iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 Issue: XI Month of publication: November 2017

DOI:

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887
Volume 5 Issue XI November 2017- Available at www.ijraset.com

Detection of Black Hole Attack in Wireless Sensor Networks Using Support Vector Machine

Manish Kumar[1]
[1]Research scholarDepartment of computer sciencesJJT University ,Jhunjhun,Rajasthan

Abstract: The research demonstrates simulation of black hole attack in wireless sensor networks in NS2. A node is suspected to be malicious in case there is a large drop of packets by the node and as a result very few or none of the packets are allowed to reach the destination. In the first case a modified AODV protocol is presented for wireless network. The modification allows the creation of black hole node in the network and advanced dynamic routing in the simulating environment. Thereafter detecting the same by making use of random forest confusion table and contingency table generated by the classification model trace file created during simulation.

Keywords: Black hole; Wireless sensor network; AODV, malicious; SVM; Contingency, confusion

I. INTRODUCTION

A wireless sensor network (WSN) is based on a mesh network topology. It comprising of a set of compact and automated devices. These devices called sensing nodes have their own limited resources and computational capabilities. The sensing nodes form a distributed network across a well-defined area. There are nodes having capability to communicate among themselves, process the data as well as store the information collected over the network. These nodes are better known as sink nodes. The communication between two nodes takes place over multiple hops if they are not within each other's transmitting and receiving range [1]. The wireless sensor network are most commonly used to collect the vital data from the installed environment from where they are deployed. The sensor nodes process the collected data before it is forwarded over non-secure channels to the sink node for auxiliary processing. The sensor networks find applications in diversified areas including environment, infrastructure, public safety, medical, security and transportation. These applications areas being open are likely to be attacked. Many different types of attacks exist in todays WSN. Some of these involve the spoofing a variety of fields of a message packet while it is in transit. It is done in such a way that the recipient receives an intentionally altered copy instead of original message being sent by the source [2]. The black hole is well-known denial of service attack, in which a malicious node attracts all packets by false claiming a new route to the destination. It absorbs all the packets instead of forwarding them to the destination. A black hole node is actually the one that always respond to each RREQ (request) message with a RREP (reply) message, even when it does not have an actual route to the destination node. When the data packet reaches the black hole node, it absorbs all packets instead of forwarding them to next in route hop. Thus none of the packets are able to reach the destination resulting in total denial of service. The paper presents the denial of service attack. Which is actually packet dropping attack and is described as black hole node attack in the wireless sensor network. The type of attack in which a malicious node absorbs all data packets is similar to the black hole in the universe which absorbs everything that comes near to it. It makes use of all the liabilities towards the route discovery of the packets based on on-demand protocol better known as AODV [3]. In case of a black hole attack in wireless sensor network there is an attempt to compromise route establishment in a network. A malicious node that broadcasts a routing message with an tremendous high power is in fact a a successful attempt to mislead a large number of nodes. As these nodes attempt to use the malicious node as their next hop in their route to the sink. While the far-away distant nodes would simply be sending their messages in the state of unawareness. In a similar scenario, black-hole attack the node acting as a malicious node is able to convince all neighboring nodes who are normally multiple hops from the sink node that they are actually one hop away from the destination node. These nodes try to send their packets directly to the sink node in response, which is unable to hear them [4]. A novel approach presented by Hu, Perrig, and Johnson in order to countermeasure these malicious attacks in ad hoc networks. It suggests inclusion or encapsulation of additional information to the standard packets in order to restrict its maximum allowed travel distance. The mentioned approach is better known as packet leash. The packet leash approach is known to have its own disadvantages including the increase in the processing time of the packets and its size [5]. The research involves a malicious node detection mechanism involving the study of behavior characteristics of each node in the wireless sensor network during transmission. The simulation was done against two cases, first in the presence black hole attack when a node acts as a black hole and the second, when the a node behaved as non-malicious or inother words in the absence of black hole attack. The trace files are generated by monitoring the network behavior during transmission against each case. The analysis of generated trace files for the mentioned cases was carried out using a classification model based on support vector machine and correlation leading to the prediction of a suspected node as a black hole. The features including total packets send, received, forwarded and dropped at each hop were monitored, recorded and provided as an input to the classification model.

II. THE MODEL

In the research a homogeneous WSN environment is considered. Which consist of network nodes with similar hardware and software configuration? The simulating environment is assumed to possess symmetricity in which node can only communicate with another node subject to the condition there exists a bidirectional communication between node Y and X. All the nodes in the network were defined to have the same operating characteristics. Which includes similar transmission power (tx), antenna height (H) and antenna gain (G) throughout the network lifetime. All nodes are assigned a unique identification number better known as node identifier and have fixed geographical position. The geographical position of each node can be obtained using a GPS positioning system. The value of a geographical position of each node as well as it's identify arisen capsulated in each of the message packet its ends. It is also as summed that message exchanges in the network are encrypted in order to provide necessary security in the network. The radio propagation is further assumed to follow well-defined models including the Free Space Model and the Two- Ray Ground Model [6]. They specify how the values of transmission power, received signal strength and distance between the transmitter and the receiver relate to each other. In this paper a wireless sensor network is supposed to satisfy following:

1) Homogenity[1] in which all nodes in the network are having same configuration.
2) Static[2] All the nodes in the network are having predefined fixed coordinates and they do not change their position once deployed.
3) Symmetricity[3] The simulating environment is assumed to be symmetric in which the node X can only communicate with node Y, in case Y is also able to communicate with X.

Finally, it is assumed that malicious nodes are capable of performing black hole internal attack only. The presence of a malicious node is confirmed in case there is large difference in the number of packets sent by the source and the packets received by the predefined destination node. Under mentioned conditions anode can be classified under the category of suspicious or non suspicious.

III. SIMULATION MODEL

The network simulator NS2 is used to simulate the wireless sensor network environment in order to evaluate the data and carry out necessary analysis. The wireless sensor network is created with the properties as described in the table (1) where the channel or the medium for transmission is wireless, the propagation is set to be Two ray ground making an assumption that a signal sent from one node to another does not travel in a straight line or a unique path but eventually also through a reflection in the ground as well, topology used is wireless physical. The address associated with each node is of type MAC in accordance to IEEE standard 802.11. The Improvement of performance at the destination node by applying different types of queues at the routers observed. The drop tail queue with priority is implemented where drop of packets can only take place at the rare end of the queue. The relationship between congestion and the packet drops states that congestion can be reduced at the link node by appropriate selection of queue type at the link node [7].

Table 1. Shows the wireless sensor network configuration

S. No.	Attributes	Value
1	Channel	Wireless Channel
2	Propagation	Two Ray Ground
3	Phy	Wireless Phy
4	Mac	802_11
5	Queue	DropTail/PriQueue
6	Link Layer type	LL
7	Antenna	OmniAntenna
8	ifqlen	50
9	Nodes	7
10	Routing protocol	AODV

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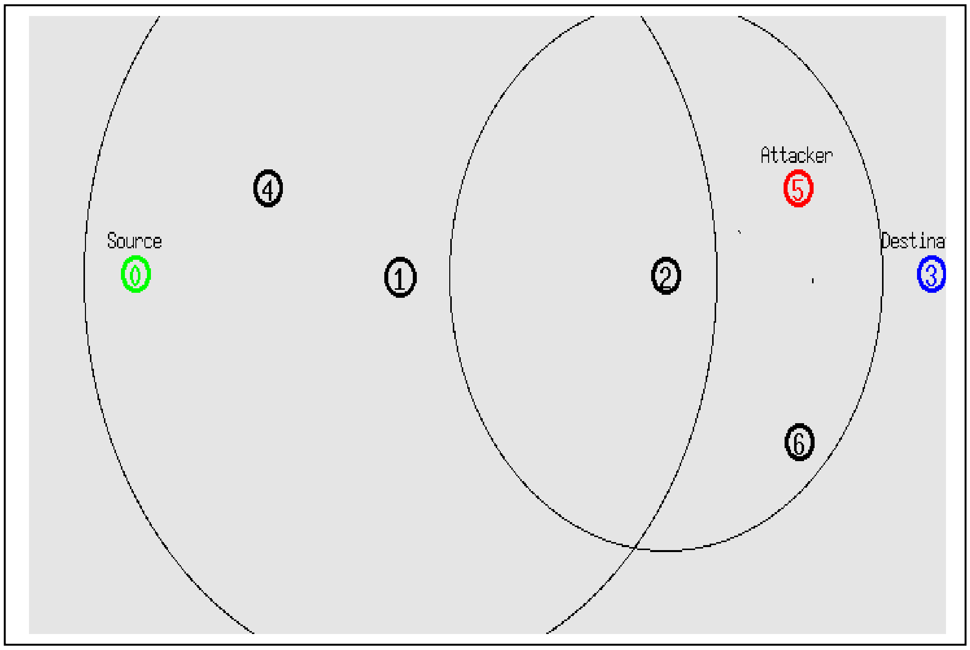
All the nodes are located on a grid of 900 X 900 field with well-defined specific x and y coordinates. The nodes are located in such a way that no two nodes share the same coordinates on the grid as shown in fig.(1).



Fig(1). Showing the deployment of seven nodes in the wireless sensor network

The N number of nodes was used in the simulation. Where N = {n_0, n_1, n_2, n_3, n_4, n_5, n_6}. The node n_0 is defined as source node, the node n_5 as malicious black hole attack node and node n_3 is defined as destination node also known as sink node. The traffic is sent by the source node n_0 to the sink node n_3 over multiple hops in the network.

IV. RESULTS

The simulation was run for 100 ms with packet size = 1000, traffic type = CBR (Constant bit rate), traffic rate =0.1Mbs. The AODV (Ad hoc on demand) routing protocol after making necessary modification is used to perform the desired routing of packets from source to sink node and following observations were made.

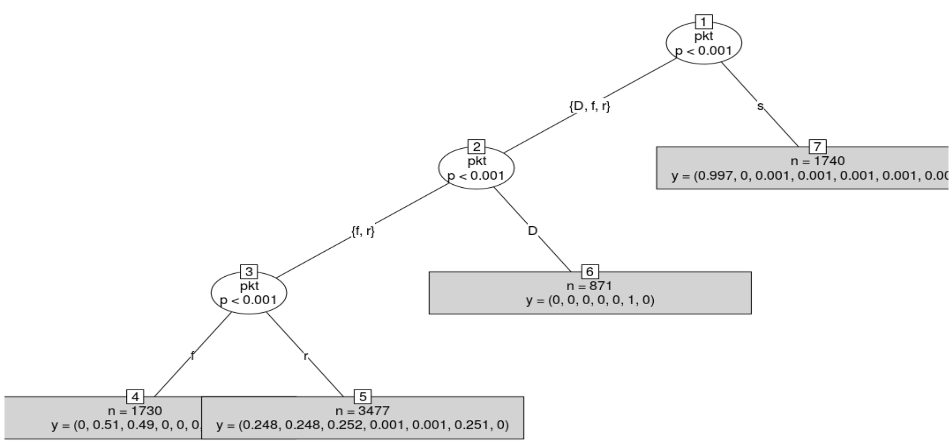


Fig.2. Showing the random forest plot of nodes in presence of black hole attack.

The three levels as 1,2 and 3 in random forest plot of nodes generated from the trace files as shown in fig.2. clearly shows drop of packet at level two in the tree. It is clear confirmation of black hole presence in the wireless sensor network.

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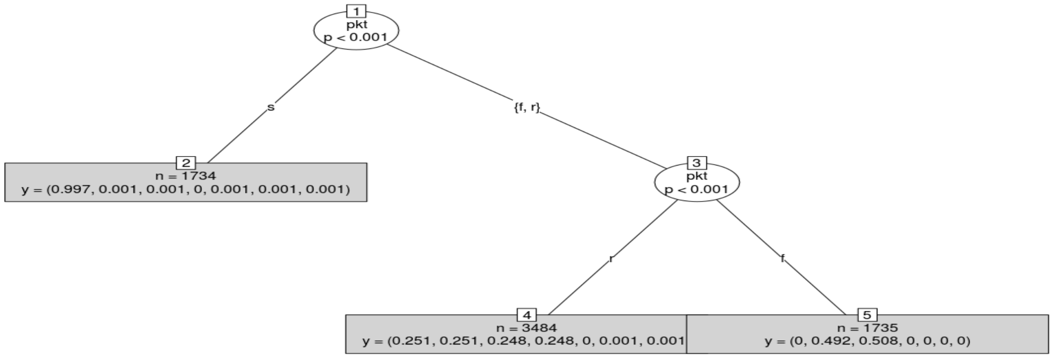

Fig.3. Showing the random forest plot of nodes in the absence of black hole attack.

The three levels as 1,2 and 3 in random forest plot of nodes as shown in fig.2. clearly shows no drop of packet at any level in the tree. It is clear confirmation of absence of black hole in the wireless sensor network

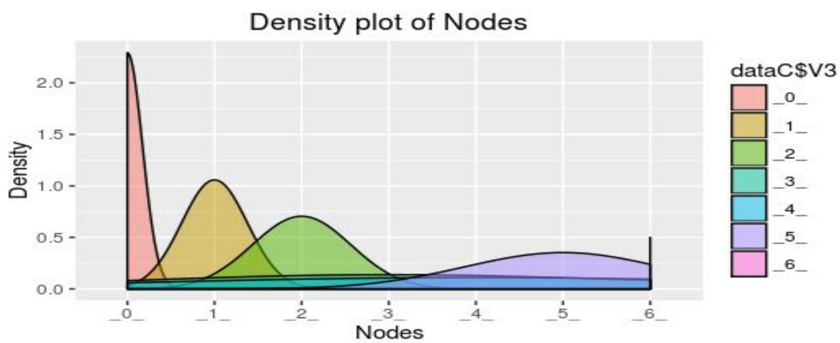

Fig 4: Showing the density plot of nodes in presence of black hole attack.

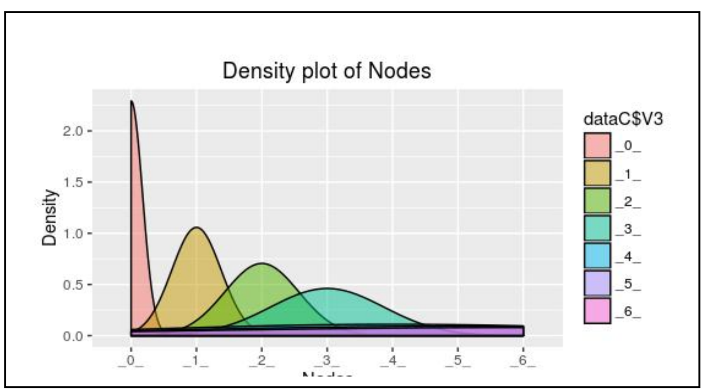

Fig 5: Showing the density plot of nodes in absence of black hole attack

It can be clearly observed the low density peak in fig(4) at destination node indication of no packets reaching the destination (n_3) as there is black hole
present in network.
While in the fig(3). a high peak can be observed at destination node (n3) which is an indication that the packets are arriving at the destination node and further the absence of any balckhole attack.

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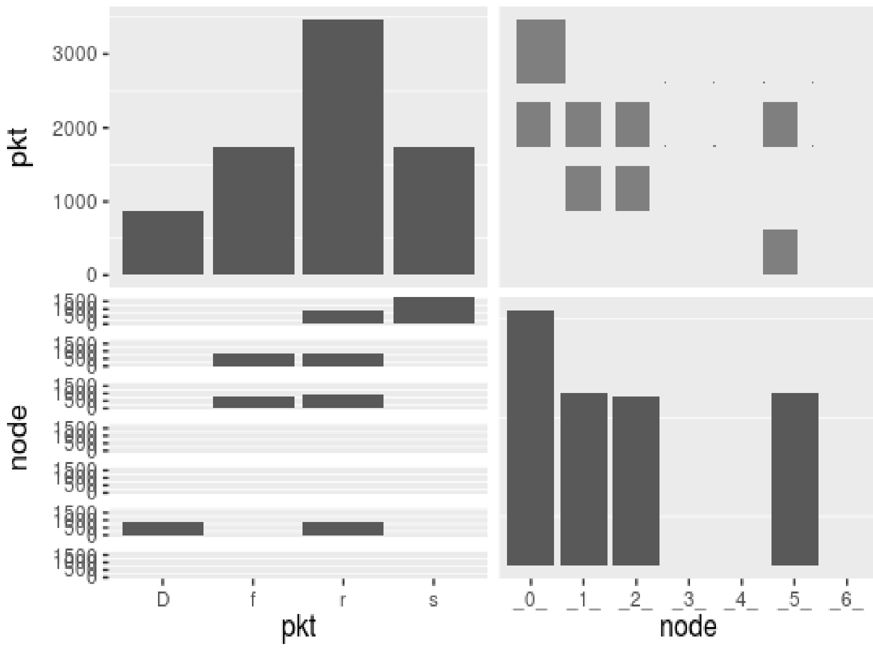

Fig.6. Showing the in presence of black hole attack

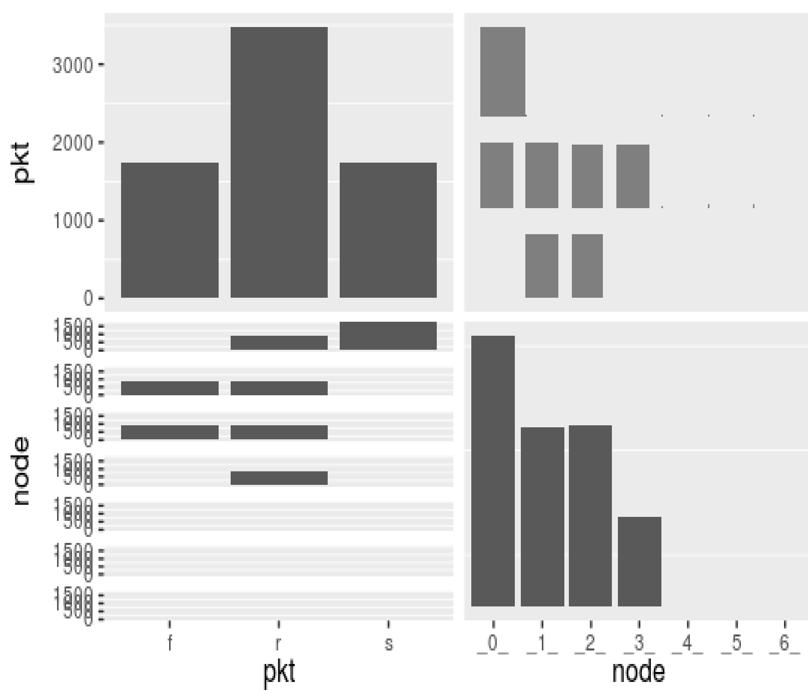

Fig 7: Showing the in absence of black hole attack

It was observed there is high drop of packets at node (n_2).Which is an indication on some malicious activity in the network. While in the node graph one can see no packets received at the node (n_3) confirming the same. These two observation form the conclusion that node (n_2) to be malicious as can be seen in fig(6) and fig(7).

Table 2: showing total packets send, received, forwarded, dropped and packet density ratio during different intervals in the presence of black hole attack.

S.no	Run time	Send	Received	Forwarded	Dropped	Packet density ratio
1	0-10	113	452	228	113	901.769
2	10-20	238	952	478	238	428.151
3	20-30	363	1452	728	363	280.716
4	30-40	488	1952	978	488	208.811
5	40-50	613	2452	1228	613	166.231
6	50-60	738	2952	1478	738	138.075
7	60-70	863	3452	1728	863	118.076
8	70-80	988	3952	1978	988	103.137
9	80-90	1113	4452	2228	1113	91.554
10	90-100	1238	4952	2478	1238	82.310

The increase in the drop of packets was observed in the presence of black hole attack while the simulation was run over period of 100ms.The number of packets dropped were found to be equal to the number of packets being sent by the source node as shown in table (2).

Table 3: Showing total packets send, received, forwarded, dropped and packet density ratio during different intervals in the absence of black hole attack.

S.no	Run time	Send	Received	Forwarded	Dropped	Packet density ratio
1	0-10	113	339	228	0	901.769
2	10-20	238	714	478	0	428.151
3	20-30	363	1089	728	0	280.716
4	30-40	488	1464	978	0	208.811
5	40-50	613	1839	1228	0	166.231
6	50-60	738	2214	1478	0	138.075
7	60-70	863	2589	1728	0	118.076
8	70-80	988	2964	1978	0	103.137
9	80-90	1113	3339	2228	0	91.554
10	90-100	1238	3714	2478	0	82.310

There was no drop of packets observed in the absence of black hole attack while the simulation was again run over period of 100ms.The number of packets sent from the source were found to be equal to the number of packets received at the destination as shown in table (3).

The predicted contingency table in the presence of black hole attack by the SVM model is shown in table (4). It is observed that the total number of packets sent by the source node (n_0) = 1238, the number of packets received by the sink node (n_3) = 0 as there is drop of 1238 packets at the black hole node (n_5).

Table 4: Showing the packets dropped, forwarded, received; send as per the contingency table in presence of black hole attack.

S. No.	Nodes	D	F	R	S
1	n_0	0	2	1256	1238
2	n_1	0	1238	1857	0
3	n_2	1238	0	1857	0
4	n_3	0	0	0	0
5	n_4	0	0	0	0
6	n_5	0	0	0	0
7	n_6	0	0	0	0

The predicted contingency table was generated without black hole attack by the SVM model as shown in table (5). It is observed that the total number of packets sent by the source node (n_0) = 1238, the number of packets received by the sink node (n_3) =1238 as there was no drop in packets in the absence of black hole attack.

Table 5: Contingency table showing the packets dropped, forwarded, received; send in absence of black hole attack.

S. No.	Nodes	F	R	S
1	n_0	2	1258	1238
2	n_1	1238	1238	0
3	n_2	1238	1238	0
4	n_3	0	1238	0
5	n_4	0	0	0
6	n_5	0	0	0
7	n_6	0	0	0

V. CONCLUSION

1) The drop in the density curve can clearly be observed with respect to time while the packets travel from source (n_0) to sink node (n_3) as shown in fig (4). This drop in the density curve is a clear indication of the presence of some malicious activity during the transmission. The low peaks in the density curve for node (n_3), (n_4), (n_5) and (n_6) proves these nodes are either malicious or not present in the route to the destination.
2) There is a no drop in the density curve with respect to time once the packets travel from source (n_0) to sink node (n_3) as shown in fig (4). This no drop condition in the density curve clearly depicts the absence of any malicious activity during the transmission.
3) The plots shown in the fig(2) and fig(6) support the fact that there is a malicious node present in the network as indicated by the drop field presence and fig(6) and fig(7) clearly indicate the absence of drop field in the data in the absence of malicious node.
4) The SVM model was able to predict the malicious node (n_5) from the suspected nodes n_3, n_4, n_6 with great accuracy using the trace file data.

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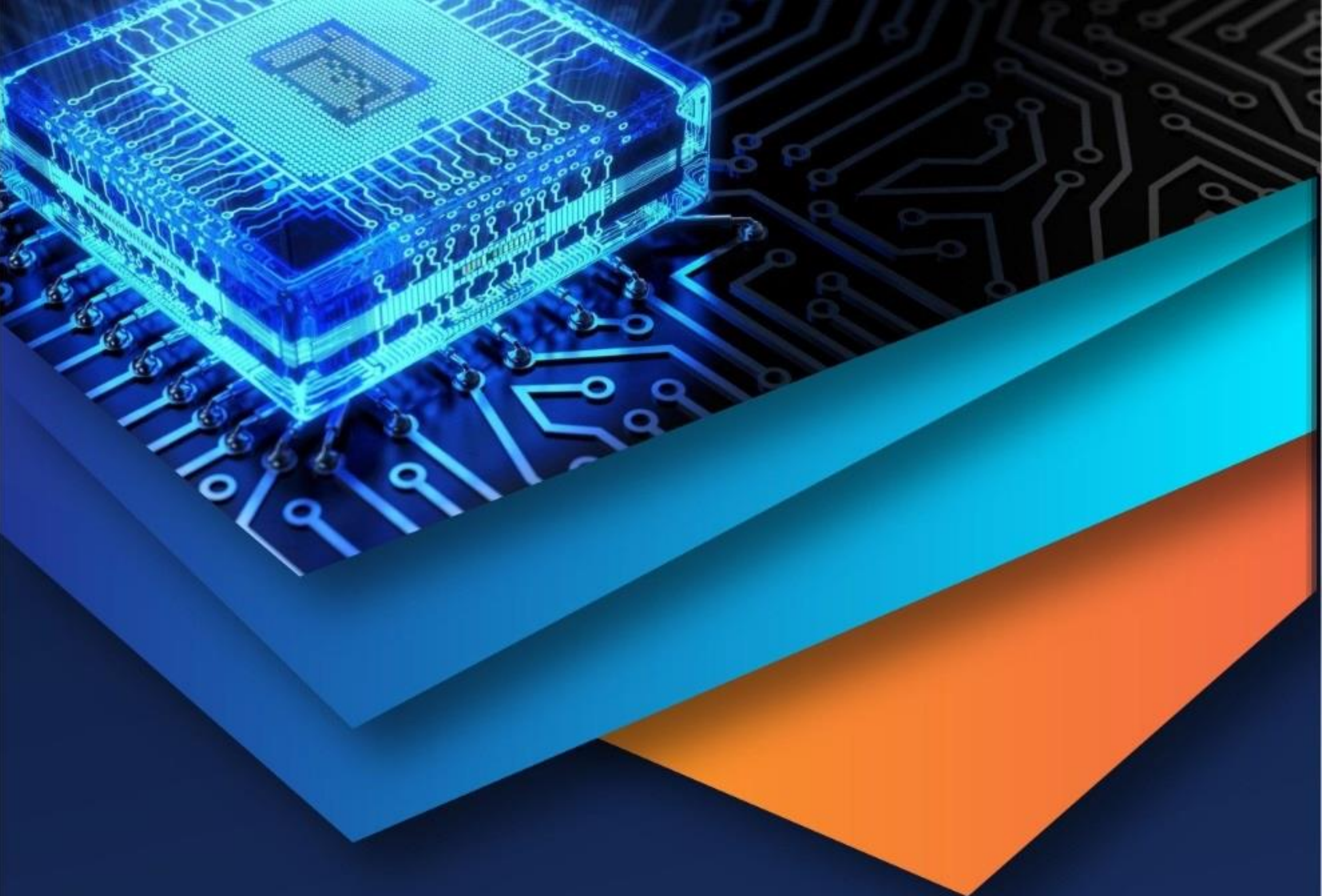

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