iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 5 **Issue:** V **Month of publication:** May 2017

DOI:

www.ijraset.com

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Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Comparative Study on IEEE 802.11 N/AC/AD for WLAN

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Abstract: ***Wireless communication is one of the essential technology in the modern era . From the beginning communication is the part of our life, which is in the form of either analog or digital, can be used in radios , mobile phones ,laptops etc to access the global network. Location Independent Network Access can be provided by WLAN between the computing devices using radio waves rather than wired infrastructure. 802.11 is the specification developed by IEEE for WLANs. The WLAN standard operates on the 2.4 GHz and 5 GHz ISM bands(Industrial, Science and Medical frequency bands). In this manuscript we cover different WLAN standards with comparative study which will help the technical aspirants to work on.***
Index Terms : WLAN , IEEE 802.11 a/b/g/n/ac/ad

I. INTRODUCTION

In 1990 with the invention of products operated within 900mhz frequency band initiated the massive use of WLAN. These non-standard solutions provide approximately 1mbps data transfer rates and also had proprietary designs which are slower than the wired LAN in which the data rates are of 10mbps speed.

In 1992 vendors started selling 2.4GHz WLAN products. These products are designed to use proprietary radio frequency technologies and work at higher data rates but expensive and also prone to radio frequency interference .

The IEEE 802.11 started in 1990 with PHY and MAC layer specification for wireless connectivity for mobile ,portable and fixed stations with in the area

Due to high speed data rates and low cost of user equipment IEEE 802.11 standards got outspread popularity and acceptance. At the beginning ,IEEE 802.11 standards specified data rates of 1mbps and 2mpbs based on DSSS(Direct Sequence Spread Spectrum) ,FHSS(Frequency Hopping Spread Spectrum) and IR(Infrared) techniques for three different PHY layers. CSMA/CA(Carrier Sense Multiple Access with Collision Avoidance) is the basic MAC protocol in IEEE 802.11 WLAN which allows only one user to utilize the radio channel at specific time. There after several new PHY layer specifications were added while the MAC specifications remained largely unchanged.

The basic standards of IEEE 802.11a,b,g are used for browsing , sending electronic mail in outdoors environments like hotels, shopping zones , airports and internet centres. Now a days many devices are operating based on the same technology devices like smart televisions, printers, scanners gaming devices and many more at home, and every one want to get the data very fastly in large volumes like in wired standards(Ethernet) . There is a steady growth in IEEE 802.11x to meet the present trends(Fig1)[1][2]

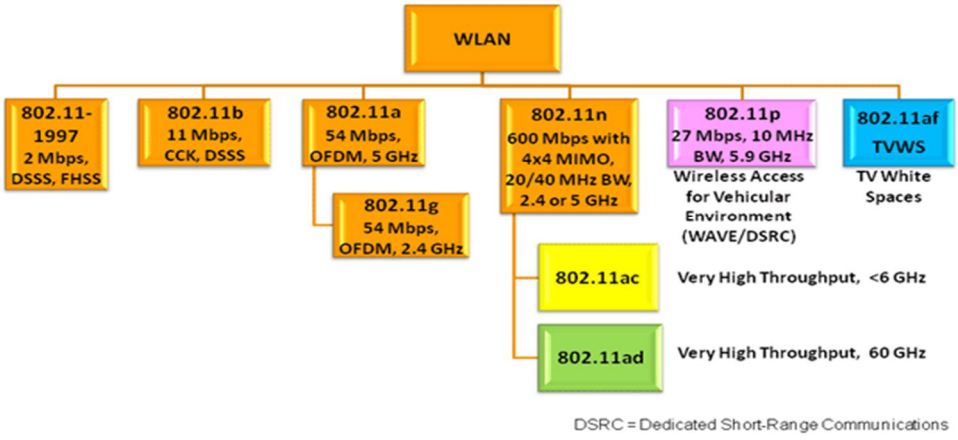

Fig 1: IEEE 802.11 standards

Volume 5 Issue V, May 2017
ISSN: 2321-9653
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II. IEEE802.11WLAN STANDARDS

Table 1: LIST of some IEEE STANDARDS discussed in this manuscript [1][2]

SNO	IEEE standard	Year of amendment /release	Scope
1	802.11a	1999	5GHz band and speed 54Mbps
2	802.11b	1999	Enrichment to support 5.5 Mbps & 11Mbps
3	802.11g	2003	2.4GHz band, 54Mbps
4	802.11n	2009	Higher throughput improvements by MIMO
4	802.11ac	February 2014	Very high throughput <6GHz
5	802.11ad	December 2012	Very high throughput 60GHz

III. IEEE 802.11N

IEEE 802.11 task group started work in January 2004. Due to lack of some agreements and delays among the committee members, the amendment proposals have been postponed till the end of 2009. In September 2009 the technical team promised to improve the performance up to six times. The new standards of WLAN IEEE 802.11n ratified as "WLAN Enhancements for Higher Throughput" [3]

The improvement in the new technologies have higher effective data throughput. Present WLAN IEEE 802.11a/g gives data rates up to 54Mbps in specification but on the net it is approximately 22Mbps only. IEEE 802.11n based networks gives data throughput up to 300Mbps on net it is 120 to 130 Mbps but theoretically defined up to 600Mbps with 4 data streams.

A. *New Features of 802.11N*

1) *Compatibility with other Standards (802.11a/b/g):* The 802.11n is advance in compatibility to the previous standards (IEEE 802.11a/b/g), which can benefit its clients. Only in all 802.11n environments the "green field mode" is used which can exploit all the advantages of the new technology.
2) *Improved OFDM Modulation:* IEEE 802.11n uses the Orthogonal Frequency Division Multiplex(OFDM) modulation as IEEE 802.11a/g. OFDM modulation parameters are

a) *IEEE 802.11 A/G:* Used 48 carrier signals - 802.11n uses 52 carrier signals
b) *IEEE 802.11A/G:* Uses payload rates of ½ or ¾ - 802.11n uses 5/6

3) *MIMO Technology:* Multiple Input Multiple Output is the new technology which uses multiple transmitters and receivers to send up to 4 parallel data streams on the same channel (in IEEE 802.11 a/g has 2 parallel streams) which improves data throughput and wireless coverage by using MIMO spatial streams aspect. The notation "transmitter x receiver" describes number of antennas for transmitting and receiving . Ex: 3X3 MIMO means 3 antennas for transmitting and receiving. By additional antennas the coverage will be more stronger for clients but no increment in data throughput.
4) *MIMO in Outdoor Use:* In IEEE 802.11n signal transmission is direct in directional antennas which uses polarization channels at 90 degrees to each other. This is called "dual-slant" antennas ie., two antennas at one location.
5) *40Mbps Channels:* In IEEE 802.11n uses second transmission channel and maintains compatibility to 802.11a/g devices. It transmits data over 2 continuous channels one for control channel and other for data transmission. It is more efficient than conventional turbo mode. The maximum data throughput rises to 270mbps.
6) *Short Guard Interval:* In IEE802.11 a/g uses transmission of 3.2µs , symbol length of 4µs and with break of 0.8µs. In IEEE 802.11n it is decreased by 50%. i.e, 0.4µs which is short guard interval .In WLAN terminology the total duration of break and transmission period are referred as "symbol length" and the break itself is referred as the "guard interval"
7) *Spatial Multiplexing :* At transmitter out going signals streams are divided into many sub signals which are transmitted through separate spatial signals signature . At the receiver with different spatial stream signature receiver can build the original signal

stream. Dual streams are multiplexed into single which in turn maximizes the data rates and doubles the capacity.

8) *Frame Aggregation :* The process of combining several data packets into one large packet is called as Frame aggregation. Each data packet includes management information(to be specified only once per complete data packet)

9) *Block Acknowledgement :* The receiver need to send separate data acknowledgement for each data frame in aggregated frame and these acknowledgements are again combined to form a block and relayed back to the sender as block acknowledgment[3]

IV. IEEE 802.11AC (THE MULTIMEDIA HOME)

The official working name for the 802.11ac specification is "Enhancement for Very High Throughput" for WLAN operates in 6GHZ and informally referred as "Gigabit Wi-Fi" or "5G Wi-Gi". A WLAN that delivers wireless data transfer rates of 433 Mbps per spatial stream which support up to 8 streams. The 802.11ac specification offers a theoretical maximum data transfer speed of more than 3GBps and in practical it delivers 1.3GBps. It operates at 5Gz frequency range.

IEEE 802.11ac has two releases i.e., WAVE 1(initial version),WAVE 2(additional to WAVE1)(wireless access in vehicular environments)[5]

A. *The Differences among WAVE1 and WAVE2 are*

1) *Wave 1 generally Supports:*

a) Channels of 80 MHz (all 11ac devices must)
b) 5/6 code rate and 256-QAM modulation (an optional feature for 11ac, but all devices should support it)
c) Spatial streams : 2 or 3 (as in 11n)
d) Silicon better than 802. 11n
e) Explicit transmit Beamforming
f) Dynamic Bandwidth selection and additional MAC layer enhancements
g) Wave 1 products support three spatial streams. When all these are combined together, we get a maximum RF data rate of 1.3Gbps on a single radio

2) *Wave 2 generally Supports :*

a) similar to Wave 1, and many more
b) channels of 160 MHz (real-world relevance for enterprises is small)
c) downlink MU-MIMO. The use of wider channels and MU-MIMO builds upon features released in wave 1 chipsets.
d) spatial streams up to 4
e) Support for multi-user MIMO (MU-MIMO)
f) advancements to help increase theoretical maximum wireless speeds for the spec to 6.93 Gbps.

B. *The IEEE 802.11ac Key Optional Features are*:

1) Bonding more channels into the same transmission
2) Higher bit density
3) Downlink Multi-user MIMO to support concurrent transmission to multiple clients
4) *Increase the Number of Spatial Streams:*

a) *Channel Bonding:* In IEEE 802.11n two 20MHz channels are bonded together into single channel of 40MHZ wide. In 802.11ac four 20MHZ channels are bonded together into single channel of 80MHZ This specification allows another doubling up to 160MHZ (eight 20 MHZ) *Mandatory 80MHZ, Optional up to 160MHZ*

b) *Higher Bit Density with 256QAM:* I n 802.11n HT frames support 64QAM. In 802.11ac VHT frames support 256QAM bit density to improve the effective RF data rate . Pay load transmission in 64QAM is 33% less than 256QAM. *Optional in the standard and considered in the market*

c) *Downlink(DL) Multi-User MIMO:* The access point uses four spatial streams to transmit , but client receives only one at most two. In theory four MU-MIMO clients , one spatial stream(1SS) will be served by the access point at the same time and if client supports 2SS will serve two clients.*Optional in the standard and considered in the market*

d) *Increased Spatial Streams:* In 802.11n, spatial streams are combined using MIMO. Each Spatial streams need some additional transmitter power , radio chain , antenna element . Most of mobile devices like tablets, smart phones are optimized for space for additional antenna element and long battery life. Most of the client devices support one stream atmost two. Laptops support

Volume 5 Issue V, May 2017
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

three streams for space and power.Mandatory one spatial stream , optional eight spatial streams.

Table 2: Comparing 802.11ac Wave 2, Wave 1, and 802.11n

	802.11n	802.11n IEEE specification	802.11ac wave1 today	802.11ac wave2 WFA certification process continues	802.11ac IEEE specification
Band	2.4GHz to 5 GHz	2.4GHz to 5 GHz	5GHz	5GHz	5GHz
MIMO	Single user (SU)	Single user (SU)	Single User(SU)	Multi user(MU)	Multi user(MU)
PHY Rate	450 Mbps	600Mbps	1.3Gbps	2.34Gbps-3.47Gbps	6.9gbps
Channel width	20 or 40MHz	20 or 40 MHz	20,40,80 MHz	20,40,80,80-80,160 MHz	20,40,80,80-80,160MHz
Modulation	64QAM	64QAM	256QAM	256QAM	256QAM
Spatial streams	3	4	3	3-4	8
Mac throughphut*	293Mbps	390Mbps	845Mbps	1.52Gbps-2.26Gbps	4.49Gbps

Fig 2: The Multimedia Home

V. IEEE 802.11AD (THE WIRELESS OFFICE)

The 802.11ad specification operates in the 60GHz frequency band, as opposed to earlier 802.11 specifications such as 802.11ac, which operates in the 5 GHz range, and 802.11n, which operates in both the 5 GHz and 2.4 GHz ranges. It is also designed to offer much higher transfer rates than previous 802.11 specs, with a theoretical maximum transfer rate of up to 7Gbps (Gigabits per second).

WiGig is the name given by IEEE engineers and Wireless Gigabit Alliance for marketing reasons for products as per IEEE 802.11ad standard. This standard based devices operate in 60 GHz band and hence it is often referred as microwave wifi.[6]

A. 802.11ad Features

Table3 : summarizes the features of WiGig Standard i.e. WLAN 802.11ad standard

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Specification	802.11adWiGiG support
RF carrier Frequency	Operates at 60GHz unlicensed band with different allocations from 57GHz to 66GHz in different regions of the world
Channel bandwidth	About 2.16GHz
Data rate/Data throughput	7Gbps
Distance coverage	About 1 to 10 meters
Data Symbol modulation	Single carrier/OFDM
Mac layer	Should support switch from existing 60gHz Wigig to previous 2.4GHz /5Ghz wifi network
Beamforming	Supported

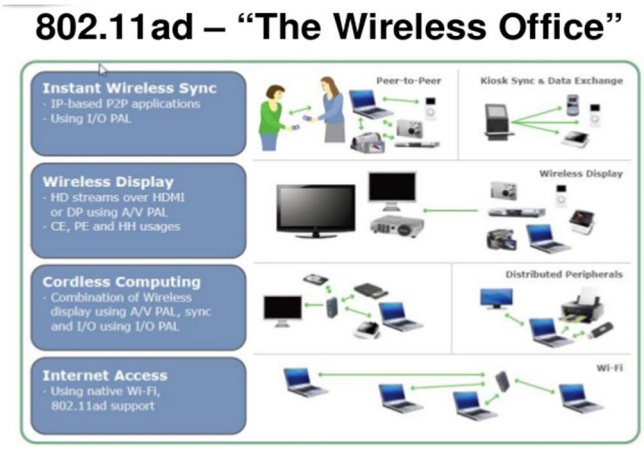

Fig 3: The Wireless Office

VI. COMPARATIVE OVERVIEW ON 802.11 N/AC/AD

In this paper, we have compared of IEEE 802.11 n/ac/ad standard of WLAN/ WiFi we use some basic characteristics like Operating frequency, Modulation technique, Data rate (Mbps), Slot time (µs), Preamble, Throughput, Speed, Indoor Outdoor Range, Multiple Access, infrastructure, Channel Bandwidth, Half/ Full duplex, Number of spatial streams, Mode of operation Ad-hoc, FEC Rate, License /Unlicensed.

Table 4: Comparing IEEE 802.11n, 802.11ac, 802.11ad [1][2][3][4][5][6][7][8][9]

	Features	IEEE 802.11n	IEEE 802.11ac	IEEE 802.11ad
1	Operating Frequency	2.4-5GHz ISM	5.8GHz ISM	60MHz ISM
2	Modulation techniques	OFDM,CCK, DSSS 64-QAM,	BPSKs,QPSK,16-QAM,64-QAM,256-QAM optional	Various : single carrier BPSK, QPSK or 16-QAM and OFDM
3	FEC Rate	¾,2/3 and 5/6	½,2/3,¾ and 5/6	
4	Channel Bandwidth	20 or 40 MHZ	20 or 40 or 80 mandatory and 160 MHz & 80+80 MHz(optional)	20 or 40 or 80 or 160 MHz
5	Number of Spatial Streams & MIMO	1,2,3 or 4 SU-MIMO	1 (mandatory)2 to 8 (optional) TX beamforming , STBC Multi-User MIMO	-

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ISSN: 2321-9653

6	Band width/Data rate(Mbps)	20	400nGI: 7.2,14.4,21.7,28.9,43.3,57.8,65,72.2	400nGI: 7.2,14.4,21.7,28.9,43.3,57.8,65,72.2,86.7,96.3	--
			800ns GI : 6.5,13,19.5,26,39,52,58.5,65	800ns GI : 6.5,13,19.5,26,39,52,58.5,65,78,86.7	
		40	400nGI: 15,30,45,60,90,120,135,150	400nGI: 15,30,45,60,90,120,135,150,180,200	
			800ns GI :13.5,27,40.5,54, 81, 108,121.5,135	800ns GI : 13.5,27,40.5, 54, 81, 108, 121.5,135, 162,180	
		80	N/A	400nGI:32.5,65,97.5,130,195,260,292.5,325,390,433.3	
				800ns GI :29.2,58.5,87.8,117,175.5,234,263.2,292.5, 351,390	
		160	N/A	400nGI: 65,130,195,260390,520,585,650,780,866.7	
				800ns GI 58.5,117,175.5,234,351,468,702,780	
		2160	N/A	N/A	upto 6,912(6.75 Gbit/s)
7	Maximum data rate(Mbps)		600	1.3gbps	7gbps
8	Preamble		HT PHY for 2.4 and 5GHz	VHT	VHT
9	Throughput		74Mbits	Minimum 1Gbps maximum 7Gbps 1 Gbps(Multi station) 500 Mbps(Single link	Uptp 7Gbps
10	Throughput speed		300mbps	1.3Gbps	7Gbps
11	Indoor Range		70 Mrs-230Mrs	35-115Mrs	60-200Mrs
12	Outdoor Range		250-820Mrs	-	100-300Mrs
13	Multiple Access		CSMA/CA	CSMA/CA	CSMA/CA
14	Half/ Full Duplex		Full Duplex	Full duplex	Full duplex
15	Ad-hoc (mode of operation)		Yes	Yes	Yes
16	Infrastructure		Yes	Yes	Yes
17	VANET		Yes	Yes	Yes
18	License/Unlicensed		Unlicensed	Unlicensed	Unlicensed
19	Transmit beamforming		Present MIMO	Respond to beam forming (optional)	Beam forming
20	Compatibility		IEEE 802.11 a/b/g	IEEE 802.11b/g/n	IEEE 802.11b/g/n

VII. CONCLUSION

In the modern era wireless communication got a vital role with the help of various electronic gadgets. High speed WLANs based on the Institute of Electrical and Electronics Engineers (IEEE) 802.11 standard is one of the emerging technologies continues to evolve which can offer several advantages over other existing technologies such as improved reliability and greater application data throughput. In this paper we concentrated on IEEE 802.11n/ ac/ ad standards and comparison of their basic characteristics. This comparative study helps the students, researchers and different users to know about the different standards of Wi-fi, understand their purpose and comparison to select the best standard.

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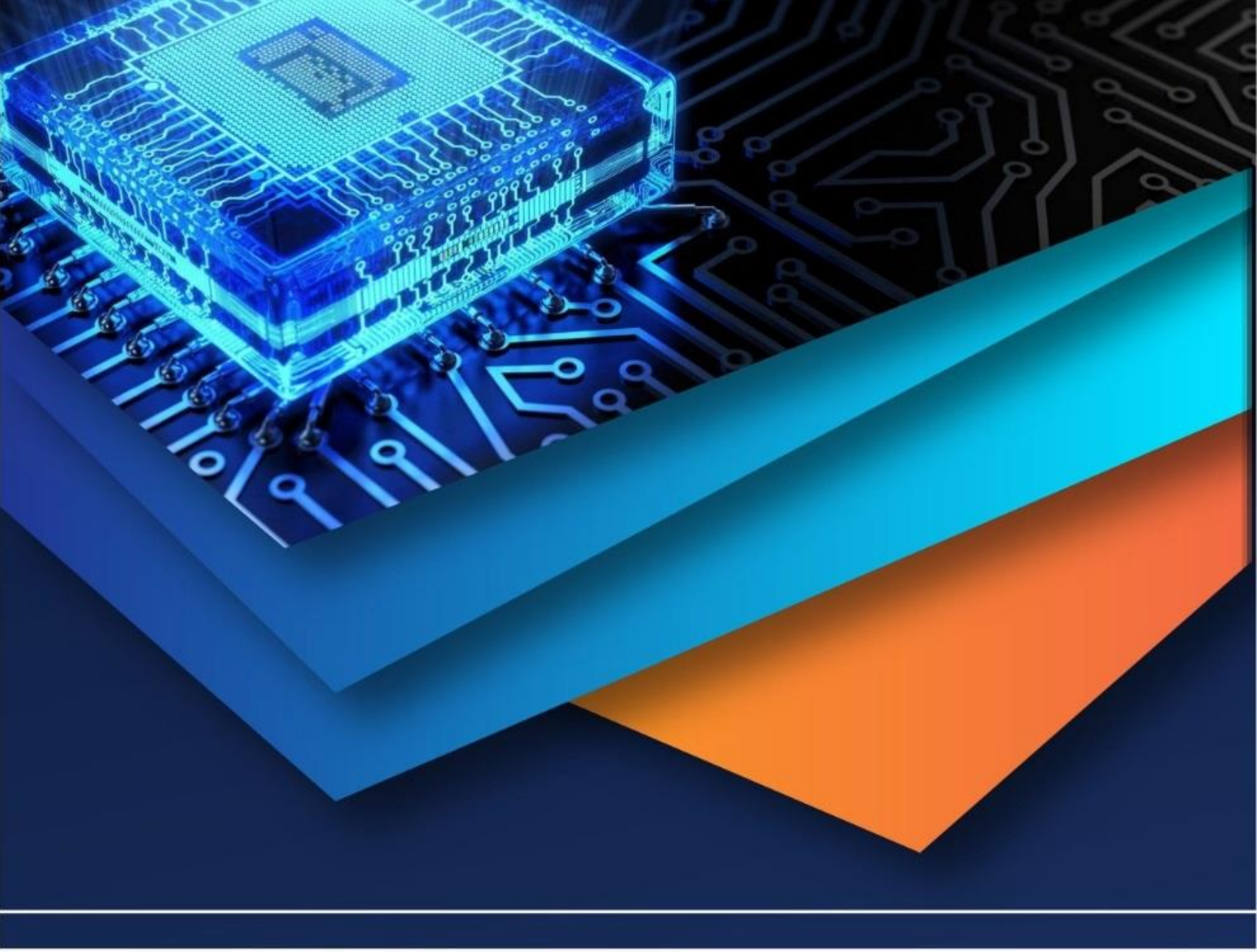

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