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A Review of Fog Computing Framework with IoT: Architecture, Integrations and Challenges

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Abstract: ***The classical centrally controlled cloud computing system faces several challenges as high latency, low capabilities, and networking inability with the explosive growth of Internet of Things (IoT) implementations. Fog computing takes the cloud closer to IoT devices in order to tackle these problems. Instead of being sent to the cloud, the fog supports local IoT data processing and shop. The fog provides quicker response and higher quality services than the cloud. Thus, fog computing can be seen as the best way to allow IoT to give many IoT users successful and safe services. In this review research work, we highlight the architecture of fog computing, the latest in the area of fog computing and its incorporation with IoT by underlining the advantages and difficulties of deployment. Eventually, there is a discussion of limitations and possible recommendations for fog computing and IoT research.***
Keywords: Fog Computing, Internet of Things, Fog layer, Cloud Computing.

I. INTRODUCTION

The interconnection of those devices permits advanced IoT applications, e.g., product following, setting watching, patients police investigation and energy management, and expands the automation to our everyday life. one among the IoT applications is wise home, that permits residents to mechanically open their garage once incoming home, begin air condition, prepare low, and management lights, TV and alternative appliances. IoT conjointly plays associate more and more necessary role in alternative domains, as well as sensible town, smart grid, e-healthcare, intelligent transportation, industrial automation and disaster response. It opens the door to innovations that facilitate new interactions among “things” and human, and provides new opportunities to applications, infrastructures and services that improve the standard of our everyday life. the expansion of IoT ends up in the generation of enormous amounts of knowledge, that possess large computing resources, space for storing and communication information measure. Cisco predicts that fifty billion devices would connect the web by 2020 [1], this variety would reach five hundred billion by 2025 [2]. the info made by human, machines and “things” would reach five hundred zettabytes by 2019Some IoT applications may want quick response, some may involve non-public information, that ought to be keep and processed regionally, and a few may manufacture giant volumes of knowledge, that may be a significant burden for networks [3].

Moreover, associate increasing variety of devices (e.g., sensible glasses, sensible phones and vehicles) are concerned in IoT for aggregation and delivering fine-grained information, which can contain multimedia system info (e.g., photos, videos and voices). the big amounts of knowledge end in serious network congestion and complex process load on devices and management systems. With the advance of IoT [4], fog computing has been introduced to bring the availability of services nearer to the end-users by pooling the accessible computing, storage and networking resources at the sting of the network. it's a suburbanised computing infrastructure, that utilizes one or a lot of IoT devices or near-user edge devices to collaboratively perform a considerable quantity of communication, control, storage and management.

Through the connections between fog nodes and devices, fog computing will scale back the process burden on resource-constrained devices, reach the latency needs of delay-sensitive applications and overcome the information measure constraints for centralized services. Fog computing offers on-demand services and applications proximate to devices, dense geographical distributed and low-latency responses, leading to superior user expertise and redundancy just in case of failure.

The IoT devices have forced computing, storage and battery resources and are simple to be hacked, broken or purloined. though the present solutions in cloud computing may be migrated to handle some security and privacy problems in fog computing, it still has its specific security and privacy challenges because of its distinctive options, like suburbanised infrastructure, quality support, location awareness and low latency.

On the opposite hand, fog computing offers a safer infrastructure than cloud computing thanks to the native information storage and also the non-real time data exchange with cloud centres [5].

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II. ARCHITECTURE OF FOG COMPUTING

Fog computing could be a paradigm with restricted capabilities like computing, storing and networking services during a distributed manner between totally different finish devices and classic cloud computing. Fog Computing could be a geographically distributed computing design with a resource pool that consists of 1 or a lot of ubiquitously connected heterogeneous devices (including edge devices) at the sting of network and not completely seamlessly backed by Cloud services, to collaboratively offer elastic computation, storage and communication (and several different new services and tasks) in isolated environments to an oversized scale of purchasers in proximity. .Fog computing [6-10] architecture is divided into 2 classes, Cloud-Fog-Device framework, and Fog-Device framework. the previous consists of 3 distinct layers, namely, the device layer, the fog layer and therefore the cloud layer, as pictured in Fig. 1, and therefore the latter has 2 layers, the device layer and therefore the fog layer. These layers are organized in Associate in Nursing increasing order of computing and storage capabilities. to attain entomb layer and cross layers' communications, numerous communication technologies are accustomed connect every entity, together with wired communication, wireless communication (e.g., Bluetooth, LTE, ZigBee, NFC, IEEE 802.11 a/b/c/g/n, satellite links) or a mixture of each. The visual image technologies, like network functions virtualization and software-defined network , are accustomed bring home the bacon network virtualization and traffic engineering. every layer is scalable and versatile, indicating that it is increased to involve various entities if the demand arises. All 3 layers is connected with public authorities (e.g., certificate authority, key generation center, judgers and police) through direct or indirect links. just in case of any threat is detected, the general public authorities now be part of to handle the accident.

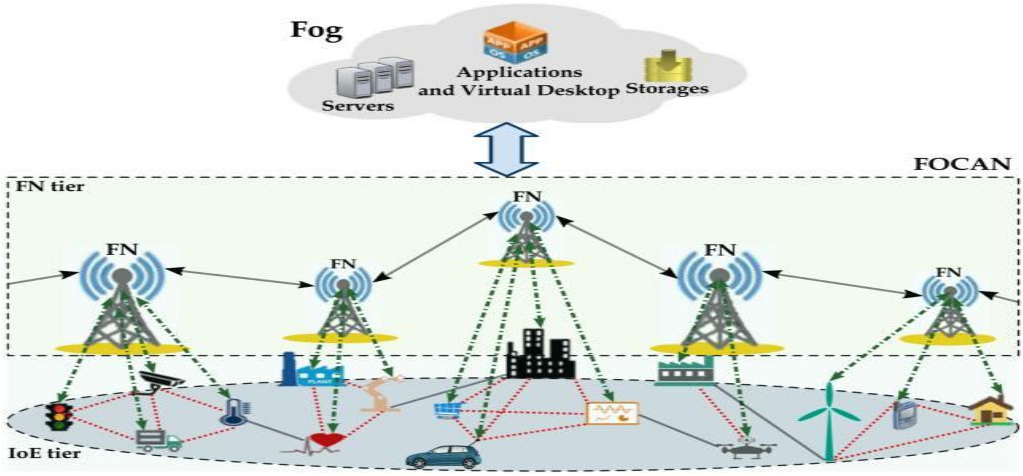

Fig 1. Architecture of Fog Computing [11]

The device layer has 2 forms of devices, mobile IoT devices and stuck IoT devices. The mobile IoT devices are carried by their homeowners, like wearable devices (e.g., fitness trackers, wearable cameras, good garments and sports bracelets) and mobile smart devices (smartphones, good watches, good glasses, vehicles). All devices remain connected to identical owners will kinda bunch and communicate with one another victimization wireless unexpected networks. The fastened IoT devices (e.g., sensors and RFID tags) are pre-deployed in specific areas or on specific merchandise to meet pre-defined tasks (e.g., merchandise tracing, fire detection, and air quality monitoring). These IoT devices have restricted computing and storage resources, and restricted information measure general, specified they can't respond to rising events. Their responsibility is to gather information and report them to the higher layer. for instance, to create the good town, there'll be various IoT devices each fastened and mobile put in round the town, and connect with one another and collect knowledge on all aspects of the town. The fog layer consists of network instrumentality, like routers, bridges, gateways, switches and base stations, increased with process capability, and native servers . These devices, known as fog nodes in fog computing, is deployed anyplace with network connections: during a good phone, on an industrial plant floor, on an edge unit, during a vehicle or on high of an influence pole. The fog nodes are hierarchically distributed between the IoT devices [12] and therefore the cloud servers within the Cloud-Fog-Device framework or higher than the IoT devices in the Fog-Device framework. This layer tends to increase cloud computing to the network edge. it's bound computing and storage artistry and autonomy to scale back the process load on resource-constrained IoT devices. with the exception of typical communications (e.g., package forwarding and routing), some time period and latency-sensitive applications are relegated from cloud servers to fog nodes. Since the applications are set within the fog nodes solely one/two-hop removed from devices, they

possess regional data regarding the devices and their homeowners (i.e., users), e.g., native network condition, users' quality pattern and precise location info. In the Fog-Device framework, the fog nodes hand in glove provide numerous services while not the involvement of cloud servers, e.g., localized conveyance navigation , indoor architectural plan reconstruction , good traffic lights and native content distribution [53]. In the Cloud-Fog-Device framework, the fog nodes offer transient storage and time period analysis on the info collected by IoT devices and sporadically send data summaries to the cloud through the forwarding of different fog nodes set at higher levels within the network hierarchy. The cloud layer in the Cloud-Fog-Device framework could be a consolidated computing and storage platform that has numerous IoT applications from a worldwide perspective. The cloud has vital cupboard space and computing resources and is accessible for users at any time and from anyplace, as long as their devices are connected to the web. It utilizes virtualization technology to attain the isolation of distinct users' knowledge and IoT applications, specified these applications will severally and at the same time offer totally different services to distinct users. The cloud receives knowledge summaries from numerous fog nodes, and performs international analysis on the info submitted by fog nodes and therefore the data from different sources to enhance business insight in IoT applications , like good power distribution , health standing observance and network resource improvement. additionally, the cloud conjointly sends policies to the fog layer to enhance the standard of latency-sensitive services offered by fog nodes.

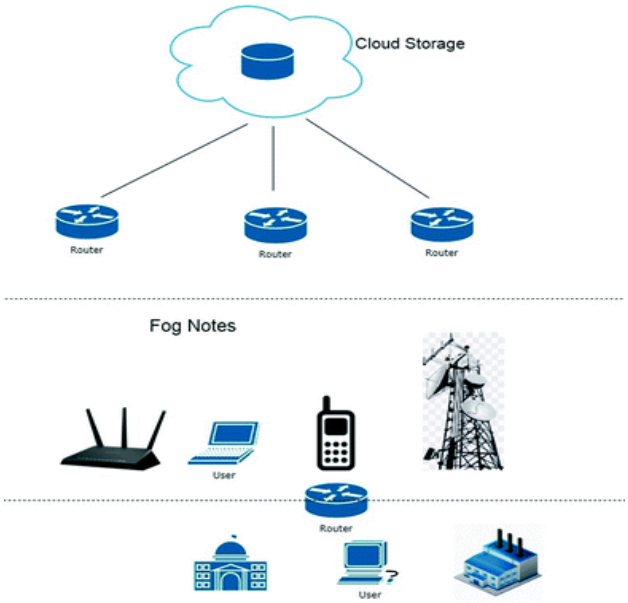

Fig 2. Fog layer

III. APPLICATION OF FOG COMPUTING

we present the application of Fog Computing, including continuous administrations, transient stockpiling, information scattering and decentralized calculation, and show some run of the mill applications as guides to exhibit the possibilities of mist registering in IoT.

1) *Ongoing Services for Fog:* With computational and capacity abilities, haze hubs carry on as a surrogate of cloud or a private cloud near IoT gadgets, taking care of nearby constant calculation administrations. In particular, the haze hubs conveyed at the system edge offer IoT applications and benefits, and get information from the IoT gadgets to settle on choices and control the exercises of these gadgets inside millisecond reaction time. In this way, many deferral delicate IoT applications can be worked to accomplish quick basic leadership dependent on gathered nearby information. We grandstand a few instances of mist helped IoT applications, in which mist hubs offer continuous control and quick basic leadership for clients.
2) *Brilliant Traffic Lights:* At a junction, a mist hub identifies the blazing lights of an emergency vehicle or a squad car utilizing camcorders and naturally changes traffic lights to open the lines for quick passing through. The mist hubs likewise can utilize the conveyed sensors on streets to identify the nearness of person on foot and bikes and measure the driving rate and separations of moving toward vehicles, and along these lines change traffic lights to make advantageous to passerby and bikes. What's more, neighboring haze hubs arrange to send notice signs to the moving toward vehicles to maintain a strategic distance from impact. Thusly, the savvy traffic lights can do quick reactions to the moving toward the person on foot, bikes, and vehicles dependent on the gathered information from camcorders and sensors. Consequently, keen traffic lights can add to make green traffic for vehicles and people on foot.

3) *Human Services and Activity Tracking:* Fog processing can assume a significant job in shrewd e-medicinal services frameworks. For instance, haze figuring can be utilized to distinguish, foresee and counteract succumbs to stroke patients and unexpected heart demise for cardiovascular patients. The haze hubs can begin alerts and send cautioning sign to medical clinics once they identify unexpected occasions occurring, with the end goal that the possibility of endurance can be drastically improved. Additionally, mist hubs can give consequently close to home consideration to patients in medical clinics. They can gather information from sensors conveyed on the collection of patients to find new occasions and in this manner take activities auspicious to give serious consideration. Along these lines, keen healthcare frameworks can abbreviate the hour of emergency treatment and improve the achievement rate in saving patients.
4) *Decentralized Vehicular Navigation:* Real-time traffic data is basic to screen clog and explore for drivers. Step by step instructions to gather continuous street conditions and react appropriate ways to drivers opportune is a basic issue in route frameworks. Mist registering assumes a significant job in nearby information accumulation and route result reaction. In particular, haze hubs, which are updated roadside units that stretch to have computational capacities and extra rooms, can keep up traffic data revealed by the driving vehicles in their inclusion zones. On the off chance that a haze hub gets a route demand from a vehicle, it can coordinate with other haze hubs to produce an appropriate driving way for the questioning vehicle to its goal, and quickly restores the way to the questioning vehicle. In this way, the vehicle can appreciate continuous route benefits deftly and take activities to abstain from being trapped in rush hour gridlock blockage speedily. Moreover, haze processing empowers other low-inactivity and self-ruling nearby IoT applications, for example, home vitality the executives, enlarged reality and gaming, indoor area and route and organize asset the executives.
5) *Decentralized Computation for Fog:* With capacity and registering assets, it is feasible for numerous haze hubs to helpfully perform decentralized information calculation. In particular, the mist hubs can not just cooperatively take calculation assignments for the cloud, yet in addition help clients to perform substantial computational tasks for the benefit of intermediaries. Consequently, either the cloud or IoT gadgets can be free from overwhelming computational undertakings.

IV. FOG COMPUTING FRAMEWORK WITH IOT AND BENEFITS

To begin with, Fog computing is beneficial from its nearest competitor and its upper layer cloud computing. Table 1 describes the differences based on distribution, no. of server nodes, mobility, real-time interaction, last line connectivity, latency, deployment, and local awareness.

Table 1. Comparison of Fog Computing and Cloud Computing

Features	Fog Computing	Cloud Computing
Distribution	Decentralized	Centralized
Number of server nodes	Large scale	Few
Mobility	Supported	Limited
Real-time interaction	Supported	Supported
Last line connectivity	Wireless	Less Lined
Latency	Low	Low
Deployment	Distributed	Centralized
Location awareness	Yes	No

The current centralized cloud computing design is facing severe challenges for IoT applications. for example, it cannot support IoT time-sensitive applications like video streaming, gaming and increased reality . in line with Cisco , fog computing could be a a part of the cloud computing paradigm that takes the cloud nearer to the sting of the network. It provides a extremely virtualized model of computation, storage and networking resources between finish devices and classical cloud servers. To increase the potency of IoT applications, most of the info generated by these IoT objects/devices should be processed and analyzed in period of time . Fog computing can bring cloud networking, computing and storage capabilities all the way down to the sting of the network, which is able to address the period of time issue of IoT devices and supply secure and economical IoT applications . Fog computing provides

totally different services and applications with cosmopolitan deployments. The fog has the flexibility to produce economical period of time communication between totally different IoT applications, such as connected vehicles, through the proxy and access points positioned in line with long highways and tracks. Fog computing is taken into account to be the simplest selection for applications with low latency requirements like video streaming, gaming, increased reality, etc. The fog performs all computation operation like managing and analyzing information and other time-sensitive actions getting ready to finish users, that is that the ideal answer to satisfy latency constraints of a number of IoT applications.

Fog computing allows gradable processing on the cloud to IoT devices. This allows processing to be allotted betting on application demands, available networking and computing resources. This, in turn, reduces the quantity of knowledge required to be uploaded to the cloud, which is able to save network information measure.

Fog computing is wont to perform operations that require Brobdingnagian resources on behalf of resource-constrained devices once such operations can't be uploaded to the cloud. Therefore, this enables reducing devices' complexness, lifecycle prices and power consumption. Fog computing will run severally to confirm continuous services even once it's irregular network property to the cloud.Resource-constrained devices have restricted security functions; so, fog computing acts because the proxy for these devices to update the software system of those devices and security credentials. The fog also can be wont to monitor the safety standing of near devices.

V. CHALLENGES AND LIMITATION FOG COMPUTING

All paragraphs musThese challenges eventually IoT faces or has limitation is that complexity, dynamicity, quantifiability, latency, resource allocation, and security. This can be solved by implementing Fog computing [13].

1) *Complexity:* Since there are several IoT devices and sensors designed by totally different makers, selecting the best parts is turning into terribly difficult, particularly with totally different software packages and hardware configurations and private needs. additionally, in some cases, applications with high-security needs need specific hardware and protocols to operate, which will increase the problem of the operation.
2) *Dynamicity:* One of the significant highlights of IoT gadgets is the capacity to advance and powerfully change their work process structure. This test will modify the interior properties and execution of IoT gadgets. What's more, handheld gadgets experience the ill effects of programming and equipment maturing, which will bring about changing work process conduct and gadget properties. Consequently, mist hubs will require programmed and smart reconfiguration of the topological structure and doled out assets.
3) *Scalability:* The quantity of IoT gadgets is in the request for billions, which produces a colossal measure of information and requires an enormous measure of assets, for example, handling force and capacity. In this manner, haze servers ought to have the option to help every one of these gadgets with satisfactory assets. The genuine test will be the capacity to react to the quick development of IoT gadgets and applications.
4) *Latency:* One of the principal motivations to supplant the cloud with haze figuring is giving low inertness, particularly for time-delicate applications. In any case, there are numerous elements exhibiting a high inertness of utilization or administration execution on haze registering stages. The haze with high inertness will prompt client disappointment.
5) *Security:* Although fog nodes will need to be protected by using the same policy, controls and procedures and use the same physical security and cybersecurity solutions, the fog environment itself is vulnerable and less secure than cloud computing. Existing security and privacy measurements of cloud computing cannot be directly applied to the fog due to its mobility, heterogeneity and large-scale geo-distribution. Many research studies focus on cryptography and authentication to improve network security to protect against cyber-attacks in fog computing.
6) *Resource Allocation:* Fog end gadgets are frequently organized gadgets furnished with extra stockpiling and figuring power. Notwithstanding, it is hard for such gadgets to coordinate the asset limit of conventional servers, not to mention the cloud. Along these lines, reasonable administration of haze assets is required for effective activity of the mist registering condition.
7) *Security:* Though fog nodes can got to be protected by exploitation identical policy, controls and procedures and uses identical physical security and cybersecurity solutions, the fog setting itself is vulnerable and less secure than cloud computing. Existing security and privacy measurements of cloud computing can't be directly applied to the fog because of its quality, heterogeneousness and large-scale geo-distribution. several analysis studies target cryptography and authentication to boost network security to guard against cyber-attacks in fog computing [8,14].

VI. CONCLUSION

Fog computing has the potential to cut back delay for time-sensitive IoT services requests with low holdup, and low information measure. Thus, with the aim to cut back the load on cloud data-centers. Fog nodes aren't a replacement for cloud nodes, however, solely extend the computation and communication facilities to the fringe of the IoT network. Although fog is a promising paradigm towards property development of IoT networks, several open challenges and problems still exist, such as resource management issues. The planned framework may have the potential in achieving the property network paradigm and highlights important advantages of fog into the computing ecosystem. the longer term work is going to be stimulating the planned framework and analysis of the results, additionally to a practicability study for the planned framework.

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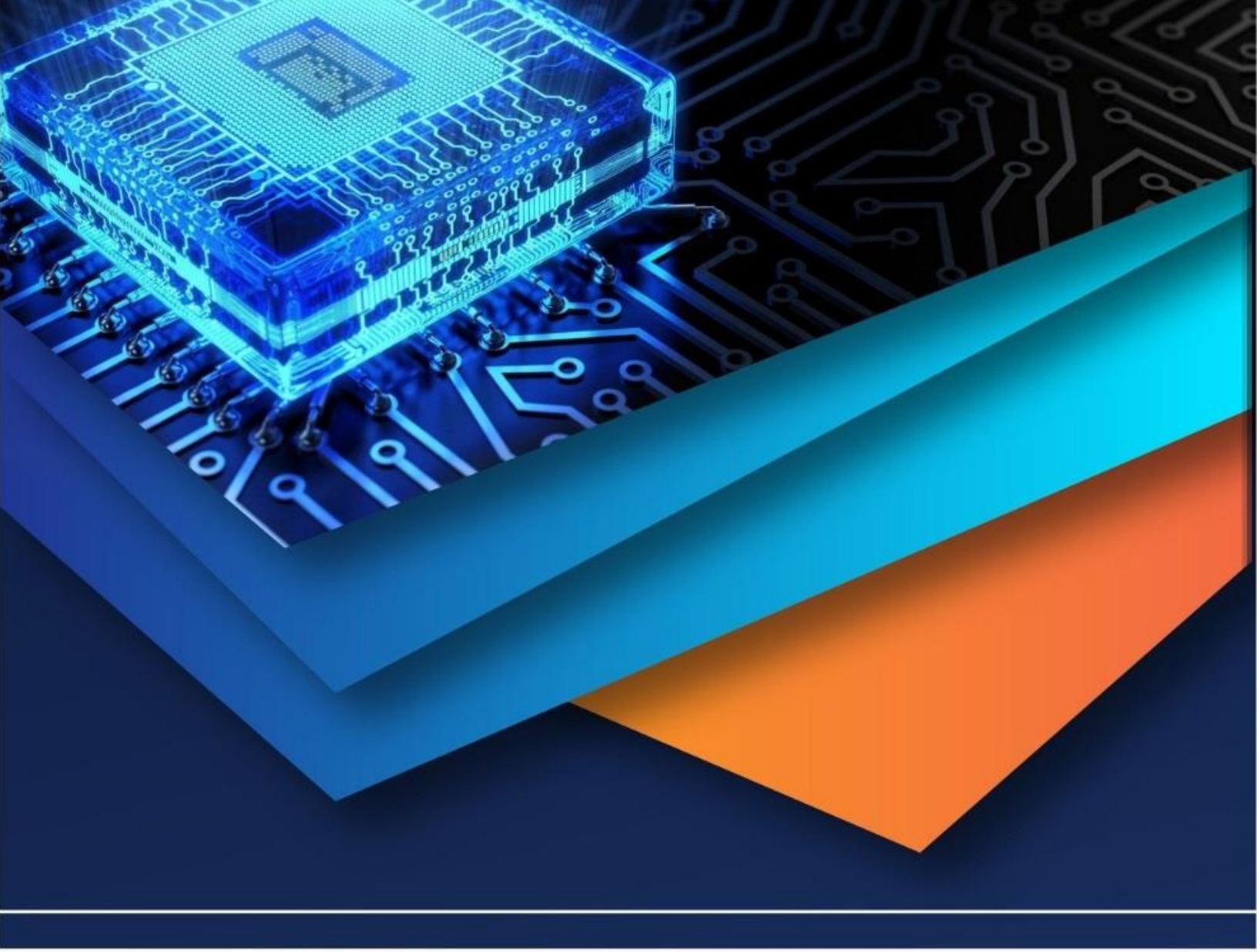

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