



## Performance analysis and Prevention of Gray Hole and Black Hole Attack in MANET

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**Abstract**— *Wireless ad-hoc network is a temporary network set up by wireless nodes usually moving randomly and communicating without a network infrastructure. Due to the massive existing vulnerabilities in mobile ad-hoc networks, they may be insecure against attacks by the malicious nodes. One of these attacks is the Black Hole Attack against network integrity absorbing all data packets in the network. Since the data packets do not reach the destination node on account of this attack, data loss will occur. In this work the effect of Black hole and Gray Hole attack on DSR protocol has been considered. Simulation has been performed on the basis of performance parameters and effect has been analyzed using NS2 simulator.*

**Keywords**— *DSR Protocol, Gray Hole Attack, Black Hole, False Positive Rate, MANET*

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### I. INTRODUCTION

Wireless adhoc networks are composed of autonomous nodes that are self- managed without any infrastructure. They usually have a dynamic topology such that nodes can easily join or leave the network at any time and they move around freely which gives them the name Mobile Adhoc Networks or MANETs. They have many potential applications, especially in military and rescue operations such as connecting soldiers in the battle or establishing a temporary network in place of one which collapsed after a disaster like an earthquake. In these networks, besides acting as a host, each node also acts as a router and forwards packets to the correct node in the network once a route is established. To support this connectivity nodes use routing protocols such as AODV (Adhoc On Demand Distance Vector) or DSR (Dynamic Source Routing). Wireless ad-hoc networks are usually susceptible to different security threats and black hole attack is one of these. In this type of attack, a malicious node which absorbs and drops all data packets makes use of the vulnerabilities of the on demand route discovery protocols, such as DSR. In the route discovery process of DSR protocol, intermediate nodes are responsible to forward the packets through a fresh path to the destination, sending discovery packets to the neighbour nodes. Malicious nodes abuse this process and they immediately respond to the source node with false information as though they have a fresh enough path to the destination. Therefore source node sends its data packets via this malicious node assuming it is a true path. Black hole behaviour may also be due to a damaged node dropping packets unintentionally [1]. In any case, the end result of the presence of a black hole in the network is lost packets.

In this study, black hole and gray hole attacks are simulated in wireless adhoc networks and evaluated their effects on the network performance are evaluated. This paper, propose a new approach to detect black hole and gray hole attacks by modifying the detecting threshold according to the network's overload. The simulation is made using ns-2 (Network Simulator version 2). Having implemented a new routing protocol which simulates the black hole and gray hole behaviour in ns-2, different tests are performed to compare the network performance with and without black hole and Gray Hole in the network. As expected, the throughput in the network deteriorated considerably in the presence of a black hole or Gray hole. Also the proposed a solution based on ignoring the established route to reduce the adverse effects of the black hole node in an ad-hoc network using DSR as a routing protocol.

The remainder of this paper is organized as follows: Section II presents the related researches. In Section III, Black Hole and Gray hole detection and prevention algorithm over DSR protocol is proposed. Advantage and disadvantage are also discussed. In Section IV, simulation results are discussed followed by conclusion.

#### A. Black and Gray hole attack

Black hole attack disturbs the routing protocol by misleading other nodes about the routing information [2]. A black hole node works in the following scheme: once receiving RREQ and RREP messages, the attacker replies RREP messages directly and claims that it is the destination node. The source node is likely to receive a pseudo-RREP from the attacker before the real RREP returns. Under these conditions, the source node sends data packets to the black hole instead of the destination node. When the source node transmits data packets through the black hole, the attacker discards them without sending back a RERR message. As for gray hole, its activities are similar to a black hole. A gray hole does not drop all data packets but just part of packets. The Gray Magnitude is defined as the percentage of the packets which are maliciously dropped by an attacker. For example, a gray hole is gray magnitude of 60% will drop a data packet with a

probability of 60% and a classical black hole has a gray magnitude of 100%. The black and gray hole attack will bring great damage to the performance of MANETs.

### B. DSR Protocol

DSR is completely on-demand ad hoc network routing protocol collected of two parts: Route Discovery and Route Maintenance. Here, the basic form of Route Discovery and Route maintenance in DSR is described. In DSR, when a node has a packet to send to some destination and does not currently have a route to that destination in its Route Cache, the node initiates Route Discovery to discover a route; this node is known as the initiator of the Route Discovery, and the destination of the packet is known as the Discovery's target. The initiator transmits a Route Request (RREQ) packet as a local broadcast, specifying the target and a unique identifier from the initiator. Each node receiving the Route Request, if it has recently seen this request identifier from the initiator, rejects the Request. Otherwise, it appends its own node address to a list in the Request and rebroadcasts the Request. When the Route Request reaches its target node, the target sends a Route Reply (RREP) back to the initiator of the Request, including a copy of the gathered list of addresses from the Request. When the Reply reaches the initiator of the Request, it caches the new route in its Route Cache. Route Maintenance is the means by which a node sending a packet along a particular route to some destination detects if that route has bricked, for example because two nodes in it have moved too apart. DSR is based on source routing: when sending a packet, the initiator lists in the header of the packet the complete sequence of nodes through which the packet is forwarded [7]. Each node along the route forwards the packet to the next hop indicated in the packet's header, and attempts to confirm this by means of a link-layer acknowledgment or network layer acknowledgment. If, after a limited number of local retransmissions of the packet, a node in the route is unable to make this confirmation, it returns a Route Error to the original source of packet, identifying the link from itself to the next node was broken. The sender then removes this broken link from its Route Cache; for following packets to its destination, the sender may use any other route to its destination in its Cache, or it may attempt a new Route Discovery for that target if necessary.

## II. BLACK HOLE AND GRAY HOLE DETECTION TECHNIQUES

Following are the different techniques available to detect and prevent Black hole attack:

- i) Neighborhood based Technique
- ii) Reputation based Technique
- iii) Digital Certificate based Technique
- iv) Hybrid Routing Technique

### i) Neighborhood-based Technique:

In neighborhood based technique once the normal path discovery process is finished, the source node sends a special control packet to request the destination to send its current neighbor set. The neighbor set of a node is defined as all of the nodes that are within the node's radio transmission range. They claim this metric provides a good "identity" of a node, that is if the two neighbor sets received at the same time are different enough, it can be concluded that they are generated by two different nodes. They verified their claim through the following two experiments:

- i) They measured the neighbor set difference of one node at different time instants  $t$  and  $t+1$  seconds under different moving speeds and network sizes. The result shows that there is not much change of a node's neighbor set during a route discovery process[8].
- ii) They examined the neighbor set difference of two different nodes at the same time, that is  $((\{A's\ neighbor\ set\} \cup \{B's\ neighbor\ set\}) - (\{A's\ neighbor\ set\} \cap \{B's\ neighbor\ set\}))$ . The result shows that the probability that node A's neighbor set is the same as that of node B is very small.

**Detection:** After source node receives the neighbor set information, it analyses them by measuring the neighbor set difference. If the difference is larger than the predefined threshold values, the source node knows that current network has black hole attacks and responds to it accordingly.

**Response:** They proposed a routing recovery protocol, with the following two-step approach:

- i) when a black hole attack is identified, the source node uses a cryptography-based method to authenticate the destination,
- ii) once verified, the source node sends a control packet to destination node to form a correct path by modifying the routing entries of the intermediate nodes between them[2].

### iii) Reputation based Technique :

CONFIDANT [1](Cooperative of Nodes, Fairness In Dynamic Ad-hoc Networks) is an extended version of Watchdog and Path rater. It is also implemented on unicast routing protocol such as DSR. Each node monitors the behavior of its next-hop neighbors. If a suspicious event is detected, the information is given to the reputation system. If the event is significant for the node, it is checked whether it has occurred more often than a predefined threshold, which is high enough to distinguish deliberate malicious behavior from simple coincidences such as collisions. If the occurrence threshold is exceeded, the reputation system updates the rating of the node that caused the event. If the rating turns out to be intolerable, the information is relayed to the path manager, which proceeds to delete all routes containing the intolerable node from the path cache. The node continues to monitor the neighborhood, and an ALARM message is sent by the trust manager component. This message contains the type of protocol violation, the number of occurrences

observed, whether the message was self-originated by the sender, the address of the reporting node, the address of the observed node, and the destination address. When the monitor component of a node receives such an ALARM message, it passes it on to the trust manager, where the source of the message is evaluated and the report is forwarded to the reputation system. Reputation system shares this information with all nodes present in network. CONFIDANT is suitable for small networks with low mobility; however it might be less efficient for large networks since each node needs to maintain a huge table for reputation purposes. Likewise, the high mobility of nodes increases significantly the communication overhead. Additionally, this protocol inherits all the problems of passive-feedback based schemes since it uses this mechanism for the monitoring function.

**iv) Digital Certificate based Technique:**

In Digital Certificate based Technique the nodes authenticate each other by issuing security certificate in digital form to all the other nodes in the network. It uses the route discovery scheme of DSR to issue security certificates. Every node participating in certificate chaining must be able to authenticate its neighbors, create and issue certificate for neighbors and maintain the set of certificates it has issued. The issue of certificates can be on the basis of security parameters of the node. Each node has a local repository consisting of certificates issued by the node to other nodes and certificates issued by others to the particular node. Therefore each certificate is stored twice. The extended route discovery process of DSR consists of the original route discovery process followed by an authentication phase[19]. To overcome black hole attack, source node does not initiate the data transfer process immediately after the routes are established. Instead it waits for the authenticated reply from the destination. The destination node sends authenticated messages appended with certificates taken from the corresponding node's repository. Since the security levels of participating nodes are updated based on their faithful participation in the network, any malicious nodes between the source and destination can be very well isolated from the network as these nodes would not be able to produce the certificates to be appended with the RREP message.

**v) Hybrid Routing Technique :**

Hybrid routing approach is designed 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 nonexistent. 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. 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[21]. Moreover, the communication overhead is also lower than watch dog scheme but slightly higher than original DSR routing protocol.

**III. PROPOSED ALGORITHM**

The algorithm is based on a course based scheme. That is, a node does not observe every node in the neighbour, but only observes the next hop in current route path. For example, in Figure 1, S is the source node; D is the destination node; and P is a gray hole. Node S is sending data packets to node D through the course S, P, Q, D. In this system, Node S only watches Node P, which is the next hop; but does not care Node 1 and Node 2.

The algorithm is represented for finding the intentional selective dropping attack by a node and if all the packets are dropped will identify the attack as a black hole attack by checking the forwarding of packets by the immediate neighbor downstream node to which the data is sent.

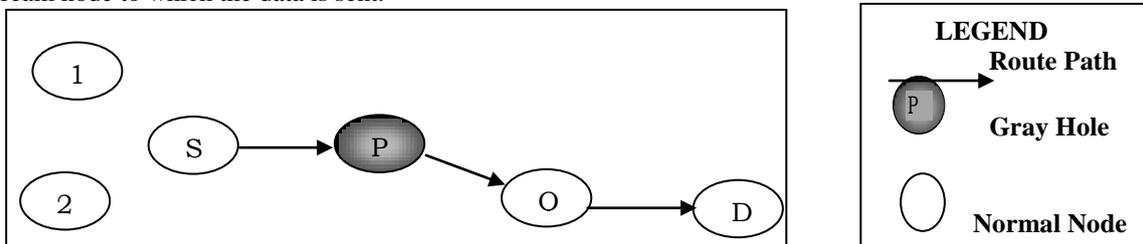


Fig 1: A course based detection scheme

In the algorithm at each node, the router will maintain a packet count history of the number of packets it has forwarded to the downstream node and also the number of packets it has overheard for the forwarded packets.

The algorithm is divided into three steps:

- i) When a router forwards a packet to the downstream node, the number of packet sent is incremented and also buffers the packet for a certain time period. Then it overhears the packet which is forwarded by the downstream node and compares with the packet in the buffer.

- ii) When a match is found the number of packets forwarded by downstream node is increased. Once the match is found or if the time period is over the packet is deleted from the buffer.
- iii) If the packet forwarding is not heard within the time period the algorithm assumes that the packet is dropped by the downstream node.

If the overhear rate of next hop is less than threshold value (TH) then the node is considered as Black Hole. After applying detection algorithm the performance of the network is further improved by applying dynamic threshold method. The node at which the attack is detected keeps the track of Black hole detection time. If Detection Time is less than Expected Time then threshold values are updated. Due to dynamic threshold values the performance of network increases.

Proposed algorithm isolates the black hole or gray hole node from path construction phase. To prevent Black hole node, the detecting node reroute the packet to another available path till no black hole or gray hole node is detected in path. DSR protocol sends the route Request for the packet and starts the route discovery process again.

**A. Advantages of Algorithm**

This method has several advantages:

- In this design, each node only depends on itself to detect a black or gray hole. The algorithm does not send out extra control packets so that Routing Packet Overhead (the ratio of total number of routing related transmissions and the total number of packet transmissions) remains the same as the standard DSR routing protocol.
- Not like other collaborative detecting architectures, this proposal requires no encryption on the control packets to avoid additional attacks on detection information sharing.
- There is no need to observe all neighbours behaviour. Only the next hop in the route course should be observed. As a result, the system performance misuse on detection algorithm is lowered.

**IV. ANALYSIS OF SIMULATION RESULTS**

The simulation has been carried out using NS-2.34. In ns2, two languages are used, tcl-tool command language as front end and c++ as back end .The user writes in tcl script, are interpreted by network simulator and give two output files. They are NAM and tr files.NAM is for visual animation of output and tr is the large text trace file consists of simulation Results. In this simulation 25 mobile nodes are considered in the terrain area of 1186 x 584 meters. Simulation parameters are considered as shown in the Table.1

TABLE I: SIMULATION PARAMETERS

Parameters	Values
Examined Protocol	DSR
Topology size	1186 X 584 m
Simulation time	100 seconds
Number of Nodes	25
Transmission Range	1.5 m
Movement Model	Random way point
Traffic Type	CBR(UDP)
Payload size	1000 bytes
Pause Time	0.001 s
Malicious nodes	1

Performance of proposed DSR can be analyzed by different simulation metrics such as throughput, end to end delay, energy and etc...

**A. Throughput**

Throughput is the number of bits received over the time difference between the first and the last received packets. Throughput graph is plotted in presence of Black hole attack and after removal of Black hole attack. Presence of black hole node in MANET degrades the performance of DSR. Comparison of the graphs in fig.1 shows that the proposed DSR method has good throughput than original DSR with Black hole attack.

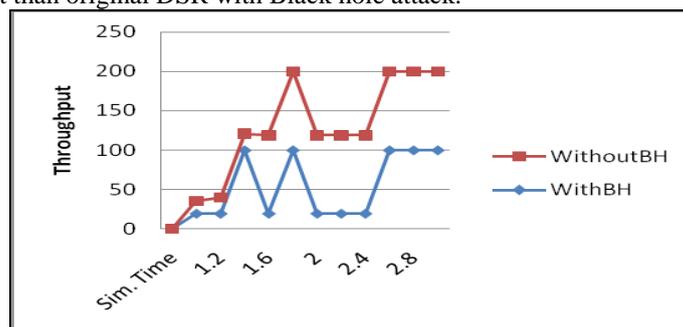


Fig.1 Comparison of Throughput of DSR with and without BH

**B. Average End To End Delay**

It is the average time taken by the data packets travel from source to destination. This includes all types of delay caused by buffering of data, Route Discovery latency, queuing, processing at intermediate nodes, retransmission delays, propagation time and etc [13].

End to end delay must be low to get better performance of DSR. Fig.2 shows that the proposed DSR method has lower End to end delay than original DSR with Black hole.

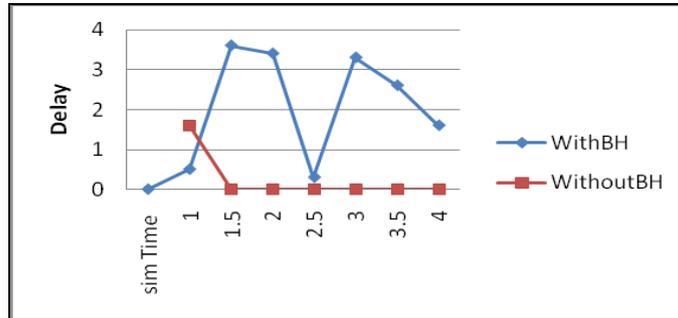


Fig.2 Comparison of Delay of DSR with and without BH

**C. Network Energy**

Devices in a mobile network may rely on batteries or other exhaustible means as their power source. For these nodes, the conservation and efficient use of energy may be the most important system design criteria. Power consumption is the total consumed energy divided by the number of delivered packet. Fig.3 shows that the proposed DSR method saves more energy as compared to than original DSR with Black hole.

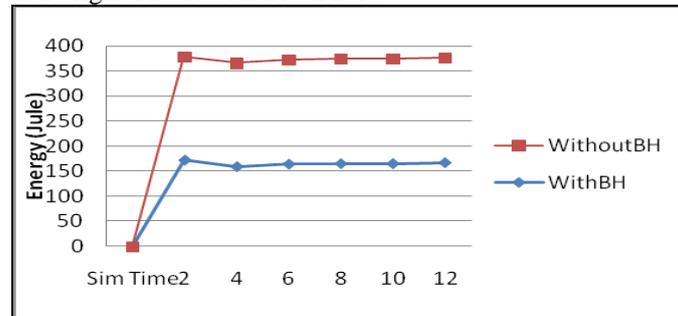


Fig.3 Comparison of Network Energy of DSR with and without BH

**D. Analysis of Gray Hole Attack:**

The Gray hole attack is analyzed against different percentage of gray magnitude. Following Graphs show the performance of proposed algorithm against DSR with Gray Hole. Proposed algorithm's performance is better as compared to DSR with Gray Hole attack.

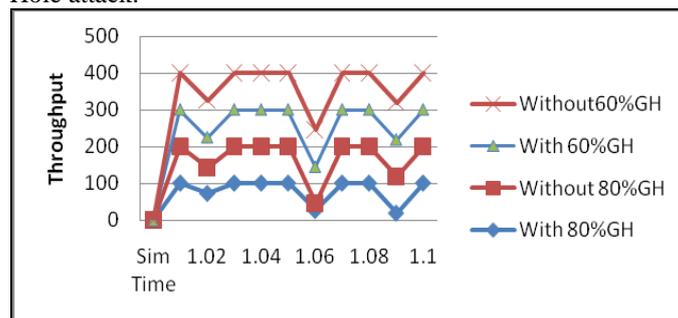


Fig.4 Comparison of Throughput of DSR with and without GH

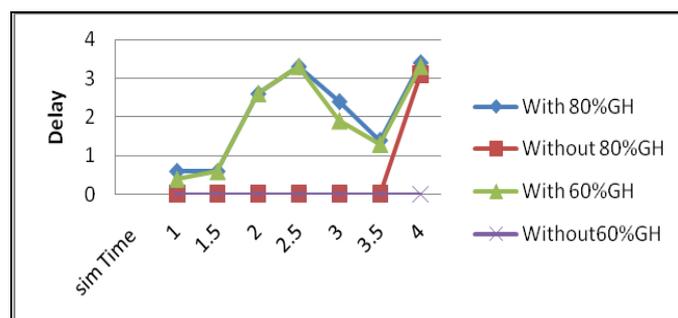


Fig.5 Comparison of Delay of DSR with and without GH

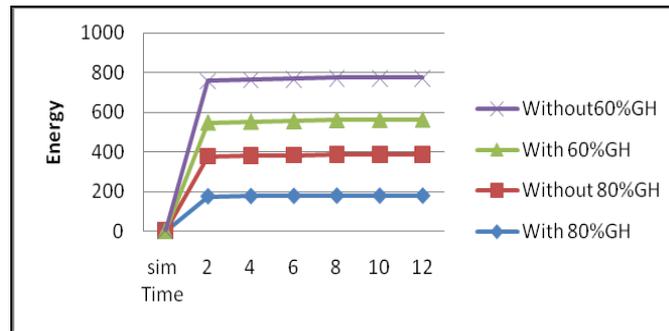


Fig.6 Comparison of Network Energy of DSR with and without GH

### E. Analysis of False Positive Probability

One problem of this detection method is that it suffers from a high false positive probability under high network overload if a constant threshold is used. False positive probability is the ratio of number of honest nodes incorrectly detected as malicious and the total number of honest nodes.

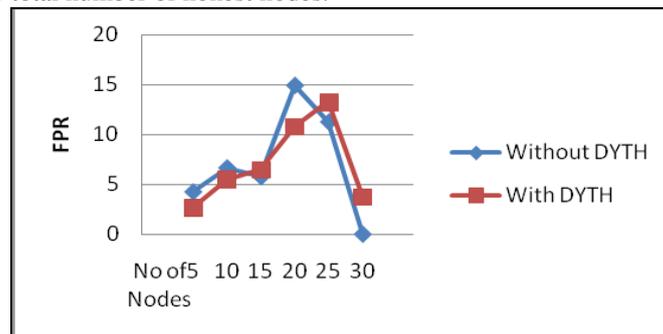


Fig.7 Comparison of False Probability Ratio against No. of Nodes

In case of network failure, nodes may be falsely accused of misbehavior. The false positive should be kept low. Fig.7 shows that by applying dynamic threshold values false probability ratio decreases. Thus ultimately it will result into the improved security of MANETs.

## V. CONCLUSION AND FUTURE WORK

Wireless mobile Ad Hoc network is likely to be attacked by the black hole and gray hole attack. To solve this problem, a course based method is presented to detect black and gray hole attack. The proposed solution is simulated using ns-2 and compared the modified DSR with original DSR in terms of throughput, end to end delay and network energy. Simulation results show that the proposed method has good performance against Black hole attack without much overhead. This solution holds good for gray hole attack also. In the future, the work may extend to propose a feasible solution which will strengthen original DSR against different types of attacks as warm hole attack.

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