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Internet of Things in Healthcare

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Abstract: ***Internet of Things (IoT) is becoming the most promising and life changing technology in todays world. It is a computing process in which the communication is made or aided with sensors. In the past few years, IoT has become most productive in the area of healthcare, to improve the quality of care to the patient's. As there is a rise in health issues, providing health assistance to each and every member is important. People nowadays are busy with their lives and even they forget about their health problems. Some people do not even take care of their health. When the healthcare system has started communicating with IoT devices, it only started to maintain the digital identity of the patient. Today, IoT in healthcare has become more productive because the communication between doctor's and patients has been improved with mobile apps. These apps are developed by the companies so that the doctors can monitor the patient's health. If any problem has occurred to the patient, then the doctor approaches the patient and gives the appropriate treatment. In this thesis, particular focus is given to infant healthcare, because the greatest fear of parents is that they would lose their infants at any time. Therefore, in this thesis, the traditional care methods for infants are reviewed first. Then, an experimental setup is proposed and implemented which is capable of monitoring the patient health. In this review a commercial device has been identified which monitors the real-time information about the infant's heart rate, oxygen levels, sleeping position, etc. If anything happens to the baby, the information will get to the mobile application which has already been developed by a company and is commercially available. Then, by doing an example field test for the baby, the information which is recorded is analyzed. The information that has been analyzed is sent to the mobile which is aided through a base station.***

Keywords: Base Station, Healthcare, Infant Healthcare, IoT, Smart Sock.

I. INTRODUCTION

A. Overview

The term "Internet of Things (IoT)" has recently become popular in communication technology. It has been developed in many ways and is called as the next frontier. IoT is set to transform many aspects of our lives, it changes our world. In the coming years, the number of IoT devices is expected to grow dramatically. The reach of IoT is more than 12 billion devices that can currently connect with Internet, but by 2020 it is estimated that there will be 26 times more connected things with the Internet than the people [1]. Today, everything around us from household lights and different home appliances to vending machines and cars has the ability to get online and interact with other machines. IoT refers to devices or objects that can interact with the Internet by making use of physical devices, sensors, microcontrollers, and network connectivity that enable these objects to collect and exchange data as shown in Figure 1. In order to collect the real time data consistently, each and every device has its unique identifier (UID), which makes the communication possible in an easy way like machine to machine (M2M) communication. A massive amount of data is collected from devices all over the world which is stored in the cloud. As a result, systems will become more efficient and smarter.

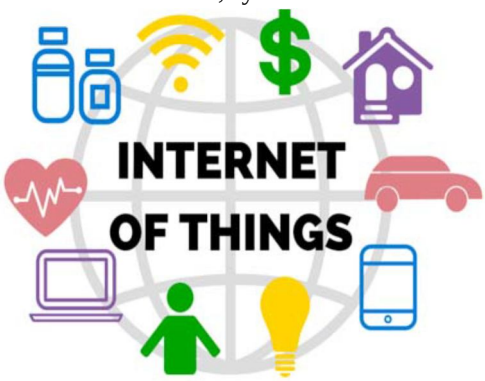

Figure 1: Internet of Things connected to many physical things and objects [2].

IoT creates smart objects which constitute eventual building blocks in the improvement of cyber-physical smart universal frameworks. It is intended for billions of physical things or objects that will be equipped with different kinds of sensors and actuators, that are joined by the Internet through diverse access networks assisted by different technologies such as wireless sensor networks (WSN), radio frequency identification (RFID), real time and semantic web services [1]. IoT which allows the people seamless interactions among different types of devices such as medical sensors, monitoring cameras, home appliances and so on [3]. By keeping all these things in view, we all know several applications which have been developed for IoT, in which each and every physical object is connected through the Internet by employing sensor devices [4]. The communication is aided through the sensors installed into the participating devices. Sensors play a vital role in detecting signals. Sensors are now found in many applications, such as smart devices (mobile devices, tablets, etc.), automotive systems, climate monitoring, industrial control and healthcare. Recently, IoT has become more productive in the area of healthcare systems. Specifically, IoT in the healthcare field combines sensors, microcontrollers etc., to analyze and send the sensor data to the cloud and then onwards to caregivers (doctors). Integrating the IoT features into medical devices improves the quality and service of care for elderly patients and also for kids. IoT in healthcare could maintain thousands of patient's data which is computerized and helps the patients to capture their data anytime. Many health sensing components have been developed more that are portable, this allows the patients to wear them for monitoring. The health monitoring device is connected to the patient such that the doctor can observe the patient's condition at any-time. As IoT assisted patients can be accessed over the Internet, the health state of the patient can be detected at the right time so that proper action is taken [1]. The most of the developing countries have very poor healthcare infrastructure. If the health sensing device is made to communicate with portable devices like smart phones and tablets etc., communicating with the cloud is possible. People have access to these portable communication devices which are now becoming cheap [5]. The healthcare industry has made patient care more reliable. The real-time information of the patient data is analyzed and recorded, and the doctors/caregivers can monitor them by using handheld computers.

B. Motivation

Today, IoT has become the most powerful communication paradigm of the 21st century. Now, in the IoT environment, all objects which are in our daily life become a part of the Internet due to their communication and computing capabilities [3]. By 2020, 90 percent of all the healthcare organizations will have implemented IoT technology. Improving the efficiency of healthcare and the need of delivering quality care to patients is one of the challenging things of modern society [6]. Some healthcare organizations do not apply data from connected devices to other business processes. Effective healthcare depends on speed and accuracy, supporting many people and a huge range of devices which are connecting with IoT. Therefore, IoT has become more productive in the area of healthcare systems. In the past few years, many premature babies were dying or suffering with health complications. To solve this problem, IoT has developed a new technology in healthcare to improve the quality of care for infants.

C. Problem Statement

Health support of each individual should be considered as very important in todays world because of a rise in many health problems. If there is an increase in the number of patients, then this leads to a decrease in the relative number of doctors. As a result, the diagnostics are delayed or some patients are ignored. This makes patients more dependent on doctors for their check-up. Keeping all these issues in mind, healthcare systems have started connecting with IoT for maintaining the digital identity of each and every patient.

Due to no availability of doctors/caregivers and not being able to access the healthcare systems, many health problems are getting undetected in the healthcare system. On the other hand, these IoT based healthcare systems have helped the patients and doctors to continuously monitor and easily analyze the patient data [4]. Infant healthcare is becoming a big problem today. The greatest fear of any parents is that they would lose their infant. Today the Sudden Infant Death Syndrome (SIDS) is a big problem. The most common reason for the sudden death of infants is that they are having trouble while they are breathing. This sudden death happens without giving any signs. It may happen when the infant is in deep sleep and also when the baby is crying or struggling with any other problem [14]. To avoid this problem, IoT has ensured the personalization of infant healthcare by maintaining the digital identity of infants each and every moment. By making use of IoT smart sensors, the infant health can be monitored, data can be collected, and real-time information of the infants each and every moment can be sent to their parents.

D. Aim and Objectives

IoT holds a great potential to meet the needs of healthcare.

1) The aim of this thesis is to develop an application/architecture, which is capable of monitoring the health of infants.
2) It is being applied to improve the access to care, to increase the quality of care, and to reduce the cost of care.
3) Monitor the health status of an infant by a sensor, which creates information that passes through a network so that it can be communicated or analyzed.

E. Method

Firstly, it has been started with analyzing the traditional care methods for infants and start looking into the devices that can be placed in the process of care to improve the accuracy of measurements and the response time for result analysis. An infant monitor can collect data and send real-time information of the infants breathing phase, heartbeat, skin temperature, sleeping position and intestine activity level. Advances in sensor and connectivity technology are allowing devices to collect, record and analyze data that was not accessible before, this means being able to collect important data over time that can be used to help enable preventive care.

II. BACKGROUND ON IOT IN HEALTHCARE

A. Healthcare and IoT

Technology which is now based on IoT has worked its way onto many consumer devices Many people are expecting it to crossover to healthcare. IoT technology transforms the way we live and work. Also, it could change many aspects of our lives including healthcare. Nowadays, many healthcare applications are available which allows the patients to schedule their appointments through the applications on their mobile phones, smart devices etc. without any need to make a call to the hospital and wait for long time for an appointment.

1) General IoT in Healthcare

IoT transforms the medical data into insights for smarter patient care. Healthcare is now more technologically advanced and is all about connecting things together. Therefore, IoT is so important in healthcare. By leveraging devices like connected sensors and other types of things that people can wear all that information can be placed in the cloud, and doctor/caregiver can easily monitor the real-time information of the patient. IoT can support potentially life saving applications within the healthcare industry by collecting data from the bedside devices, viewing patient information, and diagnosing in real-time the entire system of the patient care (see Figure 2). Today, many healthcare devices operate throughout the world which becomes an issue as it can cause data loss and mistakes in diagnosis. To overcome this the data which is collected will be stored in cloud.

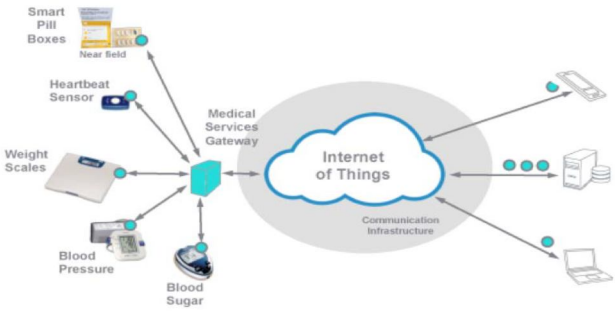

Figure 2: General IoT in healthcare [7].

The caregivers or doctors have the ability to easily monitor and manage the patient health and can save precious minutes every day. Without having to manually visit each patient, the caregiver/expert or doctor can give a remote diagnosis and track the medical assets. Usingn the sensors and Wi-Fi, the right department in the hospital can be located while retrieving sensual information.

a) Clinical Care

Making use of IoT-driven sensor, the patient is continuously monitored. The patient requires close attention due to their physiological status, which is a noninvasive monitoring. The patient status is monitored by the sensor which collects the physiological information of the patient to be analyzed, making use of gateways. The obtained information will be stored in the cloud [8]. This information is then sent to the caregivers/doctors wirelessly for further analysis as shown in Figure 3. This improves the quality of care and also reduces the cost for the patient's [8].

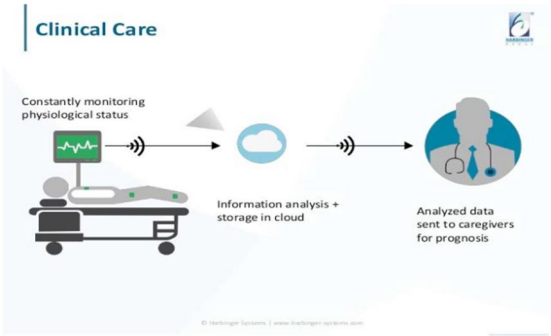

Figure 3: Clinical care system which constantly monitors the physiological status [9].

b) Remote Monitoring

The general IoT in a remote health monitoring systems tracks a patient's vital signals in realtime and responds if there is any problem in patient health. A device is attached to the patient as shown in Figure 4. It transmits the data about the vital signs from the place where the patient is located. The transmitter is connected through a telecom network to a hospital [8]. The hospital has a remote monitoring system that reads about the patient's vital signs. In the same way when the sensor is implanted into the patient's body, the data can be electronically transmitted. The information which is transmitted will be securely sent to healthcare providers/caregivers.

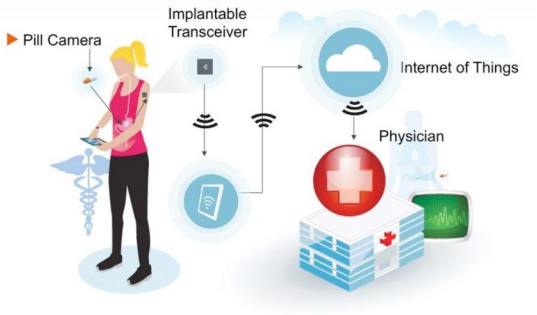

Figure 4: Remote health monitoring system [8].

2) Applications for IoT in Healthcare

a) Blood Pressure Monitoring

Blood pressure (BP) is one of the most important physiological parameters of the human body. Safe and simple to use blood pressure monitors have become common [10]. With the development in the healthcare system, the healthcare equipment/system is connected with an IoT device or sensors that makes an easy communication between the patient's and doctors/caregivers. An electronic blood pressure monitor is connected with the IoT sensor that collects the real-time information of the patient BP levels.

b) Rehabilitation System

A rehabilitation system can enhance and can restore the functional abilities and improves the quality of life for the people who are suffering with some disabilities in terms of mitigating problems that are linked with aging populations and when there is a shortage of health experts [10]. There is a community-based smart rehabilitation system that provides an effective treatment. A convenient adequate interaction and allocation of medical resources according to patient requirements can be done by an ontology-based automating designing method connected with IoT-based smart rehabilitation system [11].

c) Oxygen Saturation Monitoring

The pulse oximeter is a device which continuously monitors the blood oxygen saturation of the patient in a noninvasive way [10]. There are many advances in the communication technology, i.e., wireless networks, and medical sensors are booming at present days because of the low power consumption and low loss. The continuous monitoring pulse oximeters are used in many medical applications to know the oxygen levels in blood and also the heart rate (HR). The IoT sensor which is connected to the patient body will monitor and sense the patient's heart rate and oxygen levels, which can limit the patient activity [12].

d) Wheelchair Management

Wheelchairs are used by the people who are suffering with a physical illness and they cannot walk or any other physical disabilities. Wireless body area networks (WBANs) can connect smart objects with the Internet, to be used as a people-centric sensing (sensor) device for wheelchair users. There will be pressure cushion (which is a resistive pressure sensor) that will detect when the human body is falling down from the wheelchair. A smart wheelchair has another accelerator sensor which detects the falling of the wheelchair [13]. The doctor/caregiver can continuously monitor the patient's data from the hospital.

e) .Healthcare Solutions Using Smartphone's

Mobile devices and healthcare apps provide many benefits for health care professionals(HCPs). There are many medical healthcare applications which are now available in many ways and ready to access such as health record, information and time, communication and consulting with doctors, patient continuous monitoring and proper clinical decision making [15]. With the use of smartphone apps and sensors, the point of care and also the access to care has been increased and will support the improved patient outcomes.

3) IoT in Healthcare for Babies and Infants

For parents, nothing is more important than keeping their baby happy and healthy. Babies cannot speak and tell if they are hungry or if it feels like hot, cold, sleepy. Now, IoT wearables can make all the difference. IoT has now been developed for babies and infants to help their parents. Parents can monitor their infant's health wirelessly (for example via Bluetooth technology), there are many IoT wearables, devices and smart sensors which can continuously monitor the baby's/infants vital signs and send that data directly to a mobile device. An infant monitor can collect data and send real-time information of the infants each and every moment.

III. SELECTED CASES OF USING IOT IN HEALTHCARE

Now, mobile applications and wearable devices provide monitoring symptoms, medical education, fitness, and cooperative managing of illnesses and coherent care. Analytics software applications could increase interpreting data significantly and minimize the needed time to reassemble the produced data. Perspectives from studying big data would lead to the electronic evolution in the medical discipline, business procedures, and time deciding. Since the worldwide aging population rises, it would be vital to raising understanding and interpreting of data about health and well-being, minimize chronic and diet-derived diseases, and enhance mental abilities, boost mental health and lifestyles.

Although it is impossible to list all the IoT healthcare applications, we will provide an overview of the renowned ones. Going through the scientific literature as well as some commercial resources, it becomes obvious that IoT is expected to play soon a prominent role in cancer care, patient-driven self-assessment procedures, drug delivery and adherence monitoring, exaggerations of acute conditions management and mental health. Cancer care (CC) wearable's have already been tested in clinical practice. In 2018,a Randomized Clinical Trial was presented in the Annual Meeting of the American Society of Clinical Oncology. The study focused on patients with head and neck cancer who were monitored via a Bluetooth-enabled weight scale and blood pressure cuff, together with a symptom-tracking app that was sending regular and emergency updates to patients' physicians.

About 400 patients were involved in the study, and the patients who used this IoT-based system experienced milder symptoms in comparison with the control group, which was assessed physically on weekly basis [20, 21, 25]. Diabetes is a model disease for assessing self-monitoring and adherence to treatment in various contexts including oral pharmacotherapy, injected insulin, blood glucose measurement, and blood pressure monitoring among others. IoT-based continuous glucose monitoring can be implemented on a wealth of existing devices. Although continuous monitoring and immediate intervention are mostly needed by type 1 Diabetes Mellitus (T1D) patients, accumulating evidence suggests that more punctual or even constant monitoring could prevent complications in patients with T2D [26, 27]. Smart insulin pens are relevant tools to assess the treatment adherence of patients with Diabetes Mellitus (DM). Although the existing devices focus on insulin injections, similar devices could also be used for pillboxes. Nowadays, such wearable's are connected with smartphone apps and assessed by physicians regularly.

Incorporating these modalities in an IoT context, physicians could be notified for patients neglecting treatment sooner and act accordingly [28, 29]. Closed-loop (automated) insulin administration systems have been long-awaited in T1D care. Potential regulatory and management flaws have hindered the introduction of such devices in clinical practice. Several advocacy activities from physicians and patients networks have already been observed taking into account that IoT can contribute significantly to tackling such obstacles. Although several steps need to be taken, an automated and IoT secured closed-loop system can be very important with regard to T1D patients who are at risk of diabetic ketoacidosis [30, 31]. Rather than DM, asthma is a chronic condition with a pattern of exaggerations that offers a fertile field for IoT-based healthcare.

It represents a significant burden for hundreds of millions of people all over the globe. The majority of the patients are young and active seeking a stable quality of life. IoT wearables assessing saturation or warning about the presence of common allergens are important in the early detection and management of an upcoming exacerbation. In the same frame, IoT-based inhalers could provide the patients' physicians with reliable information about the adherence and the ability of the patient to handle the device properly [14, 32].Asthma has a chronic aspect, of course, and so do mental health disorders. Apart from the aforementioned monitoring options, IoT can enhance patient support services. In combination with AI modalities, IoT can provide supportive chatbots for a wide variety of purposes from suicidal thoughts' detection to regular cognitive rehabilitation treatment in patients with dementia or mild cognitive impairment [16].

In this section, we have presented selected cases of IoT implementation in healthcare such as cancer care, patient-driven self-assessment procedures, drug delivery and adherence monitoring, asthma exaggerations management, and supportive care of degenerative mental health conditions as shown in Fig. 3. Such modalities state the potential of IoT in transforming clinical practice, patient management, and research if further and hopefully adopted.

IV. CHALLENGES FOR IOT IN HEALTHCARE

1) *Security and privacy:* There could me many potential implications, so that the devices which are connected (connected devices like Smartphone's, sensors etc.) [2] can be at a risk from hackers or hacking [2]. Whenever there is transmission of data from one device to another it must be encrypted.
2) *Integration:* Integrating multiple devices and protocols within the network is another challenging task for implementing successful IoT in healthcare. There are many smartphones that are connected to the network which actively collect data. There are also different communication protocols that complicates the process of aggregating the information.
3) *Technology adoption:* Creating a new app with innovative ideas that helps doctors and patient's, this is not enough to pay for a new technology. The product which is developed should also be monetized in the healthcare system.

A. *Advantages of IoT in Healthcare*

1) Treatment for diseases are done before they get out of hand, because the patients are continuously monitored and the caregivers or providers can access the real-time data and improve the disease management [16].
2) The automated data and the smart monitoring which are controlled by the devices connected with the IoT and the decisions are made easily based on deep analytics which reduces errors.
3) Patient monitoring is done on a real-time basis, which significantly cuts down the unnecessary doctor visits and also cuts down the hospital stays. This can reduce the cost for patients [16].
4) Connected healthcare enables the caregivers to get access to real-time information when the patient is continuously monitored and the decisions are taken properly. This can help and provide timely care that improves the treatment outcomes.

B. *Disadvantages of IoT in Healthcare*

1) There is a compatibility problem for the IoT in healthcare, because currently there is no standard for tagging and monitoring with the sensors.
2) Privacy and security is one of the big issue with IoT in healthcare, i.e., all the patient doctor data must be encrypted.
3) The software can be hacked by other users and the personal information is misused.These possibilities are endless in IoT.

V. CONCLUSIONS AND FUTURE WORK

Firstly, it has been started by studying and finding different sensors and devices for Healthcare in IoT. The proposed solution for infant healthcare is based on the Owlet Smart Sock 2 (wearable device). This device is unique because it is working actively in any situation. It gives real-time information of the infant's heart rate and oxygen levels and notifies to the parents if readings go out of range. The reason behind choosing the metrics heart rate and oxygen levels are due to SIDS, because the sudden death happens mostly in the case where oxygen levels are low and when the heart rate goes down. The system is implemented using the Smart Sock 2, base station, smartphone, and open Wi-Fi network. However, there are some problems we need to solve. If we go in another area, which is not a home Wi-Fi network or business Wi-Fi network, it is getting trouble while connecting. It is quite difficult when getting to security matters. Also, the battery life time of the Smart Sock 2 sensor should be improved. The base station should come with a battery instead of Plugging in all the time.

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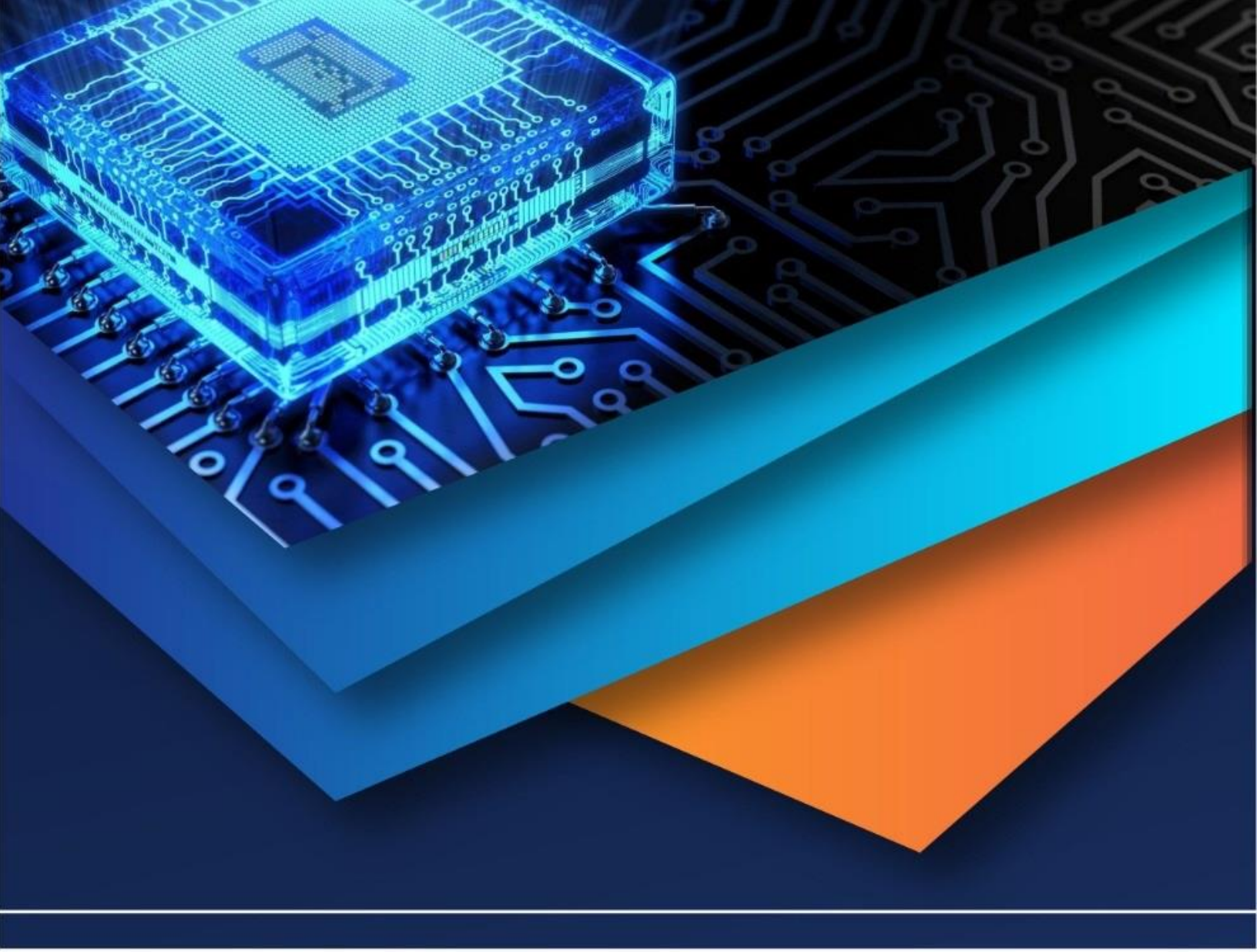

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