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Slotted ALOHA Protocol for Next Generation IoT

Aparna Pandey[1], Nayanica Srivastava[2,]
[1]M Tech. Scholar, [2]Assistant Professor, Department of Telecommunication, HBTU Kanpur India

Abstract: Machine to Machine (M2M) communication is used to maintain the connectivity between the various devices in IoT. One of the major issues of Machine to Machine (M2M) communications is to enhance the network lifetime with the help of an efficient MAC protocols. Slotted ALOHA Protocol is simple random access technique used in low power applications like LoRaWAN (Long Range Wireless Area Network). This approach gives an improved result as compared to P-persistence slotted ALOHA. In this paper, we consider an IoT -M2M network comprises of a large no of devices that transmit data packets to a gateway. We have tried to reduce the collision, which directly reduce retransmission of data packets. We propose Adaptive p-Slotted ALOHA Protocol using Successive Interference Cancellation (SIC). It offers high throughput and reduces the delay. It is the simplest way of the channel allotment among the users. The proposed p-Slotted ALOHA protocol using SIC is better than the p-persistence slotted ALOHA in term of delay and throughput.
Keywords: MAC, M2M, Slotted ALOHA, LoRa-WAN, IoT, SIC

I. INTRODUCTION

As we know in IoT, lot of devices are connected over internet. For efficient communication between these devices we use Machine to Machine communication (M2M). M2M means the communication between the various machines without human interruption. In M2M communication many devices are connected to each other. Controlling these devices is a big challenge. For control and communication between these devices, we need a MAC (Medium Access Protocol) Protocol. MAC is Random Access Protocol. MAC also reduces the chances of collision and power requirement of devices [2]. It allows the users to access a shared medium simultaneously. Slotted ALOHA is one of the Random access protocol, which is easy to implement as compared to the other technique. Other contention less protocol like TDMA, FDMA, CDMA cannot be used here because of unused slots [1]. These unused slots lead to wastage of time and frequency. Slotted ALOHA Technique work on slow data rate. IoT is a combination of heterogeneous devices. Different types of sensors, machines and network are connected in IoT. So communication between these devices needs high data rate. Slotted ALOHA is alone not able to provide the high data rate because many devices are sharing a same channel. Therefore, we are using a slotted ALOHA Protocol with combination of SIC which reduces the collision and guarantees high throughput. SIC reduces the collision and retransmissions of packets. Slotted ALOHA has higher throughput than Pure ALOHA. Here every device node transmits two replicas of a single data packet and resolve the current slot data packet with priority after that it resolves the collided packets. In this method, all sending data packets are responsible for throughput of the channel. SIC reduces average delay which is a great improvement as compared to p-persistence scheme [7]. For future IoT environment Slotted ALOHA scheme is more suitable because of higher throughput and lower delay. These are the features of this scheme :-

1) *Reliability:* After the transmission, the IoT gateway sends an Acknowledgement message for conformation that data packet is transmitted successfully.
2) *Low Control Overhead:* There is no need of the control overhead. Only beacon message is sufficient. This feature is more appropriate for data packet of having small length. New nodes need not register to the gateway.
3) *High Throughput:* Installing a SIC receiver at the gateway raise the throughput as compared to p–persistence Slotted ALOHA protocol. By reducing the number of collisions using a SIC, retransmissions is avoided that leads to the throughput enhancement. •
4) *Low Delay:* As the throughput increases, the number of collisions decreases as more data packets are transmitted successfully which avoids retransmission.

The organization of this paper is in the following order. The literature survey is discussed in Section II. Proposed model is discussed in Section III, and the simulations and compared results are shown in section IV along with features of the proposed scheme.

II. LITERATURE SURVEY

Anum Ali et al. proposed a power adaptive technique which reduce the delay for data transmission. He proposed an uplink protocol. This technique is mainly for low power devices such as weather trackers and healthcare. This technique reduces the complexity of architecture but keep throughput stable [1]. ALOHA is one of the efficient protocols that works with low traffic. An enhancement in energy efficiency was achieved by enhancing the energy efficiency at 60% rate as compared to other techniques, and life time to 45%. He kept throughput same and reduced the time. He used MATLAB for simulation of results.

Cedomir Stefanovic et al. proposed Frameless ALOHA Protocol for the Wireless Networks [5]. He said that frameless ALOHA is alike the Slotted ALOHA but it uses the successive interference cancellation method (SIC). He proposed that each user is assigned a slot with a fix probability and used the rate less code in this method. Rate less code is an erasure correcting code used in the Frameless Slotted ALOHA [5]. Rate less codes are used for enhancing capacity of the channel. These code are not affected by the channel conditions. ALOHA Protocol. SIC process resolve the users. Initially LT codes used as the rate less code. This theory is used to reduce the collisions.

Huanhuan Huang et al. proposed a Gated Slotted ALOHA Protocol for wireless network [6]. He mentioned that Gated Slotted ALOHA is not same as Slotted ALOHA protocol. Here Node can transmit the packets in a single try. It removes the traffic from network. Gated Slotted ALOHA improve the efficiency of the wireless network. It gives higher efficiency. Gated Slotted ALOHA gives the concept of Head of Line (HOL) of packet. If a node is successful it means that all the packets are transmitted successfully. Each packet header part contains the reserved address and these coding information is retrieve by the all nodes. These nodes receive the information of the reserved slot. In reserve time only, allowed node can transmit the packets. In this time no other node can transmit. This strategy helps to remove the collision and hence reduce the probability of retransmission. This method is more efficient than other method and make this access technique more reliable than others. This method can be successfully employed practically. The concept behind the Gated Slotted ALOHA is that many users try to transmit the message containing packet like HOL packets [6]. HOL packet contains bit value. This bit is added in to the header of packet containing the information. This bit value shows that packet is reserved or not. If reserve bit value is one, it means that channel is occupied by a particular node. If the bit value is zero, it means that channel is free. After completing one process, another user tries to send packet containing HOL having probability R [6]. If transmission is not successful, the user tries to send the packet again. If user transmit successfully means user continues to send the packets because user has reserved the slot for the transmission. After transmitting all the packets channel becomes free. This process is use for transmission of the packets. This method reduces the collision and increase the efficiency and channel utilization.

Asim Mazin et al. has proposed Slotted ALOHA –NOMA protocol (SAN) for M2M communication used in IoT. NOMA basically consists of two techniques. These are Non-orthogonal Multiple Access Techniques and Successive Interference Cancellation Receiver which detect the various transmitted packets with the help of power domain multiplexing [7]. SAN is used as a Gateway. SAN receiver knows number of devices used in the transmission. SAN knows the transmitting devices but using multi hypothesis testing method. This method creases the system performance. It gives higher efficiency as compared to the original Slotted ALOHA protocol by choosing Power level. Here author has compared SAN with the Carrier Sense Multiple Access with Collision Avoidance(CSMA/CA) and Slotted ALOHA Protocol. Here he compared the efficiency and delay in transmission. Slotted ALOHA NOMA is basically used in 5-G applications. Slotted ALOHA suffers from collision hence result in lower efficiency. In order to increase the efficiency NOMA is used with the Slotted ALOHA. The main feature of NOMA is higher efficiency [5]. In IoT, lot of devices are interconnected to each other's and involved in transmission simultaneously using same set of frequency level but distinct power levels. In this situation SAN is best suited Protocol. SIC receiver play a main role to differentiate the received signals. SAN protocol is mainly used in smart home implementation [7]. Here data is send to the gateway using SAN and SIC receiver help to detect the signals. SAN uses different values of powers which in result increases the efficiency of the system. SAN protocol basically used for low power small devices. It is based on multiple hypothesis testing.

Jingyun Sun et al. has proposed a random protocol which is known as Irregular Repetition Slotted ALOHA with priority (P-IRSA) [8]. This method reduced the packet retransmission because of collision and resolve the users with the help of successive interference cancellation process. This method gives higher throughput than original Slotted ALOHA protocol. This protocol avoids the repetitions of the data or packets. These repetition causes the collision between the data packets and leads. IRSA is based on the method of packets repetition in the MAC frame to avoid the data loss. If we have two users and user 1 has two replica packets (V_a and V_b) and both containing the same information. Every replica contains the data about the other replicas position. If case of collision if any one replica gets lost, then we can get information from another replica. This method removes this packet interruption.

IRSA relies on the repetition of the packet. We can take an example d header field [8]. If one replica of packet is recovered, the positions and the content of other replicas are known. This way the interference of this packet can be canceled. IRSA relies on the repetition of packets during the same MAC frame to combat the packet loss. In Fig. 1(a), User 1 has two replica packets ($U1$ 1 and $U1$ 2), both of them having the same data. In each replica, the information about the position of other, having the same data. In each replica, the information about the position of other replicas is included, e.g. in a dedicated header field. If one replica of packet is recovered, the positions and the content of other replicas are known. This way the interference of this packet can be canceled in retransmission [8].

Hemabh Shekhar et al. has proposed framework for the analysis of a slotted ALOHA (S-ALOHA) network employing a two antenna LMMSE receiver [11]. He proposed that Throughput of such a network is analyzed under a Rayleigh channel condition. He proposed two collision models, first model is signal to interference plus noise ratio (SINR) based and the second based on average bit error rate (ABER). Coding is also used with ABER collision model. He compared the throughput of one and two antenna systems under Rayleigh fading channel and demonstrate the performance improvement [11]. A closed form expression of the throughput of S-ALOHA network using a two antenna LMMSE receiver is derived

Noor Zuriatunadhirah et al. has proposed P-persistent Slotted ALOHA Protocol for Low Power devices [12]. This method improves the slotted ALOHA throughput, reduce the delay and energy consumption [12]. It provides 30% improved result as compared to standard Slotted ALOHA protocol [12]. He applied this method Long-Range Wide Area Network (LoRa WAN Network). He said that in future more devices will be installed in the network, which increase the congestion in the network. Due to higher traffic the chances of collision will increase which will lead the delay hence it leads to retransmission. So P-persistence slotted ALOHA may be a best suited technology to reduce the congestion. ALOHA protocol prefer due to its simplicity. He proposed a threshold value should be taken in between 0 and 1 and required value should be chosen on the basis of efficiency. After that random probable value is compared with P-threshold value. If probable value is higher than P-threshold, then the device starts the transmission. If probable value is less than the threshold means transmission in next slot will be different p-slot [12].

Vikash et al. has proposed a back off mechanism installed in the MAC Protocol which produces back off timers that allot proper time to complete a transmission. And discarded the unnecessary idle time which induce the delay in the system. He explained the effect of the back off process on MAC layer protocol multiple access collision avoidance protocol and other multiple access collision avoidance protocol for wireless network. This process is used by each device to back-off for a random amount of time before retrying [13]. In this method back-off process every time a collision is detected, the nodes double its maximum back-off window. Neighbor nodes near the sender that hear the RTS packet do not period for long enough period of time so that the receiver could receive the CTS packet [13].

III. SYSTEM MODEL

In this paper we consider 100 nodes over a radius 2m. We are using area = 6mx6m. We divide time into slots. The performance of Advance Slotted ALOHA Technique is evaluated by using Monte Carlo Simulation. This technique is implemented in LoRa-WAN which is low power Technology. We are using 100 nodes in the area of 6mx6m. Let us consider that there are M nodes in the system, represented by u where u ∈M = {1, 2…., M}. Nodes are ready to transmit the data packet to base station. Here time is divided into equal slots. Each slot is equal to the time required to transmit a data packet and guard time to remove the propagation delay. Here nodes are synchronized and N represent the time slot where n ∈ N. In each time slot n, each user u_i try to send its data packet with some probability $p_t(n)$. To start the transmission, node should be associate with the time slot. So node need to send the data in a particular time slot. Node start their transmissions and wait for acknowledgement message from the base station. Acknowledgement is a way to inform the sender that their data has been received successfully. If user did not get the acknowledgement means collision occurred and the data packets need retransmission again. Three steps are followed by the node during transmission, (a) If there is no transmission in the slot, it means slot is ideal, (b) If there is a single transmission, it is known as singleton slot, (c) if there are two or more transmissions means collision occurs, so collision slot. We use SIC at the base station to remove collision from data packets in a slot. SIC is used to improve the throughput of the network. With the help of SIC base station remove the interference from the packets which received in current slot. After removing collision from these packets, it removes interference from collided packets from slots need to retransmit. SIC repeat this process of removing interference till the last packet resolved.

Let us consider that user v_i is ready to transmit its data packets z_i, to the Base Station in a slot. If y(n)is the received message in slot time n. The received packets are-

$$y(n) = \sum_{i=1}^{M} z_i\,(n) x_i \qquad \forall n \in M \qquad (1)$$

Where z_i (n) is a Bernoulli random variable, which represents if the z_i is transmitting or not. It means that if z_i (n) =1, means transmission is successful in a given slot. If $z_i(n)$ = 0, it means no transmission. When y(n) receive packed, then SIC remove interference from all the remaining data packets including collided data packets. The ratio of the nodes resolved by the SIC at the base station to the number time slots is known as the throughput. S(m) is throughput at slot time n and r is the received replica, So the Average throughput is defined as –

$$S(m) = \frac{M_r(n)}{n} P_r = \lambda P_r \qquad (2)$$

Here P_r is the probability that a node (user) data packet is recovered and $\frac{M_r(n)}{n} = \lambda$ where λ the load traffic.

A. Average Packet Delay

Poisson equation data packets are ubiquitous distributed in an interval (0, T), if l is the of each slot time. Then calculated waiting time is T/2. Roundtrip propagation delay is hardly equal to an integral multiple of the length of packet, this average waiting time is same for old collided packets. The average delay td in slotted ALOHA systems is -

$$td = T_{rt\,+} + \frac{3T}{2} + \left[\frac{\lambda}{S} - 1\right] . \left[T_{rt} + \frac{(M+2)T}{2}\right] (3)$$

where M>>1 for improved result, T_{rt} shows roundtrip propagation delay and M shows maximum time delay in packet lengths involved before retransmission after facing collision. In IoT communication network Round-trip delay (RTD) is also known as the round-trip time (RTT). It is defined as the total time taken by a data packet to transmit and the time taken to get acknowledgement of that data packet having been received. Propagation time between two end devices is also included in the RTT time. RTT time is also known as ping time.

B. Simulation Parameters

Table :1 Simulation Table

Parameters	Value (Proposed P – Slotted ALOHA)
Channel Bit Rate	250Kbits/s
Data Packet Length	1044
ACK Packet Length	30 bits
No of Nodes	100
Radius	2m
Maximum Transmission Range	6m*6m

IV. SIMULATION AND RESULT ANALYSIS

In this section, p-persistence Slotted ALOHA technique is compared with the proposed advance Slotted ALOHA technique using SIC. We have analyzed the throughput and the average delay involved during the transmission. We have simulated 1024 samples. The proposed adaptive p-Slotted ALOHA protocol aim is to achieve higher throughput and lower delay. We are comparing, the parameters of two protocols (proposed adaptive p-Slotted ALOHA with p-persistence Slotted ALOHA protocol). The transmitting node of p-persistence slotted ALOHA is transmitting at a maximum of 250k bits/sec. But in our scheme, we kept the bit rate constant in bits per second.

A. Theoretical Throughput

Theoretical Results has been shown in the following figure- 2. Graph is drawn in between throughput and Load offered. X axis shows the Load offered in Erlangs and Y axis shows throughput in bits per seconds. Throughput is drawn on load =0, 0.5, 1, 1.5. We can see that throughput is very high at load 1 and then gradually decrease with increase in loads. The theoretical result shows the standard Slotted ALOHA protocol has the highest throughput 0.3679 bits per second as derived in [5] [7], in which only one packet is allowed to transmit in a single slot. Initially throughput increased and as load increase and get maximum at load = 1 Erlangs and then start decrease as load increase.

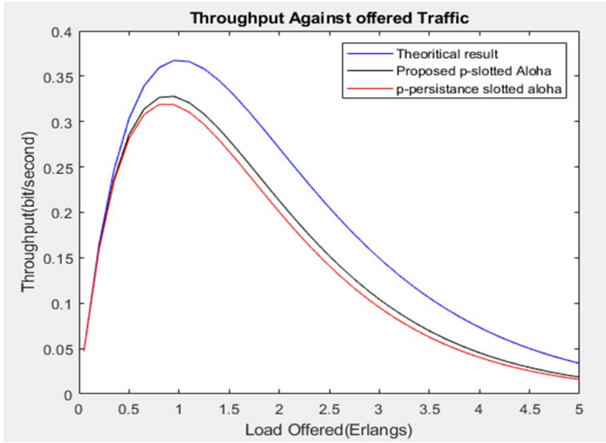

Fig 1. Throughput of Slotted ALOHA using SIC

B. Throughput Analysis

We can see in the following figures that in p-Persistence Slotted ALOHA throughput is 0.3164 bits/seconds which is very low as compared to the theoretical result. Initially throughput increases and shows highest value at traffic =1 Erlangs and start decreases when traffic load increases. In case of proposed Slotted ALOHA Technique throughput increases in same manner and gives maximum throughput 0.3278 bits per second, when traffic = 1 Erlangs, which is higher than p-persistent slotted ALOHA protocol. Hence shows that proposed ALOHA Technique gives better performance in term of throughput.

C. Delay Analysis

In fig. 2 Delay performance using SICIn fig. 3 we can see the delay performance of proposed technique and p-persistent Slotted ALOHA Technique. p-persistent Slotted Alohoa has higher delay which is 139.79seconds when offered traffic is low but proposed p-Slotted ALOHA shows better perfomance with delay 116 which is better than previous thechinique. Proposed technique is 17% better delay performance than p–persistance slotted ALOHA.

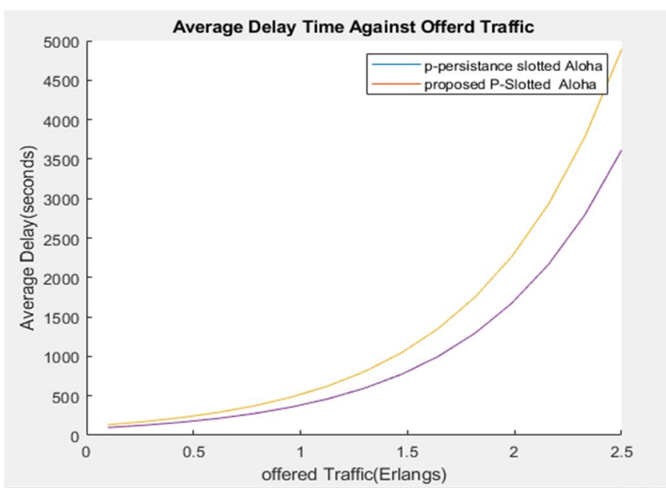

Fig. 2 Delay of P-slotted ALOHA protocol using SIC

V. CONCLUSION

In this Paper, we have analyzed the throughput increment in slotted ALOHA systems using SIC, which is a collision resolution algorithm. With the help of SIC method, we are able to reduce the average delay and improved the throughput. This technique is helpful in decreasing the delay efficiently. We are successfully able to reduce the delay and increase the throughput which shows the improved performances. After analyzing the both result we can see that analytical result and simulation results are almost same. It also shows that at throughput increases initially. As we increase traffic above this optimum value, we can see that both performance of throughput and delay start degrading.

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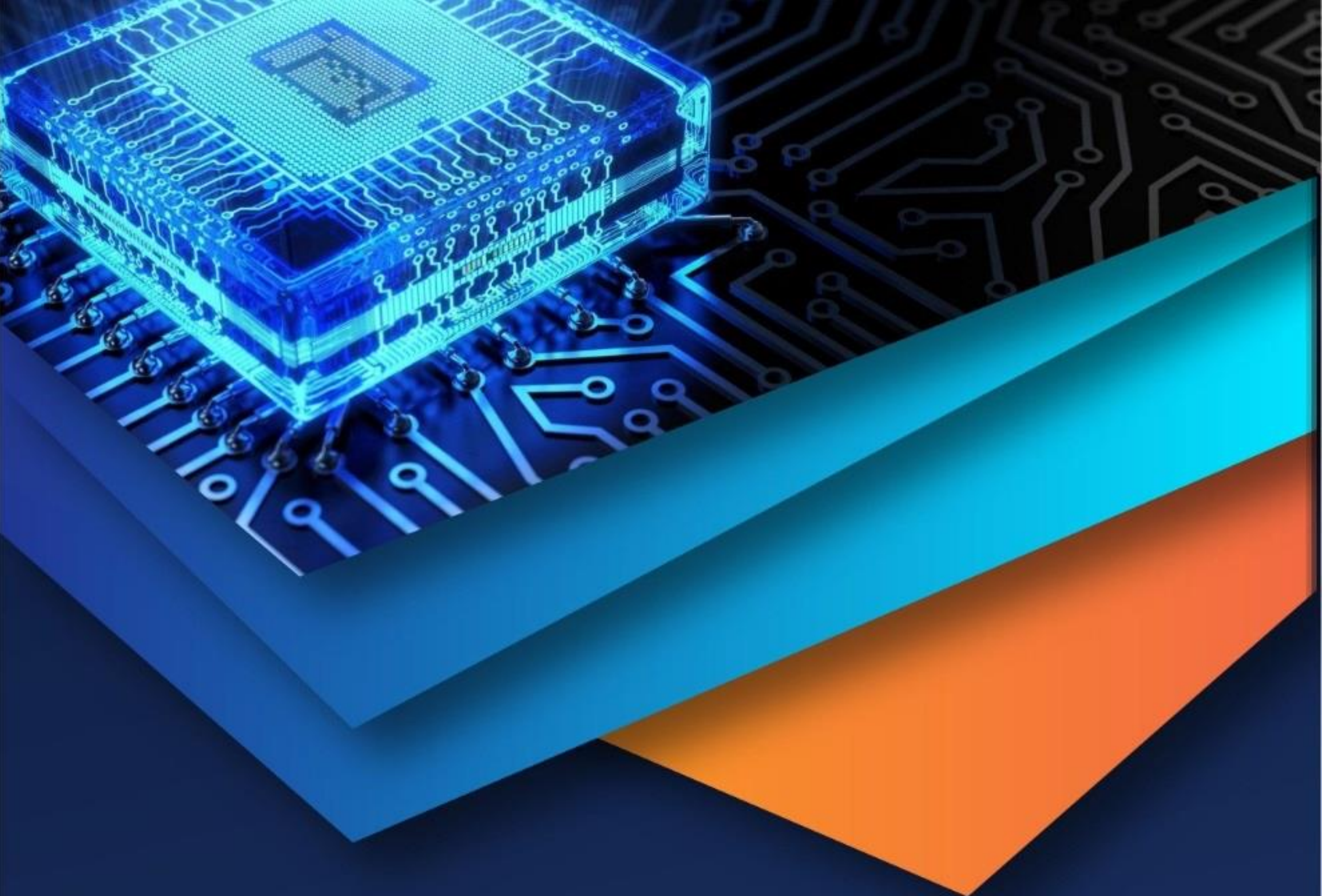

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