iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 3 **Issue:** X **Month of publication:** October 2015

DOI:

www.ijraset.com

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Volume 3 Issue X, October 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Multi-Hop LEACH with Energy Based Cluster Head Rotation

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Abstract—Wireless Sensor Network (WSN) is a growing field of interest now days. It is attracting researchers in application areas of surveillance, defense, security, patient monitoring, automated perking, weather forecasting, etc. The WSN deployment faces various issues because of its infrastructure-less implementation and tiny sized components i.e. sensor nodes. The scalability, reliability and energy efficiency are the key parameters. LEACH is the basic protocol, developed to optimize the energy consumption of sensor nodes. To overcome the issues faced in LEACH, descendants of LEACH have been developed. One of these is the M-LEACH. In this paper, we are providing with a proposed approach that shows better throughput, lower power consumption and decreased delay in compared to simple LEACH. The simulation results have been shown as graphs for better understandability. In this paper, the first section provides with a basic introduction to WSN. The second and third section provides an overview to LEACH and M-LEACH. In the next two sections, the proposed protocol is described and the simulation results are illustrated.

Keywords- WSN; Issues; Scalability; Reliability; Energy Efficiency, LEACH; M- LEACH.

I. INTRODUCTION

WSN are becoming part of our daily lives, especially in the monitoring fields. WSNs are applicable in very sensitive areas of application, where even a little ignorance may result into disasters. The Figure 1 shown here provides with the overview about the basic component [1] arrangement in WSNs.

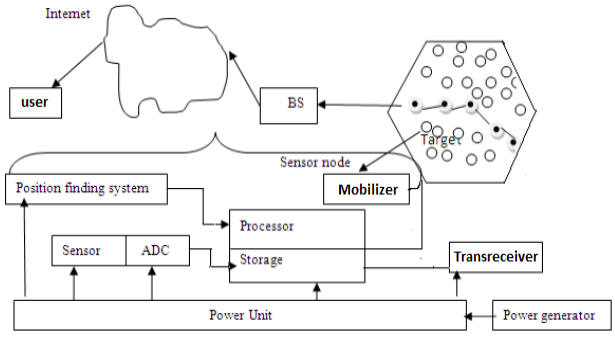

Fig. 1. Overview of WSN deployment

As the figure illustrates, the WSNs are composed of compact sized sensor nodes, distributed throughout the network. These sensor nodes are responsible for sensing the activities happening around and this data is further forwarded to BS (Base Station) for end-user usability.

The sensor nodes [2] are also composed of sub-components. These components are classified as four units:

Sensing Unit

Processing Unit

Power Unit

Communication Unit

Volume 3 Issue X, October 2015
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

WSNs are usually deployed to monitor the environment and the applicability fields are usually the harsh environments are un-approachable, thus are difficult to maintain. This results in number of issues [3] that are faced during designing the routing protocols. One of the crucial issue is the achieving the energy efficiency. The sensor nodes are battery operated and theses batteries become irreplaceable once installed due to harsh environmental application fields. The nodes may die soon if energy depletes at a rapid rate. The dead nodes are of no use but these degrade the performance of WSNs by adding overhead to the WSN processing.

The various protocols have been developed for making the WSN work efficiently. The traditional routing protocols are not suitable for WSNs because of its distinguished features [4] from Ad-hoc Wireless networks. The WSNs are composed of thousands of nodes, where simple wireless networks are composed of limited components. In addition to this the tiny size of nodes restrict the resources supported by them i.e. memory, battery, processor capability, etc. The routing protocols are mainly classified [5] into two broad classes: Network Structure based and Protocol Operation based. The network based classification is influenced by the arrangement of communication structure followed by the nodes in WSN. The protocols can also be classified on the basis of their functionality like pattern of route making, sharing of resources, parameters used, etc. Initially flooding technique was followed to report data to BS. This approach resulted in increased overhead in form of replicated data. Due to the repeated data transmission it also results into un-necessary collisions and traffic, resulting into delay due to collisions. So this approach is rarely used.

The clustering approach was introduced as a solution to it. The routing protocols [5] are classified as Figure 2 depicts.

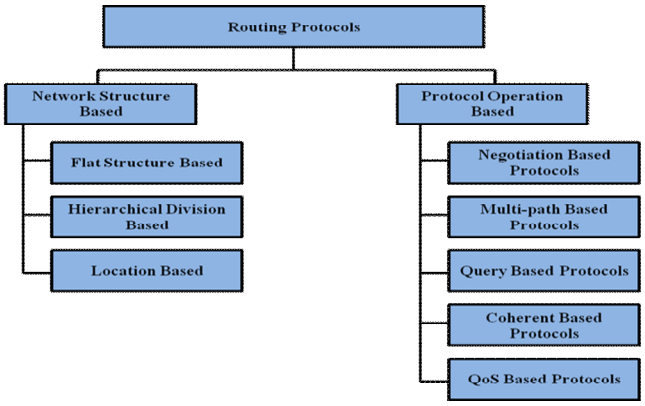

Fig. 2. Routing Protocols Classification

The hierarchical division based class makes use of clustering concept to for better communication policy. In this the nodes in WSN are grouped in form of various virtual clusters [6] and aggregated data is forwarded to the BS. The clustering evenly distributes energy throughout the network as illustrated in Figure 3.

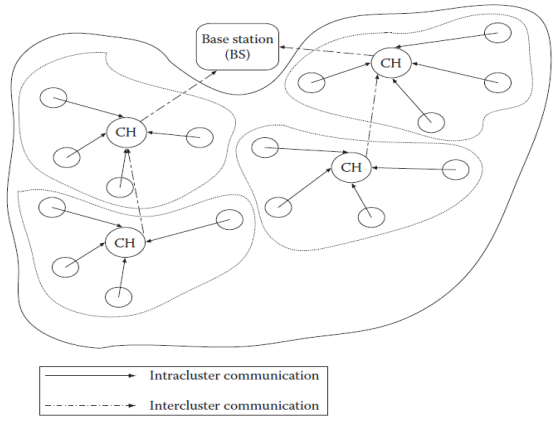

Fig. 3. Communication hierarchy in clustered approach.

II. LEACH

LEACH (Low Energy Adaptive Clustering Hierarchy) was the very first protocol [7] that implemented the concept of clustering as

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ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

its base. The protocol was implemented to reduce the energy consumption and to eliminate overheads associated with transmission of un-necessary and redundant data. In this, the nodes are arranged in forms of clusters and out of member nodes of each cluster a leader node i.e. Cluster-Head is chosen. It is the responsibility of CH to collect the data from the member nodes and to send the aggregated data to BS.

In LEACH, the rotation of C.H.s is done randomly to make it more energy efficient. The working [8] of LEACH is divided into two sub-phases:

Set-up phase

Steady set-up phase .

In the initial stage, the nodes choose a random number, 'r' between the value 0 and 1. The 'r' is compared against a threshold value, defined as T(n) [9].

$$T(n)= p/1-p *(r \bmod p^{-1}) \quad (1)$$

Here 'p' is the Cluster-head probability i.e. calculated by dividing the total number of nodes to the total number of nodes in the network. If the value chosen by node is less than threshold value then it is set as non C.H. otherwise as C.H. The basic cluster structure in LEACH is as shown in Figure 4.

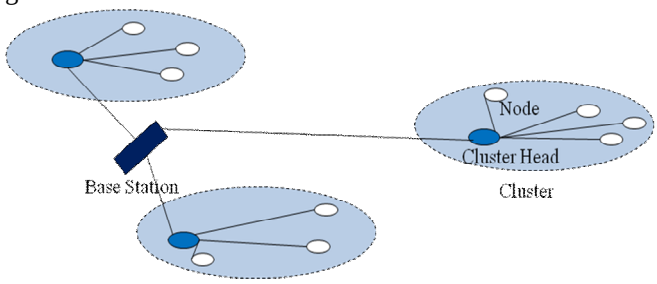

Fig. 4. Basic cluster structure

A node can send its data only in the assigned TDMA slot. It's the responsibility of C.H. to aggregate the data collected from each node and to pass it to the B.S. directly. The LEACH protocol is only efficient if the duration of the 'steady phase' is more than the 'set-up phase' [9]. The LEACH suffers from various deficiencies [8] like:

The election of CH on based of probability function does not ensure an optimal selection always. Selecting a non-feasible CH may result into rapid battery drain-out of that node.

The CHs have to send data directly to BS that limits the size of WSN.

The direct data transmission to BS by a distant CH puts extra load on it; resulting in more power consumption during data transmission period.

To overcome these issues and to make WSNs working in more optimized way, various descendants [10] have been developed as shown in Figure 5.

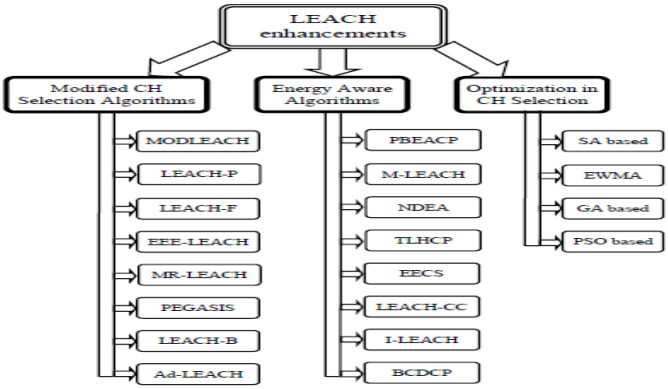

Fig. 5. Classification of Modified LEACH Algorithms.

III. MULTIHOP LEACH

M-LEACH (Multi-hop LEACH) is one of the descendents of LEACH developed till date. In this, rather than directly communicating to BS, CH transfers the data through CHs, lying in between source CH and the BS [11], as this Figure 6 shows.

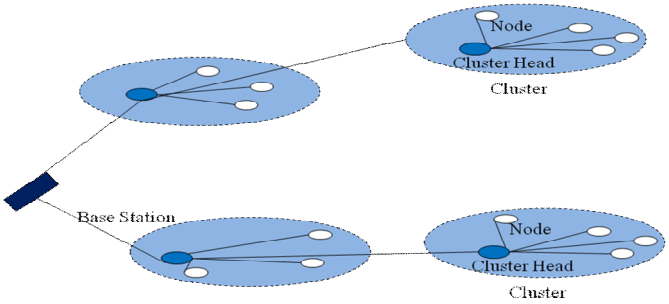

Fig. 6. M-LEACH Structure.

The working of M-LEACH [12] is performed by two forms of communication.
Intra-cluster communication
Inter cluster communication
Although the M-LEACH became successful up-to some extent in resolving the issues of LEACH deployed WSN but still some loopholes are left in M-LEACH. These are:
The CH is elected based on probability function as in simple LEACH.
The CH rotation is done after each round of communication. The CH is elected from scratch that introduces delay and increased power consumption.

IV. PROPOSED ALGORITHM

The proposed algorithm makes use of energy status to elect the node as CH. However, the CH is rotated after each round to save a node from becoming died due to its consecutive election as CH. The nodes are initially sorted down according to their associated energy levels and then after each successful round of communication the next order node is elected as CH without performing any un-necessary computation.

The concept of the proposed algorithm can be broken down into following phases.

A. Setup Phase

In this phase, the nodes are installed in the area to be monitored. After the nodes get moved to their positions, the process of cluster formation is performed. Clusters evenly distribute the energy throughout the network. The clusters are formed by dividing the network according to the distance covered. The nodes falling in a specific area range belong to a cluster.

B. Cluster Head Selection

After the initial set-up is over; the CH election is to be done. For initial selection of CH, random nodes are chosen in each CH. These nodes act as 'Initiators'. The initiator nodes ask every member node to provide its energy status. Once the energy levels of all nodes reported; the initiator node sort down the rest member nodes according to decreasing level of their corresponding energy levels. The node with maximum energy level is chosen as CH.

C. Communication Phase

After CH get elected, the communication process starts. The nodes sense data. This sensed data is collected by CH for data aggregation process. For the purpose of reporting this data to the Sink node, the Multi-hop path is followed. The Multi-hop path is defined as the CHs of various clusters falling on the way to the BS. The Multi-hop has proved to be tremendously energy efficient approach, especially for implementing wide area WSNs.

D. CH Rotation Phase

When a round of communication completes, the CH rotation process is carried out as in case of simple LEACH and M-LEACH. In

Volume 3 Issue X, October 2015
ISSN: 2321-9653
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proposed M-LEACH, the next node in the sorted list is elected as new cluster. Storing the energy levels in starting eliminates the overhead of comparing energy levels of all nodes every-time.

After the election of the next round CHs, the whole communication process takes place as depicted in Figure 7.

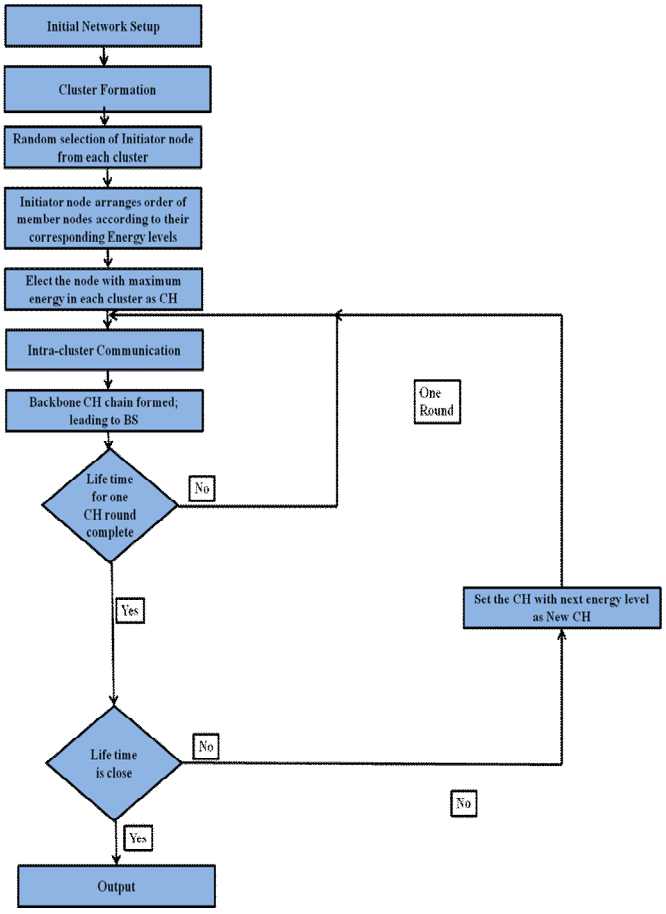

Fig. 7. Flowchart of Proposed Algorithm

V. SIMULATION AND RESULTS

NS2 is the tool that has been used to simulate the proposed algorithm and to compare the performance of the M-LEACH and Proposed Protocol.

The performance is measured against energy consumption, throughput and delay faced during communication parameters. The values set for network configuration and node deployment variables are defined in this table.

TABLE 1. PARAMETERS SET FOR NETWORK DEPLOYMENT

Parameter	Value
Channel	WirelessChannel
Propagation	TwoRayGround
Queue Interface	DropTail
Antenna	OmniAntenna
Size	1100 * 11oo
Number of Nodes	49
Energy Model	EnergyModel
Initial Energy of Nodes	100 Joules

Volume 3 Issue X, October 2015
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For both of the M-LEACH and proposed protocol, the values set for these parameters is set as same stated in above table. The comparison of both the protocols has been illustrated in form of graphs. In these, the Base refers to the basic M-LEACH and Proposed refers to the output of new protocol.

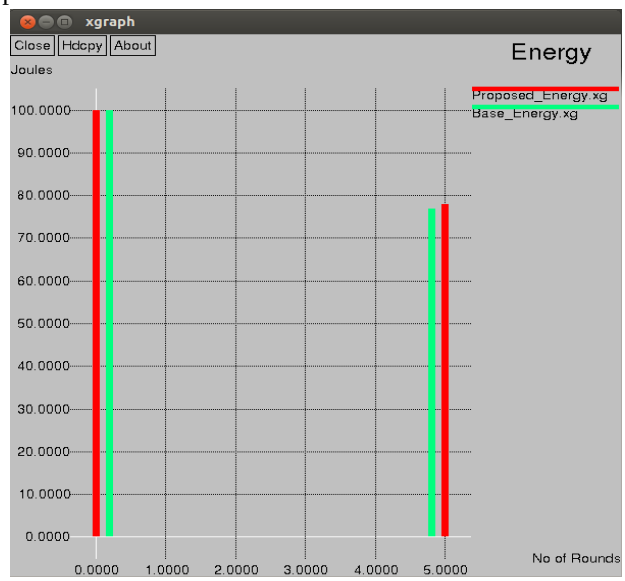

Fig. 8. Energy Comparison

The Figure 8 depicts here the initial energy of nodes in Joules in both the WSNs implemented based on M-LEACH and proposed M-LEACH. The Initial Energy provided to nodes is same in both cases i.e. 100 joules. The Energy of Base Protocol and proposed Protocol is compared after fifth round. The status of residual Energy for base nodes is less as compared to proposed Protocol nodes. Thus proposed Protocol proved to be better energy conservative than M-LEACH.

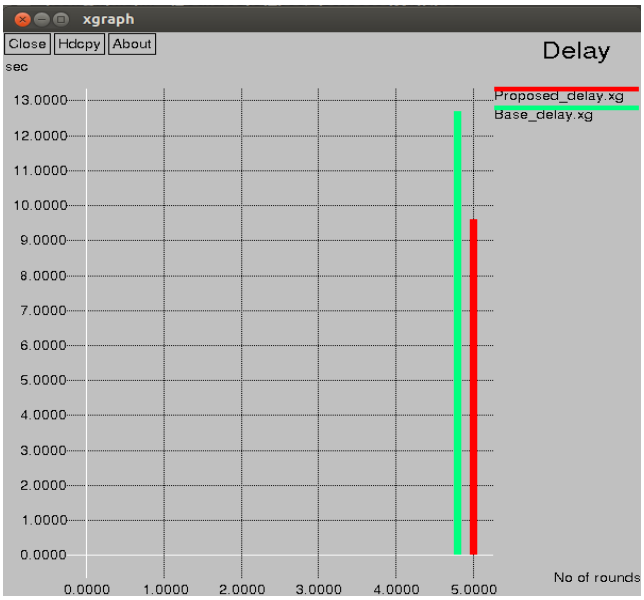

Fig. 9. Delay Comparision

The Delay faced in this example simulation is less than 10 sec. that is much less than Base protocol delay line that reaches approximately 12.5 sec.

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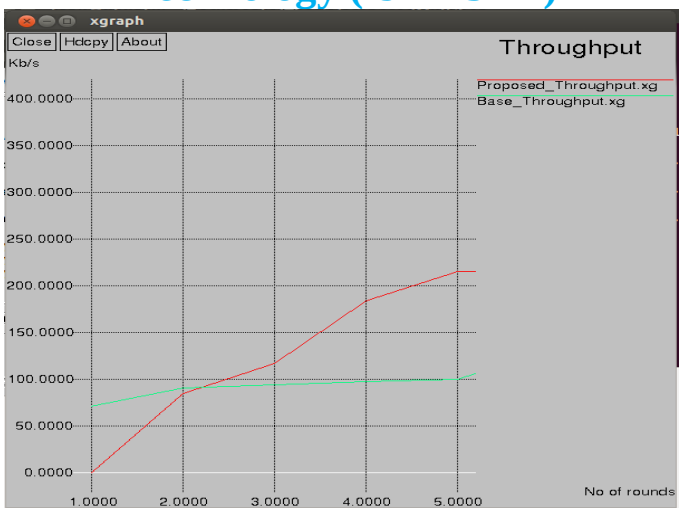

Fig. 10. Throughput Graph

The throughput is the parameter used to show the efficiency of some protocol. The throughput is used to represent the overall effectiveness of the protocol.

VI. CONCLUSION

The comparison of two M-LEACH and Proposed protocols give essential results about the energy consumption, delay faced and throughput i.e. overhead. The energy consumption rates affect network performance and also network life time. Thus, it is one of the important and vital factors about network design. According to the simulation results, energy based election of CH based protocol produce better results in delay faced, thus resulting in low power consumption and better throughput. In addition to these explored parameters, the nodes can be set heterogeneous and the parameters: energy consumption, delay and throughput should be investigated as a future work to be able to improve the network performance.

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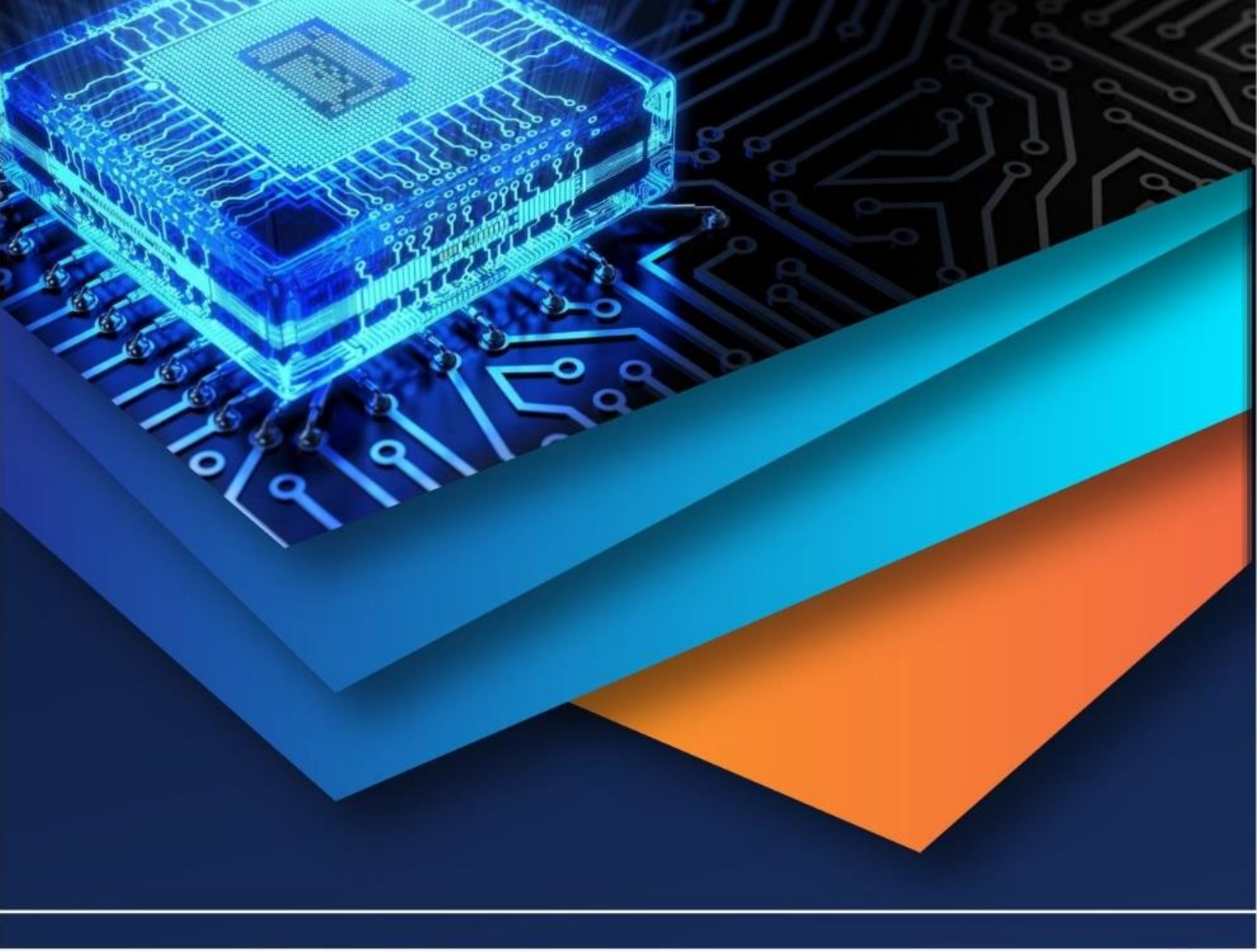

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