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Efficient Monitoring Of Transportation Networks by Mobile Sensors

Shamith Manohar[1,] Mrs.Anitha P. [2]
[1]PG Student, [2]Professor , Department of ECE, S.J.B Institute of Technology, Bengaluru, India.

Abstract - Morden day traffic management systems need to be sophisticated to handle the traffic issues efficiently. We have seen in the past till the recent days that fixed sensors were used to monitor the transportation network. In this paper, we propose a mobile sensor technology to improve the traffic surveillance of transportation networks. A mobile sensor network is proposed, is compared with the traditional fixed sensor network and bring out the differences in few common characteristics among the two to show which has a better efficiency and better performance. The mobile sensor algorithm uses a hybrid 2 - stage heuristic algorithm which is based on ant colony optimisation and particle swarm optimisation. Numerical experiments are conducted and results are recorded. The results show that the mobile sensor traffic surveillance network is far more efficient in comparison with fixed sensor network in monitoring a transportation network.
Keywords— Ant colony optimisation (ACO), Particle swarm optimisation (PSO), Mobile sensor, Fixed sensor, Transportation network.

I. INTRODUCTION

Mobile Ad-hoc networks were introduced in the 1990's and since then are subjected to wide research. It predominantly has a very different architecture and inherently different from other networks. This network changes its organization very rapidly which is a challenge when it comes to wireless transmission of data. Security also is a major issue in this kind of a network. Availability, confidentiality, integrity and authentication are some of the major parameters that are taken into consideration when any device or node has to communicate with any other node or device of the same or a different network.

Wireless sensor networks are gaining huge importance in modern day life of our civilization. Wireless, meaning that the devices or sensors are not connected to by any physical means and still help us in many activities like monitoring, information retrieval etc. Wireless sensor nodes present in the network help us to capture information, perform primary processing and then transfer them to the base stations from which the sensors are actually monitored. Two major classes of protocols are used to operate these sensors, they are multi hop routings and clustering techniques.

The main properties of wireless sensor networks is that they are not characterized by infrastructure but communicate in Ad-hoc fashion in order to interact. The nodes of the network are generally battery powered which are heterogeneous in nature and can be deployed in large scale.

Transportation management and control is significantly affected by the traffic information, transportation surveillance network is necessary in order to obtain real-time traffic information. Traffic sensors cannot be deployed everywhere in transportation networks due to limited budgets, where as the real-time traffic data is provided by optimal sensor locations. These data is used in different applications of traffic such has flow estimation , observation , travel time estimation and bottleneck identification. This problem aiming to observe and estimate traffic flow attracted several researches from decades.

Upon the formulation of problem statement it is clear that there is a high demand for Mobile traffic sensors which are capable of recording the traffic flow and to identify the license plates so that information pertaining to travel time can be obtained ,thereby in order caters this need following objectives are undertaken for implementation.

II. THEORY

A. Ant Colony Optimization

In this algorithm, the ant plays the role of an agent of computation. For a given problem in hand, solution is constructed iteratively with intermediate solutions called states. Suppose at each iteration, say an ant moves from x to y state in order to form a more complete solution. So a random ant k, computes a set of $A_k(x)$ values for the present state iteration. So for an ant k the

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probability of moving from x to y state is actually influenced by

η_{xy} = the attractiveness of the move

τ_{xy} = the trail level of the move

So in general, an ant k moves from x to y state with probability

$$p_{xy}^{k} = \frac{(\tau_{xy}^{\alpha})(\eta_{xy}^{\beta})}{\sum_{z\in \mathrm{allowed}_x}(\tau_{xz}^{\alpha})(\eta_{xz}^{\beta})}$$

where,

τ_{xy} = amount of pheromone deposited when an ant transits from state x to y,

$0 \leq \alpha$ is a parameter to control the influence of τ_{xy},

η_{xy} is the desirability of state transition xy

$\beta \geq 1$ is a parameter to control the influence of η_{xy}.

So when all the ants have completed one set of solutions, the pheromone trails of all the ants are cumulatively updated by the below formula:

$$\tau_{xy} \leftarrow (1-\rho)\tau_{xy} + \sum_{k} \Delta\tau_{xy}^{k}$$

where,

τ_{xy} = amount of pheromone deposited when an ant moves from x to y state,

ρ = *pheromone evaporation coefficient*

$\Delta\tau_{xy}^{k}$ = amount of pheromone deposited by kth ant, given by

$$\Delta\tau_{xy}^{k} = \begin{cases} Q/L_k & \text{if ant } k \text{ uses curve } xy \text{ in its tour} \\ 0 & \text{otherwise} \end{cases}$$

where,

L_k = length of the path travelled by the ant.

Q = constant.

B. Particle Swarm Optimisation

The PSO works on a swarm of nodes which keep moving along the space based on a simple formulae These nodes are guided by best known position updates by their own peer nodes which keep moving along the space and keep discovering new positions and updating them.

If $f:\mathbb{R}^n \rightarrow \mathbb{R}$ be the problem function that is to be optimised, the main aim is to find a solution 'a' such that f(a) is less than or equal to f(b) in all the set of solutions available. If S is the number of nodes in the swarm positioned at x such that $\mathbf{x}_i \in \mathbb{R}^n$ in the space with a velocity v such that $\mathbf{v}_i \in \mathbb{R}^n$, then let $\mathbf{g}_i$ be the best known position of the node and $\mathbf{h}_i$ be the best known position of the swarm. So the algorithm is as follows:

For each node i = 1, ... , S

Proceed with a uniformly distributed random vector $\mathbf{x}_i \sim U(\mathbf{b}_{lo}, \mathbf{b}_{up})$, where $\mathbf{b}_{lo}$, $\mathbf{b}_{up}$ are the lower and upper limits of the space

Assign the particles best known position to its initial position

$$\text{i.e } \mathbf{g}_i \leftarrow \mathbf{x}_i$$

If $f(\mathbf{g}_i) < f(\mathbf{h})$, then update swarm best known position to $\mathbf{g}_i$.

Assign node velocity to $\mathbf{v}_i \sim U(-|\mathbf{b}_{up}-\mathbf{b}_{lo}|, |\mathbf{b}_{up}-\mathbf{b}_{lo}|)$

C. Hybrid Two-Stage Heuristic Algorithm

Based on Particle Swarm Optimization and Ant Colony Optimization, the below 2-stage algorithm is designed,

```
Set parameters for PSO and ACO, respectively
  while ACO termination condition not met do
    Construct route
    Pass the constructed route to PSO
    Initialize stay time solution particles for PSO
    while PSO termination condition not met do
      Evaluate all particles
      Update pbest and lbest
      Update velocity and position for each particle
    end while
    Return optimal stay time solution and fitness function value to ACO
    Update pheromones
  end while
```

III. PROPOSED METHOD

The block diagram in Fig1 shows the design flow of the proposed methodology. Explained below, the working of each block, they contribute uniquely to the efficient working of the proposed design.

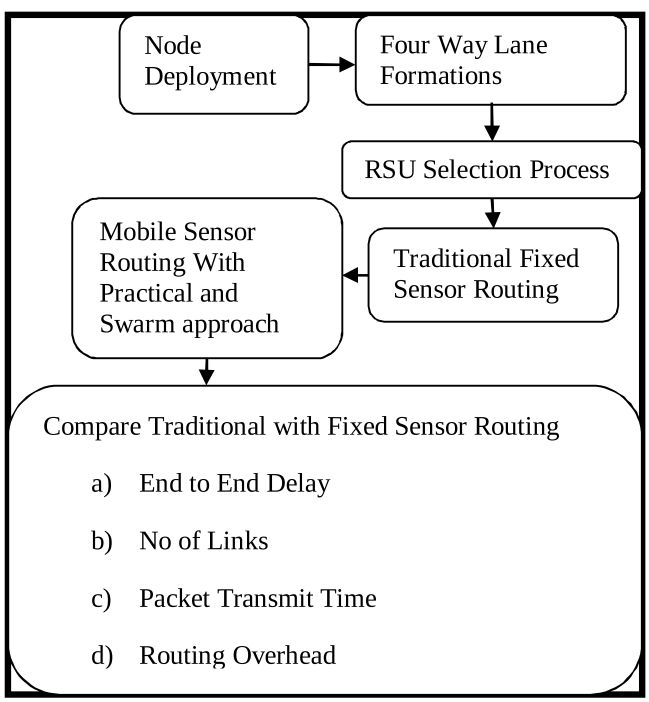

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Fig1:Block Diagram of the Proposed Methodology

The proposed design in this paper completely emphasizes on the data retrieval capacity of a wireless sensor network. Where information becomes a vital parameter to be obtained from the network, the cost is a compromise on energy. So a transportation surveillance network has to be more efficient in terms of data handling.

Here we propose two kinds of network, keeping in mind the data handling efficiency and also the energy factor. The first kind of network is a fixed sensor network and the second is the mobile sensor network which are described later.

A. Node Deployment And Four Way Lane Formation

The node deployment block deploys the sensor nodes quite randomly over the network. The node deployment block takes the lane information, start and end points, lane id's and number of vehicles or nodes on each lane as input to produce The node deployment does not follow any particular algorithm but ensures that the nodes are placed in the specified range that has been given as an input to the lane formation block. Both the blocks work in sync so as to place the specified set of nodes in the network or lanes as it is called throughout. Fig2 shows the result of the node deployment and lane formation blocks.

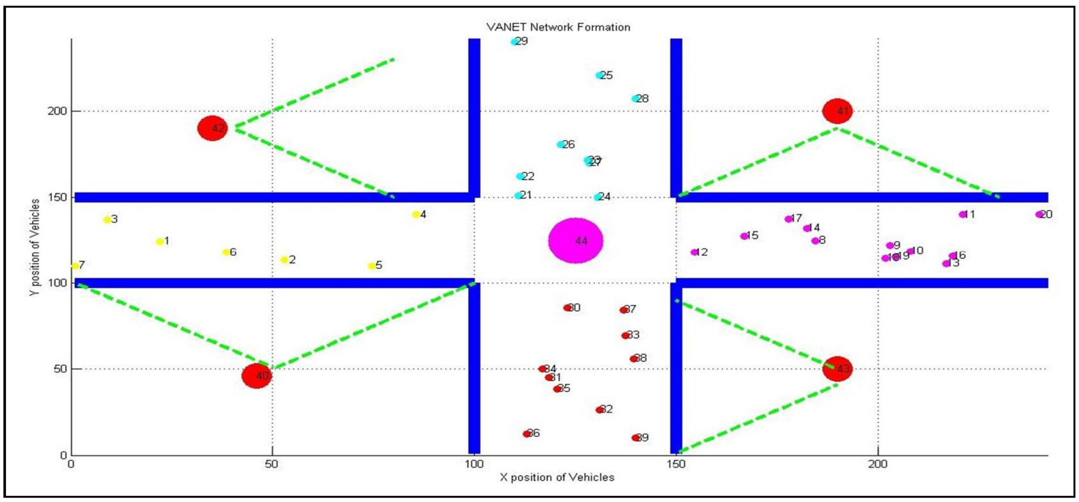
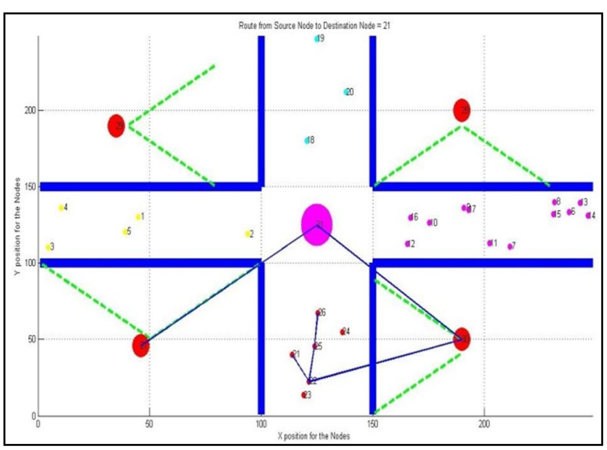


Fig2: Node Deployment and Four Way Lane Formation

Fig3 and Fig4 shows the path formation of fixed sensor and mobile sensor network that was mentioned earlier. To elaborate, fixed sensor network has nodes fixed at particular points and try retrieving information about the network. But there is a limitation that encounters. If there is a congestion beyond the range of the sensor node, then the sensor is unable to transfer that information to the base station. Here the mobile sensor network actually plays a crucial role in overcoming the limitation. The sensor nodes are mobile in nature i.e the can move from one place to another hence making it more efficient for the network to retrieve information.



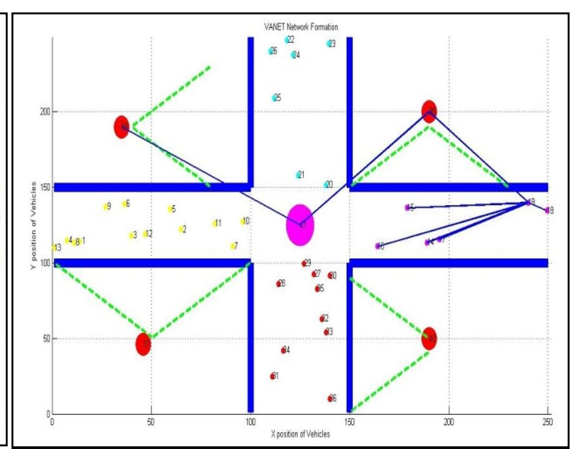


Fig3:Fixed Sensor Network

Fig4:Mobile Sensor Network

IV. NUMERICAL INTERPRETATIONS

Numerical analysis are discussed and plotted below. Each block in the block diagram performs a set of mathematical iterations in order to produce a precise output which is carried forward as an input to the next block as explained previously.

Here we consider 4 major parameters to estimate the performance of the networks considered. They are

Time

Hops

Energy

Routing Overhead

The Fig4, Fig5, Fig6 and Fig7 shows respectively each parameter plotted against number of iterations. All the graphs show that the mobile sensor network has an upper hand over the traditional fixed sensor network.

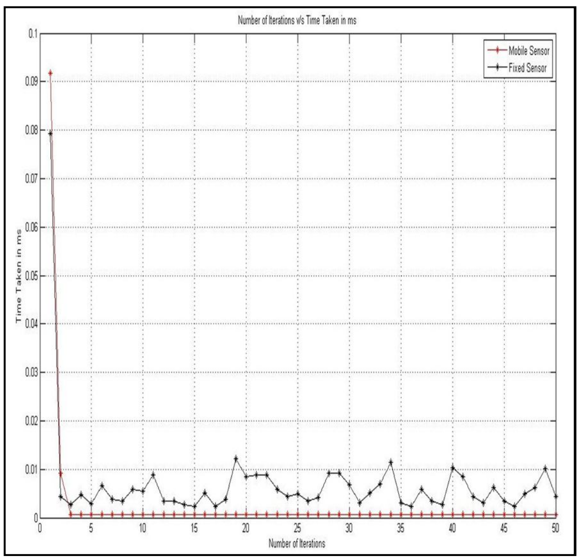


Fig4:Time v/s Iterations

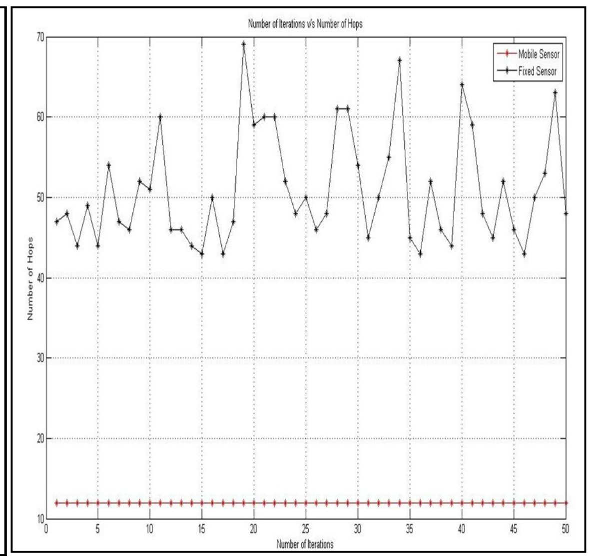


Fig5:No. of Hops v/s Iterations

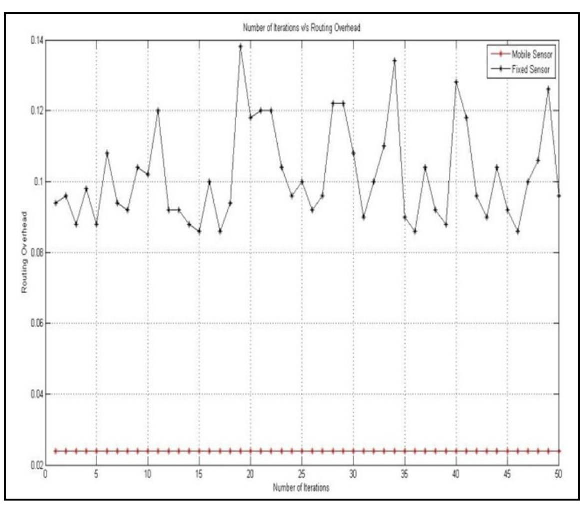


Fig6:Energy v/s Iterations

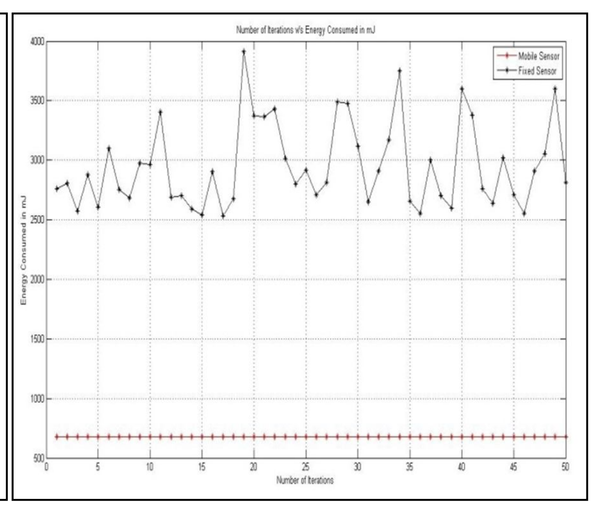


Fig7:Routing Overhead v/s Iterations

V. CONCLUSIONS

In transportation networks, efficient sensors networks are very necessary to monitor and maintain a smooth flow of traffic. If a sensor network fails, it can prove to be fatal and thereby reduce the efficient maintenance of traffic networks. So a sensor network plays a key role in collecting info and maintaining the free flow of traffic along the designated path. But as pointed out, a key challenge arising here is that, if the sensors are fixed, then they will be unable to identify or monitor remote areas beyond its range. So an efficient algorithm has been laid out in the above project discussing the issues related to the traditional methods of maintaining a vigilance over the traffic network and how it has been overcome using the current method and what are the key differences and efficiencies of the latter over the former. We also come on to say that there are certain shortcomings of the current method employed in the traffic sensing and information retrieval system but these are unimportant in the present context as we mainly focus on the strength of the system in the ability to mine the information and pass it on to the controlling system. With this, the main objective of maintaining the traffic efficiently can be achieved.

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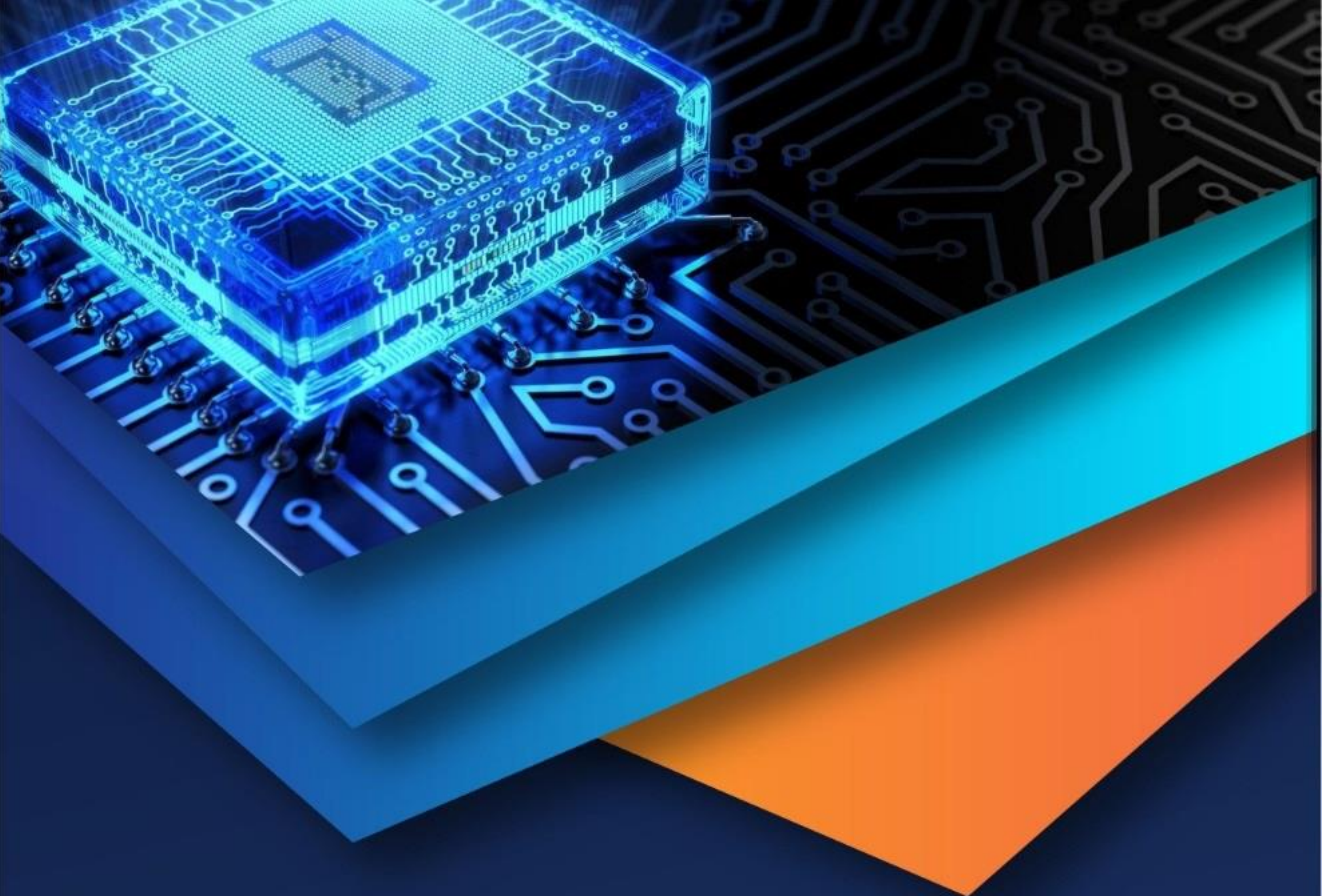

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