanced Adaptive Acknowledgment (EAACK) specially designed for MANETs which performs better than the previous techniques such as Watchdog, TWOACK and AACK.

Keywords— Mobile Ad hoc Network (MANET) Acknowledgment (ACK), Secure Acknowledgment (S-ACK), Misbehaviour Report Authentication (MRA), Digital Signature Algorithm (RSA), Enhanced Adaptive Acknowledgment (EAACK).

I. INTRODUCTION

Wireless networking is the need of hour for many applications because of its easier network expansion, increased mobility [27] [29], improved responsiveness, better access to information, and enhanced guest access. In addition, with the maturing of industry standards and the deployment of lightweight wireless networking hardware in devices that are ever smaller, and so increasingly mobile, wireless technology has come of age. Mobile ad hoc networks (MANETs) enhance wireless communication with a high degree of node mobility.

II. PROPOSED ESTIMATION TECHNIQUE

A **Mobile Ad Hoc Network** (MANET) [28] is a self-organizing and self-maintaining network that is formed automatically by a collection of mobile nodes without the help of static infrastructure or centralized management. Each node is provided with a wireless transmitter and receiver, which enable it to communicate with other nodes in its radio communication range. This means that two parties cannot communicate with each other when the distance between them is far off their communication range. MANET [28] solves this issue by allowing the intermediate nodes to transmit data transmissions. This is attained by dividing MANET into two

types of networks, viz, single-hop and multi-hop. In a single-hop, all mobile nodes which lie in the same radio communication range transfer data directly among each other [9]. On the other side, in a multi-hop network, nodes depend on other intermediate nodes to transmit data, if destination node is beyond their radio communication range. MANETs have been developing rapidly and are increasingly being used in many applications, ranging from military to civilian and industrial uses, since setting up such networks can be done without the help of any infrastructure or interaction with a human.

The network topology changes frequently [29] as the mobile nodes have an important property i.e. the mobility that gives them the flexibility to move anywhere in the network or can move outside the network. This flexibility provided is useful but on the other hand makes it vulnerable to new security risks due to the cooperativeness and open broadcast medium of the mobile devices (that generally possess computational capacities and different resource, and limited battery power). As a result, intrusion detection becomes an indispensable part of security for MANETs. The intrusion detection techniques designed for traditional wired networks cannot be implemented for wireless networks due to different characteristics. Therefore, to make intrusion detection systems work effectively new techniques need to be developed for MANETs.

This paper is divided into different sections as follows. Section II gives brief idea on the background of intrusion detection systems, existing techniques for intrusion detection in MANETs are presented. Some of the problems of the existing IDS for MANETs are given in Section III. Then, our proposed EAACK scheme in Section IV, along with the simulation results. Finally, the conclusion and future directions are given in Section V and VI

In traditional networks many intrusion detection systems have been proposed, the routers, gateways or switches are used for network traffic. Hence, it is easy to implement IDS in these networks. In MANETs we do not use such devices. Moreover, due to its openness so both malicious and legitimate users can access. In mobile environment it is very difficult to separate normal and unusual activities. Sometimes the false routing information can be generated by outdated node or from a malicious node due to the arbitrarily movement of nodes. Thus, the available intrusion detection techniques used in simple wired networks cannot be implemented to MANETs directly. Researchers have developed many intrusion detection systems for the MANETs. In the next section, we briefly explain three existing techniques, i.e. Watchdog [17], TWOACK [34], and Adaptive Acknowledgment (AACK)[25].

1) WATCHDOG: Marti *e tal.*[17]*the* watchdog method was proposed to improve throughput when malicious nodes are present in network .This scheme is used as IDS in MANETs. WATCHDOG scheme is used to detect any malicious node in network. The WATCHDOG works in two parts, namely, Watchdog and Path rater. The malicious nodes are detected by listening to all nodes that lie in transmission range. WATCHDOG scheme ensures that the packet is forwarded to next node. If the packets is not send to next node then the node is labeled as malicious. A match confirms that the packet has been successfully forwarded, causing the neighbor's trustworthiness to be increased. If a packet is not forwarded within a timeout period, then a failure tally for the node responsible for forwarding the packet is incremented. If this tally exceeds a predetermined threshold, then the node is termed as malicious.

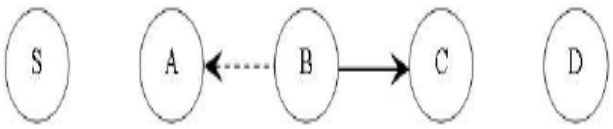


Figure 1: How watchdog works: Although node B intends to transmit a packet to node C, node A could overhear this transmission

In the Path rater scheme, every node uses the information provided by watchdogs to rate neighbors. The Route guard mechanism combines the watchdog and Path rater solutions to classify each neighbor node as Fresh, Member, Unstable, Suspect or Malicious. As a result, paths containing malicious nodes will be avoided. As can be seen, watchdogs are at the core of the most important types of IDS solutions for adhoc networks. The main advantage of the watchdog is that it uses local information to detect an attacker, thus avoiding that a malicious node affects the decisions made by the mechanism. In contrast, the watchdog has a well-known drawback: it fails to detect when two nodes are consecutively attacked, the watchdog can only monitor the first one while the second malicious node performs an attack.

Nevertheless the Watchdog scheme fails to detect malicious misbehaviors with the presence of the following:
1) Receiver collisions;
2) Limited transmission power;
3) False misbehavior report.

2) TWO ACK:

To overcome the drawbacks of WATCHDOG Liu *et al.* [16] designed TWOACK scheme. The TWOACK scheme is implemented by using any source routing protocol such as DSR [11]. It is neither WATCHDOG based scheme nor enhancement. It is implemented to solve the receiver collision and limited transmission power problems. This method works on the fact that a TWOACK packet derives its route from the source route established for the corresponding data packet. The TWOACK scheme uses a special type of acknowledgment packets called TWOACK packets, which are assigned a fixed route of two hops (or three nodes) in the direction opposite to that of data packets. Upon retrieval of a packet, every node along the route is required to send back an acknowledgment packet to the node that is two hops away from it down the route.

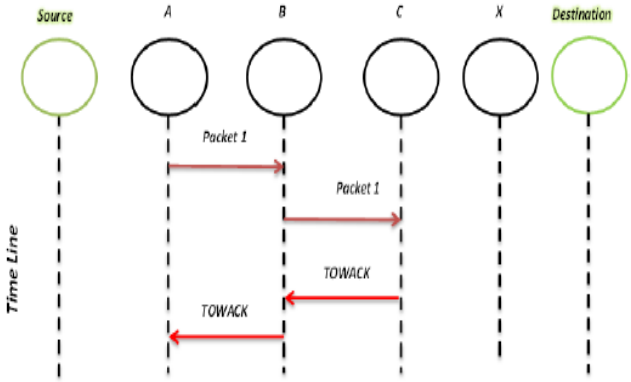


Figure 2: TWO-ACK scheme: Each node is required to send back an acknowledgment packet to the node that is two hops away from it.

In figure 2 a packet1 is sent to B from A and the same packet is forwarded to node C as the C receives the packet, it generates TWO-ACK packet as two hops are completed and sends the packet back through same route. If the packet is received in well-defined time then it is successful otherwise both nodes B and C are tagged as malicious.

The TWOACK scheme proves successful in solving the receiver collision and limited transmission power problems [25],[28],[29]. However, the acknowledgment process required in every packet transmission process added a significant amount of undesirable network overhead.

3) AACK: Sheltami *et al.*[25]AACK solves the two problems of watchdog and improves the performance of TWOACK by reducing the routing overhead while maintaining better performance. AACK is actually combination of two namely TACK(identical to TWOACK) and ACK (end-to-end acknowledgment). The network overhead is reduced but malicious nodes with false misbehavior report and forged acknowledgment packets cannot be detected. The end-to-end acknowledgment scheme in AACK is shown in Fig. 3

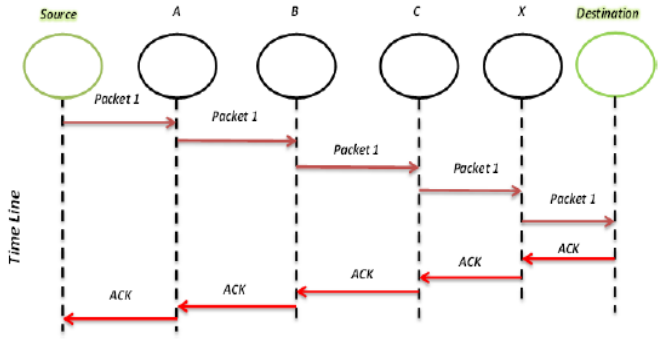


Figure 3: End-to-End ACK IDS for MANETs ACK scheme: The destination node is required to send acknowledgment packets to the source node.

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 fake ACK packets. Hence, it is important to guarantee that the acknowledgment packets are authentic and valid, thus we incorporated Digital Signature [18] in our proposed scheme.

III. PROBLEM IDENTIFICATION

In this section, we will highlight three major problems namely: limited transmission power, false misbehavior and receiver collision report which will be resolved by our proposed EAACK approach.

a) Receiver collision:

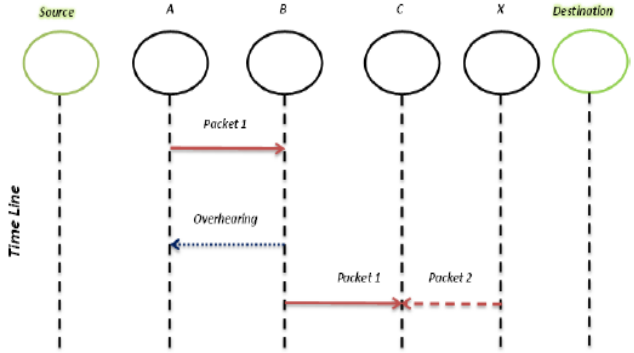


Figure 4: Receiver collisions: Both nodes B and X are trying to send Packet 1 and Packet 2, respectively, to node C at the same time.

b) Limited transmission power:

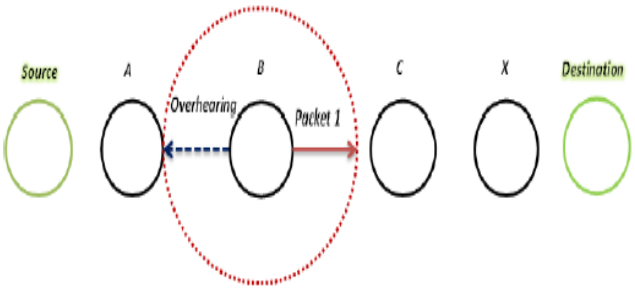


Figure 5: Limited transmission power: Node B limits its transmission power so that the packet transmission can be overheard by node A but too weak to reach node C.

c) False misbehavior report:

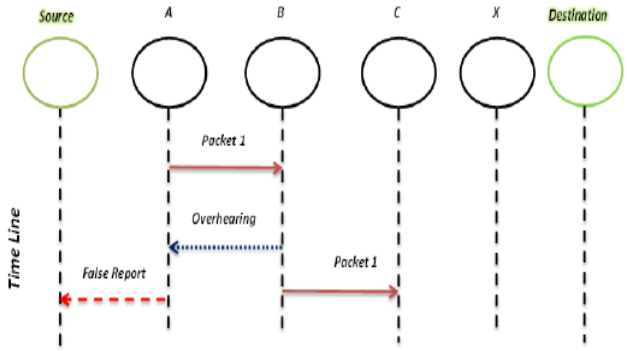


Figure 6: False misbehavior report: Node A sends back a Misbehavior report even though node B forwarded the packet to node C.

IV. PROPOSED EAACK SCHEME

In this section, we are going to discuss our proposed EAACK model in detail. EAACK scheme consists mainly three major modules, namely ACK, S-ACK and MRA (misbehavior report authentication).

A. ACK

ACK is actually an end to end acknowledgement scheme. It functions as a part of hybrid scheme and is used to reduce network overhead. .InFig.7,inACKmode,nodeSsendsoutanACKdatapacket$Pad1$ to the destination node D. If the destination D receives packet successfully, it means there is no malicious node present in route. The node D sends an acknowledgment packet $Pak1$ in reverse order but along same route. Within a specified time period ,if source node S receives $Pak1$, then the packet transmission from source to destination is successful. Otherwise, source node S will switch to S-ACK mode by sending out an S-ACK data packet to detect the malicious nodes in the route.

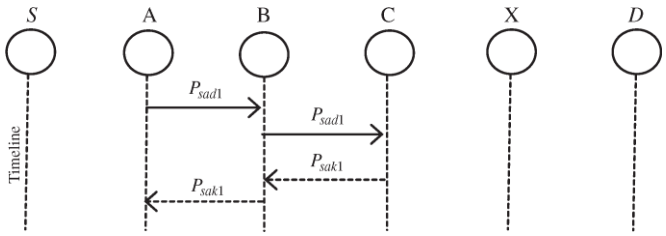


Fig.7. ACK scheme an acknowledgment packet is send by destination node when it receives new packet.

B. S-ACK

The S-ACK scheme is an improved version of the TWO ACK scheme proposed by Liu *et al.*[16]. This works on basic principle that every three consecutive nodes works in a group to detect malicious nodes . In every three node group in the route, the third node is required to send an S-ACK acknowledgment packet of the first node. The S-ACK mode is introduced to detect malicious nodes in the presence of limited transmission power or receiver collision. As shown in Fig.8, in S-ACK mode, the group of three consecutive nodes (i.e.,F1,F2,andF3) work together in order to detect any malicious nodes in the network. The node F1 first sends out S-ACK packet $Psad1$ to the node F2.Then, the packet is forwarded to node F3 from the node F2. When node F3 receives packet $Psad1$, the last node in group, node F3 sends back an S-ACK packet $Psak1$ to nodeF2 and F2 sends this packet to node F1. If node F1 does not receive the acknowledgment packet on time, both the nodes F2 and F3 in group are reported as malicious nodes. Moreover, the node F1 generates a misbehavior report and is sent to the source node S.

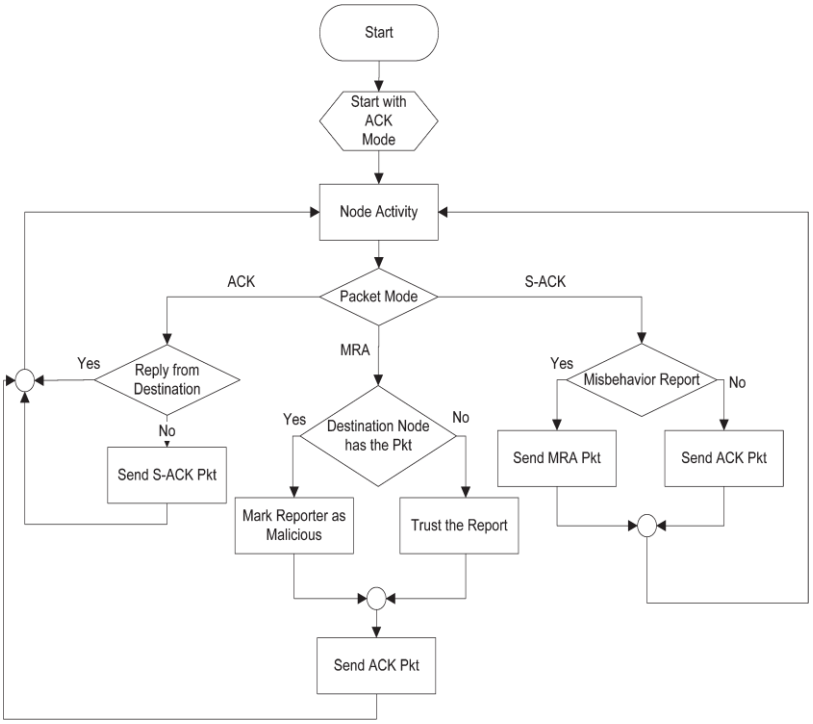


Fig.8: *System control flow: This figure shows the system flow of how the **EAACK** scheme works*

C. *MRA*

The MRA scheme is designed to detect misbehaving nodes when a false misbehavior report is generated. In false misbehavior report the innocent nodes are represented as malicious nodes by attacker. This attack can damage the entire network and sufficient nodes can be broken down to cause a network division. The aim of MRA scheme is to authenticate the misbehavior report. In MRA mode, the local knowledge base is searched by the source node to check for an alternative route to the destination node. If no other route exists, then source node starts a DSR [11] routing request to search another route. In MANETs, it is possible to find out multiple routes between two nodes. By routing through an alternative route to the destination node, we check the authenticity of the misbehavior reporter node. When the MRA packet is received by destination through alternative route, the local knowledge base is searched to check whether the reported packet was received or not. If the packet is already received, then the misbehavior report generated is false and the node is marked as malicious. Otherwise, the misbehavior report is trusted and accepted. By adopting MRA scheme, EAACK is capable of detecting malicious nodes despite the existence of false misbehavior report.

D. Digital Signature

EAACK works on an acknowledgment-based IDS. All three modules of EAACK, namely, ACK, S-ACK, and MRA, are acknowledgment-based detection schemes. They all depend on acknowledgment packets to detect misbehaviors in the network. Thus, to acknowledge that all the packets are untainted and authentic. Otherwise, if the attackers are able to forge acknowledgment packets, all of the three schemes will be vulnerable. To address this issue, we incorporated digital signature [32] in our proposed scheme. The integrity of the IDS, EAACK can be maintained by digitally signing all acknowledgment packets before they are sent out and verified before they are accepted. However, we require some extra resources are required with the introduction of digital signature in MANETs. To address this concern, we implemented both RSA [23] and DSA [33] digital signature schemes in our proposed approach. Our aim is to find the optimal solution for implementation of digital signature in MANETs.

V. PERFORMANCE EVALUATION

In this section, we concentrate on describing our simulation environment as well as comparing performances metrics [13] through simulation results among TWOACK, AACK and EAACK schemes.

a) Simulation parameters: Our simulation is conducted within the Network Simulator (NS) 2.34 environment with Ubuntu 12.04. The system is running on a laptop with core i5 CPU and 4-GB RAM.

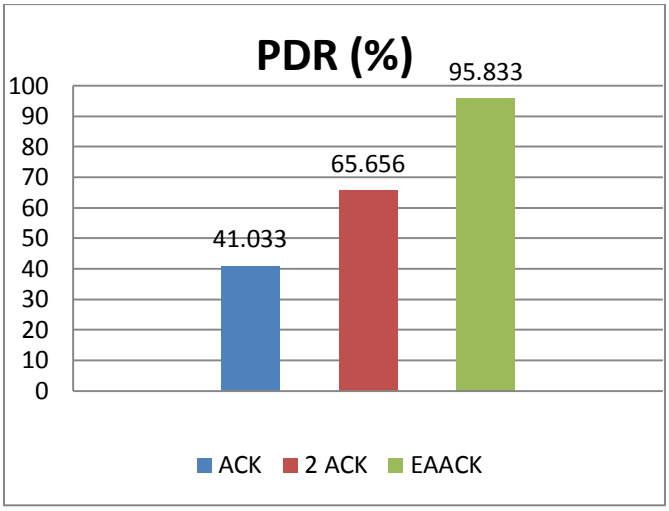
Table 1: Simulation parameters

channel type	Wireless
MAC type	Mac/802.11
max packet in ifq	50
number of mobile nodes	18
routing protocol	AODV
X dimension of topography	1216
Y dimension of topography	743
time of simulation end	50.0

b) Performance metrics: In order to measure and compare the performances of our proposed model, we continue to adopt the following three performance metrics to evaluate the performance of IDS for existing and proposed technique which are defined as follows:

Packet delivery ratio (PDR): PDR defines the efficiency of the network and hence signifies the efficiency of the routing protocol used. The Packet delivery ratio (PDR) is computed as shown in Equation below:

$$PDR = \sum \text{Number of packets received} / \sum \text{Number of packets send}$$

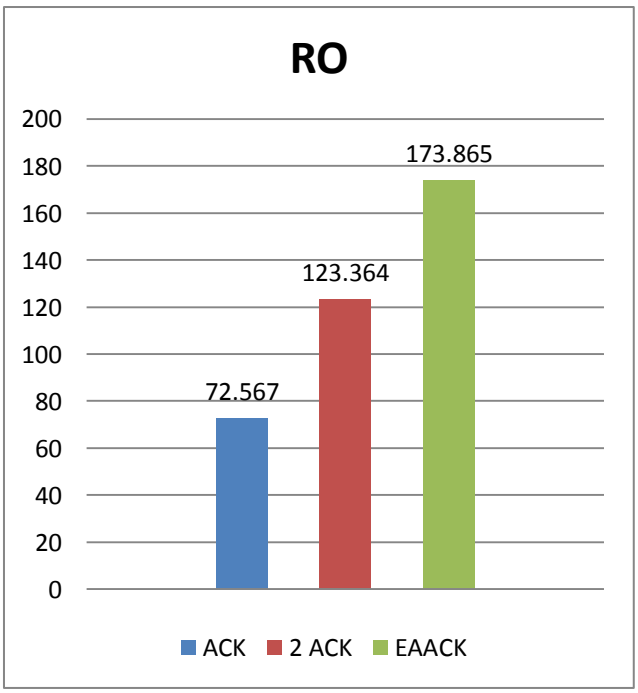


Thus, it is the ratio of packets that are successfully delivered to a destination compared to the number of packets that have been sent out by the sender. This illustrates the level of delivered data to the destination. The greater value of PDR means the better performance of the protocol.

Routing Overhead (OH): RO defines the ratio of the amount of routing related transmissions. It also signifies the stress that a specific protocol offers. The Routing overhead (RO) is computed as shown in Equation below:

$$RO = \sum \text{Routing transmissions} / (\sum \text{Data transmissions} + \sum \text{Routing transmissions})$$

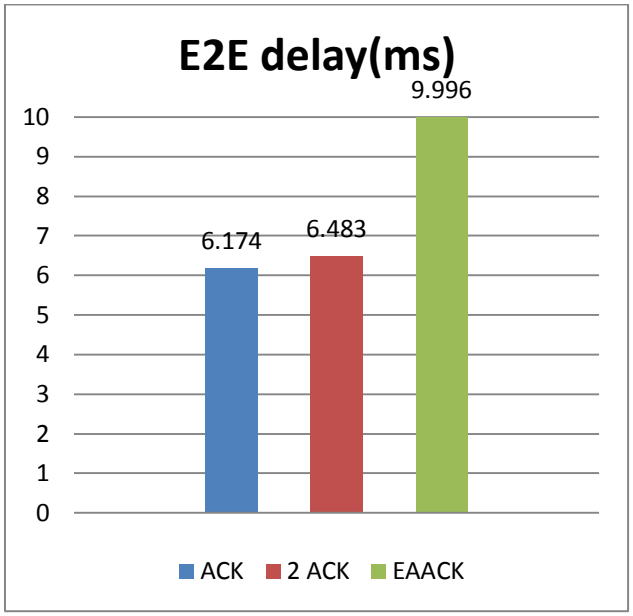
Thus, it is the ratio of routing related packets in bytes (RREQ, RREP, RERR, ACK, S-ACK, and MRA) to the total routing and data transmissions (sent or forwarded packets) in bytes. The lower value of RO means the better performance of the protocol.



End-to-End delay (E2E delay): Network delay is an important design and performance characteristic. The delay of a network specifies how long it takes for a bit of data to travel across the network from one node or end point to another.

$$\text{E2E delay} = \sum (\text{arrive time} - \text{send time}) / \sum \text{Number of connections}$$

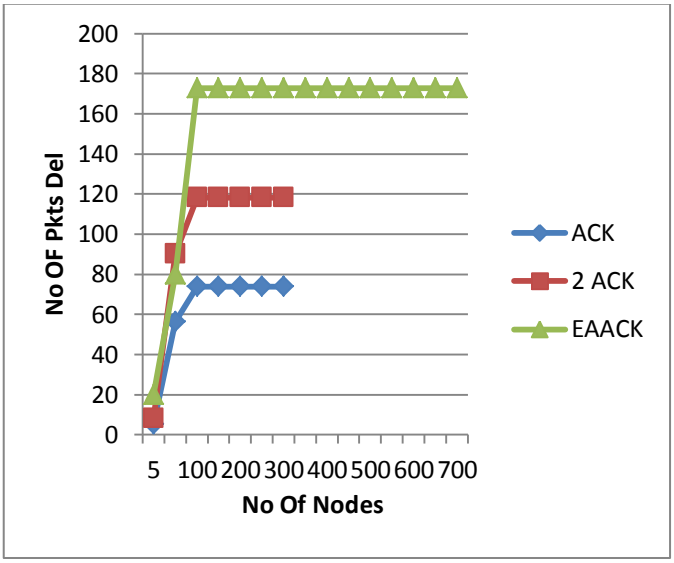
Thus, E2E delay is the average time taken by a data packet to arrive in the destination. It also includes the delay caused by route discovery process and the queue in data packet transmission. Only the data packets that are successfully delivered to destinations are counted. The lower value of end to end delay means the better performance of the protocol.



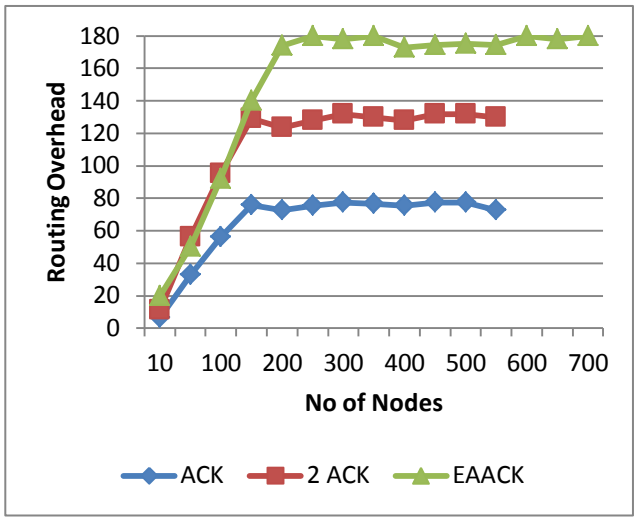
C) Simulation results (X-GRAPH):

In this module, the performance of the proposed EAACK is analyzed. Based on the analyzed results X-graphs are plotted. Packet delivery ratio, Routing overhead, E2E delay, are the basic parameters considered here and X-graphs are plotted for these parameters. Finally, the results obtained from this module are compared with TWOACK and AACK results and comparison X-graphs are plotted for these parameters as:

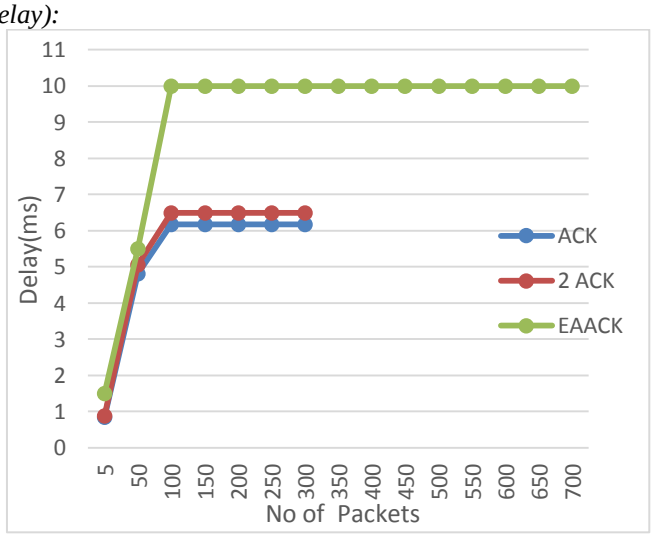
Packet delivery ratio (PDR):



Routing Overhead (OH):



End-to-End delay (E2E delay):



VI. CONCLUSION AND FUTURE WORK

To provide security in the mobile Ad-hoc networks we implemented a new intrusion-detection system named Enhanced Adaptive Acknowledgment (EAACK). In the EAACK all acknowledgement packets are digitally signed before they sent out and verified until they are accepted. The proposed Model completely overcomes the weaknesses like false misbehavior, limited transmission power, and receiver collision. All acknowledgment packets in the proposed Model are authentic and untainted. The proposed model significantly improves the Packet Delivery Factor (PDF) as compared to TWOACK and EAACK. However the inclusion of digital signature generates more routing overhead. This tradeoff is worthwhile when network security is the top priority.

To enhance the merits of EAACK scheme, we plan to investigate the following issues in our future research:

1) Try to implement hybrid cryptography techniques to further reduce the routing overhead caused by digital signature.

2) Examine the possibilities of adopting a key exchange mechanism to eliminate the requirement of pre distributed keys.

3) Testing the performance of proposed model (EAACK) in real network environment.

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