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Tracing the Location of Alzheimer's Patient Using Location Fingerprinting

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Abstract: Alzheimer's disease is the most common type of Dementia in which the person's memory, behavior, and thinking get affected. This work is majorly focused on helping Alzheimer's patient and the Guardians/Caretakers, who are responsible for the safety of Alzheimer's patients. Trapping the patient inside a care facility or home isn't a solution for them, but at the exact moment, we can't let them free outside which is way riskier. Therefore, the objective of our work is to design a system that can trace the location of Alzheimer's patient using Location Fingerprinting and intimating the Guardian/caretaker about their location through a Mobile Application. Among all the available approaches in Location Fingerprinting, we are making use of Bluetooth Based Positioning for location tracing within the Apartment or Care facility premises. By using RSSI and Trilateration based techniques in Bluetooth Low Energy (BLE) positioning, we can trace the location and map it into a Map in our Mobile application in terms of Latitude and Longitude.
Keywords: Location Fingerprinting, Bluetooth low energy, Trilateration, Alzheimer's, Mobile Application

I. INTRODUCTION

Alzheimer's patients suffer from memory loss which gets worse as the disease progresses. Across the world, the prevalence of dementia was estimated to be 3.9 % in people aged 60+ years, with the regional prevalence being 1.6 % in Africa, 4.0 % in China and Western Pacific regions, 4.6 % in Latin America, 5.4 % in Western Europe. Due to degeneration of memory and self-caring capabilities, Alzheimer's patients need various levels of care and help on their daily lives from their family members or caregivers. To help Alzheimer's patients with their freedom and also to help the caretaker, there are various different location tracking devices. Most of these products' working is restricted to only a few geographical boundaries such as US, Canada and UK while some of these products are costlier and require much post-installation management.

Location Fingerprinting involves the use of Received signal strength and thereby determining the distance from it. In this, various technologies such as Ultra-Wide Band (UWB), Bluetooth positioning, and RFID tracking have been used. In all these technologies[7], various central devices are deployed as the signal scanners along with a peripheral device as signal transmitter. Once the Peripheral device comes into the reception range of the Central, a connection is established between them. The signal strength of the connection is determined and it is converted into the corresponding distance. These distance values obtained from different Centrals are used for Location Tracing. Mobile application is used as a platform to display the location of patient to their loved ones/ caretakers.

When compared with the existing products, our work will be efficient in terms of cost and provides an optimal level of performance. Location Fingerprinting works much more effective than GPS which fails to trace location in congested places like the streets of India and Indoor places.

II. MATERIALS AND METHODS

Location fingerprinting is majorly used in Indoor positioning where the RSSI(Received Signal Strength Indicator) values are used to trace the location. A wide range of techniques are available such as UWB based positioning, BLE based positioning, and RFID tracking. On comparing all these methods on the basis of cost, range, location tracing accuracy, latency in data transmission and compactness, we were able to find BLE as an optimal solution.

For the implementation of BLE based positioning, we are making use of Arduino Nano 33 IoT as Anchor Nodes which are shown in Fig. 1 and Arduino Nano 33 BLE acts as the Location Tag which is shown in Fig. 2.

Arduino Nano 33 IoT is a dual processor device with both Bluetooth and Wi-Fi connectivity. The board's main processor is a low power Arm® Cortex®-M0 32-bit SAMD21. The WiFi and Bluetooth® connectivity is performed with a module from u-blox, the NINA-W10, a low power chipset operating in the 2.4GHz range.

Arduino Nano 33 BLE is a powerful processor with Bluetooth® pairing via NFC and ultra low power consumption modes.

Fig. 1 Arduino Nano 33 IoT acting as Anchor node in BLE based positioning

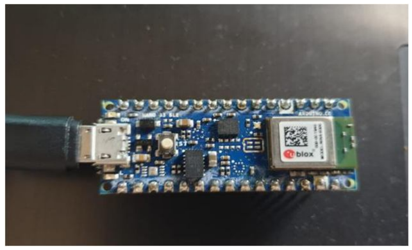

Fig. 2 Arduino Nano 33 BLE acting as Location Tag/Peripheral device in Bluetooth based positioning

The BLE positioning for the location tracking of patient can be decomposed into four major functions as follows:

A. Detection

Before deploying the Anchor Nodes and the Location Tag, the connectivity for Bluetooth is checked using simple Bluetooth connectivity examples such as LED light control. Arduino Nano 33 IoT consists of both Wi-Fi and Bluetooth technology, thereby the Wi-Fi connectivity of Arduino Nano 33 IoT is checked through LED control and a Web page.

After completing the connectivity test, we move forward towards the Integration of Anchor Nodes and Location Tag. The location Tag will be advertising itself at a periodic delay. Each anchor node will be scanning for the presence of any peripheral device.When the location tag comes within the range of coverage of any Anchor Node, the central device immediately establishes a connection with the available peripheral device and based on the signal strength of the connection, each anchor node calculates the distance of location tag from it. The received signal strength is converted to distance using the following equation:

$$d = 10^{\left(\frac{txPower-RSSI}{10\times FreeSpaceFactor}\right)}$$

Where ,

txPower=Transmission Power

RSSI=Received Signal Strength in dB

Free space Factor-= 2 to 4

We can view the estimated distance values through the serial monitor as shown in Fig. 3.

Fig. 3 RSSI value and corresponding distance of the discovered Peripheral from one of the Anchor Node

B. Data Collection

The distance measured based on the Bluetooth connectivity strength in between the Anchor node and Location Tag must be stored in Cloud for the further computation. ThingSpeak is a platform which helps in the storage of data as well as helps in further computation by integrating with MATLAB. In Arduino Nano 33 IoT, Bluetooth is enabled to estimate the distance between itself and the Location tag. After distance is obtained, Bluetooth is disabled and Wi-Fi is enabled so that the obtained distance data can be transmitted to ThingSpeak. The distance data which is collected at ThingSpeak is shown in Fig. 4.

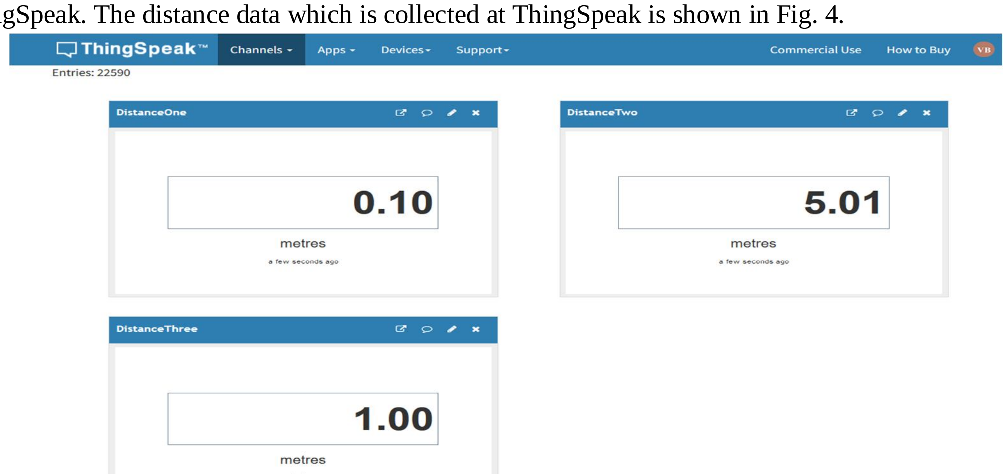

Fig. 4 Distance values updated in ThingSpeak from Three Anchor Nodes

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Volume 10 Issue VI June 2022- Available at www.ijraset.com

C. Localization

In order to pinpoint the exact location of the Patient, the collected Distance data is supposed to be further computed. Trilateration Algorithm is used to obtain the exact coordinates of the Location Tag using the distances collected at ThingSpeak. The concept behind Tilateration Algorithm can be understood through the Fig. 5. With the movement of the patient, distance values will be updated and again the same computation to obtain coordinates happens iteratively. Trilateration Algorithm is of two types in which the resultant coordinates could be either in the form of Latitude and Longitude or in the form of newly defined 2D Spatial Coordinate.

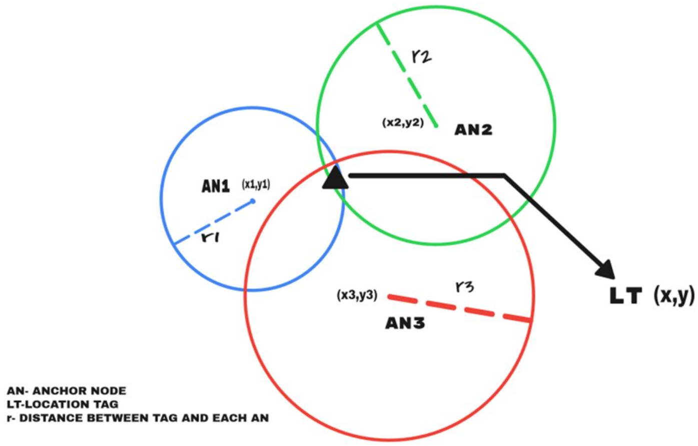
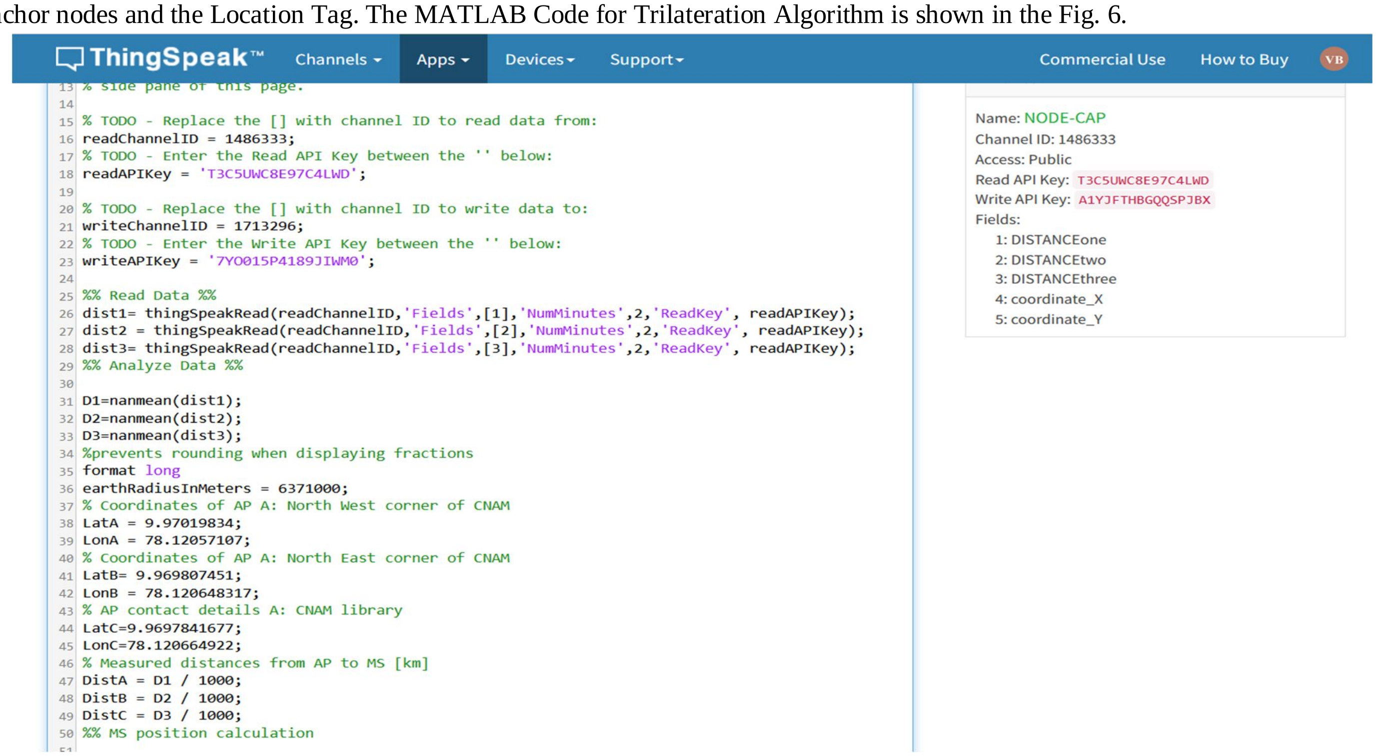


Fig. 5 Concept behind the Working of Trilateration Algorithm

We have made use of the Trilateration Algorithm involving Latitude and Longitude coordinates, which is implemented in the form of MATLAB code[5] whose inputs are the Fixed Latitude and Longitude coordinates of Anchor node and the Distances between the Anchor nodes and the Location Tag. The MATLAB Code for Trilateration Algorithm is shown in the Fig. 6.




```
% side pane of this page.

% TODO - Replace the [] with channel ID to read data from:
readChannelID = 1486333;
% TODO - Enter the Read API Key between the '' below:
readAPIKey = 'T3C5UWC8E97C4LWD';

% TODO - Replace the [] with channel ID to write data to:
writeChannelID = 1713296;
% TODO - Enter the Write API Key between the '' below:
writeAPIKey = '7YO015P4189JIWM0';

%% Read Data %%
dist1= thingSpeakRead(readChannelID,'Fields',[1],'NumMinutes',2,'ReadKey', readAPIKey);
dist2 = thingSpeakRead(readChannelID,'Fields',[2],'NumMinutes',2,'ReadKey', readAPIKey);
dist3= thingSpeakRead(readChannelID,'Fields',[3],'NumMinutes',2,'ReadKey', readAPIKey);
%% Analyze Data %%

D1=nanmean(dist1);
D2=nanmean(dist2);
D3=nanmean(dist3);
%prevents rounding when displaying fractions
format long
earthRadiusInMeters = 6371000;
% Coordinates of AP A: North West corner of CNAM
LatA = 9.97019834;
LonA = 78.12057107;
% Coordinates of AP A: North East corner of CNAM
LatB= 9.969807451;
LonB = 78.120648317;
% AP contact details A: CNAM library
LatC=9.9697841677;
LonC=78.120664922;
% Measured distances from AP to MS [km]
DistA = D1 / 1000;
DistB = D2 / 1000;
DistC = D3 / 1000;
%% MS position calculation
```

Fig. 6 MATLAB Code for Trilateration Algorithm in ThingSpeak

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Volume 10 Issue VI June 2022- Available at www.ijraset.com

The resultant Latitude and Longitude coordinates are updated at ThingSpeak which is shown in Fig. 7. Further from ThingSpeak, the obtained coordinates are taken to the developed Mobile Application.

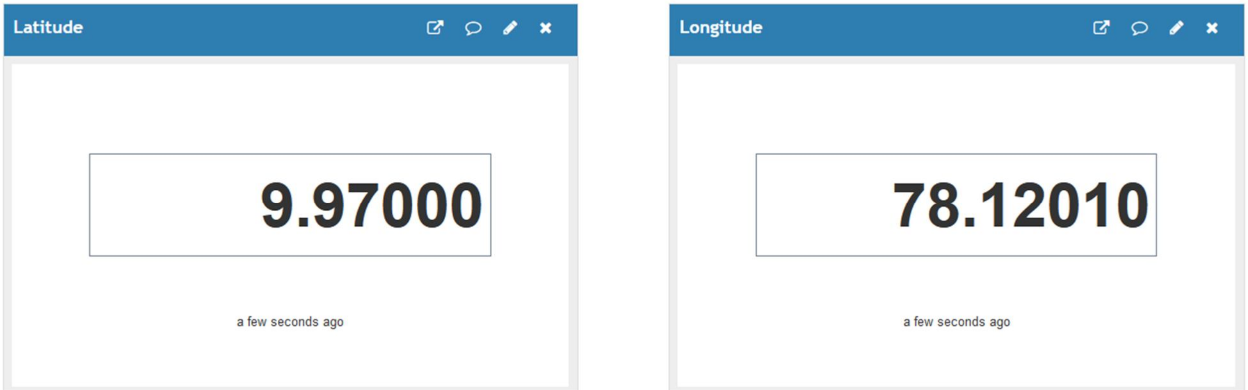

Fig. 7 Computed Latitude and Longitude coordinates using Trilateration Algorithm

D. App Development

We are making use of MIT app inventor for the purpose of developing Mobile Application. It is a visual environment created by Google and now maintained by the Massachusetts Institute of Technology. This platform provides us with all the tools required to create an Android/iOS based Mobile application. Here, all the interfaces are available for the creation of app. Moreover, coding is done in the background where the functionality of the application is explained

ARWAR is the mobile application that we have developed. It involves the Log In and Sign Up page. Once the user has signed up an account later on they can access the account using the Registered Email ID and Password in Log In page. The location coordinates which are computed at ThingSpeak is Transmitted to ArWar App, for which separate coding is done. The ArWar App is designed for the Guardian/ Caretaker to consistently track the patient . This app is shown in Fig. 8.

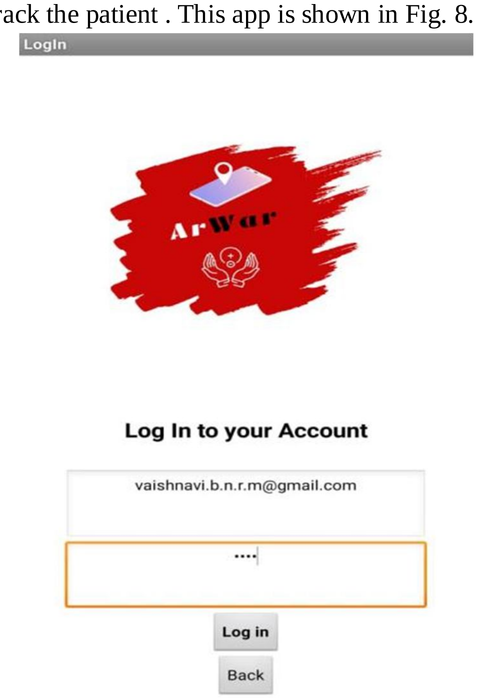

Fig. 8 Log In page of the App through which the user can access their Registered Account

For each of the user, after logging into their account, further the app takes them to next page of Location Trace, where the coordinates of the patient's location is displayed. In order to have a visual display of their position, the Location of Patient is displayed on Map.

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III.RESULTS AND DISCUSSIONS

The Anchor Nodes are deployed at some fixed coordinates and they consistently scan for the presence of Location Tag. Once the tag comes within the Reception range of the Anchor node, Bluetooth connection is established but before that, the MAC address of the Location Tag is checked. Checking of MAC address works as a part of Authenticating a patient among many patients.

For different positions of the Location Tag, we have obtained the corresponding distances from Anchor node and the final position Coordinate of the Tag is updated to the ArWar app which can be seen in Table I. For each position change, the map in ArWar app also gets updated.This updation can be observed in Fig. 9 and Fig. 10.

TABLE I
DIFFERENT POSITIONS OF TAG AND THE CORRESPONDING LOCATION COORDINATES

Position	Distance 1	Distance 2	Distance 3	Latitude	Longitude
I	10.00	3.98	3.16	9.970091818225811	78.12107195207646
II	7.08	6.78	10.56	9.970093027225811	78.12107074307646
III	4.47	3.55	15.85	9.97011302722581	78.12057183117646
IV	7.94	15.85	19.95	9.97011302722581	78.12157207297646
V	44.67	25.12	22.39	9.97011302722580	78.12157207207646

For each of the new position of Location Tag, coordinates are obtained with respect to the Fixed coordinates of the Anchor node.

The fixed coordinates of all the three Anchor nodes are as follows:

Anchor Node 1: Lat: 9.97019834, Lon:78.12057107
Anchor Node 2: Lat: 9.969807451, Lon:78.120648317
Anchor Node 3: Lat: 9.9697841677, Lon:78.120664922

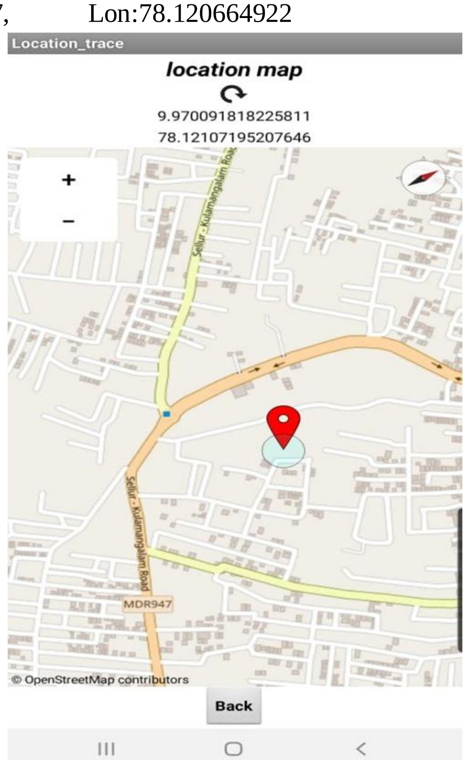

Fig. 9 Location marked on the Map when the Patient is at Position I

With the changing position of the patient, distance and the corresponding coordinates also gets updated to the ArWar App.

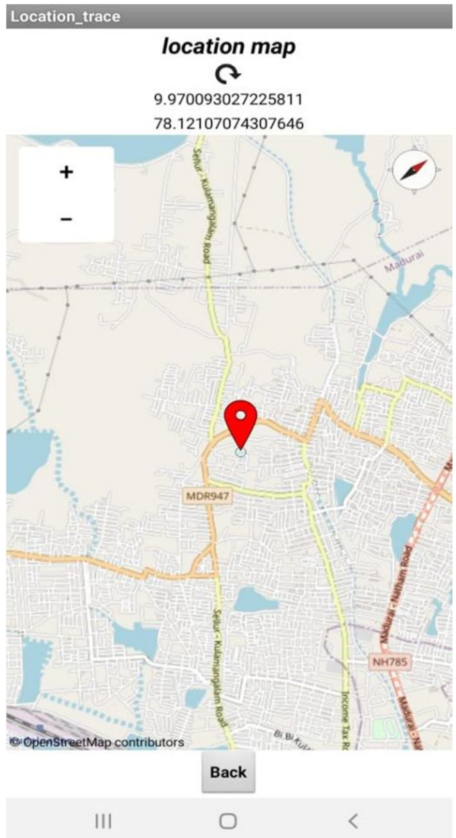

Fig. 10 Location marked on the Map when the Patient is at Position II

The position of Patient updates every 60 seconds and depending on the new position, the marker on Map also changes. This updation happens as soon as the distance values are updated in ThingSpeak. Therefore, using Bluetooth Low Power positioning, we have successfully traced the location of Alzheimer's patient and created an Application for the Guardian/Caretaker to track them.

IV. CONCLUSION

In this work, we have successfully traced the location of Alzheimer's patient using BLE based positioning. As an outcome of this work, we are able to achieve an accuracy level of 75 to 80 percent, and the range of each Anchor node is around 50 m. We can further increase the efficiency by increasing the number of Anchor nodes and by keeping the position of Anchor nodes approximately more similar to that of Equilateral Triangle. Using the MAC address , we can authenticate each connections. Therefore, we have achieved optimal accuracy at low cost.

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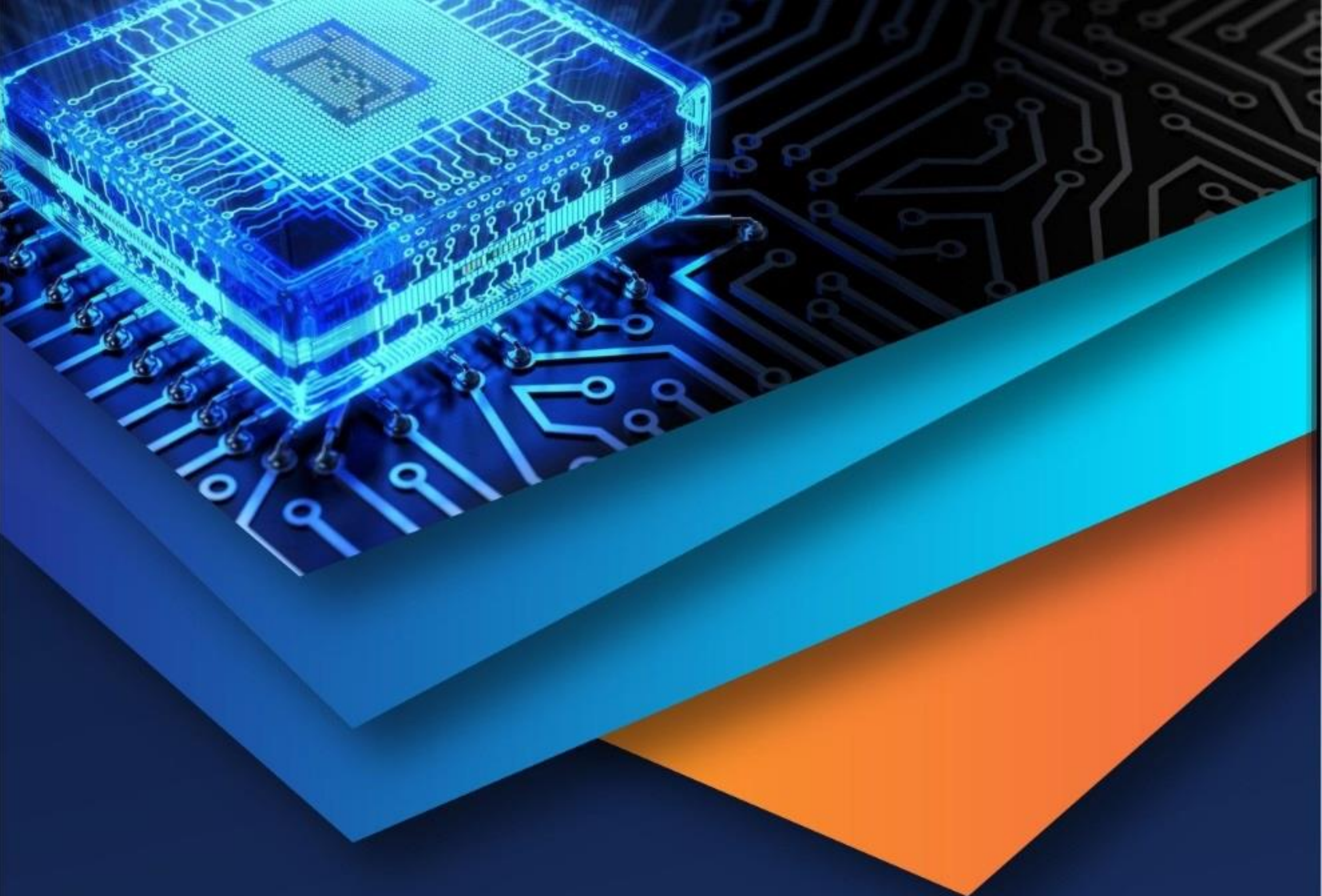

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