

# A survey of black hole attacks in wireless mobile Adhoc networks

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*Abstract*--- The black hole attack is one of the well-known security dangers in remote mobile ad hoc network. The interlopers use the escape clause to complete their malicious behaviors in light of the fact that the track revelation process is important and inescapable. Numerous scientists have led diverse location methods to propose distinctive sorts of recognition plans. In this paper, we review the existing results and examine the state-of-the-symbolization steering routines. We not just group these suggestions into single black hole attack and community black hole attack additionally dissect the classifications of these results and give a correlation table.

*Keywords*: mobile ad hoc networks; routing protocols; black hole attack; community black hole attack

## I. INTRODUCTION

Wireless mobile ad hoc network (or essentially Manet all around this paper) is a self-arranging system which is made out of some mobile client gear. These mobile nodes speak with one another without any base, moreover, the sum of the transmission connections are secured through remote medium. As per the correspondence mode specified in the recent past Manet is generally utilized within military reason, calamity zone, individual range network and so on [1]. Nonetheless, there are still numerous open issues about MANETs, for example, security issue, limited transmission data transmission [2], oppressive television messages [3], solid information conveyance [4], alterable connection foundation [5] and confined fittings brought on transforming capacities [6]. The security dangers have been broadly talked about and examined in the wired and remote systems [7], the correspondingly bewildering circumstance has additionally happened in MANET because of the innate outline imperfections [8]. There are numerous security issues which have been concentrated on as of late. For example, snooping attack, wormhole attack, black hole attack [9], routing table flood and harming attack, packet replication, Denial of service (Dos) attacks, distributed Dos (Ddos) attacks, and whatnot [10]. Particularly, the misconduct routing issue [11] is one of the advanced security dangers, for example, black hole attack. A few scientists propose their protected tracking thought [12-15] to explain this issue, yet the security issue is still unable to counteract totally. In this paper, we keep tabs on diverse sorts of black hole attack in MANET which might be isolated into normal black hole attack strike and community black hole attack. Also, some discovery plans are talked about unmistakably and similarly. The assessment measurements of routing protocol include packet delivery ration (PDR), versatility variety with aggregate number of blunders, packet routing overhead, end-to-end delay by

shifting in hub thickness [16]. In the accompanying, we first present various types of routing protocols in Sec. 2, which incorporates proactive protocol, reactive routing and hybrid routing protocol. In Sec. 3 and Sec. 4, we separately group the black hole attacks from their vindictive working movements into black hole attacks and collaborative black hole attack, and additionally examine the rowdiness to give the examinations between identified writings in both segments. At last, we close this review in Sec. 5.

## II. BACKGROUND

There is bounty and diverse routing protocols in MANET and sorts of examinations have been finished in later decades [17, 18]. In this area, we present the celebrated internationally and prominent tracking protocols in MANET. Soon after a versatile hub needs to correspond with a target hub, it might as well telecast its available status to the neighbors because of the present routing data is new. As per how the data is obtained, the routing protocol could be ordered into proactive, reactive and hybrid routing.

### A. PROACTIVE (TABLE-DRIVEN) ROUTING PROTOCOL

The proactive routing is likewise called table-driven steering convention. In this routing protocol, portable hubs intermittently telecast their tracking data to the neighbors. Every hub needs to uphold their routing table which not just records the neighboring hubs and reachable hubs additionally the amount of bounces. As it were, the greater part of the hubs needs to assess their neighborhoods with the assumption that the network topology has changed. Consequently, the detriment is that the overhead climbs as the network estimate increments, a noteworthy correspondence overhead inside a bigger arrange topology. Nonetheless, the focal point is that network status could be promptly reflected if the malicious attacker joins. The most natural sorts of the proactive sort are destination sequenced distance vector (DSDV) [19] routing protocol and optimized link state routing (OLSR) [20] protocol.

### B. REACTIVE (ON-DEMAND) ROUTING PROTOCOL

The reactive routing is provided with an alternate designation named on-interest routing protocol. Not at all like the proactive routing, the reactive routing is essentially begun when hubs yearning to transmit information packets. The quality is that the squandered data transfer capacity instigated from the cyclically telecast might be decreased. By the by, this may likewise be the deadly wound when there are any malicious hubs in the nature. The shortcoming is that passive routing system accelerates some packet misfortune. Here we quickly portray two common on-

demand routing protocol which are ad hoc on demand distance vector(AODV) [21] and dynamic source routing(DSR) [22] protocol.

AODV is built dependent upon DSDV routing. In AODV, every hub just records the following jump data in its tracking table yet administers it for manage a routing way from source to end of the line hub. Provided that the end hub can't be arrived at from the source hub, the track revelation process will be executed instantly. In the track finding stage, the source hub shows the route request (RREQ) packet first. At that point all middle of the road hubs accepts the RREQ packets, yet parts of them send the route reply (RREP) packet to the source hub if the end hub data is happened in their routing table. Then again, the track support methodology is begun when the network topology has changed or the association has fizzled. The source hub is educated by a track slip (RRER) packet first. At that point it uses the present routing data to choose another tracking way or restart the track disclosures prepare for upgrading the data in routing table.

The configuration thought of DSR is dependent upon source routing. The source routing implies that every information protocol holds the routing way from source to objective in their headers. Dissimilar to the AODV which just records the following jump data in the routing table, the portable hubs in DSR uphold their track reserve from source to objective hub. Regarding the above discourse, the routing way might be dictated by source hub on the grounds that the routing data is recorded in the track store at every hub. Nonetheless, the execution of DSR reductions with the versatility of network expansions, a more level packets conveyance degree inside the higher organize portability.

### C. HYBRID ROUTING PROTOCOL

The Hybrid tracking protocol joins together the focal points of proactive protocol and reactive protocol to beat the imperfections of them. The majority of half and half routing protocol are planned as a hierarchical or layered system structure. To start with, proactive routing is utilized to totally accumulate the new routing data, then utilizing the reactive routing to keep up the routing data when network topology changes. The familiar hybrid routing protocol are zone routing protocol (ZRP) [23] and temporally-ordered routing algorithm (TORA) [24].

### III. SINGLE BLACK HOLE ATTACK

A black hole problem means that one malicious node utilizes the routing protocol to claim itself of being the shortest path to the destination node, but drops the routing packets but does not forward packets to its neighbors. A single black hole attack is easily happened in the mobile ad hoc networks [25]. An example is shown as Figure 1, node 1 stands for the source node and node 4 represents the destination node. Node 3 is a misbehavior node who replies the RREQ packet sent from source node, and makes a false response that it has the quickest route to the destination node. Therefore node 1 erroneously judges the route discovery process with completion, and starts to send data packets to node 3. As what mentioned above, a malicious node probably drops or consumes the packets. This suspicious node can be regarded as a black hole problem in

MANETs. As a result, node 3 is able to misroute the packets easily, and the network operation is suffered from this problem. The most critical influence is that the PDR diminished severely.

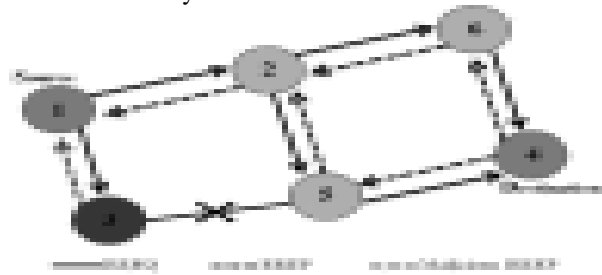


Fig. 1: The single black hole problem

Figure 1 is an example of single black hole attack in the mobile ad hoc networks [25]. Node 1 stands for the source node and node 4 represents the destination node. Node 3 is a misbehavior node who replies the RREQ packet sent from source node, and makes a false response that it has the quickest route to the destination node. Therefore node 1 erroneously judges the route discovery process with completion, and starts to send data packets to node 3. In the mobile ad hoc networks, a malicious node probably drops or consumes the packets.

Schemes	Routing protocol	Simulator	Detection type	Publication year	Results	Defects
Neighborhood-based and Routing Recovery [26]	AODV	NS-2	Single detection	2003	The probability of one attacker can be detected is 93%	Failed when attackers cooperate to forge the fake reply packets
Redundant Route and Unique Sequence Number Scheme [27]	AODV	NS-2	Single detection	2004	Verify 75% to 98% of the routes	Attackers can listen to the channel and update the tables for last sequence number
Time-based Threshold Detection Scheme [28]	Secure AODV (SAODV)	GloMoSim	Single detection	2007	The PDR of SAODV is around 98 to 100% when AODV is around 80%	The end-to-end delay increases when the malicious node is away from source node
Random Two-hop ACK and Bayesian Detection Scheme [29]	DSR	GloMoSim-based	Cooperative detection	2007	The true positive rate can achieve 100% when existing 2 witness	The proposed scheme is not efficient when it equals to 3, reducing the true positives

Table 1: Comparison of Single Black Hole Attack Detection Schemes

This suspicious node can be regarded as a black hole problem in MANETs. As a result, node 3 is able to misroute the packets easily, and the network operation is suffered from this problem.

In the following, different detection schemes for single black hole attack are presented in a chronological order. The comparisons of different schemes are shown in Table 1.

#### A. NEIGHBORHOOD-BASED AND ROUTING RECOVERY SCHEME [26]

Bo Sun et al. use AODV as their routing example, and claim that the on-demand routing protocols such as DSR are also suitably applied after a slightly modified. The detection scheme uses on a neighborhood-based method to recognize the black hole attack, and a routing recovery protocol to build the correct path. The neighborhood-based method is employed to identify the unconfirmed nodes, and the source node sends a *Modify\_Route\_Entry* control packet to destination node to renew routing path in the recovery protocol.

In this scheme, not only a lower detection time and higher throughput are acquired, but the accurate detection probability is also achieved. To deserve to be mentioned, the routing control overhead does not increase in Bo Sun et al.'s proposal. However, this scheme is useless when the attackers cooperate to forge the fake reply packets.

#### B. REDUNDANT ROUTE METHOD AND UNIQUE SEQUENCE NUMBER SCHEME [27]

Mohammad Al-Shurman et al. propose two solutions to avoid the black hole attacks in MANET. The first solution is to find more than one route from the source node to the destination node. In other words, there exist some redundant routes within the routing path, and authors assume there are three routes at least in the scenario. The working flow of redundant route mechanism is described briefly as below. First, the source node sends a ping packet, a RREQ packet, to the destination. The receiver who has a route to the destination will reply this request, and a acknowledge examination is executed at source node. Then the sender will buffer the RREP packet until there are more than two received RREP packets, and transmit the buffered packets after identifying a safe route. It represents that there are at lowest two routing paths coexisting at the same time. After that, the source node recognizes the safe route from the number of hops or nodes, and prevents the black hole attacks.

In the second solution, an idea of unique sequence number is mentioned. The sequence value is accumulated; hence it's ever higher than the current sequence number. In this solution, two values are needed to be recorded in two additional tables. One is the last-packet-sequence-numbers for the last packet sent to every node and the other is for the last packet received. When any packet are transmitted or received, these two tables will be updated automatically. According to these two table values, the sender node can identify whether there is malicious nodes or not.

In the simulation results, these two solutions have less RREQ and RREP numbers than AODV. Furthermore, solution two is better than solution one due to the sequence number included in every packet in the original routing protocol. The communication overhead can be eliminated by this solution because of the inbound cryptography method. Nevertheless, the cooperative black hole attacks can't be detected in both proposed solutions. The redundant route

and unique sequence number can be easily broke by two collaborative black hole nodes.

#### C. TIME-BASED THRESHOLD DETECTION SCHEME [28]

Latha Tamilselvan et al. propose a solution based on an enhancement of the original AODV routing protocol. The major design concept is setting timer in the *RimerExpiredTable* for collecting the other request from other nodes after receiving the first request. It will store the packet's sequence number and the received time in a *Collect Route Reply Table (CRRT)*, counting the timeout value based on the arriving time of the first route request, judging the route belong to valid or not based on the above threshold value. The simulation using global mobile simulator (GloMoSim) shows that a higher packet delivery ratio is obtained with only minimal delay and overhead. But the end-to-end delay might be raised visibly when the suspicious node is away from the source node.

#### D. RANDOM TWO-HOP ACK AND BAYESIAN DETECTION SCHEME [29]

Djamel Djenouri et al. propose a solution to monitor, detect, and isolate the black hole attack in MANETs. In the monitor phase, an efficient technique of random two-hop ACK is employed. The simulation result shows that random two-hop ACK hugely reduces the cost with a higher true and lower false detection than ordinary two-hop ACK scheme. A local judgment approach based on Bayesian technique is penetrated in the detection phase. The proposed Bayesian detection method does not use any periodic packets exchanging, therefore the familiar overhead problem can be eliminated from this solution. And after a mobile node is determined that it is a misbehavior node by the proposed detection scheme, this judgment must be proved by all nodes. Hence, authors propose a witness-based protocol that forces the recognized node to ensure this decision from other nodes. Before isolating the misbehavior node at the same time, the witness-based protocol enforces the detector to gather *k* witnesses at least. However, the decision of *k* value is a trade-off problem. A higher *k* value eliminates the false detection and attack probability, but reduces the detection efficiency, and vice versa.

The simulation shows that the proposed solution can achieve a lower false detection rate and higher true detection rate than watchdog (WD) approach. The solution utilizes cooperatively witness-based verification, nevertheless, it's difficult to prevent collaborate black hole attack for the judgment phase is only running on local side. It might be failed if some malicious nodes deceive the detection node cooperatively.

#### E. RESOURCE-EFFICIENT ACCOUNTABILITY (REACT) SCHEME BASED ON RANDOM AUDITS [30]

William Kozma Jr. et al. propose a reactive misbehavior detection scheme called REACT scheme. When the performance is descended between source and destination node, the REACT is triggered automatically. REACT constitutes of three phases: (a) the audit phase, (b) the search phase and (c) the identification phase. To simply describe the REACT scheme, the target node sends a feedback to the

sender when a biggish packet drop ratio is recognized. Then the source node chooses an audit node, and utilizes the bloom filter to produce a behavioral proof. Finally, the segment location of malicious node can be distinguished from comparing the source node's behavioral proof.

The simulation shows that REAct scheme not only reduces the communication overhead, but enlarges the identification delay because REAct is based on reactive DSR routing protocol. Furthermore, there are some critical weaknesses in REAct. First, the REAct is designed for non-cooperative black hole attack only. It's unsuccessful in the collaborative black hole scenario because other malicious node is able to manipulate a fake proof and send to the audit node. Second, the behavioral proof only records the information of transmission packets rather than the nodes. It fails to verify who the producer of the behavioral proof is. Finally, using the binary search method to find the attacker is easily expose audit node's information. The attacker is able to cheat source node by changing its behavior dynamically.

#### F. DETECTION, PREVENTION AND REACTIVE AODV (DPRAODV) SCHEME [31]

A new control packet called ALARM is used in DPRAODV, while other main concepts are the dynamic threshold value. Unlike normal AODV, the RREP\_seq\_no is extra checked whether higher than the threshold value or not. If the value of RREP\_seq\_no is higher than the threshold value, the sender is regarded as an attacker and updated it to the black list. The ALARM is sent to its neighbors which includes the black list, thus the RREP from the malicious node is blocked but is not processed. On the other hand, the dynamic threshold value is changed by calculating the average of dest\_seq\_no between the sequence number and RREP packet in each time slot. According to this scheme, the black hole attacks not only be detected but also prevented by updating threshold which responses the realistic network environment.

In the simulation results, the packet delivery ratio is improved by 80-85% than AODV when under black hole attack, and 60% when traffic load increases. The advantage of DPRAODV is that it achieves an obviously higher packet delivery ratio than the original AODV, except for it takes a little bit higher routing overhead and end-to-end delay. But DPRAODV simply detects multiple black holes rather than cooperative black hole attack.

#### G. Next Hop Information Scheme [32]

N. Jaisankar et al. propose a security approach which is composed of two parts, detection and reaction. In the first part, the field\_next\_hop is added to the RREP packet. Before source node sends the data packets, the leading RREP packet is examined between intermediate node and destination node. Each node maintains a black identification table (BIT), and the fields in this table are <source, target, current\_node\_ID, Packet\_received\_count (PRC), Packet\_forwarded\_count (PFC), Packet modified count (PMC)>. Then the PMC is updated by tracing the BIT from their neighborhoods. If the node acts correctly, the corresponding count value multiplies. After that, a malicious node can be found out if the number of receiving packets differentiates from sending packets. The second part is isolating the black hole, thus each node maintains an

isolation table (IT) and stores the black node ID. The ID is broadcasted to all nodes in order to eliminate the malicious node by checking the isolation table.

In the simulation result, the packet delivery ratio is improved by 40-50% than AODV when facing attacks, and the number of packets dropped is decreased by 75-80%. Unlike the conventional next hop method, this solution modifies the original RREP packets to collect the information of malicious nodes rather than sending further packets. The proposed solution provides a higher packet delivery ratio and lower packet loss rate than conventional with little additional delay.

#### H. NITAL MISTRY ET AL.'S METHOD [33]

Nital Mistry et al. add a new table Cmg\_RREP\_Tab, a new timer MOS\_WAIT\_TIME and a variable Mali\_node to the original AODV routing protocol. The proposed solution is basically modifies an additional function Pre\_ReceiveReply viz Packet P.

The definitions of innovative functions are clarified first. The RREP\_WAIT\_TIME is a time period during the source node sends first RREP packet until receive the RREP control messages. And the MOS\_WAIT\_TIME is half the value of RREP\_WAIT\_TIME.

The basic framework of proposed IDS is introduced as follow. In the beginning, the IDS nodes execute the ABM function in a sniff mode. According to the irregular difference between the routing information transmitted from a dubious node, a value of the suspicious node can be estimated by ABM. If the value exceeds the predefined threshold value, it can be regarded as a black hole. When a normal node receives a Block message broadcasted by the IDS node, this node adds the malicious node which stored in the Block message into the Block table. After that, the normal node forwards RREP packet to establish the routing. If the RREP packet is acquired from its neighbor node which noted in the Block table, the normal node drops this RREP packet to prevent the malicious attack.

The proposed IDS scheme simulated under the existing one and two black holes network environment. The packet loss rate for AODV are 92.40% (one black hole) and 97.32% (two black hole), and 10.05% (threshold as 5) to 13.04% (threshold as 10) for IDS system with 9 IDS nodes. However, how to decide the threshold value does not be explained clearly in this paper.

## IV. COLLABORATIVE BLACK HOLE ATTACK

There are various mechanisms have been proposed for solving single black hole attack in recent years. However, many detection schemes are failed in discussing the cooperative black hole problems. Some malicious nodes collaborate together in order to beguile the normal into their fabricated routing information, moreover, hide from the existing detection scheme. As a result, several cooperative detection schemes are proposed preventing the collaborative black hole attacks [35].

In the following, different detection schemes for the cooperative black hole attack are presented in a chronological order. The comparison of different schemes is shown in the Table 5.

### A. DRI TABLE AND CROSS CHECKING SCHEME [36,37]

Sanjay Ramaswamy et al. exploit data routing information (DRI) table and cross checking method to identify the cooperative black hole nodes, and utilize modified AODV routing protocol to achieve this methodology.

Every node needs to maintain an extra DRI table, 1 represents for true and 0 for false. The entry is composed of two bits, "From" and "Through" which stands for information on routing data packet from the node and through the node respectively. As shown in Table 6, the entry 1 1 implies that node 1 has successfully routed data packets from or through node 5, and the entry of 0 0 means that node 1 has not routed any data packets from or through node 3.

The procedure of proposed solution is simply described as below. The source node (SN) sends RREQ to each node, and sends packets to the node which replies the RREP packet. The intermediate node (IN) transmits next hop node (NHN) and DRI table to the SN, then the SN cross checks its own table and the received DRI table to determine the IN's honesty. After that, SN sends the further request to IN's NHN for asking its routing information, including the current NHN, the NHN's DRI table and its own DRI table. Finally, the SN compares the above information by cross checking to judge the malicious nodes in the routing path.

Authors propose a detection method to overcome the multiple black hole problems and the collaborative attacks, and submit the simulation result in [37]. The experiment result shows that this solution performs an almost 50% better than other solutions. However, it wastes 5 to 8% communication overhead, and slightly increases the packet loss percentage because of the secure route discovery delay.

### B. DISTRIBUTED COOPERATIVE MECHANISM (DCM) [38]

Chang Wu Yu et al. propose a distributed and cooperative mechanism viz. DCM to solve the collaborative black hole attacks. Because the nodes works cooperatively, they can analyze, detect, mitigate multiple black hole attacks. The DCM is composed of four sub-modules which shown as Figure 2.

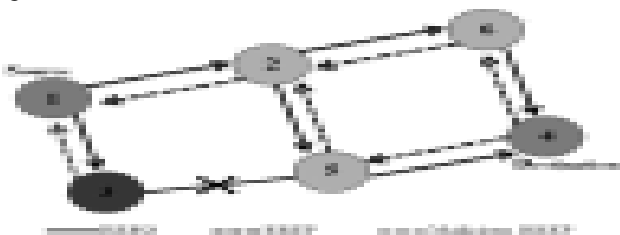


Fig. 2: is working produces and the four sub-modules of Distributed Cooperative Mechanism (DCM).

In the local data collection phase, an estimation table is constructed and maintained by each node in the network. Each node evaluates the information of overhearing packets to determine whether there is any malicious node. If there is one suspicious node, the detect node initiates the local detection phase to recognize whether there is possible black hole. The initial detection node sends a check packet to ask the cooperative node. If the inspection value is positive, the questionable node is regarded as a normal node. Otherwise

the initial detection node starts the cooperative detection procedure, and deals with broadcasting and notifying all one-hop neighbors to participate in the decision making. Finally, the global reaction phase is executed to set up a notification system, and sends warning messages to the whole network.

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In the simulation results, the notification delivery ratio is from 64.12 (*thr* as 1) to 92.93% (*thr* as 3) when using different threshold values. Compare with the popular AODV routing protocol in MANET, the simulation result shows that DCM has a higher data delivery ratio and detection rate even if there are various black hole nodes. Even though the control overhead can be reduced due to the distributed design method, DCM wastes few overhead inevitably.

### V. HASH BASED SCHEME [39]

Weichao Wang *et al.* design a hash based defending method to generate node behavioral proofs which involve the data traffic information within the routing path. The developing mechanism is based on auditing technique for preventing collaborative packet drop attacks, such as collaborative black hole and grey hole problems. The proposed solution is originated from an audit-based detection method videlicet REAct [30], which is also discussed in the subsection 0 in this survey.

The vulnerability of REAct system is that cooperative adversaries can specialize in attacker identification phase by sharing Bloom filters of packets between them. The major difference between these two schemes is discussed as follows. A hash based node behavioral proofs is proposed to defend the collaborative attacks. The audited node  $n_i$  is needed and settled by the source node  $S$ , and then  $S$  sends the sequence numbers of selected packets to auditing node. After source node sends out these packets, an additional

random number  $t_0$  is attached to the tail of every packet. The intermediate node  $n_i$  combines the received packet and its own random number  $r_i$  to calculate its value  $t_i$ , and this operation is continued within every intermediate node until  $n_i$  receives the packet. Nevertheless, this paper doesn't give the results, so that it's hard to figure out the enhancement.

#### VI. HASHED-BASED MAC AND HASH-BASED PRF SCHEME [40]

Zhao Min and Zhou Jiliu propose two hash-based authentication mechanisms, the message authentication code (MAC) and the pseudo random function (PRF). These two proposals are submitted to provide fast message verification and group identification, find the collaborative suspicious hole nodes and discover the secure routing path to prevent cooperative black hole attacks.

The public key infrastructure (PKI) is difficult to utilize in MANET due to the inherently design disadvantages, which is no centralized infrastructure. To deserve to be mentioned, authors overcome this bottleneck and design an authentication mechanism. The key point of this solution is that each node acquires a secret key  $K_i$ , and  $K_i = G_k(r_i)$ . The sharing key  $K_i$  is undisclosed to all other nodes, hence, it is formulated by choosing a random number  $r_i$  and repeatedly applying PRF on  $r_i$  by  $k$  times. When source node receives a packet, it checks  $K_{i-d}$  to find whether the key used for the MAC is disclosed or not, and checks the MAC when  $K_i$  is disclosed. After checking the above two conditions, this packet is regarded as available packet and the route is confirmed as a secure route. On the other hand, authors propose the other solution based on time stamp method and global symmetric cryptosystem. However, we don't discuss this solution due to the time stamp method is well-known, and the global symmetric cryptosystem is designed based on accompanying the time delay range.

The simulation result shows that both solutions have better data delivery ratio than AODV routing protocol. But, the detection time increases as the pause time raises, and the control overhead of both solutions is higher than the ordinary AODV. Moreover, the malicious node is able to forge the false reply packets and try to avoid the detection mechanism.

#### VII. BACKBONE NODES (BBN) AND RESTRICTED IP (RIP) SCHEME [41]

Vishnu K. and Amos J. Paul address a mechanism to detect and remove the black and gray hole attack. This solution is able to find the collaborative malicious nodes which introduce massive packet drop percentage. An idea of the group of backbone nodes used in MANET was originated from [42]. Vishnu K. *et al.* refer this method to penetrate their system model, and also add a novel scheme videlicet restricted IP (RIP) to avoid collaborative black and gray attacks.

The detailed procedure is characterized as the following. In this solution initially a backbone network is established which constructed from a set of strong backbone nodes (BBNs) over the ad hoc network. These trusted nodes can be allowed to allocate the RIP when there is new arrival node joining. A node acquires a RIP which means that it is

provided with the routing authority. The source node requests the nearest BBN to allot a RIP before transmitting data packets, then sending RREQ to the destination node and the address of RIP. If the source node only receives the destination node's RREP, it means that there is no black hole. In the case when the source obtains the RREP packet from RIP, it implies that adversary might be existed in the network. The RIP's neighbor nodes change to promiscuous mode as a result of the source node sends monitor messages to alert them. These neighborhoods not only monitor the packets of designate nodes but also the suspicious nodes. Furthermore, the source node sends few dummy data packets to test the malicious node. The neighbor nodes monitor the data packet flow and regard it as a black hole if the packet loss rate exceeds the normal threshold, and notify the source node that it is a malicious attacker. Then the neighbor nodes broadcast this alert message through the whole network, and add the malicious nodes to the black hole list. Finally, the attacker's authorization will be deleted and all of nodes drop the response from nodes in the black list.

The proposed solution not only detects black hole but also gray hole attacks, since its methodology does not utilize the trust-based method. However, it's hard to realize that how is the enhanced performance because there is no any simulation result or experiment outcome. Moreover, the proposed system might be crashed if the numbers of attackers are higher than the numbers of normal nodes.

#### VIII. BAIT DSR (BDSR) BASED ON HYBRID ROUTING SCHEME [43]

Po-Chun Tsou *et al.* design a novel solution named Bait DSR (BDSR) scheme to prevent the collaborative black hole attacks. The proposed mechanism is composed of proactive and reactive method to form a hybrid routing protocol, and the major essence is the DSR on-demand routing. This solution is briefly introduced as below.

In the beginning of routing stage, the source node sends bait RREQ packet before starting route discovery. The target address of bait RREQ is random and non-existent. To avoid the bait RREQ inducing the traffic jam problem, BDSR use the same method with DSR. That is all bait RREQ packets only survive for a period time. The malicious nodes are easily expelled from the initial phase, because the bait RREQ is able to attract the forged RREP from black hole node. In authors' mechanism, the generator of RREP is recorded in the RREP's additional field. Therefore the source node can recognize the location of attacker from the reply location of RREP. All of the response sent by the adversaries should be drop. After the initial phase, authors employ the original DSR route discovery procedure. If the data delivery rate is lower than the pre-defined threshold value, the bait procedure will be triggered again to examine the uncertainly suspicious nodes.

Compare with the primitive DSR scheme and watch dog method, the simulation results show that BDSR provides an excellent packet delivery rate. The packet delivery ratio of BDSR is 90% which is more superior to DSR and WD approach. Moreover, the communication overhead is also

lower than watch dog scheme but slightly higher than original DSR routing protocol.

## IX. CONCLUSIONS

Due to the inherent design disadvantages of routing protocol in MANETs, many researchers have conducted diverse techniques to propose different types of prevention mechanisms for black hole problem. In this paper, we first summary the pros and cons with popular routing protocol in wireless mobile ad hoc networks. Then, the state-of-the-art routing methods of existing solutions are categorized and discussed. The proposals are presented in a chronological order and divided into single black hole and collaborative black hole attack.

According to this work, we observe that both of proactive routing and reactive routing have specialized skills. The proactive detection method has the better packet delivery ratio and correct detection probability, but suffered from the higher routing overhead due to the periodically broadcast packets. The reactive detection method eliminates the routing overhead problem from the event-driven way, but suffered from some packet loss in the beginning of routing procedure. Therefore, we recommend that a hybrid detection method which combined the advantages of proactive routing with reactive routing is the tendency to future research direction. However, we also discover that the attacker's misbehavior action is the key factor. The attackers are able to avoid the detection mechanism, no matter what kinds of routing detection used. Accordingly, some key encryption methods or hash-based methods are exploited to solve this problem. The black hole problem is still an active research area. This paper will benefit more researchers to realize the current status rapidly.

## LIST OF ABBREVIATIONS

Acronym: Definition; ABM: anti-black hole mechanism; AODV: ad hoc on-demand distance vector; BBN: backbone nodes; BDSR: bait DSR; BIT: black identification table; CRRT: collect route reply table; DCM: distributed cooperative mechanism; DDoS: distributed denial of service; DoS: denial of service; DPRAODV: detection, prevention and reactive AODV; DRI: data routing information; DSDV: destination sequenced distance vector; DSR: dynamic source routing; GloMoSim: global mobile simulator; IDS: intrusion detection system; IN: intermediate node; IT: isolation table; MAC: message authentication code; MANET: mobile ad hoc network; NHN: next hop node; OLSR: optimized link state routing; PDR: packet delivery ratio; PFC: packet forwarded count; PKI: public key infrastructure; PMC: packet modified count; PRC: packet received count; PRF: pseudo random function; REAct: resource efficient accountability; RIP: restricted IP; RREP: route reply; RREQ: route request; RRER: route error; SAODV: secure AODV; SN: source node; TORA: temporally-ordered routing algorithm; WD: watchdog; ZRP: zone routing protocol.

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