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An Overview on Internet of Things (IoT): Architecture, Technologies, Applications, Challenges

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Abstract: ***The primary aim of this paper is to give an overview on the Internet of Things encompassing its architecture, technologies, its various applications and challenges associated with it. The Internet of Things refers to billions of physical devices that are connected to the Internet, all collecting and sharing data. Electronic sensors are embedded into everyday objects which allow them to communicate and exchange data over a network. It is a system comprising of interrelated computing devices, objects, animals or people that each have unique identification number (UID) for identification and have the ability to communicate and exchange data over a network without the need of human-to-human or human-to-machine intervention. This paper aims to provide concise yet detailed and structured concepts on IoT, discusses its various technical aspects and gives our view on IoT technologies, applications and related issues with comparison of other papers.***
Keywords: Internet of Things (IoT), Wireless Sensor Networks (WSN), User Identification number (UID), Big Data, cloud computing.

I. INTRODUCTION

The Internet of Things (IoT) is a recent and evolving communication paradigm in which daily objects, people, animals, will be equipped with microcontrollers, transceivers for digital communication. According to Gartner, around 26 billion devices are expected to be part of the loT by 2020. IoT will become the technological innovation driving applications that have the power to change the markets across different domains.

Thousands of applications can be identified in each domain and new ones appear everyday, requiring a strong interconnection among things [1]. The Internet of Things (IoT) has become such a great deal because it helps people live and work smarter, it makes the lives of people easier and more convenient, and in addition this IoT is also essential to businesses. IoT is also a popular area for researchers, businesses and industries alike.

The organization of this paper is as follows: Section I gives an introduction on IoT. In section II we discuss the layered architecture of IoT and break down each layer in detail. Section III covers the technologies enabling IoT and applications of IoT are discussed thereafter in section IV. Section V of the paper explores the various challenges and opportunities of IoT system and finally we make some concluding remarks in section VI.

II. ARCHITECTURE

IoT devices typically connect to the Internet through the IP (Internet **Protocol**) **stack**. However, the IoT connects billions of objects which will create much larger traffic and much more data storage is needed [2]. As such, it becomes a heavy burden for the existing architecture of Internet with TCP/IP protocols to handle a network as big and dynamic as the IoT network which caused a need for new architecture. The new architecture for IoT needs to address a number of factors like scalability, interoperability, reliability, QoS, etc.

Figure 1 shows a generalized IoT Architecture composed of equipments, networks, cloud and application users. The architecture consists of four layers such as Perception, Network, Processing and Application layers.

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A. Perception Layer

This layer consists of sensors in different forms like RFID, gas sensors, IR sensors or other sensor networks which sense various environment variables like temperature, air quality, humidity etc. The sensor layer has the responsibility to recognize things and gather the data from them [3]. This layer gathers the useful information of the objects from the sensor devices linked with them and converts the information into digital signals which is then passed onto the Network Layer for further action [4].

B. Network Layer

This layer is also called the transmission layer and it receives the information collected through various sensors in perception layer in the form of digital signals and transmits it to the processing layer through various transmission mediums like Wi- Fi, Zigbee, Bluetooth, GSM etc. The mediums can be wired or wireless.

C. Processing Layer

The processing layer is also known as the middleware layer. It stores, analyzes, and processes huge amounts of data that comes from the transport layer. It employs many technologies such as databases, cloud computing, and big data processing modules [5].

D. Application Layer

The application layer defines all applications in which IoT can be deployed for example, smart homes, smart cities, smart healthcare. It is responsible for delivering application specific services to the user [5].

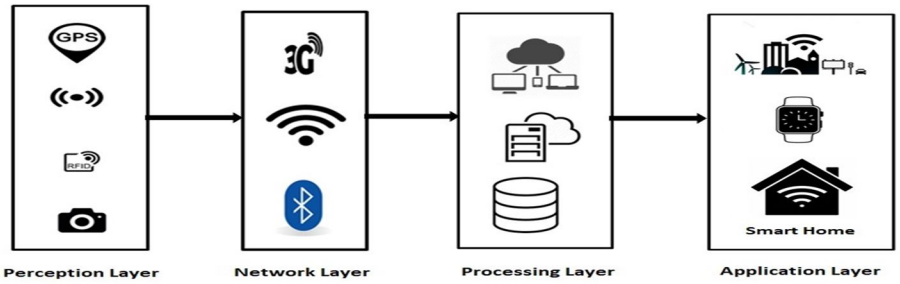

Figure 1. IoT 4 Layer Architecture

III. TECHNOLOGIES

The Internet of Things (IoT) is a network of interconnected devices, machines, animals or people each with a unique identifier and the ability to communicate and share data over the network without the need for human-to-human or human-to-machine intervention.

A. IoT Technology Stack

The IoT technology stack can be classified into four categories and are discussed below:

1) *Device Hardware:* Devices are the objects which constitute the "Things" in the Internet of Things (IoT). This includes sensors, actuators and various other IoT devices. They come in different shapes, sizes and levels of complexity depending on the task they are designed to perform.
2) *Device Software:* The devices may be in place, but appropriate software is needed to make them functional. This is what actually makes the connected devices smart. Software is responsible for implementing the communication with the Cloud, collecting data, integrating devices as well as performing real-time data analysis within the IoT network. Also, it is device software that also caters for application level capabilities for users to visualize data and interact with the IoT system.
3) *Gateway:* An IoT gateway is a solution for enabling communication, which may be device-to-device or device-to-cloud communications. The gateway facilitates the connections between different sources and destinations. It provides smart objects with the capability to exchange information with the rest of the IoT world.
4) *Platform:* An IoT platform is a place where all the data generated are gathered, analyzed, processed and presented in a user friendly way. It provides an interface to the users to interact with the IoT system. Platforms can be both on premise or cloud based.

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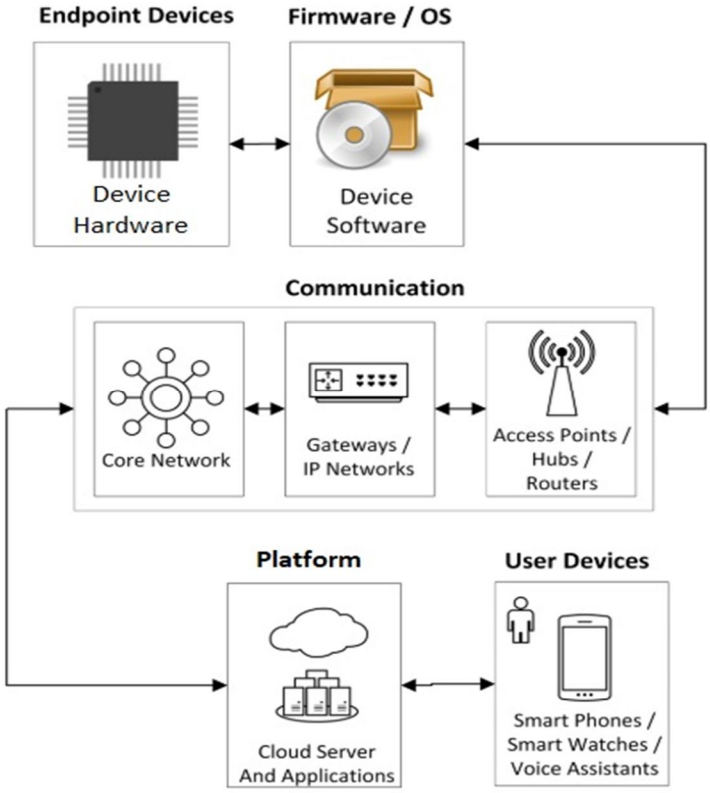

Figure 2. IoT Technology Stack [6]

B. Technologies Enabling IoT

IoT is a broad term in which many technologies are involved. In this section we discuss the major IoT enabling technologies.

1) *Wireless Sensor Networks (WSN):* Wireless sensor network is considered as the key enabler for the Internet of Things (IoT) paradigm. Wireless sensor networks consists of large number of sensors nodes connected to each other that are scattered in different geographical areas for collecting various data such as temperature, humidity, air quality, speed etc. These tiny nodes are capable of sensing, computing and actuation. A wireless sensor network may consist of tens to thousands of such nodes and these nodes communicate in multi- hop fashion and are generally distributed in an ad-hoc fashion. Every node in a sensor network comprises of three subsystems which are sensing subsystem for sensing the environment, processing subsystem for local computation of sensed data and communication subsystem for message communication.

2) *Cloud Computing:* Cloud computing is the delivery of on demand computing services over the Internet varying from applications to platforms, infrastructure and processing power. Various vendors/cloud service providers offer a wide range of cloud services over the Internet and these services can be availed on subscription basis (monthly/annually). The key benefit of using cloud computing for companies is that rather than owning computing infrastructure or data centers, companies can rent them and scale it up or down depending on their needs and they do need to worry about the up cost and complexity of owning and maintaining their own IT infrastructure. The Internet of Things suffers from limited capabilities in terms of processing power and storage, it must also contend with issues such as performance, security, privacy, reliability. The integration of the IoT into the Cloud is certainly the best way to overcome most of these issues [7].

3) *Big Data Analytics:* Big data analytics is the process of collecting, organizing and analyzing data to discover patterns and useful insights. Organizations can benefit from big data analytics to better understand the information contained within their data which helps to identify trends in their business and help make better business decisions. The volume of data generated by sensors, devices, social media, health care applications, temperature sensors, and various other software applications and digital devices that continuously generate large amounts of structured, unstructured, or semi-structured data is strongly increasing [8].

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4) *Communication Protocols:* communication protocols are considered to be the backbone of any IoT system. It allows devices to communicate and exchange data over a network. IoT communication protocols can be classified into:

a) IoT Data protocols
- Constrained Application protocol (CoAP)
- Message Queuing Telemetry Transport Protocol (MQTT)
- Advanced Message Queuing Protocol (AMQP)

b) Wireless IoT Network Protocols
- Short Range
  - Bluetooth
  - NFC
  - RFID
- Medium Range
  - Wi-Fi
  - Zigbee
  - Z-wave
- Long Range
  - LoraWan
  - Sigfox
  - Cellular

5) *Embedded Systems:* The IoT is an embedded microprocessor controlled system connected to the web. Embedded system can be considered as the bridge between IoT devices and the Internet due to the fact that it enables the data from sensors to get connected to the Internet. Without embedded systems, it would not be possible for sensor data to go anywhere. Embedded systems plays a vital role in IoT because of their useful features like low power consumption, real time computation and easy maintenance. It is a key enabler for any IoT system and will lay the foundation for the deployment of many IoT solutions.

IV. APPLICATIONS

IoT has a wide array of applications and promises to bring immense value to our lives. The applications of IoT expand in different domains and are ever increasing. It seems as though with each passing day, a new company comes up with a newly IoT enabled product. It is estimated that by 2025 connected devices across all technologies will reach to 1 trillion. With newer wireless networks, superior sensors and revolutionary computing capabilities, the Internet of Things could looks promising and could bring its share of changes in the field of technology.

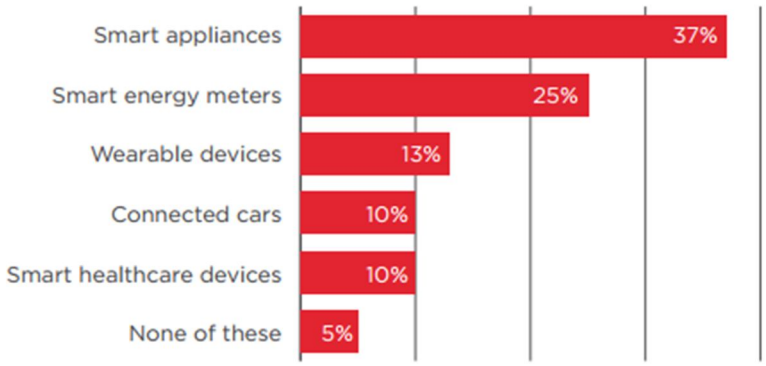

Figure 3. Popular IoT Applications [9]

A survey conducted by KRC Research in UK, US, Japan and Germany the early adopters of IOT has revealed which devices are the customers more likely to use in the coming years. Smart Appliances like thermostat, smart refrigerator to name a few are most liked by the customers and are seem to change the way we operate [9].

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1) *Smart Homes:* Smart home also referred to as home automation provides home owners security, comfort, energy saving and convenience allowing them to monitor and control different devices that are connected to the Internet through their smart devices (smart phones, tablets, laptops) and use it to perform different task making things easier, efficient and convenient. This includes everything from remotely switching off home appliances as you have left home, floors equipped with pressure sensors which keep track of the movement of an individual and aids in detecting if a person has fallen down, automatic adjustment of room temperature according to the temperature outside, etc. Smart home has become one of the most popular IoT applications and is predicted that many people will adopt it in the coming years.

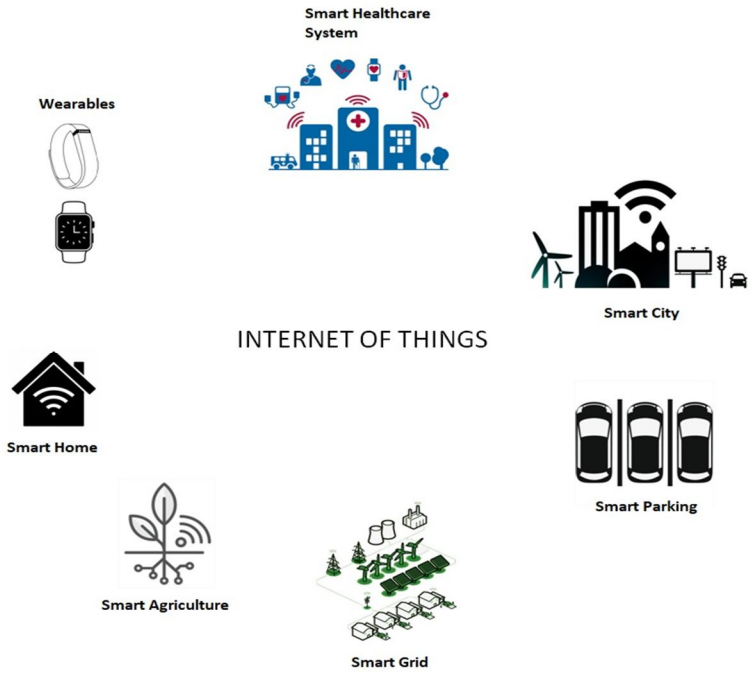

Figure 4. Applications of IoT

2) *Wearables:* Wearables can be in the form of smart watches, fitness trackers, or other form of accessories which are capable of monitoring various health parameters like heartbeat, perspiration levels, and complex measurements like oxygen levels in blood stream. They can be classified into Health, activity recognition and sports, tracking and localization and safety. In the case of health, the sensors collect the health-related data and the device may perform limited computation prior to transmitting the user/patient's health information to the Internet for further analysis. The health wearable IoT device is mainly used for remote patient monitoring, treatment and in some cases for rehabilitation purposes. Wearables are also used in activity recognition and sports to record different metrics of the user/athlete activity in order to improve his/her performance. They can be also used in tracking and localization for tracking human and animal, to determine their location online. Finding the position of a person or animal who is wearing a wearable device is important in many applications [10].
3) *Smart Grid:* smart grid is an electricity network that consists of a system of infrastructural, hardware and software solutions that enable two-way communication between all system parts and participants and provide efficient power generation and distribution in the supply chain. All the devices in this network are connected with sensor that regularly sends the data related to power consumption to the central server. Central server determines the consumption pattern and amount of power. This will improve the production to achieve the transient power targets [11]
4) *Smart Parking:* Smart parking is another popular application of IoT. Smart parking is a parking solution that involves accurately predicting and sensing vehicle occupancy in real time. It serves to guide residents and public to available parking space. In a nutshell, it simplifies the whole process of parking by providing live status of available slots to anyone who is searching for a parking space with the help of a parking assistance system and thereby making parking experience finer and more convenient. The parking assistance system consists of monitoring module, control module and display module which all work in conjunction with each other to send live feeds to the user's mobile phone.

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5) *Smart Cities:* IoT enabled smart city use cases span multiple areas like smart waste management, street lighting, environment monitoring, smart parking, and public safety. Smart cities use Internet of Things (IoT) devices such as connected sensors, lights, and meters to collect and analyze data. The cities then use this data to improve infrastructure, public utilities, services etc. A city which has smart waste management, environment monitoring, smart parking, smart grid etc can be termed a smart city.

6) *IoT in Healthcare:* Before Internet of Things, patients' interactions with doctors were limited to visits, telephonic and text communications. There were no way doctors or hospitals could monitor patients' health continuously and make recommendations accordingly. Internet of Things (IoT) enabled devices have made remote monitoring in the healthcare sector possible, unleashing the potential to keep patients safe and healthy, and empowering physicians to deliver superlative care. It has also increased patient engagement and satisfaction as interactions with doctors have become easier and more efficient. Furthermore, remote monitoring of patient's health helps in reducing the length of hospital stay and prevents re-admissions. IoT also has a major impact on reducing healthcare costs significantly and improving treatment outcomes [12].

7) *IoT in Agriculture:* Smart agriculture is a broad term that covers agriculture and food production activities powered by IoT, big data and advanced analytics technology. Popular IoT applications in smart agriculture include:

a) Sensor based systems for monitoring crops, soil, fields, livestock, storage facilities.

b) Smart agriculture vehicles, drones, agricultural robots.

c) Green house automation and crop management.

V. CHALLENGES

The Internet of Things (IoT) has drastically changed the way people live, communicate and do business. There are many benefits if using IoT and many areas where it can be deployed. However, IoT has its fair share of challenges like any other IT and Networking technologies and are listed below:

1) *Interoperability:* The term interoperability means the ability of different information systems, devices and applications to access, exchange, integrate and cooperatively use data in a coordinated manner. Interoperability is significantly more challenging for the IoT as it is not (only) about connecting people with people, but about a seamless interaction between devices and people with devices. These devices can differ regarding their technological capabilities [13].

2) *Security:* IoT makes everything and everyone locatable and addressable which raises the question of security and privacy. Data integrity, unique identification, and encryption are considered core challenges for IoT, as much of the data being acquired and communicated contain personal information [13]. From the perspective of consumer, loT device security may open multiple potential risks by enabling unauthorized access, misuse of customer personal information, facilitating attacks on the other integrated systems which may cause individual physical harms [14].

3) *Addressing and Identification:* Uniquely identifying objects is a critical issue for the operation and success of IoT applications [14]. Since millions of smart things will be connected to the Internet, they each will have to be identified through a unique address, on the basis of which they communicate with each other. For this, we need a large addressing space for accommodating all the smart devices, and a unique address for each smart object.

4) *Energy Consumption:* Most of the IoT devices are battery powered or uses energy harvesting techniques (eg. Solar energy). Communication consumes a lot of energy so they cannot communicate all the time. Hence, designing energy efficient network architecture and intelligent routing mechanism is still a great challenge in IoT networks [15].

5) *Scalability:* Billions of devices get connected to a huge network and large volumes of data are needed to be processed. And the number of connected devices are ever growing, so more devices means the system that stores, analyzes the data from these IoT devices needs to be highly scalable. The raw data obtained from various devices needs big data analytics and cloud storage for interpretation of useful data.

6) *Transmission Medium:* IoT networks use different types of technology to transmit or receive the data such as RFID, Bluetooth, Zigbee, LoraWAN, Sigfox, etc. The traditional problems associated with transmission media (e.g., high error rate, bandwidth, fading, inference, etc.) exists for IoT as well. Each transmission medium requires specialized energy, network hardware, the bandwidth that has to be compatible with that medium. Therefore, optimizing the TM is a challenge in IoT applications to sustain and prolong the lifetime of networks [16].

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VI. CONCLUSION

The Internet of Things (IoT) has a lot of potential and is still evolving, ever expanding its reaches to various areas of application. It is applicable and useful in any field today from businesses to industries to healthcare to agriculture. IoT has the capability to exponentially increase the availability of information, and will likely transform companies and organizations. IoT is changing every aspect of our lives and with proper adoption, implementation and leveraging its potential; it will prove to be a great boon for humanity.

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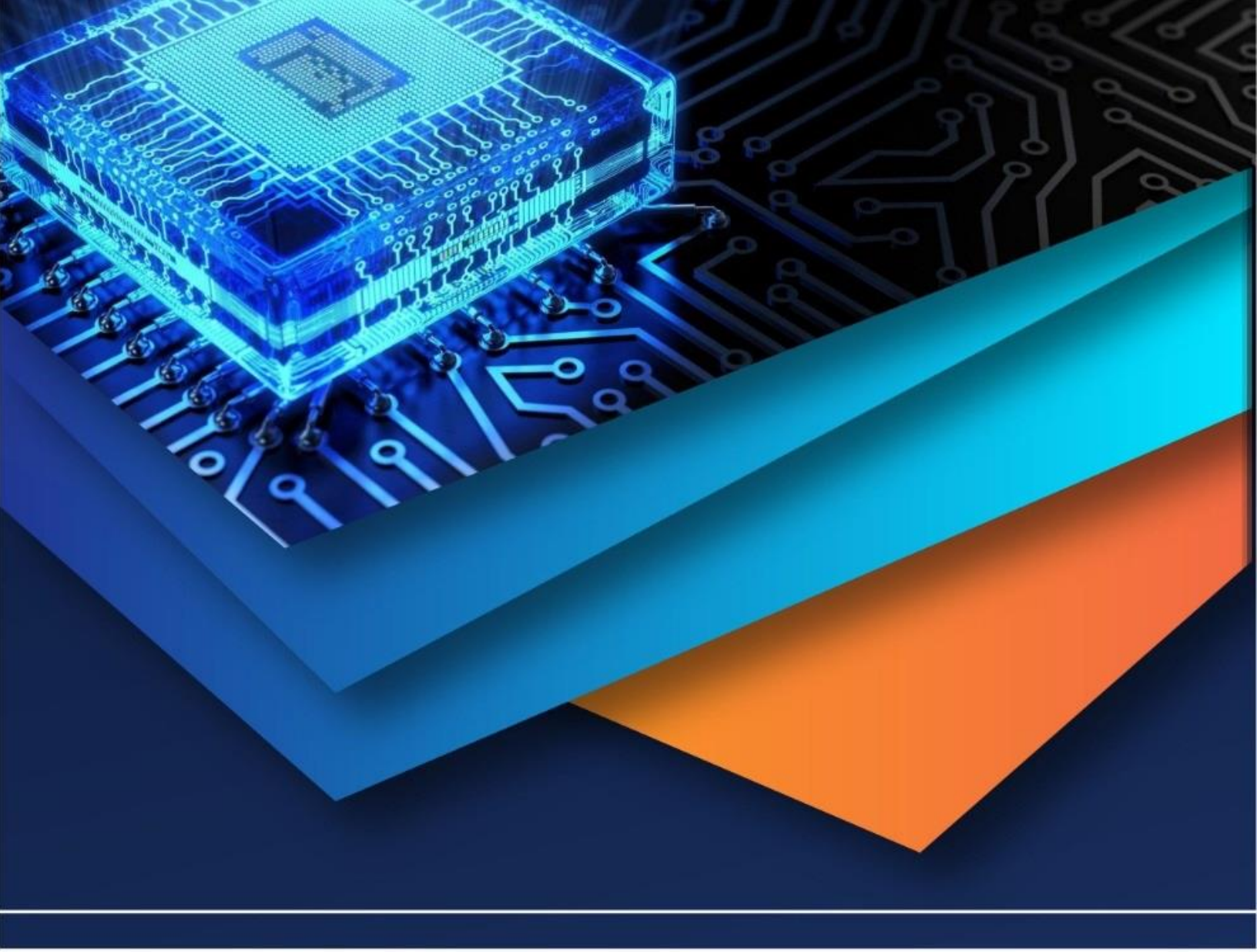

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