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An Energy Efficient Decentralized Detection Of System For Structural Health Monitoring In Wireless Sensor And Actuator Networks

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***Abstract:** In smart cities, infrastructures, such as bridges and buildings, are equipped with smart sensing and actuator devices interconnected via wireless links composing a wireless sensor and actuator network (WSAN). The WSAN nodes are able to measure a variety of environmental parameters, process the sensing data locally, work in a collaborative way, make decisions on the occurrence of relevant events, and react to such events performing local control actions or sending warnings to remote operators. The unprecedented capabilities of monitoring and responding to stimuli in the physical world of wireless sensor and actuator networks (WSAN) enable these networks to provide the underpinning for several Smart City applications, such as structural health monitoring (SHM). In those applications, civil structures, endowed with wireless smart devices, are able to self-monitor and autonomously respond to situations using computational intelligence. A decentralized algorithm for detecting damage in structures by using a WSAN. As key characteristics, beyond presenting a fully decentralized (in-network) and collaborative approach for detecting damage in structures, our algorithm makes use of cooperative information fusion for calculating a damage coefficient. The algorithm in terms of its accuracy and efficient use of the constrained WSAN resources.*
***Keywords**: Decentralized Algorithm, Information Fusion, Structural Health Monitoring, Wireless Sensor and Actuator Networks, Smart Cities*

I. INTRODUCTION

ADVANCED detecting systems play a major role as empowering technologies to construct brilliant urban areas. In urban areas, infrastructures, such as flyovers, bridges and buildings are furnished with smart sensing and actuator gadgets interconnected by means of wireless connections creating a wireless sensor and actuator network (WSAN) [1]. The WSAN hubs can able to measure a variety of natural parameters, process the detecting information locally, work cooperatively, make choices on the occurrence of significant events, and respond to such events performing nearby control activities or sending notices to remote administrators. Applications running on top of WSAN can give a wide assortment of services to the citizens. The SHM is a rising innovation, managing with the improvement and execution of continuous and reliable monitoring frameworks for civil foundation structures using a thick WSAN. The detecting devices normally utilized for SHM applications are strain gauges, anemometers, thermistors, and accelerometers. These gadgets gather information from the monitored environment, for example, vibration estimations using accelerometers, and convey them as advanced information. In this manner, by preparing this information, the SHM techniques permit the identification, localization and degree of extent determination of harm in structures.

Most of the SHM algorithms found in the literature employ centralized architectures with sensing nodes transmitting messages to a centralized entity wherein the damage detection processes effectively happen [4]. A feasible approach to overcome this architectural restriction is to perform damage detection processes inside the WSAN nodes. A key test is the manner by which to augment WSAN lifetime while keeping up the functionality of damage detection inside the system. Such diminishment in energy consumption is important since WSAN hubs exceptionally restricted vitality assets, regularly provided by non-rechargeable batteries. One conceivable approach used to decrease WSAN energy utilization is creating energy proficient procedures, protocols and methodologies [1].Algorithm make utilization of a data fusion process that acts in the three information reflection levels (measurement, highlight feature and choice) frequently considered in the data fusion literature [2]. This is normally the instance of a completely in-network system SHM process, thus algorithm is delegated as a multilevel fusion process. It is observable, particularly in the SHM literature, the broad utilization use of damage coefficients as consequences of multilevel fusion processes [3], [4], [5]. The quick advantage of utilizing information fusion techniques for calculating a damage coefficient is that only such coefficient, with a diminished measure of information, is transmitted for further examination. Thusly, less energy is spent in the WSAN because of information transmissions.

II. RELATED WORK

In this section, we present existing approaches for damage detection algorithms that are fully decentralized, a procedure for damage location detection and localization on a truss structure WSAN progressively partitioned into groups, diminishing the measure of transmissions in the network system, since it is not necessary that all sensors forward their information to the sink. In the meantime the amount of information sent to the sink is littler and as of now consolidated; there is a decrease in the season of damage recognizance. The proposed damage representation, the CDC (cooperative damage coefficient), which is capable of representing damage utilizing a littler amount of information, and utilization data from both amplitude and frequency moves all the while.

A decentralized algorithm called Sensor-SHM, for damage identification, localization and extent determination in common structures utilizing a WSN. The basic leadership procedure of decision making about damage detection is performed cooperatively between the neighboring sensor hubs without the assistance of the sink node, neither the group-head, and here utilize a flat topology. Our damage portrayal, CDC, contrasts from the damage coefficient of which uses a bigger amount of information for speaking to damage. The CDC is utilized for showing which modular frequencies have changed utilizing just an amount of data in the scale of bits. In the algorithm, the hubs have just an incomplete view about the integrity of the structure and collaborate among themselves to achieve a consensual multilevel choice to have an extensive perspective of the result of damage identification.

A. Limitation of the Existing system

1) Energy saving is not achieved.
2) Less accuracy in detection of damage.
3) Large amount of data is required to calculate damage coefficient.
4) Performs a collaboration procedure in a single level.

B. Problem Statement

1) How to build WSAN lifetime while keeping up the usefulness of damage detection inside the network system.
2) Damage disclosure algorithms based on just in the variety of modular frequencies, are for the most part less accurate when applied to specific structures
3) How to outline algorithms to fit for supporting accurate damage detection, as far the rate of accomplishment in the recognition of damage in different structures.
4) A primary issue that can emerge is that SEN can be biased due to, for example, sensor malfunctioning, malicious behavior because of attacks, low battery level, environmental impacts or electro-magnetic disturbances. In all such cases, SENs may bring about the wrong behavior of the actuators, activating them when redundant.

III. DESCRIPTION OF THE PROPOSED ALGORITHM

A decentralized algorithm is used for distinguishing damage in structures by utilizing a WSAN. The utilization of the data fusion strategies decreases the transmissions of information messages. Every node might be furnished with both sensing and actuating gadgets. Here consider two roles for the nodes: sensor (SENs) and actuator (ATNs). A SEN is viewed as the fundamental “sensing, processing and decision unit” in the WSAN. Each ATN is considered the basic “actuation unit” in the WSAN. Such nodes are furnished with no less than one physical actuation gadget. Such nodes are equipped with at least one physical sensing device, and have their logical sensing ability dynamic. It is conceivable to detect a solitary position of damage utilizing this algorithm for a situation where damage on a structure makes its frequencies and amplitudes move. The information fusion procedures decreased data and, subsequently, permitted a speedier and less energy consumptive data exchange among WSAN nodes. False positive and false negative shirking is a portion of the principle motivations to stimulate such collaboration mechanisms among the nodes in this algorithm.

A. Advantages of Proposed System

1) It is possible to detect a single position of damage.
2) Fusion techniques helped to reduce data and consequently allowed a faster information exchange among WSAN nodes.
3) Less energy consumption
4) Algorithm in terms of its accuracy and efficient use of the constrained WSAN resources.

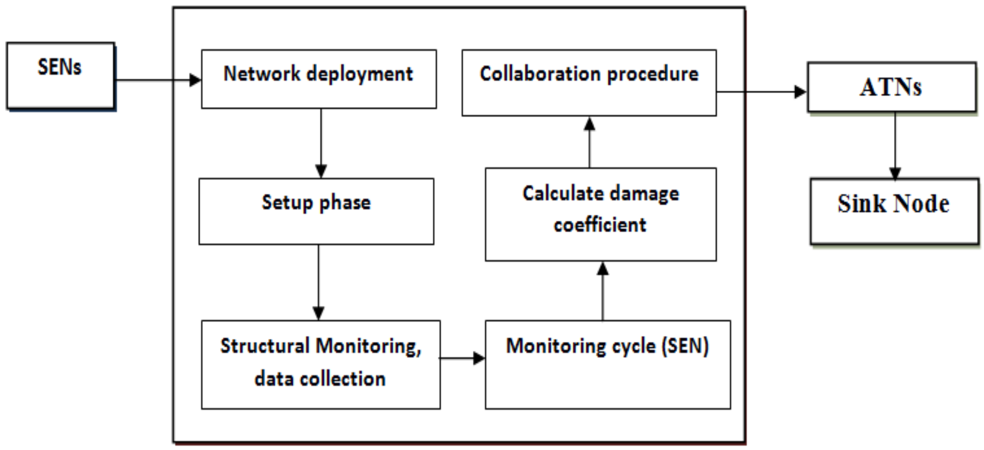

Figure 1: shows overall process of proposed system, all above steps should perform carefully so that damage can be detect with high accuracy.

Figure.1 shows the Architecture design where the user will configure the system using sensors, actuators and sink node. The configuration will be in terms of the number of nodes, mobility pattern of the nodes, etc. setup phase is done with initialization of parameters which are required. Structural monitoring is made by all sensor nodes and calculates the damage coefficient among them and reaching a general agreement that will be more accurate that is single position of damage in structures. Collaboration procedure is made among those sensors nodes and sends the resulting information to actuator nodes to do some control actions and then it sends report of damage to the sink node. Decentralized algorithm and collaboration procedure is mainly used to find accurate damage in structures. Statistics module gathers the result from the wireless simulator like packet deliver ratio, energy consumed, end to end delay, etc. and plot in a x- graph.

IV. MODULES IN IMPLEMENTATION

A. *Network Deployment*

Proposed algorithm is performed by the set of WSAN nodes including sink node deployed over monitoring area of structure. Each node may be equipped with both sensing and actuating devices. First define the Network configuration parameters i.e., specify the number of nodes, initial energy, MAC, propagation, Receiver power, sleep power, transmission power, Channel Type, Propagation or Two Ray Ground i.e., radio-propagation model, network interface (Physical/Wireless), MAC type (Mac/802_11), interface queue type, link layer type, antenna model (Antenna /Omni Antenna), number of mobile nodes, X axis distance, Y axis distance Initial Energy, Initial energy in Joules. Then deploy all the nodes into the network with some moving velocity. The network stack for a mobile node consists of a link layer (LL), an ARP module connected to LL, an interface priority queue (IFq), a mac layer (MAC), a network interface (net IF), all connected to the channel. These network components are created and plumbed together in OTcl.

B. *Setup Phase*

Setup phase is performed after the network is physically deployed. The procedure of this phase is performed for all the network nodes and consists on setting the algorithm initial parameters and performing initializations required.It encompasses five procedures that are performed by all the nodes in the network.

1) *Boot() :-* It represents the hardware initializations of each node for making the node operational and ready to run the algorithm. During this procedure the node unique identification parameter is set to each node.
2) *Set_role():-* It sets the logical sensing and actuating capabilities of the node. These capabilities identify during the execution of the algorithm, the respective SEN (sensor), ATN (actuator) or SKN (sink) role for a node. All the roles can be set by operator and disseminated in the network through the SKN.
3) *Init():-* It consists of setting the initial values of the parameters such as N modes, limited frequency and amplitude, number of samples, neighbor node ID which are used in monitoring area of structure. An expert of an application divide the monitoring area into small sensing zones then assign nodes to a zone.

4) *Frist_time_sync():-* Synchronization procedure has to be maintained and adjusted during monitoring cycle phase that is each node must be synchronized such that it has both transmitting and receiving capabilities.
5) *Ref_values_acquitisation():*-SENs must collect the values from fixed position of the structure and store them as reference frequency and reference amplitude data and some limited frequency and amplitude values are taken from expert of structure which are used while calculating CDC(cooperative damage coefficient) in monitoring cycle phase.

C. Monitoring cycle phase

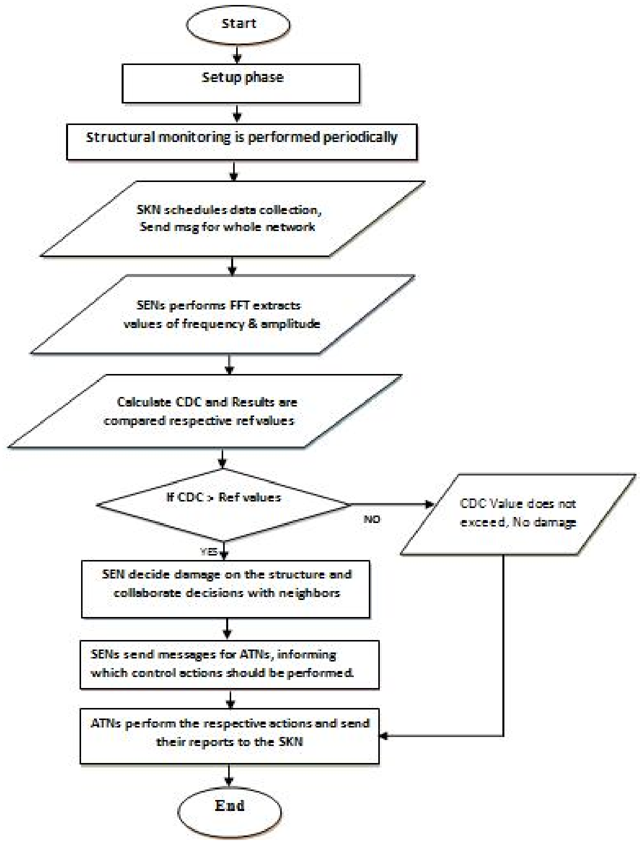

Figure 2: shows the sequence of stepsthat make up a Decentralized algorithm easy to understand.

Figure 2 shows the flow diagram of decentralized algorithm for damage detection. Set up phase, monitoring cycle phase, collaboration procedure are the three main phases in this algorithm. Setup phase consists of network deployment with initial parameters and each node must be synchronized. An application expert divides the monitoring area into small sensing zones. Sink node sends the monitoring request to all sensor nodes then these sensors generates the current frequency and amplitude values from the data of structure by calculating FTT. CDC is calculated by each sensor node and compares those values among themselves and reaching a general agreement about damage in structure. Sensor node with smallest node ID will send the decision about damage to actuator node then ATN will do some control actions and send the report to sink node.

This phase contains the working of sensors, actuator and sink node in a structure. The following algorithm shows the monitoring cycle algorithm.In this paper the proposed CDC Protocol is implemented in the MAC and used to test variations on the amplitudes of each vibration mode of the structure. This protocol is initialized during this procedure. CDC is the artifact used for indicating which modal frequencies and amplitudes have changed from the viewpoint of a SEN. CDC is subdivided into two parts: shifts in frequencies ($\Delta\omega$) and shifts in amplitudes(Δa). variations_due_damage() procedure, passing the recently calculated CDC as a parameter. Calculation of CDC is showing below.

$$\Delta\omega = \{1 \text{ if } (Freqs - RefFreqs) > LFreqs$$
$$\{0 \text{ if } (Freqs - RefFreqs) \leq LFreqs$$
$$\Delta a = \{1 \text{ if } (Amps - RefAmps) > LAmps$$
$$\{0 \text{ if } (Amps - RefAmps) \leq LAmps$$

D. Collaboration phase

The nodes can communicate their local decisions among themselves, and evaluating neighbor decisions and reaching a general agreement which may be more accurate about damage detection is mean to be collaboration procedure. SENs may cause the wrong behavior of the actuators due malfunctioning, malicious behavior due to attacks so to reduce those faulty SENs and to achieve consensus we adopt byzantine algorithm as collaboration procedure.

V. RESULTS AND ANALYSIS

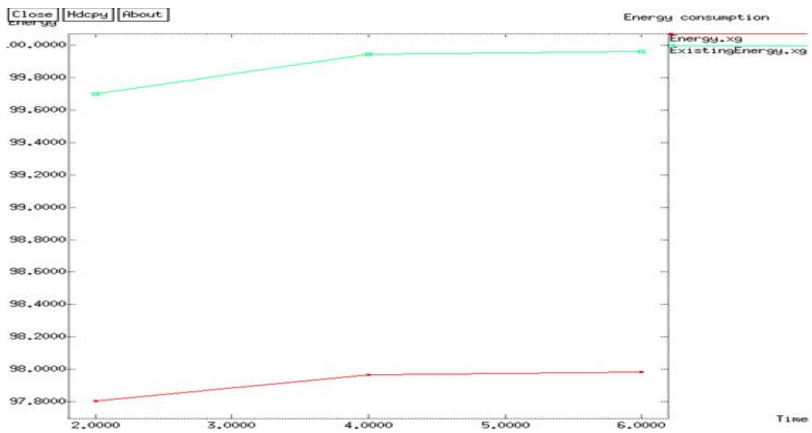

Fig a: Graph for WSAN Lifetime Metric

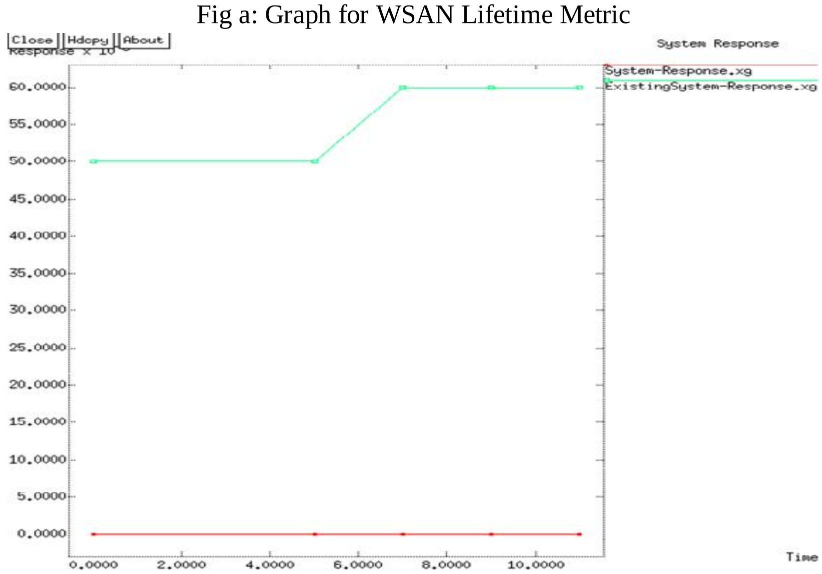

Fig b: Graph of System Response Time

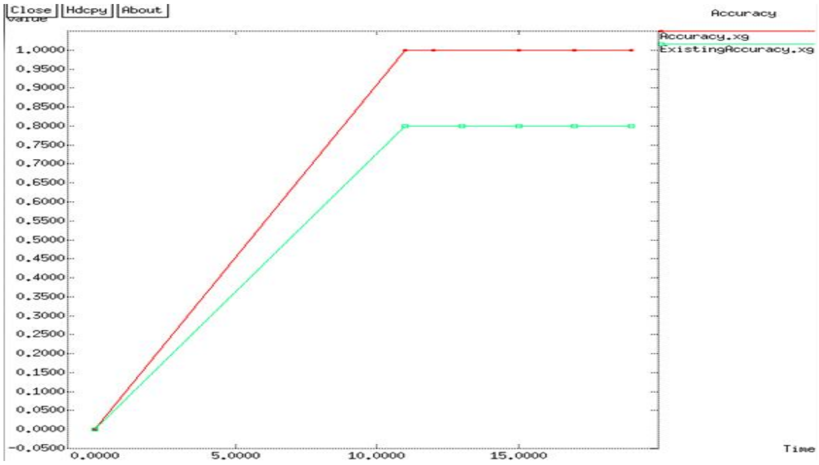

Fig c: Graph for Accuracy of Damage.

VI. CONCLUSION AND FUTURE SCOPE

A decentralized algorithm for detecting damage in structures by using a WSAN is proposed. The fusion technique reduces the transmissions of data messages because of this we can detect a single position of damage where if damage is their then there will be shift in amplitude and frequency. By this we can reduce data collision and allows faster and less energy consumption exchange of information between WSAN nodes. False positive and false negative avoidance are some of the main reasons to stimulate such collaboration mechanisms among the nodes in our algorithm. In future works, we intend to explore the cooperative information fusion along with data from different kinds of sensors, such as strain gauges. Another future direction is to investigate the existence of an optimal point where data reduction and information fusion should be applied in our assessment, relating in a trade-off the reduction in overhead and the loss of accuracy.

VII. FUTURE SCOPE

Future scope is to investigate the existence of an optimal point where data reduction and information fusion must be applied, relating in a trade-off the reduction in overhead and the loss of accuracy.

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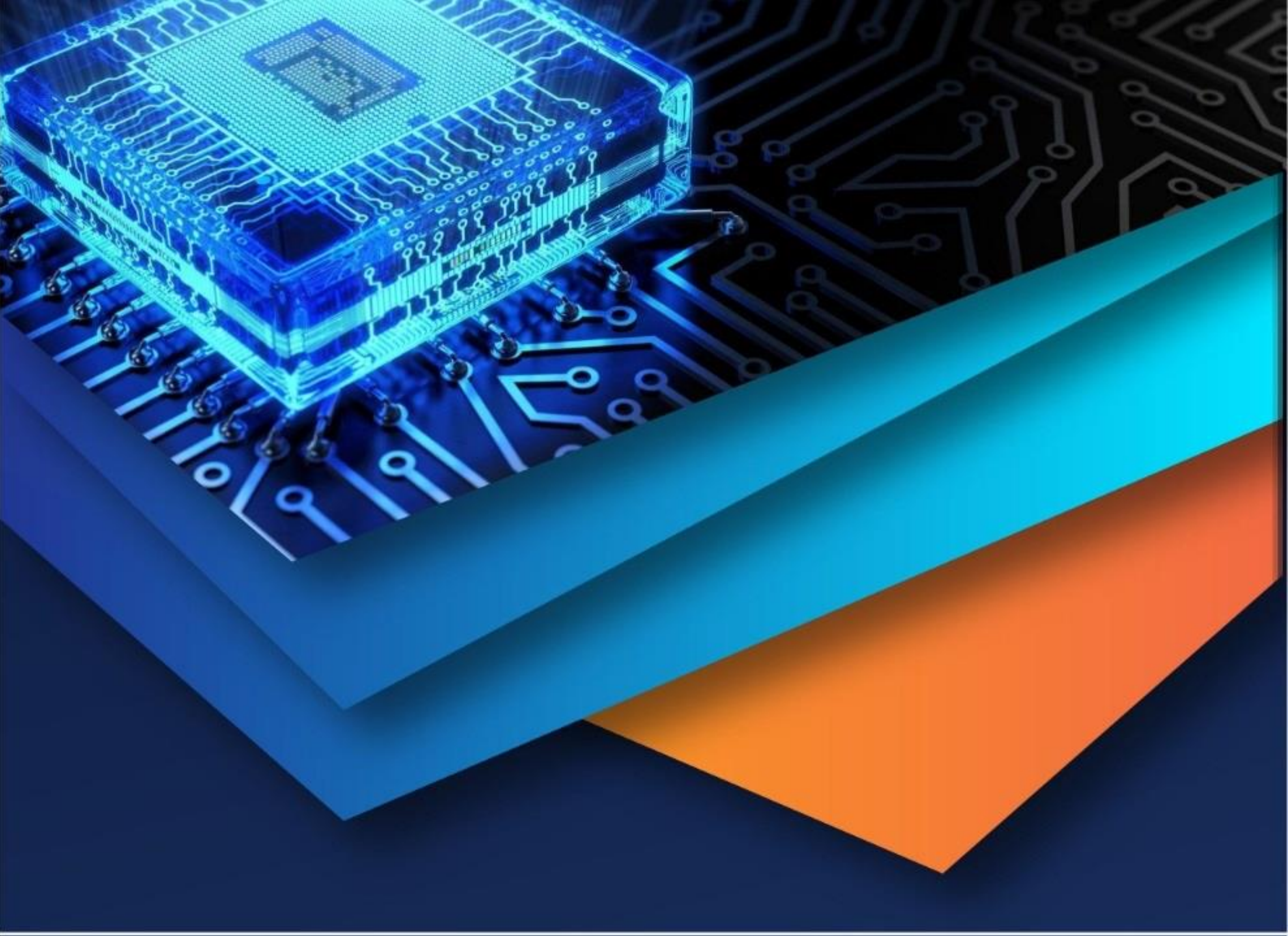

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