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SURVEY ARTICLE

MANET Attacks and their Countermeasures: A Survey

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Abstract— MANET "Mobile ad hoc network" is an autonomous system of mobile nodes connected by wireless links. Each node behaves as an end system, but also as a router to forward packets. Nodes can move freely, change locations and organize/configure themselves into a network. MANET poses challenges such as open peer-to-peer network architecture, shared wireless medium, stringent resource constraints and highly dynamic network topology. To accommodate the challenges special/proper routing protocols are necessary. Also choosing the algorithms needed to consider the network characteristics such as density, size and the mobility of the nodes. In MANETS establishing an optimal and efficient route between the communicating parties is the primary concern of the routing protocols. Any attack in routing phase may disrupt the communication, paralysing the entire network. So, security has become a primary concern in order to provide protected communication between mobile nodes in MANETS. Dependability and security aspects of MANET, such as jamming and eavesdropping are to be looked for users to perform protected peer-to-peer communication over multihop wireless channel. Security services such as authentication, integrity, non repudiation, confidentiality, key and trust management and access control must be provided a user depending on the application context.

A multifence security solution needed to achieve both bound protection and desirable network performance, considering all three security components prevention, detection and reaction.

Keywords— MANET; vulnerabilities, routing protocols; protocol stack; security; multifence security solution

I. INTRODUCTION

Mobile ad hoc networking (MANET) is gradually emerging to be one of the more innovative and challenging area of wireless networking. MANETS consists of mobile nodes (MNs) with autonomously self-organizing capabilities in arbitrary and temporary network topologies, communicating over wireless links. MANETs have self-configuration and self-maintenance capabilities in which network topology may change rapidly and unpredictably over time due to the mobility of nodes. All the network activity including discovering the topology and messages delivery is executed by the nodes in self/themselves. Routing functionality incorporated into the mobile nodes in MANETs. Peer-to-peer communication over multihop channels will be provided in MANETs through ensuring on-hop connectivity through link layer protocols and extending connectivity to multiple hops through network layer routing and data forwarding protocols. As the communication carried out

over wireless links, contend with effects of radio communication, such as noise, fading and interference. In addition the links have less bandwidth than wired network. The wireless network is accessible to both legitimate users and malicious attackers making the network vulnerable, as there is no place to define traffic monitoring or access control. Hence security issues in MANETs rely on implicit trust relationship to route packets among participating nodes. The general security objectives like authentication, confidentiality, integrity, availability and non repudiation are to be addressed along with location confidentiality, cooperation fairness and absence of traffic diversion. The provision of security services in MANET is dependent on the characteristics of the supported application and the networked environment which may vary significantly. The unique characteristics of mobile ad hoc networks pose a number of nontrivial challenges to the security design.

II. MANET VULNERABILITIES

Mobile Ad-hoc network are more vulnerable in comparison to the traditional wired network due to their characteristics, which are to be discussed next.

A. Unreliability of wireless Link

Wireless links have a poor protection to noise, fading and signal interferences so routing related control message can be tampered. Also the wireless links have less bandwidth in comparisons to the wired networks. This makes the wireless links between mobile nodes in the ad hoc network inconsistent and unreliable for the communication participants [1].

Figure 1.1: Structure of MANET

B. Dynamic topologies

In MANET nodes are free to move arbitrarily; and the network topology is typically multihop in nature. It may change randomly and rapidly at unpredictable time. As the MANET topology is changing frequently, it is necessary for each pair of adjacent nodes to incorporate in the routing issue to prevent some kind of potential attacks that try to make use of vulnerabilities in the statically configured routing protocol [1]. Here due to the mixing of several ad hoc networks there can be duplication of IP addresses making the impersonation attack to occur.

C. Implicit trust relationship between neighbours

Actual ad-hoc routing protocols suppose that all the participating nodes in the network are honest. This feature directly allows malicious a node to operate and try to paralyse the whole network, just by providing wrong information and spreading over the network [2].

D. Lack of Secure Boundaries

As compared to traditional wired network, the mobile ad hoc network is more vulnerable which means self-evident. No such clear secure boundary in the MANET compared with the clear line of defence in the traditional wired network. In mobile ad hoc network nodes have freedom to join, leave and move inside the network. Lack of secure boundaries makes the mobile ad hoc network susceptible to the attacks. Due to this mobile ad hoc network suffers from all attacks coming from any node that is in the radio range of any node in the network, at any time, and target to any other node(s) in the network. To make matters worse, there are various link attacks that can jeopardize the mobile ad hoc network, making it even harder for the nodes in the network to resist. The attacks mainly include passive eavesdropping, active interfering, and leakage of secret information, data tampering, message replay, message contamination, and denial of service [3].

E. Threats from Compromised nodes Inside the Network

In a MANET mobile nodes are autonomous units that are free to join or leave the network, it becomes so difficult for the nodes themselves to make some effective policies which can prevent the possible malicious

behaviours from all the nodes it communicate with because of the behavioural diversity of different nodes. Furthermore, it is very difficult to track the malicious behaviour performed by a compromised node especially in a large scale ad hoc network due to change in their attack target frequently because of their mobility aspect. Therefore, threats from compromised nodes inside the network are far more dangerous than the attacks from outside the network, and these attacks are much harder to detect because they come from the compromised nodes, which behave well before they are compromised.

F. Unavailable Centralized Management Facility

Ad hoc networks do not have a centralized piece of management machinery such as a name server. Due to absence of centralized management facility each node is allowed to take its own decision and hence problems like detection of attacks, path breakages, transmission impairments and packet dropping, breakage of the cooperative algorithm take place.

G. Restricted Power Supply

MANET nodes are battery powered and for which energy must be conserved. For these nodes, the most important system design criteria for optimization may be energy conservation. The problem that may be caused by the restricted power supply is denial-of-service attacks [3]. Since the adversary knows that the target node is battery restricted, either it can continuously send additional packets to the target and ask it routing those additional packets, or it can induce the target to be trapped in some kind of time consuming computations. In this way, the battery power of the target node will be exhausted by these meaningless tasks, and thus the target node will be out of service to all the benign service requests since it has run out of power.

H. Scalability

Scalability is the problem in the mobile ad hoc network [3]. Unlike the traditional wired network in that its scale is generally predefined and will not change much during the use, the scale of the ad hoc network keeps changing all the time: because of the mobility of the nodes in the mobile ad hoc network, we cannot predict the number of nodes there will be in the future. As a result, the protocols and services applied to the ad hoc network such as routing protocol and key management services should be compatible to the continuously changing scale of the ad hoc network.

III. TYPES OF ATTACKS IN MANET

Ad-hoc networks are more easily attacked than wired network. We can distinguish two kinds of attack: the passive attacks and the active attacks. In a passive attack, the operation of the protocol does not disrupted, but tries to discover valuable information by listening to traffic. Whereas, an active attack injects arbitrary packets and tries to disrupt the operation of the protocol in order to limiting availability, gaining authentication, or attracting packets destined to other nodes. In an attacker point of view attacks can be classified into three types Attacks Using Modification, Attacks using impersonation and Attacks using fabrication. Different types of attacks on different layers of protocol stack are shown in Table 3.1.

Layers	Attacks
Physical Layer Attack	Jamming, interception, Eavesdropping
Data link Layer Attack	Traffic analysis, Monitoring, Disruption MAC (802.11) WEP weakness
Network Layer Attack	Wormhole, Blackhole, Flooding, Resource consumption, Location Disclosure, Byzantine, Rushing
Transport Attack	Session hijacking, SYN flooding
Application Layer Attack	Repudiation, Data corruption
Multilayer Layer Attack	DOS, Impersonation, Reply, Man in the middle

Table 3.1: Classification of different types of attacks on different layers of protocol stack.

A. Physical Layer Attacks

1) Eavesdropping: Eavesdropping is a passive attack carried out by unintended receivers to intercept and read the messages and conversations during communication. The main idea is to obtain the confidential information during the communication. In mobile ad hoc networks, mobile nodes share a wireless medium,

which basically uses the RF spectrum and broadcast by nature of communication. Signals which broadcast over wireless can be easily analysed and intercepted to reveal some information about the network, with receivers tuned to the proper frequency [4] [5] in comparison to wired medium.

2) Jamming: Jamming is a active attack in which radio signals can be jammed or interfered causing the message to be corrupted or lost [4] [5]. If the attacker has a powerful transmitter or a jammer device, a strong enough signal can be generated to overwhelm the targeted signals disrupting communication between two interacting nodes. Random noise and pulse are the most common type of signal jamming.

3) Interception: Signals broadcast over the wireless can be easily monitored and intercepted with intruders tuned to that communication frequency [4] [5]. In active interception the messages transmitted can be overheard by the intruder, and afterwards may inject fake messages into network on the user's behalf where as in passive interception the network traffic is routinely monitored to collect qualitative information, such as communication volume, or other information not explicitly communicated via a data stream.

B. Link Layer Attacks

1) Traffic Monitoring and Analysis: Traffic monitoring and analysis is not an actual attack, but further it may lead to various vulnerable attacks. Via traffic monitoring and analysis an attacker may receive information about the communicating users present within the network like their identity, geographical locations, network topology, and their communication functionalities like communicating bandwidth, time of communication etc. Such information allows a malicious node to attack a victim node easily with high efficiency. Hence the traffic monitoring and analysis may not be an attack itself but to be considered as a massive threat in MANET.

2) Disruption in MAC: Current wireless MAC protocol is based upon the implicit trust relationship between the nodes. The selfish nodes may deny in the participation of packet forwarding or drop packets to consume battery power or unfair sharing of bandwidth. Similarly the malicious nodes disrupt the normal operations of contention-based or reservation-based MAC protocol.

3) Weakness of 802.11 WEP: IEEE 802.11 WEP incorporates wired equivalent privacy (WEP) for providing modest level of privacy to WLAN systems a by encryption of radio signals. 802.11 WEP standards support WEP 40 bit cryptographic keys, where as 104bit and 128 bits are already implemented. As WEP is having a number of weaknesses [6] [7] [8] it is broken and is replaced by AES in 802.11.

C. Network Layer Attacks

1) Wormhole Attack: Wormhole attacks are also known as tunnelling attack in which the attacker receives packets at one region in the network and tunnels them to another location within or outside of he network, and replays the packets there. This tunnel between two colluding attackers is called a wormhole [9] [10] [11 and made of a wired or long range wireless link. Wormhole attacks can be easily implemented but very hard to detect. Wormhole attack can be classified as hidden attacks and exposed attacks. In hidden attacks attacker nodes don't realize their identity to the communicating nodes by hiding their MAC address during updating of packet header. In exposed attack, packet includes the attacker nodes identity and they communicate as legitimate nodes without any modification to the content of the packet. Wormhole attacks are launched in MANET using several modes like; using encapsulation, using out-of-bound channel, using packet relay, with high power transmission, using protocol deviation techniques.

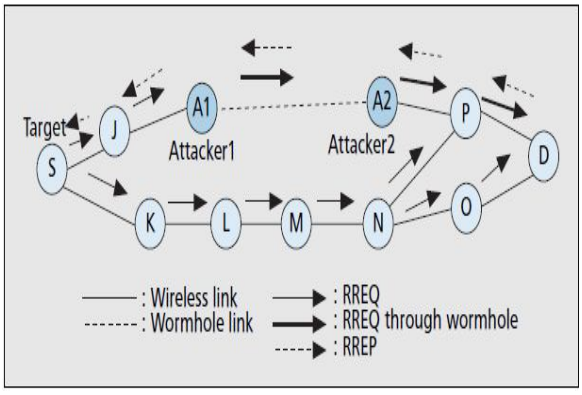

Figure 3.1: Wormhole Attack

2) Blackhole Attack: The blackhole attack has two properties. First, the node exploits the mobile ad hoc routing protocol, such as AODV, to advertise itself as having a valid route to a destination node, even though

the route is spurious, with the intention of intercepting packets. Second, the attacker consumes the intercepted packets without any forwarding. However, the attacker runs the risk that neighboring nodes will monitor and expose the ongoing attacks [12].

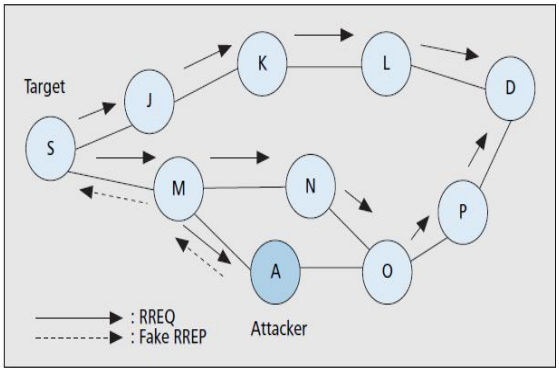

Figure 3.2: Black hole Attack

3) Rushing Attack: Two colluded attackers use the tunnel procedure to form a wormhole. If a fast transmission path (e.g. a dedicated channel shared by attackers) exists between the two ends of the wormhole, the tunnelled packets can propagate faster than those through a normal multi-hop route. This forms the rushing attack [13].

4) Byzantine Attack: A compromised intermediate node works alone, or a set of compromised intermediate nodes works in collusion and carry out attacks such as creating routing loops, forwarding packets through non-optimal paths, or selectively dropping packets, which results in disruption or degradation of the routing services [14].

5) Routing Messages Flooding Attack: Flooding attacks are basically classified into two types as control packet flooding (hello flooding, RREQ flooding and RREP flooding) and data packet flooding, which have the goal to disrupt the routing discovery or the maintenance phase within MANET. In flooding attack a malicious node/an attacker's main goal is to exhaust the network resources like network bandwidth and consume the resources of an authentic network user like computational and battery power. Furthermore influencing the network performance, by hindering the proper execution of routing algorithm during route discovery [15][16]. Using RREQ or RREP flooding a malicious node causes the routing table overflow and prevents the creation of actual routes by sending multiple RREQ or RREP packets to nonexistent recipients on a very short interval of time. Hello flooding is a active attack [17] in which a malicious node floods Hello packets unnecessarily to result in congestion and preventing its neighbour to receive other packets.

6) Resource Consumption Attack: This is also known as the sleep deprivation attack. An attacker or a compromised node can attempt to consume battery life by requesting excessive route discovery, or by forwarding unnecessary packets to the victim node [18].

7) Location Disclosure Attack: An attacker reveals information regarding the location of nodes or the structure of the network. It gathers the node location information, such as a route map, and then plans further attack scenarios. Traffic analysis, one of the subtlest security attacks against MANET, is unsolved. Adversaries try to figure out the identities of communication parties and analyse traffic to learn the network traffic pattern and track changes in the traffic pattern.

D. Transport Layer Attacks

1) SYN Flooding Attack: In SYN flooding attack main goal of attacker is to create a multiple number of half opened TCP connections as a legitimate user, but never completes the synchronization process by completing the handshake to fully open the connection [19]. In this attack adversary node using flooding via synchronization of packets, exhausts the resources of an authentic node. This attack makes an authentic node fail to initialize any new connection.

2) Session Hijacking: In session hijacking attack an attacker tries to get the identity (IP address) of the victim node [19]. Initially attacker determines the particular sequence which is expected by the target node by spoofing the IP address of the victim. Then attacker tries to perform a DoS attack on the victim node and thinks to continue the session with the target node.

E. Application Layer Attacks

1) Repudiation Attack: Repudiation attack happens when application/system doesn't control or tracks log users' actions, permitting vulnerable manipulations and forging the identifications of new actions. Encryption mechanisms and firewalls used in various layers are insufficient for providing security to packets. This attack leads to manipulation of data stored on log files making it invalid or misleading. Basically repudiation attack refers to a user denying about his participation in an action or a transaction.

2) Data Corruption: The application layer supports many protocols such as HTTP, SMTP, and FTP which includes malicious codes. Malicious codes are spread over the network widely and can affect both operating system and user data or programs. Malicious codes are nothing but a part of software system or script that causes undesired effects, security breaches or damage to computer system. These include viruses, worms, Trojan Horses, backdoors malicious active contents.

F. Multi-Layer Attacks

1) Denial-of-Service (DOS): Another type of packet forwarding attack is the denial-of-service (DOS) attack via network-layer packet blasting, in which the attacker injects a large amount of junk packets into the network. These packets waste a significant portion of the network resources, and introduce severe wireless channel contention and network congestion in the MANET. At the network layer, the routing process can be interrupted through routing control packet modification, selective dropping, table overflow, or poisoning. At the transport and application layers, SYN flooding, session hijacking, and malicious programs can cause DoS attacks.

2) Impersonation Attack: A malicious node can precede an attack by altering its MAC or IP address in the control message or persuade nodes to change their routing tables pretending to be a friendly node. It is treated as the initial case in most of the attacks and further goes for more sophisticated attacks.

3) Man-in-the-middle Attack: An attacker sits between the sender and the receiver and sniffs any information being sent between two ends.

IV. SECURITY ATTRIBUTES

MANET Security can be described by the analysis of certain attributes. These attributes are described thoroughly in this section.

A. Availability

The term Availability means the ability to provide services at any situation without considering its security state [3]. DoS attack mostly affects this attribute.

B. Integrity

Integrity of a message guarantees its identity during transmission. Integrity can be compromised mainly in two ways; malicious altering and Accidental altering. In malicious altering, a message can be removed, replayed or revised by an adversary with malicious goal; on the other hand, a message is lost or its content is changed due to some benign failures, which may be transmission errors during communication or hardware errors such as hard disk failure occurs in accidental altering.

C. Non-repudiation

Non-repudiation is related to a fact that if a node sends a message, later that node cannot deny that the message was sent by it. By producing a signature for the message, we can maintain non-repudiation. In public key cryptography, a node A signs the message using its private key. All other nodes can verify the signed message by using A's public key, and A cannot deny about the message.

D. Confidentiality

Confidentiality indicates that certain information's are only accessible to their authorized entities and never disclosed to unauthorized entities.

E. Authenticity

Authenticity assuring participation of genuine participants in communication and not impersonators [3]. The communication participants must prove their identities to avoid authorized access to resources and sensitive information.

F. Authorization

Authorization is a process in which an entity is issued a credential, which specifies the privileges and permissions it has and cannot be falsified, by the certificate authority.

G. Access control

The goal of access control is to prevent unauthorized use of network services and system resources. It governs the way the users can have accesses to data. Access control mechanism tied to authentication attributes. Access control involves the mechanism for forming a group of nodes, communicating a new logged node with other nodes present before in the network etc.

H. Anonymity

Anonymity means that all the information that can be used to identify the owner of the node should be kept private and not be distributed by the node itself or the system software for protecting the privacy of the node from arbitrary disclosure to any other entities.

V. SECURITY SCHEMES

A variety of security mechanisms have been invented to securing a MANET. Broadly we can classify them into two approaches: proactive and reactive.

Proactive mechanism is also known as preventive mechanism. In proactive approach we attempt to provide first line of defence typically through various cryptographic techniques such as hash functions, threshold cryptography, digital signature, asymmetric and symmetric key cryptography etc. On the other hand, the reactive mechanism seeks to detect threats a posteriores providing a second line of defence and react accordingly. Each approach has its own merits and is suitable for addressing different issues in the entire domain. For example, most secure routing protocols adopt the proactive approach in order to secure routing messages exchanged between mobile nodes, while the reactive approach is widely used to protect packet forwarding operations[15] [16].

A. Defence Method Against Wormhole Attacks

Wormhole attack is a threatening attack again routing protocols for the mobile ad hoc networks [20]. In the wormhole attack, an attacker records packets (or bits) at one location in the network, tunnels them (possibly selectively) to another location, and replays them there into the network. The replay of the information will make great confusion to the routing issue in mobile ad hoc network because the nodes that get the replayed packets cannot distinguish it from the genuine routing packets.

The concepts of Geographical and Temporal packet leashes were introduced first for the detection and prevention of wormholes by Hu *et al.* [21]. A leash is defined as any added information to the packet for the purpose of protecting against the wormhole. The temporal leashes ensure that the packet has an upper bound on its lifetime, which restricts the maximum travel distance. In temporal leashes, accurate clock synchronized clocks are used to restrict the propagation time of packets. Temporal lashes use TIK protocol which stands for TESLA with instant key disclosure, and is an extension of the TESL protocol [22]. When used in conjunction with precise timestamps and tight clock synchronization can prevent wormhole attacks. The geographical leashes ensure that the recipient of the packet is within a certain distance from the sender. In geographic leashes, loose clock synchronization and location information are used to restrict the migration distance of packets. Extra hardware GPS or other positioning systems are used to provide the clock synchronization and location information. Both geographical and temporal leashes need to add authentication data to each packet to protect the leash, which add processing and communication overhead.

Tran Van Phuong *et al*. [23] proposed the wormhole detection method in MANET and suggested time-based mechanism using the 'Round Trip Time (RTT)' value. The RTT is the time that elapsed for a routing packet to a remote node and back again when the route is established. To calculate RTT values, the time between sending the Route Request packet (RREQ) and receiving the Route Reply packet (RREP) on every intermediate node is considered. If a route has a considerably longer RTT value, this may indicates that a wormhole link exists between two nodes. Wormhole is identified based on the fact that transmission time between two bogus neighbors created by wormhole is considerably higher than that between two authentic neighbors which are with in radio range of each other. This mechanism do not require any special hardware and easy to implement but it can not detect exposed attacks because no fake neighbor is created in exposed attacks. An assumption made in which is not always realistic that the source node and the destination node are trustable. Also the attackers can fabricate the time stamp of RREQ or RREP to evade the detection rule.

Hu and Evans [24] propose a solution to wormhole attacks for ad-hoc networks in which all nodes are equipped with directional antennas. Nodes use directional antennas to transmit packets to their neighbor nodes in a particular direction. Each couple of nodes has to examine the direction of received signals from its neighbor. It is also assumed that all antennas on nodes are aligned. The process of neighbor discovery is implemented in a secure way using directional antennas. However, it is probably infeasible to deploy directional and aligned antennas on all of mobile nodes in practice. Hence, the neighbors relation is set only if the directions of both pairs match.

Khalil *et al.* [25] propose a protocol for wormhole attack discovery in static networks they call LiteWorp. The basic method used is local monitoring whereby a node monitors traffic in and out of its neighboring nodes and uses a data structure of first and second hop neighbors. The guard node is a common neighbor of two nodes to detect a legitimate link between them. The guard node can detect the wormhole if one of its neighbors is behaving maliciously. LiteWorp does not require any specialized hardware, such as directional antennas or fine granularity clocks. In a sparse network, however, it is not always possible to find a guard node for a particular link.

A statistical analysis of multipath (SAM) [26] is proposed to detect wormhole attacks in the network adopting multi-path routing protocol. Due to tunneling by wormhole nodes, the number of hops of the path with wormhole nodes appears to be smaller than normal paths. Thus, the routing path with the wormhole nodes is more attractive to routing discovery of the sources. Through statistics calculation of relative frequency of each routing path, the path that has the biggest relative frequency is identified as the path with the wormhole nodes. However, the drawback is that, in non-multipath routing protocol e.g., AODV, this proposal cannot work.

Recently a method of providing security against wormhole attacks to a MANET by learning about the environment dynamically and adapting itself to avoid malicious nodes was introduced with the assistance of Honey pot [27]. The principle scope of a honey pot is to discover and learn the actions of the intruders and that to improve the network security. Honey pot is a trap to detect, capture, and misguide the intruders who try to attack the system or gain unauthorized access to it. Honey pots can be used to know the methodology used by the intruder, detect the threats, tools used and vulnerabilities the attackers are looking for, know the motives of an attacker and distract the attacker and provide early warning to the system about the attack.

B. Defence Against Blackhole Attacks

Some secure routing protocols, such as the security-aware ad hoc routing protocol (SAR) [28], can be used to defend against blackhole attacks. The security-aware ad hoc routing protocol is based on on-demand protocols, such as AODV [29] or DSR. In SAR, a security metric is added into the RREQ packet, and a different route discovery procedure is used. Intermediate nodes receive an RREQ packet with a particular security metric or trust level. At intermediate nodes, if the security metric or trust level is satisfied, the node will process the RREQ packet, and it will propagate to its neighbours using controlled flooding. Otherwise, the RREQ is dropped. If an end-to-end path with the required security attributes can be found, the destination will generate a RREP packet with the specific security metric. If the destination node fails to find a route with the required security metric or trust level, it sends a notification to the sender and allows the sender to adjust the security level in order to find a route.

C. Defence Against Impersonation and Repudiation Attack

ARAN [30] can be used to defend against impersonation and repudiation attacks. ARAN provides authentication and non-repudiation services using predetermined cryptographic certificates; certified keys and certified node characteristics are used for end-to-end authentication. Route discovery is accomplished by broadcasting a route discovery message *RDP* from the source node. The reply message *REP* is unicast from the destination to the source. Each hop verifies the signature of the previous hop and replaces it with its own, authenticating routing messages at each intermediate hop in both directions.

D. Watchdog and Path rater

Marti et al. [31] proposed the concept of watchdog and path rater to improve performance of ad hoc networks in the presence of disruptive or misbehaving nodes. A misbehaving node may be overloaded, selfish, malicious, or broken in nature. Watchdog copies packets to be forwarded into a buffer and monitors the behaviour of the adjacent node to these packets. Watchdog promiscuously snoops the packets and if matches with the observing node's buffer, then they are discarded; whereas packets staying in the buffer beyond a timeout period without any successful match are flagged as having been dropped or modified. The node responsible for forwarding the packet initially noted as being suspicious and later on making greater number of violations marked to be malicious. Information about malicious nodes is passed to the path rater component for inclusion in path rating evaluation. Path rater works on an individual node to rate all the neighbouring nodes in

its network with respect to their reliabilities based upon the information passed by the watchdog. Each node starts with a neutral rating which is modified during packet routing depending upon their behaviour and reliability. Misbehaviour and unreliability of nodes are distinguished separately from each other.

E. Secure Adhoc Routing Approach using Localize Self healing Communities

The "self-healing community" based security is proposed by Jiejun King *et. al*. [32] which shows effectiveness towards defending adhoc routing protocols against adversary nodes. In community based security, node redundancy explored at each forwarding step based on per-community basis instead of per-node basis. A self healing community can be created or configured with compatibility to adhoc routing protocols. Further they can be reconfigured to adapt the changes in the network due to mobility, channel fluctuation, addressing and resolving non-cooperative nodes etc. throughout the common entire path a chain of self healing communities may be present, where each community comprising of multiple service provider peer members. A self healing community functions well until at least one cooperative node in the community exists.
Self healing community defends the attacks that use n cooperative network members and distinguished packet losses to deplete adhoc network resources by providing a countermeasure using the cooperative network members to tolerate the presence of non cooperative members and stopping disruption attacks locally and immediately, which can't be answered by purely cryptographic solutions. Community based security can be integrated with on demand routing schemes like AODV [33], ARAN [30], DSR [34], Ariadne[35].

F. Secure Message Transmission (SMT)

SMT (secure Message Transmission) protocol combines end-to-end secure and robust mechanism, dispersion of transmitted data, simultaneous usage of multiple paths and adapting the dynamic changes in the network. SMT mainly supports quality of service (QoS) for real time traffic.

In SMT source and destination nodes employ a secure communication in between them by authenticating each other. Then a set of diverse paths are found in between the source and destination node from the current network topology. Source disperses a message into N number of pieces [36] and transmit them across the paths, so that destination can reconstruct the original dispersed message by combining successfully received pieces. Each dispersed piece assigned with a MAC [37] or verifying its integrity, reply protection and authenticity of origin. Destination acknowledges each successfully received message piece by a feedback to the source. If sufficient number of pieces are received successfully at the destination then the message is reconstructed, otherwise I awaits for the missing packet that are retransmitted by the source. Source re-encodes and re-allocates the undelivered messages over the path set for the transmission.

The end nodes need to be successfully associated to each other, where as none of them needs to be securely associated with any of the remaining nodes in the network. As a result no cryptographic operations are needed at the intermediate nodes. Using feedback mechanism, a successfully received piece implies route to be operational while a failure indicates the route to be broken or compromised.

G. Intrusion Detection Techniques

An Intrusion Detection System [38] (or IDS) generally detects unwanted manipulations to systems [39]. In IDS basically two types of models are implemented; anomaly detection and misuse detection [40]. It works in three basic steps; to control the collection of data (monitor), decides the data collected indicates an intrusion or not (analyze), and manages the response action to the intrusion (response). Intrusion Detection may work in a distributive or cooperative environment for MANET. Each mobile node in a MANET has an individual IDS agent running independently to monitor local activities and identify possible intrusions. Various solutions are proposed to address intrusion detection in MANET[41].

H. Message Authentication Primitives

1) MAC (message authentication codes): MAC algorithms referred as keyed hash functions [42] as they use one way hash function and take a secret key as argument to produce a fixed length output from an arbitrary length input message. For two nodes with a shared secret key K, a authentication tag $T=MAC_k(P)$ is generated for message P using key K by the sender and(P,T) pair is sent to the receiver. Using the same key K and the authentication tag the message pair is verified on the receiver side, assuring authentication to the legitimate users only.

2) CMAC: CMAC[43] is a derived version of CBC-MAC[44] (Cipher-Block-Chaining) in which the plaintext or the input message is broken into N block encrypted iteratively and XORed with next block until the last block. The last block is XORed with two key dependent constants to yield a authentication tag. Here the message size must be known before the computation of the tag and for each message of different length additional encryption needed.

*3) PMAC1 (parallelizable MAC version 1):*PMAC1[45] is a refined version of PMAC [46], in which offsets re generated though finite field multiplications of an offset seed R. further variants of this are propose to be iPMAC[47] which is supporting faster ad word oriented generation of offset.

4) GMAC (galois MAC): GMAC [48] is a variant of the GCM[48] authenticated encryption which follows Carte-Wegman design [49] to reduce the amount of processing for its operation. GMAC are difficult to implement an main focused for powerful platforms.

I. Digital Signature

In RSA like symmetric cryptographic schemes much more computations are needed for the signing and verifying operations of a signature. An attacker node floods victim node with a large number of bogus signatures, exhausting victims computational resources used for verification purpose. Along with that a certificate of revocation (CRL) must have to be kept with each node. Whereas digital signature scheme uses symmetric key cryptography and can be verified by any node that knows the public key of signing node. Same number of pubic/private key pairs needed as the size of the network, which makes digital signature scalable to a large number of receivers. It provides more resilience against DOS attacks and the digital signature approach used by SAODV [50] protocol.

VI. CONCLUSION

It is clear that the security aspects related to Ad Hoc Networks form a very complex problem fields, due to the dynamic and unpredictable nature of most of the Ad Hoc networks. As no recognized infrastructure or centralized administration exists, attackers can access the network with ease. We have discussed about some typical and dangerous vulnerabilities and security threats in the MANET, classified a variety of attacks related to different layers and how the security services can be achieved through various security criteria's. High degrees of security are required for the security sensitive applications of Ad hoc networks as they are inherently vulnerable to security attacks. Therefore security mechanisms are indispensable for Ad Hoc Networks. Ad Hoc Networks need very specialized security methods, as there is no approach fitting all the networks. Because the nodes can be any devices that are depending upon the type of node: and no assumptions on the node can be made.

The research on MANET is still in an early stage. Existing papers are typically based on one specific attack. They could work well in the presence of designated attacks, but there are many unanticipated or combined attacks that remain undiscovered. Research is still being performed and will result in the discovery of new threats as well as the creation of new countermeasures. More research is needed on robust key management system, trust-based protocols, integrated approaches to routing security, and data security at different layers.

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