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A Review on Hybrid Channel Allocation Schemes for Cellular Mobile Telecommunication Systems

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Abstract: Mobile phones are now inexpensive, easy to use, and comfortable and capable of providing every latest feature we desire. Now a days, mobiles phones are equipped with number of applications to provide these features. Even the voice call in a mobile phone is just an application now. To get these features with good quality it is mandatory to have good connectivity with the backbone network. The tremendous growth of the wireless/mobile user population, coupled with the bandwidth requirements of multimedia applications, requires efficient allocation of the scarce radio spectrum to the wireless/mobile network. The mechanisms are based on the basic channel allocation schemes like Fixed Channel Allocation, Dynamic Channel Allocation, and a Hybrid or a Borrowing Channel Allocation. A Hybrid Channel Allocation scheme is the best mechanism to manage the channel cost effectively. Few basic hybrid channel allocation schemes are compared here to evaluate the network performance in terms of call processing and call dropping

Keywords: Channel Allocation, FCA, DCA, HCA, ILP

I. INTRODUCTION

Cellular network has become the backbone for today's communication using mobile devices. It is the underlying technology for mobile telephones, personal communications systems, wireless Internet and wireless Web applications, and much more. An architectural view of the entities of GSM cellular system is shown in Fig 1.Cells for communication in a classical cellular system are formed by dividing geographical area based on the service area provided by a base station (BS). Different base stations are usually connected each other through wired network (Backbone Network). Several base stations are controlled by a base station controller (BSS) and the heart of the cellular system is the Mobile Switching Centre (MSC) which manages the entire cellular system. There are many other information storage entities like Home Location Register (HLR), Visitor Location Register (VLR), Equipment Identity Register (EIR), and Authentication Centre (AUC) are associated with each MSC for the network and device management and billing purposes.

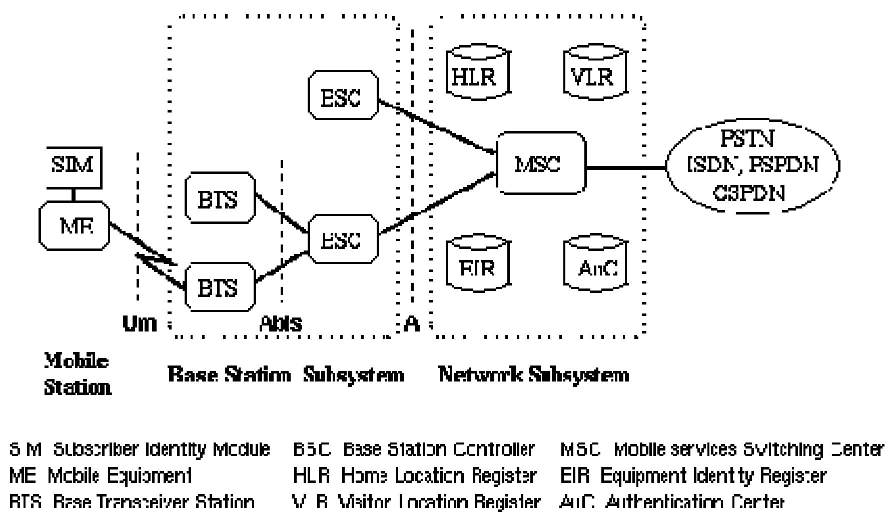

Fig. 1 Cellular System

In any wireless mobile system radio bandwidth is divided into channels [1]. Only a finite set of channels (radio spectrum) are available for one entire network. A channel or group of channels can be used to support a call or communication session. These channels are represented in terms of frequency channels (FDM), time slots (TDM), or modulation code (CDM). These channels are used for communication in a certain cell, and further, system allows the same channel to be reused in a number of different cells provided these cells are at least the minimum reusable distance away from the current cell. Always the co-channel cells (Cells that can use same channel) in a system should be minimum reusable distance (Dmin) away. A channel can be used simultaneously by a number of different cells only if the distance between each pair of cells using the channel is greater than or equal to Dmin. The minimum reuse distance depends both on the radius R of the cell and the minimum SIR (signal to interference ratio). One of the most basic level interference is caused by the proximity of other cells sharing the same channels. One of the objectives of channel assignment algorithms is to allocate channels in such a way that minimises the carrier-to-interference ratio (CIR) and hence increase the radio spectrum reuse efficiency. There are two major interference problems in wireless systems are adjacent-channel interference (ACI) and co-channel interference (CCI) [5]. Adjacent Channel Interference (ACI) is the interference due to signals which are adjacent in frequency to the desired allocated signal to a call. Adjacent-channel interference is basically due to equipment limitations such as frequency instability, receiver bandwidth, and imperfect filtering, which allow nearby frequencies to leak in to the pass-band and also results from imperfect receiver filters which may allow nearby frequency leakage. To minimize ACI, channels need to be allocated in such a way that the frequency separation between channels in a given cell is maximized. Although cellular equipment are designed for maximum interference performance of the system, a combination of factors, such as cellular architecture and random signal fluctuation, generally cause deterioration of the received signal, primarily due to interference of adjacent channels. To minimize ACI, proper filtering and channel assignments is essential. Co-Channel Interference (CCI) is the interference due to the same signals assigned to different cells. In a given coverage area there is several cells that could use the same set of frequencies. The interference between signals from this cell is called co-channel interference. When the size of each cell is approximately the same and the base stations transmit the same power, the co-channel interference ratio is independent of the transmitted power and depends on the radius of the cell (R) and the distance between centers of the nearest co-channel cells (D). By increasing the D/R ratio, the spatial separation between co-channel cells relative to the coverage distance of a cell is increased. Thus, interference is reduced from improved isolation of RF energy from the co-channel cell. The parameter Q, called the co-channel reuse ratio (the co-channel reduction factor), is related to the cluster size. For a hexagonal geometry;

$$Q = D/R = 3N;$$

where N be the number of co-channel interfering cells. If Q is high, then co-channel interference decreases. Also, Q may increase in the cases when R is small i.e. cell size is small and D is large i.e. signal strength is high.

II. CHANNEL ALLOCATION SCHEMES

Channel allocation schemes can be divided into a number of different categories depending on the comparison basis. On the manner by which co-channels are separated, they can be divided into fixed channel allocation (FCA), dynamic channel allocation (DCA), and hybrid channel allocation (HCA) [6].

In FCA schemes, the area is partitioned into a number of cells, and a fixed number of channels are assigned to each cell according to some reuse pattern, depending on the desired signal quality. FCA schemes are very simple, however, they do not adapt to changing traffic conditions and user distribution. In order to overcome these deficiencies of FCA schemes, DCA strategies have been introduced.

In DCA, all channels are placed in a pool and are assigned to new calls as needed such that the CIRmin criterion is satisfied. At the cost of higher complexity, DCA schemes provide flexibility and traffic adaptability. However, DCA strategies are less efficient than FCA under high load conditions. To overcome this drawback, HCA techniques were designed by combining FCA and DCA schemes.

Channel assignment schemes can be implemented in many different ways. For example, a channel can be assigned to a radio cell based on the coverage area of the radio cell and its adjacent cells such that the CIRmin is maintained with high probability in all radio cells. Channels could be also assigned by taking the local CIR measurements of the mobile's and base station's receiver into account. That is, instead of allocating a channel blindly to a cell based on worst-case conditions (such as letting co-channels be located at the closest boundary), a channel can be allocated to a mobile based on its local CIR measurements.

Channel assignment schemes can be implemented in centralized or distributed fashion. In the centralized schemes the channel is assigned by a central controller, whereas in distributed schemes a channel is selected either by the local base station of the cell from which the call is initiated or selected autonomously by the mobile. In a system with cell-based control, each base station keeps information about the current available channels in its vicinity. Here the channel availability information is updated by exchange of status information between base stations. Finally, in autonomously organized distributed schemes, the mobile chooses a channel

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based on its local CIR measurements without the involvement of a central call assignment entity. Obviously, this scheme has a much lower complexity at the cost of lower efficiency.

III.HYBRID CHANNEL ALLOCATION SCHEMES

In HCA, the total number of channels available for service is divided into fixed and dynamic sets. The fixed set contains a number of nominal channels that are assigned to cells as in the FCA schemes and, in all cases, are to be preferred for use in their respective cells. The second set of channels is shared by all users in the system to increase flexibility. When a call requires service from a cell and all of its nominal channels are busy, a channel from the dynamic set is assigned to the call. The channel assignment procedure from the dynamic set follows any of the DCA strategies. Three simple and basic hybrid channel allocation schemes are discussed in the following section.

Rana Ejaz Ahmed proposed a new hybrid channel allocation algorithm that sends a multi-level "hot-spot" notification to the central pool on each channel request that cannot be satisfied locally at the base station [2]. This notification will request more than one channel be assigned to the requesting cell, proportional to the current hot-spot level of the cell. When a call using such a "borrowed" channel terminates, the cell may retain the channel depending upon its current hotspot level.

The proposed hybrid channel allocation algorithm is described in two phases below: channel acquisition phase and channel release phase. The steps taken by mobile host, base station and MSC are clearly outlined.

Set L to 0 at the beginning to indicate that, at the present time, the channel request can be accommodated from the fixed (static) list assigned to the cell.

A. The following steps are Taken From Mobile host/ Base Station Sides during a Channel Acquisition Phase

1) When a mobile host wants to initiate a call, it sends the channel request on the control channel to its related base station.
2) If the base station has an available channel from its current fixed channel list (i.e., set F), it will assign the channel to the mobile host, and channel acquisition phase terminates.
3) If no channel from the fixed list for the cell is available, then the base station updates the value of L as follows:

$$L = L + 1;$$
$$L = \max(L, M);$$

4) The base station then sends a request to borrow a channel from the central pool located at MSC. It also includes the current value of L in the channel request; and the maximum value of L is a pre-defined number M.
5) When the base station successfully acquires a channel from the dynamic pool at MSC, it also adds the channel to its temporary pool (T).

B. The following Steps Are Taken From MSC Side During a Channel Acquisition Phase

1) The MSC, on receiving a channel request from the base station assigns up to L channels, if available, from the pool allocated for dynamic assignment to the base station (even the call generated by the mobile host needed only one channel) and the channel acquisition phase terminates. The main reason of assigning up to L channels, is a proactive measure that cell covered by the requesting base station is becoming a "hot-spot", and an assignment of several channel with one request will involve less overhead (in terms of control messages) as compared to several single channel requests.
2) If the MSC cannot assign even one channel, then the call will be blocked and the channel acquisition phase terminates.

If h is greater than the old value of level L (i.e., h > L), meaning that the congestion in the cell is getting worse, the channel ci is retained in the cell and is returned to the base station's temporary pool (T); the channel ci is not returned back to MSC. The cell can be in normal state or hot-spot rate based on the call arrival rate. The system load (or traffic) intensity is defined with respect to arrival rates and call service rate in a cell that can switch back and forth from "normal" to "hot-spot" state. The parameters considered in the simulation are the ratio r, the ratio of the number of dynamic channels to the total number of channels available in the system, which is changed from 0.1 to 0.8 and The value of M, the maximum "hot-spot" level supported by the system.

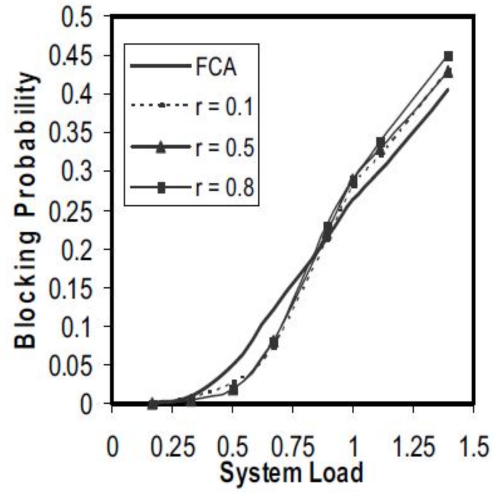

Fig 2 Simulation Results of proposed algorithm for various values of r, and their comparison with FCA.

The main advantage of the proposed protocol is that it can adapt to dynamic strategy at low traffic load to static strategy (FCA) at higher traffic load. If we increase the value of maximum “hot-spot” level (M), the system performance, in general improves, in both regions of low and high system loads. The main reason of improvement in result is due to the fact that at higher traffic load, the more channels are available and retained in a “hot spot” cell.

From the simulation results it is shown that the call blocking probability is consistent for different values of r and is close to the fixed channel allocation scheme.

In another work Dr. Helonde et al. proposed a new HCA strategy which uses hybrid channel assignment strategy based on fixed reuse distance concept [3]. It also works on two channel sets: Fixed channel (FC) and Dynamic channel (DC) set.

C. The steps of the Mechanism Are as Follow.

1) When a call arrives in a cell k at time t, it first searches for a channel in the FC set that can serve the call.
2) If no such channel is available from FC then it apply Integer Linear Program (ILP) formulation on the DC set to obtain a best assignment of channels in cell k.
3) Soft constraints for channel selection are satisfied by the objective function of the ILP formulation.
4) Hard constraints for channel selection are satisfied by the conditions to which objective function is subjected to.
5) This formulation (ILP) does not allow channel reassignment of existing calls.

In order to avoid radio frequency interference between channels, the selected channel must satisfy the following electromagnetic compatibility constraints, also referred to as hard constraints.

6) Co-channel constraint (CCC): The same channel cannot be assigned to two cells that are separated by a distance less than a specified minimum reuse distance, Dmin.
7) Co-site constraint (CSC): Channels in the same cell must be separated by a minimum amount g.
8) Adjacent channel constraint (ACC): Channels assigned to neighbouring cells must be separated by a minimum amount w.

In addition to the above hard constraints, which must be satisfied, there are a number of soft constraints. Such soft constraints can be further used to guide our channel assignment scheme to give optimized solution, Soft constraints are: First is packing condition, which tries to use the minimum number of channels every time a call arrives. This condition encourages the selection of channels already in use in other cells as long as the hard constraints are satisfied. Second is Resonance condition, which tries to assign the same channels to cells that belong to the same reuse scheme.

The method handles the channel allocation in a simple manner. It works well for less traffic situations and for fewer channels in dynamic set. But the call processed time increases with increase in traffic. Call process time at particular traffic increases with increase in number of channels in dynamic set (DC) due to increased computations. As the network traffic increases, blocking probability also increases.

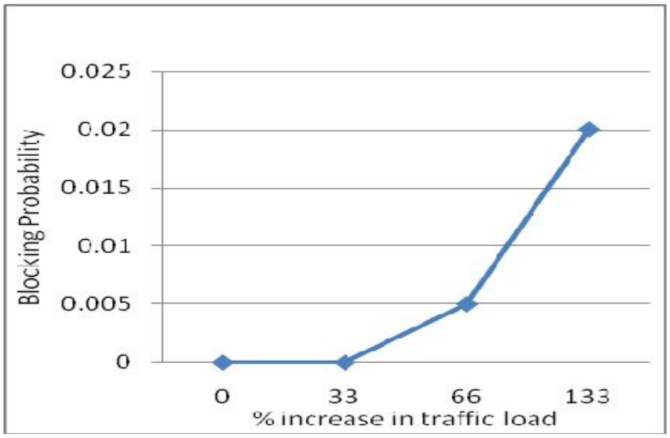

Fig 3 Blocking Probability of ILP with increase in traffic

Xin Wu et al. present two efficient integer linear program (ILP) formulations that optimally allocate a channel to an incoming call from a pool of available channels such that the "hard" and "soft" constraints are satisfied [4]. The first formulation does not allow channel reassignment of existing calls where allocates a free channel is allocated to a new call without any reassignment of existing channels, while the second formulation allows such reassignment.

Here it assumes each base station j in a cellular network has a computer that stores the current state of its cell. The state of the cell includes information about channels, mobiles, and ongoing calls in the cell. Each base station sends its state to other base stations through a wired network between their computers. Channel assignment is made by the computer of the concerned base station according to the channel usage information stored in the allocation matrix.

The allocation matrix is updated every time a channel is allocated or released in the network, and each base station receives a copy of the allocation matrix. The total number of channels is divided into two sets: FC and DC. If FC is empty, then the problem reduces to the classical DCA problem. When a call arrives in a cell k at time t, we first search for a channel in the FC set that can serve the call. If no such channel is available from FC then we apply our ILP formulations on the DC set to obtain a best assignment of channels in cell k. The solution contains channels to be assigned to all ongoing calls in the cell k (ongoing calls maybe re-assigned new channels to minimize blocking or dropping of calls, for ILP2) and the channel to be assigned to the new call.

ILP1 formulation is considers the hard constraints first and chooses the best from the many channels satisfying the constraints. It ensures that each call is allocated exactly one channel from the pool of available dynamic channels that are currently not in use in cell k. It ensures no neighbouring cells within minimum reuse distance (Dmin), uses the same channel. It also considers the co-site interval as well as adjacent channel interval while allocating the channel to a new call.

ILP2 formulation is similar to ILP1 except in the process of transferring an ongoing call to a new channel without call interruption. This can improve the quality of service in terms of lowering call blocking probability.

It can be seen that there is significant reduction in call blocking when the channel reassignment is allowed. Even the call blocking probability increases with the traffic load and the co-site constraint (*g*) and adjacent channel constraint (*w*).

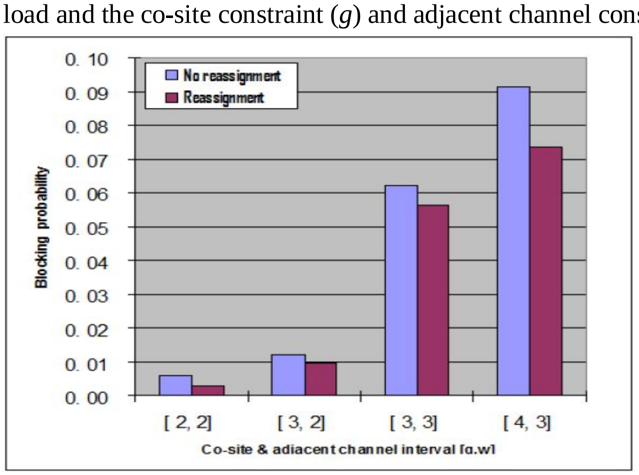

Fig 4 Blocking probabilities of no reassignment VS reassignment for ratio 21:49 with initial traffic load.

While comparing with the previous work of Dr. Helonde et al., this work allows channel reassignment and which can improve the quality of service in terms of lowering call blocking probability. Still the results indicate that although channel reassignment does reduce blocking probability, the amount of improvement seems to vary with traffic load. The hard and soft constraints are significant in the performance of every strategy while allocate the channels.

IV. CONCLUSIONS

Channel allocation is one of the major factors that decides the success of any wireless communication network. In cellular network, with the availability of limited radio spectrum, the channels must be reused properly in many cells to ensure maximum customers get the services and call block and call drops are avoided maximum. Among the three basic strategies of Fixed, Dynamic and Hybrid Channel Allocation schemes Hybrid Channel allocation scheme outperforms the other two in terms of better channel reusability and better interference management. In many HCA mechanisms the pool of channels are divided into fixed pool and dynamic pool of channels. In the later mechanism the strategy requires some additional computing in order to ensure the need of channel from dynamic pool as well as to avoid the call blocking in the network. The channel reuse can be optimized if we can reassign the allocated channels depending on the demand and other factors. Even if it add more call processing steps it provides better assignment strategy. It reduces the call dropping while new calls are initiated in a cell. So a resource exchange mechanism is well suited in a cellular network in order to have an efficient channel allocation as well as a channel reuse strategy with optimal interference management.

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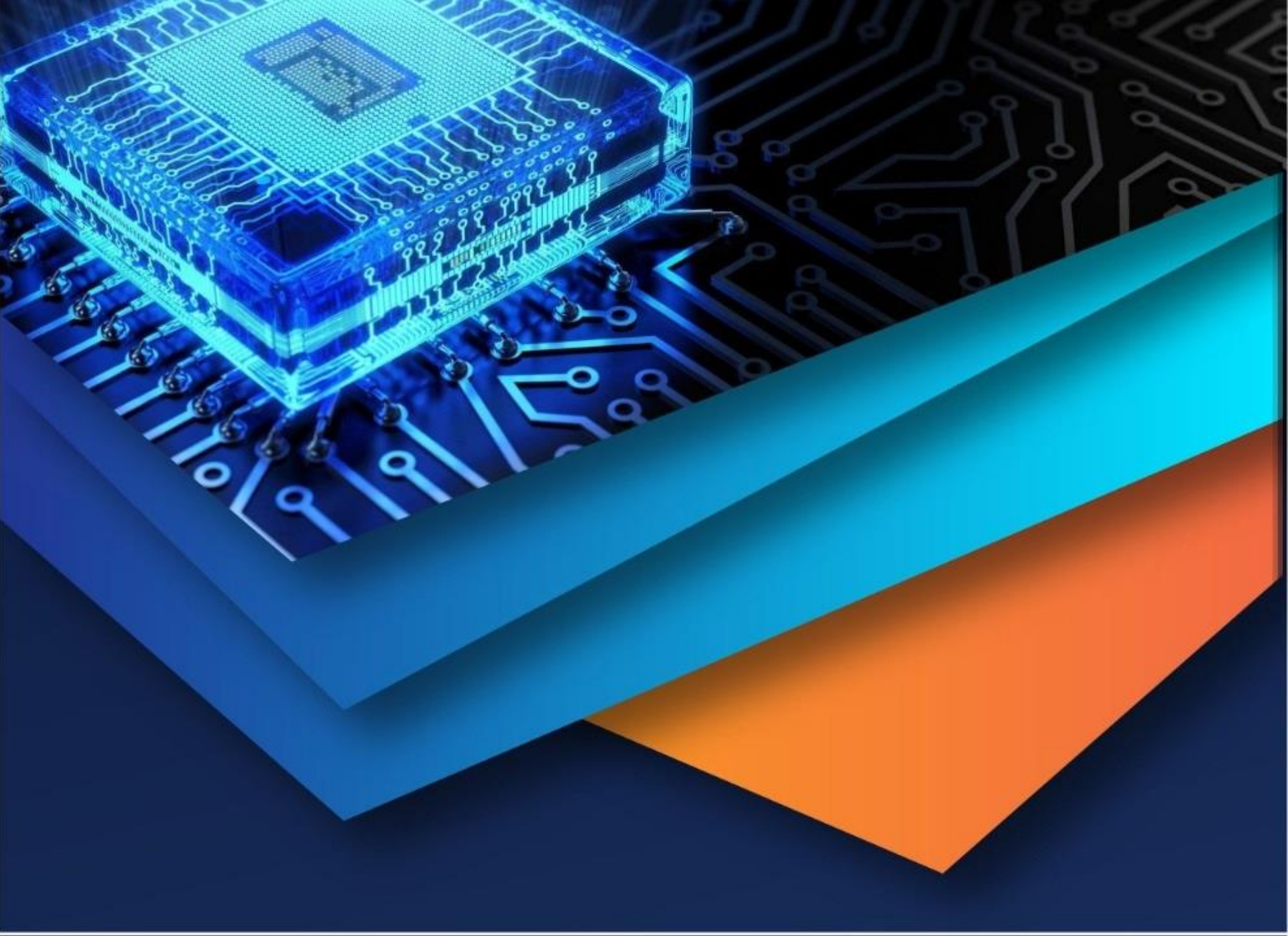

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