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Efficient MAC Protocol for MANET

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Abstract--- MANET an acronym for mobile AD HOC network is one of the most recent emerging trends in research areas of computer science. Mobile refers to movement, AD HOC means temporary and network meaning collection of nodes interconnected with each other MANETS are self organized. Medium Access Control protocol for ad-hoc wireless networks that utilizes multiple channels dynamically to improve performance. The IEEE 802.11the use of multiple channels but MAC protocol only design single channel. A single channel MAC protocol does not work well in a multi-channel environment, because of the multi-channel hidden terminal problem. The protocol requires only one transceiver per post, but solves the multi-channel hidden terminal problem using temporal synchronization our scheme improves network throughput significantly, especially when the network is highly congested. Also, the performance of our protocol is comparable to another multi-channel MAC protocol that requires multiple transceivers per host. Since our protocol requires only one transceivers per host, it can be implemented with a hardware complexity comparable to IEEE 802.11.

Keywords--- MANET, ad hoc networks, medium access control, multi-channel

I. INTRODUCTION

Present wireless networks are based on a static or fixed spectrum assignment policy that is regulated by government agencies, has let to a quasi-scarcity of the spectrum. Traditionally, spectrum segments are licensed on a long term basis in particular geographic regions. Only small segments of unlicensed spectrum remain available. Cognitive radio (CR) [1] technology has been proposed as a promising solution to share the scarce spectrum resources in an opportunistic way while avoiding disruptions to the legacy devices of wireless networks i.e. TV broadcast stations and wireless microphone. The CR user also called secondary user (SU) is allowed to use only locally unused spectrum so that it does not cause any interferences or collisions to the incumbent or primary users (PUs). Recent spectrum measurements [2] show that fixed spectrum policy is becoming unsuitable for today's wireless communications. As the frequency spectrum becomes exhausted [3], CR is becoming a hot research topic in the wireless communications arena. The throughput of multi-hop wireless networks can be significantly improved by multichannel communications compared with single channel communication, as transmission can be processed on different channels simultaneously while avoiding collisions and interference in wireless ad hoc networks. We consider a multichannel CRN, in which every node is equipped with single network interface card (NIC) and can be tuned to one of the available channels. A pair of NICs can communicate with each other if they are on the same channel and are within the transmission range of each other. Although the basic idea of CR is simple, the efficient design of CRNs imposes the new challenges that are not present in the traditional wireless networks. Specifically, identifying the time-varying channel availability imposes a number of nontrivial design problems to the MAC layer. One of the most difficult, but important, design problems is how the SUs decide when and which channel they should tune to in order to transmit/receive the SUs' packets without interference to the PUs. This problem becomes even more challenging in wireless ad hoc networks where there are no centralized controllers, such as base stations or access points.

By exploiting multiple channels, we can achieve a higher network throughput than using one channel, because multiple transmissions can take place without interfering. How-ever, the MAC protocol of IEEE 802.11 Distributed Coordinate Function (DCF) is designed for sharing a single channel between hosts. Designing a MAC protocol that exploits multiple channels is not an easy problem, due to the fact that each of current IEEE 802.11 device is equipped with one half-duplex transceiver. The transceiver is capable of switching channels dynamically, but it can only transmit or listen on one channel at a time. Due to this, a new type of hidden terminal problem occurs in this multi-channel environment, which we refer to as multi-channel hidden terminal problem (we identify this problem in more detail in Section IV). So a single-channel MAC protocol (such as IEEE 802.11 DCF) does not work well in a multi-channel environment where nodes may dynamically switch channels.

A distributed cognitive radio MAC (DCR-MAC) protocol is proposed in [23] for wireless ad hoc networks that provides for the detection and protection of incumbent systems around the communication pair. DCR-MAC operates over a separate common control channel and multiple data channels; hence, it is able to deal with dynamics of resource availability effectively in cognitive networks. A simple and efficient sensing information exchange mechanism between neighbor nodes with little overhead is proposed. A cognitive MAC protocol for multichannel wireless networks (C-MAC) is proposed in [24], which operates over multiple channels, and hence is able to effectively deal with the dynamics of resource availability due to PUs and mitigate the effects of distributed quiet periods utilized for PU signal detection. In C-MAC, each channel is logically divided into recurring super frames which, in turn, include a slotted beaconing period (BP) where nodes exchange information and negotiate channel usage. Each node transmits a beacon in a designated beacon slot during the BP, which helps in dealing with hidden nodes, medium reservations and mobility.

II. RELATED WORK

The underutilization of spectrum under the current static spectrum management policy has stimulated a flurry of existing research activities in searching CR MAC protocols. Recently, several attempts were made to develop MAC protocols for CRNs [13]-[21]. One of the key challenges to enabling CR communications is how to perform opportunistic medium access control (MAC) while limiting the interference imposed on PUs. The IEEE 802.22 working group is in the process of standardizing a centralized MAC protocol that enables spectrum reuse by CR users operating on the TV broadcast bands [22]. In [17]-[19], centralized protocols were proposed for coordinating spectrum access. For an ad hoc CRN without centralized control, it is desirable to have a distributed MAC protocol that allows every CR user to individually access the spectrum.

A number of multichannel contention-based MAC protocols were previously proposed in the context of CRNs [13]-[16]. The CRN MAC protocol in [13] jointly optimizes the multichannel power/rate assignment, assuming a given power mask on CR transmissions. How to determine an appropriate power mask remains an open issue. Distance and traffic-aware channel assignment (DDMAC) in cognitive radio networks is proposed in [14]. It is a spectrum sharing protocol for CRNs that attempts to maximize the CRN throughput through a novel probabilistic channel assignment algorithm that exploits the dependence between the signal’s attenuation model and the transmission distance while considering the prevailing traffic and interference conditions.

A bandwidth sharing approach to improve licensed spectrum utilization (AS-MAC) is presented in [15] is a spectrum sharing protocol for CRNs that coexists with a GSM network. CR users select channels based on the CRN’s control exchanges and GSM broadcast information. Explicit coordination with the PUs is required. In [21], the authors developed a spectrum-aware MAC protocol for CRNs (CMAC). CMAC enables opportunistic access and sharing of the available white spaces in the TV spectrum by adaptively allocating the spectrum among contending users.

Compared to the above works, our protocol operates with one transceiver per host. Also, it does not require a dedicated control channel. Instead, our scheme requires clock synchronization among all the hosts. During this interval hosts do not exchange data packets. So this duration of time is an overhead in our scheme. However, as we will see in later sections, it achieves better throughput than maintaining a separate control channel.

III. PRELIMINARIES

In this section, we present some background information on IEEE 802.11’s DCF and power saving mechanism.

A.IEEE 802.11 Distributed Coordination Function (DCF)

In IEEE 802.11 DCF, a node reserves the channel for data transmission by exchanging RTS/CTS messages with the target node. Figure 1 illustrates the operation of IEEE 802.11 DCF. When node B is transmitting a packet to node C, node A overhears the RTS packet and sets its NAV until the end of ACK, and node D overhears the CTS packet and sets its NAV until the end of ACK. After the transmission is completed, the stations wait for DIFS and then contend for the channel. In this figure, node B is a *hidden terminal* to node D. Without virtual carrier sensing, D would not know of B’s transmission. So D may start transmitting a packet to C while B is transmitting, which results in a collision at C.

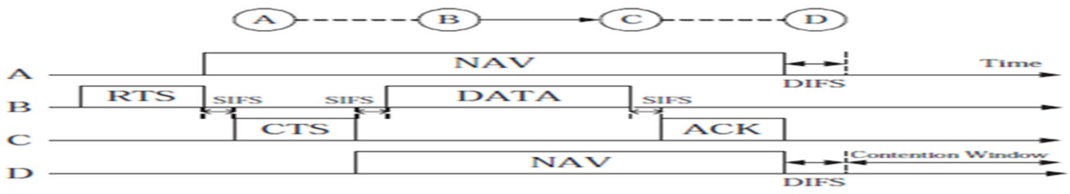

Figure 1: Operation of IEEE 802.11 DCF

B. IEEE 802.11 Power Saving Mechanism

In this section, we describe IEEE 802.11 PSM to explain how ATIM windows are used. A node can save energy by going into *doze* mode. In doze mode, a node consumes much less energy compared to normal mode, but cannot send or receive packets. It is desirable for a node to enter the doze mode only when there is no need for exchanging data. In IEEE 802.11 PSM time is divided into beacon intervals, and every node in the network is synchronized by periodic beacon transmissions. So every node will start and finish each beacon interval at about the same time.

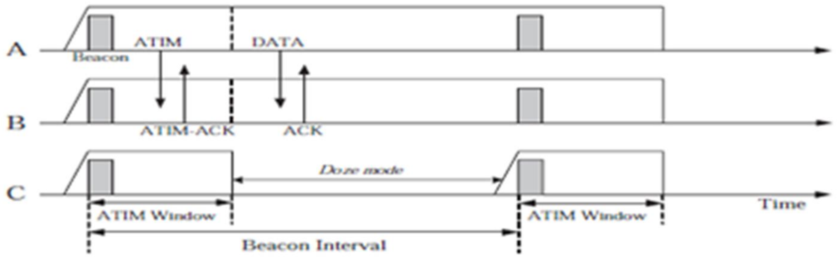

Figure 2: Operation of IEEE 802.11 PSM

IV. MULTICHANNEL HIDDEN TERMINAL PROBLEM

Normally, when a node is neither transmitting nor receiving, it listens to the control channel. When node A wants to transmit a packet to node B, A and B exchange RTS and CTS messages to reserve the channel as in IEEE 802.11 DCF [12]. RTS and CTS messages are sent on the control channel. When sending an RTS, node A includes a list of channels it is willing to use. Upon receiving the RTS, node B selects a channel and includes the selected channel in the CTS. After that, node A and B switch their channels to the agreed data channel and exchange the DATA and ACK packets.

For the sake of illustration, we start with a simple multi-channel MAC protocol that does not address this problem. The protocol is similar to, except it assumes each node has one transceiver. Suppose there are *N* channels avail-able. One channel is dedicated for exchanging control messages (control channel), and all the other channels are for data. When a node is either transmitting or receiving, it listens to the control channel.

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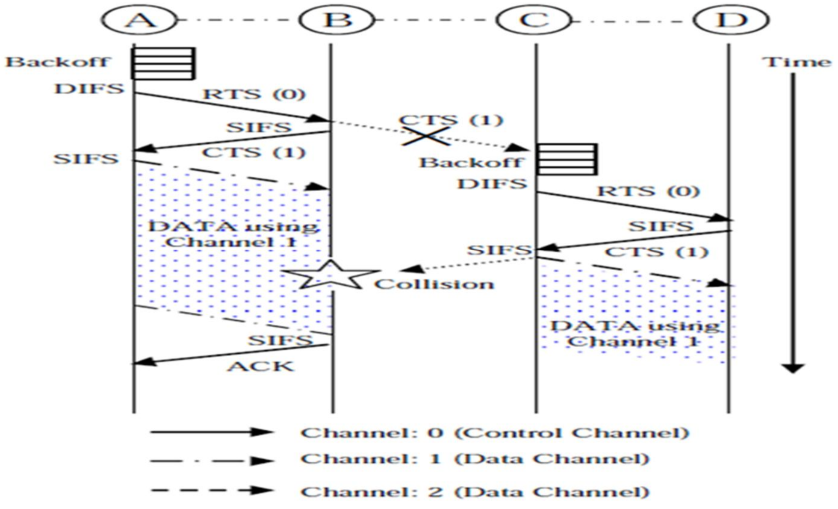

Figure 3: Multichannel hidden terminal problem

A new type of hidden terminal problem pertaining to multi-channel environment, which we call the *multi-channel hidden terminal problem*. For the sake of illustration, we start with a simple multi-channel MAC protocol that does not address this problem. The protocol is similar to [8], except it assumes each node has one transceiver. Suppose there are *N* channels available. One channel is dedicated for exchanging control messages (control channel), and all the other channels are for data.

V. PROPOSED MULTI-CHANNEL MAC (MMAC) PROTOCOL

In this section, we present our proposed scheme. Before describing the protocol in detail, we first summarize our as-assumptions.

A. *Preferable Channel List (PCL)*

Based on this information, the channels are categorized into three states.

1) *High preference* (HIGH): This channel has already been selected by the node for use in the current beacon interval. If a channel is in this state, this channel must be selected. For each beacon interval, at most one channel can be in this state at each node.
2) *Medium preference* (MID): This channel has not yet been taken for use in the transmission range of the host. If there is no HIGH state channel, a channel in this state will be preferred.
3) *Low Preference* (LOW): This channel is already taken by at least one the node's immediate neighbors. To balance the channel load as much as possible, there is a counter for each channel in the PCL to record how many source-destination pairs plan to use the channel for the current interval. If all channels are in LOW state, a node selects the channel with the smallest count.

B. *Channel Negotiation during ATIM Window*

In MMAC, periodically transmitted beacons divide time into beacon intervals. A small window called the *ATIM window* is placed at the start of each beacon interval. The nodes that have packets to transmit negotiate channels with the destination nodes during this window. In the ATIM window, every node must listen to the *default channel*. The default channel is one of the multiple channels, which is predefined so that every node knows which channel is the default channel. During the ATIM window, all nodes listen on the default channel, and beacons and ATIM packets are transmitted on this channel. Note that outside the ATIM window, the default channel is used for sending data, similar to other channels.

C. *Rules for Selecting the Channel*

When a node receives an ATIM packet, it selects a channel and notifies the sender by including the channel information in the ATIM-ACK packet. The receiver tries to select the "best" channel based on information included in the sender's PCL (preferable channel list) and its own PCL.

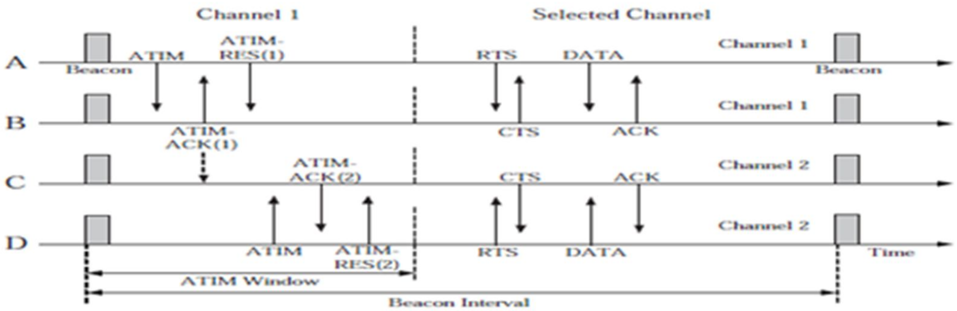

Figure 4: Process of channel negotiation and data exchange in MMAC

A TDMA scheme is used in the communication window of our proposed ECR-MAC as depicted in the figure 2. The ECR-MAC scheme has some similarities with TMMAC [36]. We assume that time domain is divided into fixed length beacon intervals and each beacon interval consists of an ad hoc traffic indication messages (ATIM) window, a sensing window, and a communication widow.

If a node has negotiated to send or receive a packet in the j^{th} time slot, it first switches to the negotiated channel and transmits or waits for the data packet in that slot. If a receiver receives a uncast packet, the receiver sends back an ACK in the same time slot as shown in the slot structure of figure 2. Note that proposed MAC scheme does not guarantee 100% collision-free communication in the communication window, since packet collision may occur in the ATIM window which may convey incorrect information of negotiation.

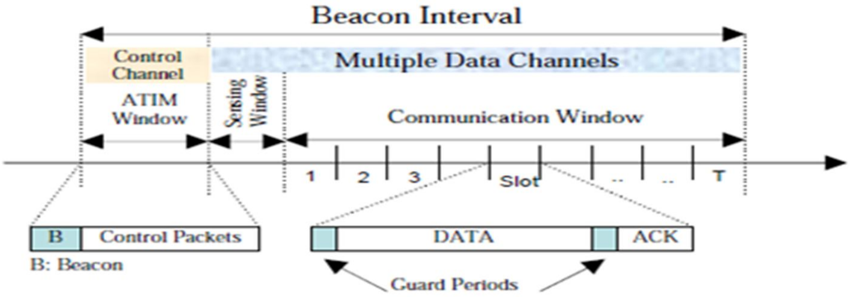

Figure 5: Structure of MAC protocol

VI. PERFORMANCE EVALUATION

We compare our scheme with IEEE 802.11, and the Dynamic Channel Assignment (DCA) protocol (DCA was explained in section II).

A. Aggregate throughput over all flows in the network:

Our protocol is expected to increase the total through-put of the network by exploiting multiple channels. Thus, this metric will directly show how our protocol achieves this goal. Ideally, a multi-channel MAC will improve the total throughput by a factor of *N* over a single-channel MAC given that *N* data channels are available.

B. Average packet delay over all flows in the network:

Average packet delay is the duration between the time when the Link layer of the sender receives a packet to send, and the time the packet reaches the destination.

C. Wireless LAN

In the simulated wireless LAN, all nodes are within each other’s transmission range. So every source node can reach its destination in a single hop. The number of nodes we used is 6, 30, and 64. For each scenario, half of the nodes are sources and the other half are destinations. So a source has at most one destination. The impact of a source having multiple destinations or a destination having multiple sources is not studied in this scenario, but it is studied in the multi-hop network scenario.

D. Multi-hop network

For a multi-hop network, 100 nodes are randomly placed in a 500*m* × 500*m* area. 40 nodes are randomly chosen to be sources, and 40 nodes are chosen to be destinations. A node may be the source for multiple destinations and a node may be the destination for multiple sources. In a multi-hop network

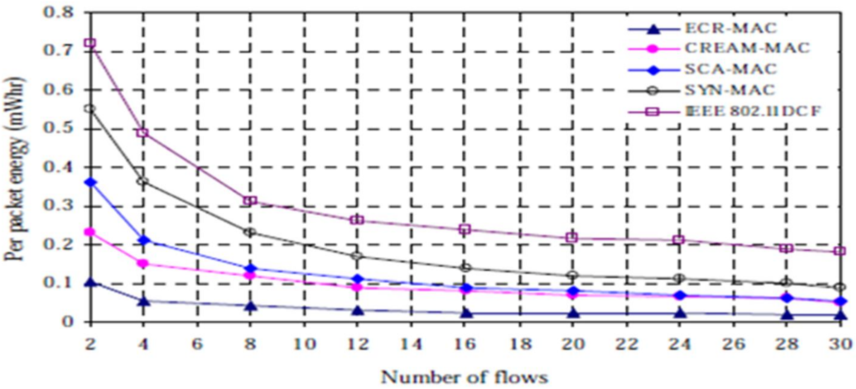

Figure 6: Per packet energy varying number of flows

shows that MAC consumes much less per packet energy compared to other protocols. IEEE 802.11 MAC becomes more significant as the number of flows increases. We conclude the following reasons for the low per packet energy consumption in MAC. Firstly, MAC allows a node to switch to mode in a time slot whenever it is not scheduled to transmit or receive a packet. In other protocols, due to the lack of time negotiation, a node needs to stay awake during the whole communication window when it has negotiated to transmit or receive packets. Finally, MAC achieves much higher aggregate throughput, which further reduces its per packet energy consumption.

VII. DISCUSSION

The MMAC protocol requires all clocks in the network to be synchronized, so that all nodes start a beacon interval at the same time. To model the overhead, we have implemented the beaconing mechanism similar to IEEE 802.11 At the start of a beacon interval, each node waits for a random delay and transmits a beacon. At the start of a beacon interval, each node chooses a random delay and transmits a beacon. It might happen that node A always transmits a beacon before B, and node D always transmits a beacon before C. Then the clocks of (A, B) and (C, D) may drift away, because they never exchange beacons.

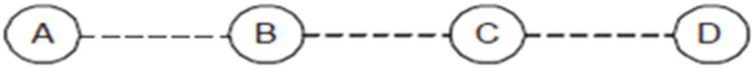

Figure 7: A chain topology of 4 nodes

When a node is sending packets to two different destinations, these two destination nodes may select a different channel. For example, suppose that we have nodes A, B and C in the network, as in Figure 13. Node A has some packets destined for B and others destined for C. During channel negotiation, node B selects channel 1 and node C selects channel 2. If A selects channel 1, it can only transmit packets destined for B, and all the packets destined for C must wait until next beacon interval to negotiate the channel again. This behavior of MMAC protocol raises several issues. First, to avoid *head of line blocking* problem, the packets that cannot be transmitted because of channel mismatch must be kept in a separate buffer, and restored to the queue at the end of the beacon interval. This complicates the queue management. Also, it is possible that the same channels are selected by each node in the subsequent beacon intervals, starving the flow from A to C.

In our scheme, if node A has to send ATIM packets to B and C, A chooses randomly which one to send the packet to first. This randomness should prevent complete starvation, although there can be short-term unfairness among the flows. Instead of randomly choosing among the destinations, node A can send an ATIM packet first to the destination which is the target node of the first packet in its queue. This modification will improve the fairness of the protocol.

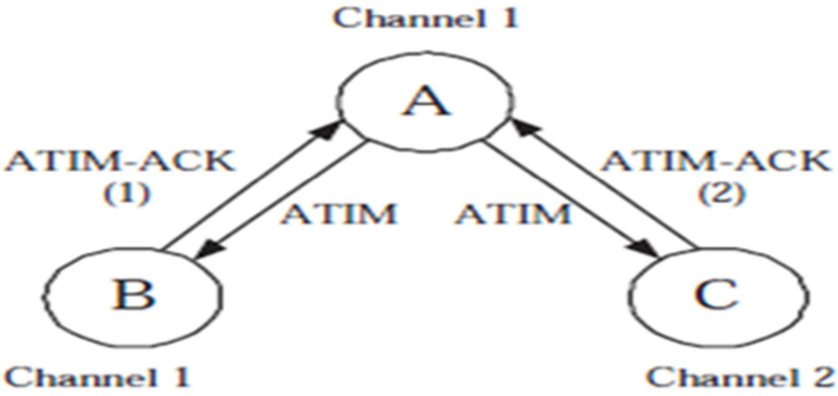

Figure 8: An example network scenario. Assume there are other nodes in the vicinity of these three nodes that affect the PCL of these three nodes. Node A has packets for B, and also packets for C. A exchanges ATIM messages with B first, and both select channel 1. After that, A sends an ATIM packet to C, and C selects channel 2. Since A will stay in channel 1 for the beacon interval, packets for C must be deferred until the next beacon interval.

VIII. CONCLUSION

In this paper, we have presented a multi-channel MAC protocol that utilizes multiple channels to improve through-put in wireless networks. The proposed scheme requires only one transceiver for each host, while other multi-channel MAC protocols require multiple transceivers for each host. Nodes that have packets to transmit negotiate which channels and time slots to use for data communication with their destinations. This negotiation enables MAC to exploit the advantage of both multiple channels and TDMA in an efficient way. In addition, MAC is able to support broadcast in an energy effective way. Since ECR-MAC only requires one transceiver per node, it can be implemented with hardware complexity comparable to IEEE 802.11.

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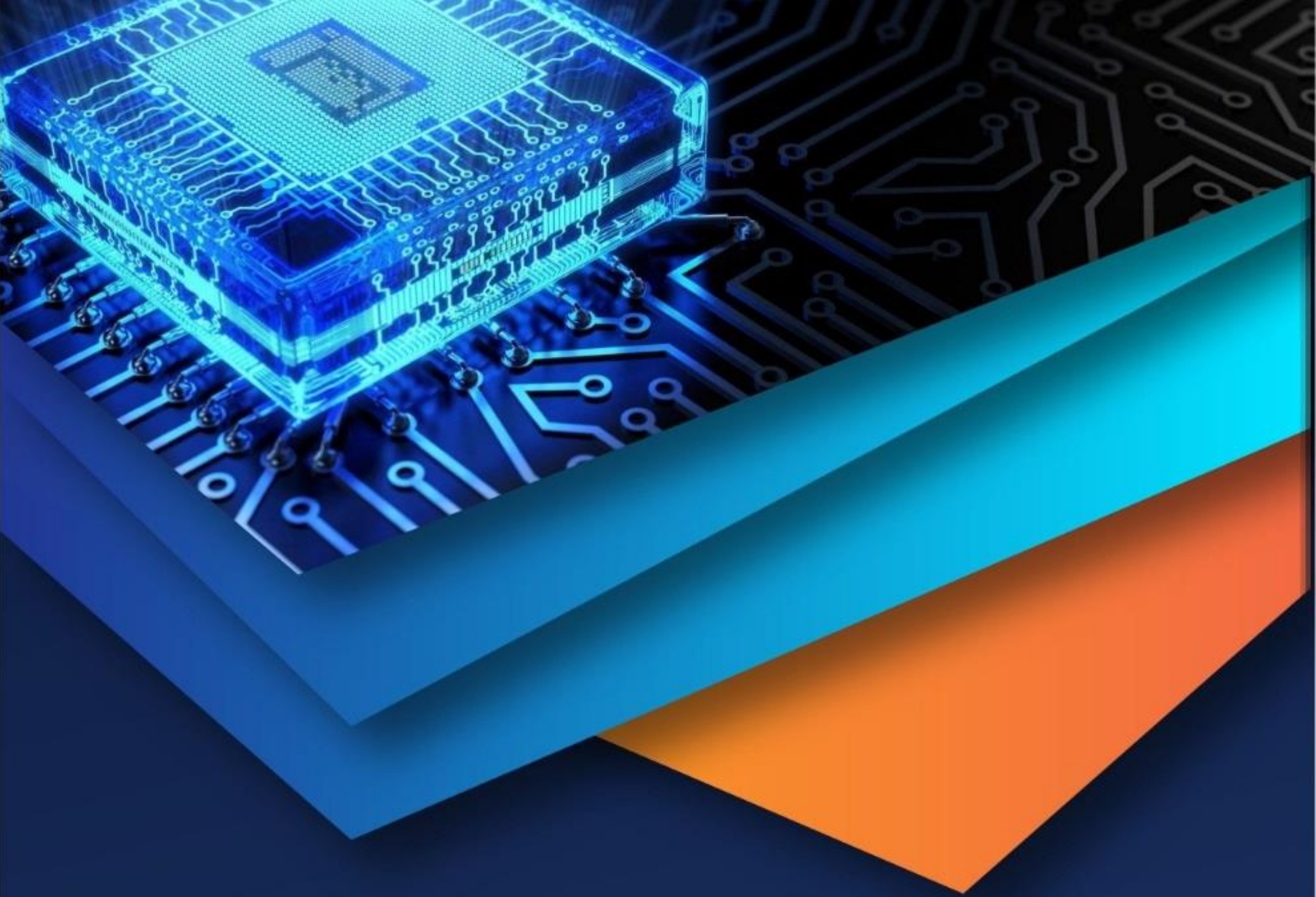

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