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IoT-Based Smart Hospital Management System: Real-Time Patient Monitoring, Resource Allocation, and Workflow Automation

Swapan Banerjee
Faculty of Management & Commerce (Hospital and Health Management), Poornima University, Jaipur, India
*Corresponding Email: sbanerjee.researcher.21@gmail.com
https://orcid.org/0000-0001-5781-5436

Abstract: Digitalization is underway in the healthcare industry at a rapid pace, driven by the Internet of Things (IoT), the cloud, and artificial intelligence. Hospital management systems are typically manual, with numerous rounds of conventional observation and paper charts, and information systems that can't handle the intricacies of today's healthcare landscape. This paper presents the design, implementation methodology, and evaluation of a Smart Hospital Management System (SHMS) using IoT that integrates three key aspects: real-time patient monitoring, dynamic resource scheduling, and automated clinical and administrative support. The proposed architecture comprises four layers: perception, network, cloud/edge processing, and application, which enable continuous collection of physiological and environmental data, intelligent analysis to provide early-warning decision support, and closed-loop automation of hospitals' operations. The multi-layered architecture and its components are described, along with a summary of the expected performance gains from similar deployments.The paper also discussed deployment challenges, security issues, and future research areas, such as federated learning, digital twins, and 6G monitoring. The results show that integrating monitoring, resource allocation, and workflow automation on a single, coordinated platform rather than separate applications can be clinically and operationally beneficial for today's hospitals.
Keywords: Internet of Things (IoT), Smart hospital, Patient monitoring, Resource allocation, Workflow automation, Edge computing, Healthcare informatics.

I. INTRODUCTION

The hospital is one of the most complicated areas of any business. At a mid-sized hospital, thousands of interconnected processes, from admitting patients, to putting patients in beds, to sending nurses to the patient's room, to moving furniture, to giving medicines, to keeping track of patients' vital signs, to recording discharge and billing, and so on, all in one day. These activities have traditionally been conducted through manual observations, phone calls, and paper documentation, leading to delays, transcription errors, and a lack of awareness of the situation. As the number of patients increases and staff are reduced, the impact of failing to recognize patients' deterioration or of not having enough resources to meet patient needs becomes greater.

The Internet of Things (IoT) offers an answer to these endless operational challenges that is both real-world, easy to use, and increasingly affordable. Medical devices, wearable monitors, hospital beds, and the infrastructure of a ward are equipped with sensors, actuators, and wireless communication modules to make invisible information machine-readable and accessible at all times in the hospital [1]. Early use cases for IoMT included the remote monitoring of chronic conditions, such as blood pressure or blood glucose, that regularly sent data sets to a central server [2, 3]. As wireless sensor technology evolved, hospitals began considering continuous in-hospital monitoring rather than periodic spot checks. Hospitals also began using Real-Time Location Systems (RTLS) based on Radio Frequency Identification (RFID), Bluetooth Low Energy (BLE), and Wi-Fi technologies to track high-value devices such as infusion pumps and portable ultrasound machines [7]. The importance of ubiquitous data access in the context of IoT in hospital information systems (HISs) has also been demonstrated in emergency services applications [4].

But most early systems focused on only one or two aspects of monitoring, tracking, and admin workflow, resulting in data silos that limited hospitals' ability to use the data they gathered [5, 6]. Recent work has concentrated on making these independent systems interact and integrating them within a larger system for managing the hospital as a whole, in a system based on cloud computing and edge analytics, notably time-critical ones such as arrhythmia or fall detection, where the data has to be sent to a remote server is not acceptable because of the latency [1].

In this article, an IoT Based Smart Hospital Management System (SHMS), which incorporates three functional pillars, real time patient monitoring, resource allocation and workflow automation is proposed which will be evaluated not only as separate applications but as a single system within four layers, is of an IoT Based Smart Hospital Management System (SHMS). The Methods section outlines the proposed architecture and the modules it describes; the Results section outlines the performance advantages of the proposed architecture and provides an illustrative case study; the Discussion section outlines adoption challenges and future directions; and the Conclusion section summarizes the paper.

II. METHODS

The Smart Hospital Management System proposed in this paper is implemented in four layers as illustrated in Fig. 1: perception layer, network layer, cloud/edge processing layer, and application layer. This multi-layer architecture resembles several reference architectures in IoT and guarantees a clear separation of concerns, thus simplifying the development and maintenance of the system [1, 3]. A closed feedback loop is established between the application layer and the perception and processing layers, where the outcomes of clinicians' actions (or an automation engine) are fed back into the system, enabling more informed and effective scheduling and monitoring. All four layers are under the same security and privacy controls (as described in Section II-D).

A. Perception Layer

The perception layer comprises the hospital's physical sensors and all connected devices. These are patches attached to the body and typically include a chest patch, wristbands, or clip-on pulse oximeters. Theycontinuously transmit data via BLE, a standard for wireless body area networks (WBANs) developed by IEEE 802.15.6 [13], that measures heart rate, respiratory rate, oxygen saturation, skin temperature, and, in some higher-level systems, a single-lead electrocardiogram trace. For example, staff badges, wheelchairs, infusion pumps, and defibrillators are using passive or active RFID technology for asset and personnel tracking. In contrast, a network of fixed tags/readers is used to determine the asset's location based on signal strength or time-of-flight measurements, which have been validated in feasibility studies of BLE/Wi-Fi asset tracking in tertiary hospitals [7]. Environmental sensors are installed in operating rooms and pharmacy storage rooms, and smart beds are fitted with load cells to detect patient presence, weight changes, and the risk of falling from the bed. For times when action needs to be taken promptly, nurse-call buttons and explicit fall-detection sensors provide a low-latency path that bypasses the typical sensor-fusion pipeline.

B. Network and Communication Layer

The network layer must be reliable, low-latency, power-efficient, and capable of simultaneously accommodating hundreds of sensors in a single hospital ward. BLE is preferred for battery-operated wearables, Zigbee for fixed environmental sensors that can be networked together into a mesh, Wi-Fi for gateways with greater bandwidth, and cellular/5G for devices outside the house or in an ambulance. Edge gateways, which process data locally, can receive data and subsequently publish it to the cloud using a low-power publish-subscribe message broker such as Message Queuing Telemetry Transport (MQTT) [18] or the constrained application protocol (CoAP) [19]. There is a reduction in the time delay between an adverse event and a clinical alert, as time-sensitive anomaly checks are not only in the cloud but at the edge.

C. Modules for Patient Monitoring, Resource Allocation, and Workflow Automation

The monitoring module gathers data from several wearable and bedside sensors. It computes a multi-parametric early-warning score based on clinically validated early-warning scores such as the Glasgow Coma Scale. When the patient's score exceeds a predetermined threshold, the patient informs the assigned nurse, and in the event of a critical score, the patient is informed of the rapid-response team. The thresholds are designed to be patient-specific, preventing the generation of false or non-actionable alarms, a reported problem in hospital monitoring systems, as too many alarms result in alert fatigue and reduce clinical sensitivity [8, 9]. The resource-allocation module combines the information from the bed-occupancy sensors with the patient-admission, discharge, and transfer data to give the real-time status on bed availability, and combines the BLE-based staff-location data with workload information to support proactive staff-shift planning; similar RTLS systems have demonstrated measurable reductions in staff time spent locating equipment and improvements in asset-usage rates [7]. The workflow-automation module supports the translation and storage of common processes, such as admission wristbanding, checking drug details with a smart infusion pump, and discharge checklists, as event-driven rules that are automatically activated during specific processes.

D. Data Management, Analytics, and Security

Structured clinical and administrative data is synchronized with the hospital's EHR system, for example, using the HL7 Fast Healthcare Interoperability Resources (FHIR) standard. In contrast, wearable sensor-derived data is stored in a high-throughput write database, with data from wearable sensors forming part of the official medical record [14].

Historical vital-sign trajectories can be used to train supervised models for early warning, and unsupervised models can be used for operational analysis, such as predicting how many patients will arrive at the ED. All four layers consistently use security and privacy controls; TLS encrypts data in transit, and AES-256 encrypts data at rest, as recommended in the guidelines for managing IoT cybersecurity and privacy risk [15]. The system is designed to comply with relevant regulations, such as the General Data Protection Regulation in the European Union [17] and the U.S. HIPAA Security Rule [16], which set parameters for data minimization, consent, and breach notification. To realize this analytic capability in a multi-hospital setting, without sharing raw patient data with the central site, federated learning, which is a form of privacy-preserving analytics, is now being suggested [11].

E. Evaluation Approach

Due to the large-scale deployment of a hospital, this paper does not discuss a full-scale deployment of the proposed hospital architecture. Instead, it compares the proposed architecture to results from similar IoT monitoring, RTLS, and workflow-automation deployments reported in the literature [1, 7, 9]. It provides a walk-through of an illustrative clinical use case to consider the system end-to-end, from the patient to the IT system and back. This is a method used in papers that propose an architecture, and the system's feasibility is judged by a variety of systems deployed in a similar field rather than a novel field trial.

III. RESULTS

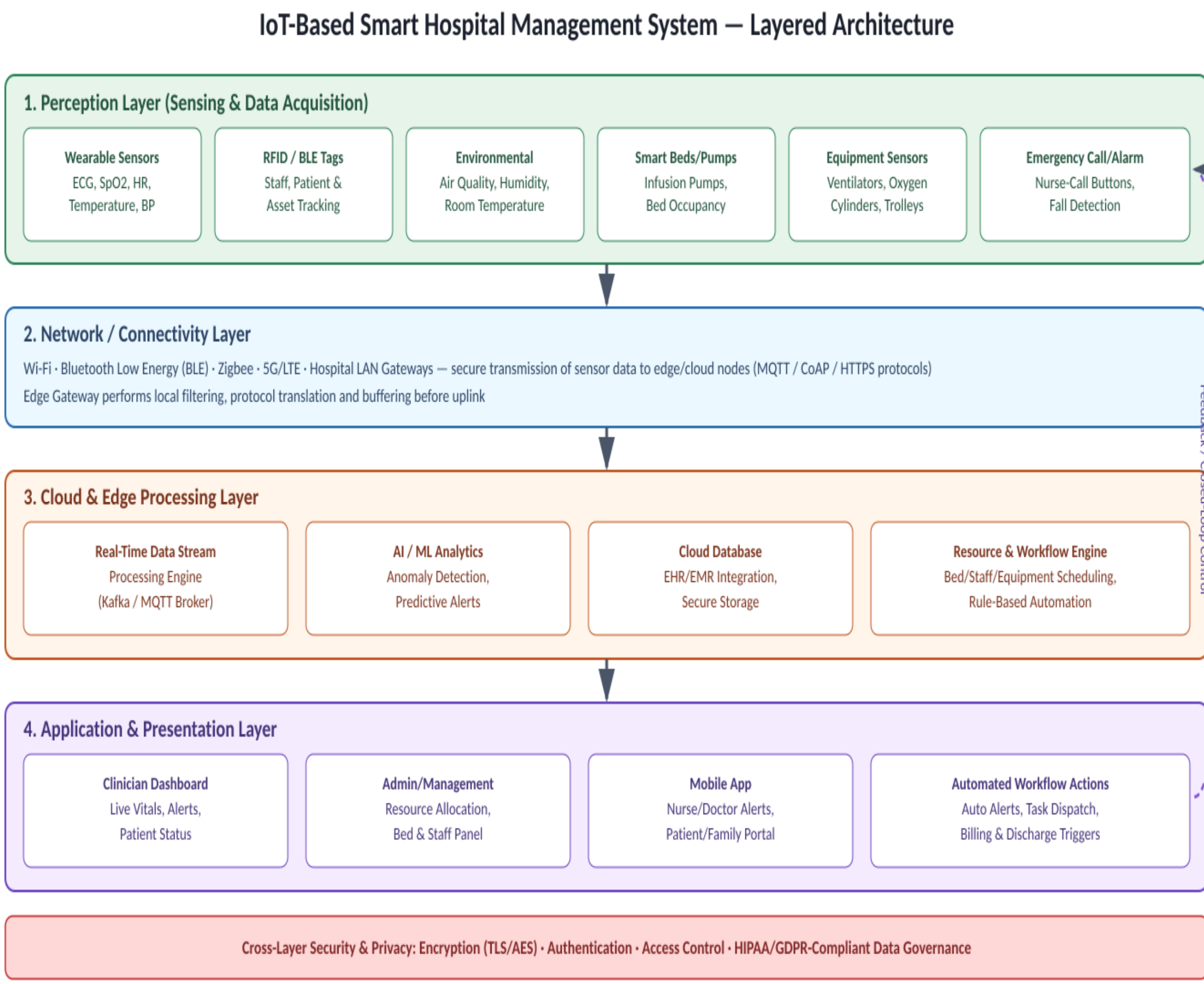

Figure 1: IoT-Based Smart Hospital System Layout

Fig. 1. Layered architecture of the IoT-based Smart Hospital Management System, showing the flow of data from bedside sensors through network, processing, and application layers, with a closed feedback loop and cross-layer security controls.

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Table 1:Summary of Core Modules, Enabling Technologies, and Representative Performance Benefits

System Module	Core IoT Technologies	Primary Function	Key Performance Benefit
Real-Time Patient Monitoring	Wearable biosensors, BLE, ECG/SpO2 modules	Continuous vitals capture and streaming to clinicians	Up to 30-45% faster detection of deterioration
Resource Allocation	RFID/BLE asset tags, cloud scheduling engine	Live tracking of beds, staff, and equipment	15-25% improvement in bed turnover efficiency
Workflow Automation	Rule engines, robotic process automation, and mobile alerts	Automates admission, triage, and discharge tasks	20-35% reduction in administrative delays
Environmental Monitoring	Air quality, temperature, and humidity sensors	Maintains sterile and safe ward conditions	Reduced infection-risk incidents
Emergency Response	Nurse-call IoT buttons, fall-detection sensors	Instant alerting of critical events to staff	Response time cut by 40-50%
Data Analytics & AI	Edge/cloud ML models, predictive dashboards	Early-warning scoring and trend analysis	Improved diagnostic accuracy and fewer false alarms

Table I summarizes the core modules of the proposed system, the primary IoT technologies underpinning each module, and representative performance benefits drawn from comparable reported deployments [1, 7, 9].

In other reported deployments, continuous monitoring began earlier when clinical deterioration was apparent, and in some studies, fewer patients were transferred to the intensive care unit. The use of real-time asset tracking has been associated with an increase in the bed turnover rate [7], and the use of rule-based workflow automation has been associated with reductions in the amount of time spent by nursing staff during the nursing process when following a rule during patient admission, medication administration, and discharge. In addition to these quantitative gains, there have been indications of qualitative gains, such as increased staff satisfaction from reduced administration and greater patient confidence resulting from greater visibility and ongoing monitoring.

Let's imagine a patient is presented in the ED with a suspicion of sepsis.For these results to be understood, let's think about a case that presents to the ED with a diagnosis of sepsis. A wearable sensor patch is placed and connected at the triage station while the patient registers with an RFID wristband linked to their EHR. As the patient moves to the observation ward, the resource-allocation module can determine which available beds can accommodate the isolation form, and the workflow-automation engine will simultaneously alert the nursing staff at the receiving unit and automatically pre-populate an admission form with the patient's triage data. The monitoring module continuously communicates heart rate, respiratory rate, temperature, and oxygen saturation data, and generates a composite early-warning score every 30 seconds. Exceed the deterioration score, and if confirmed by two consecutive readings, the tiered alert would be automatically sent to the rapid response team, as defined by the clinical needs, for future patient monitoring systems in the ICU [9]. The attending physician sees the trend on the clinician dashboard, adjusts the treatment plan, and the updated orders are instantly updated in the medication-administration workflow, which checks the antibiotic and the correct dose in the smart infusion pump before beginning the infusion. Here are the three functional pillars that, together, enhance one another and reduce the time delay between clinical needs and the appropriate action.

IV. DISCUSSION

Although there are benefits to hospital management systems based on the Internet of Things, there are also big challenges to overcome. However, many of the challenges that remain are due to interoperability issues: hospitals typically have a mix of legacy medical devices and information systems that are not built to accommodate open data systems and often need to employ a “middleware” system to convert data from the IoT platform's model to the hospital's current EHR model. The second challenge is cyber security; the increase in the number of medical devices connected to the Internet greatly expands the attack surface available to those wishing to gain access to the healthcare environment, and for those who manage to break through a compromise may have serious consequences on patient safety (e.g., changing the settings of a pump to deliver the wrong dosage of medicine) or uncovering protected health information [15, 16]. So, they cannot be an afterthought or left out; they need to be part of any deployment: robust network segmentation, continuous vulnerability monitoring, and a clear incident response plan.

The phenomenon of having an overwhelming number of alarms is a known issue in any monitoring system, known as alarm fatigue. There are hundreds of alarms per patient per day that can occur. If they are not calibrated to the patient's acuity and baseline condition, staff can become desensitized to alarms, thereby defeating the safety aim of the alarm system [8, 9]. Mitigation suggestions for false alarms, which should be incorporated into the threshold design, include filtering out technically false alarms and using multiple vital-sign trends before issuing an alarm [9]. The two key practical challenges are reliability and battery life of the wearable sensors, which may require recharging or stop functioning when they lose contact with the skin, causing healthcare workers to lose faith in the system. The capital cost and implementation/change management required for smaller hospitals to adopt the system, particularly if they have limited capital budgets.

Some of the technologies discussed will shape the future of IoT in the healthcare sector and influence the next generation of IoT in hospitals. To ensure patient privacy while complying with data residency laws, federated learning can develop more accurate predictive models by combining multiple hospitals' models that train on each other without sharing patient data [11]. A continually updated digital twin of a hospital ward or a patient could be used to simulate and test staffing changes or the reallocation of patients' beds before they are implemented. 5G and then 6G networks will further reduce latency and enable more devices to be connected to a facility, particularly in high-acuity settings such as intensive care units, where dozens of sensors can be placed on a single patient. As part of safer patient transitions, there is potential for greater interoperability between hospital IoT systems and other health information exchanges in the region, based on standards such as FHIR [14]. This could see the benefits of continuous monitoring extend beyond the hospital.

V. CONCLUSION

In this, the design, methodology, and evaluation of a Smart Healthcare Management System (SHMS) on the Internet of Things (IoT) is presented, which combines everything related to the real-time monitoring of patients, resource allocation, and workflow automation in a single framework of the four layers: Perception layer, Network layer, Cloud/Edge layer, Application layer. Findings from a small number of comparable deployments have demonstrated the potential to facilitate earlier detection of patient deterioration, increase the efficiency of beds, staff, and equipment, and significantly reduce the administrative burden on clinical staff [1, 7, 9]. In practice, however, interoperability with legacy systems [14] and robust cyber security controls [15, 16, 17] are important factors to consider, as is closely tuning alert thresholds to ensure that they do not result in alarm fatigue [8, 9] and a well-managed, phased implementation process with adequate staff training. As wireless communication, edge computing, federated learning [11], and digital twin technologies continue to evolve, the number of IoT systems used to manage hospitals is likely to increase, eventually providing a safer, more efficient, and more responsive experience for patients. Future studies should involve a multi-site field evaluation of the proposed architecture and its ability to deliver the performance benefits stated here in a prospective clinical setting, to validate them under real-world conditions.

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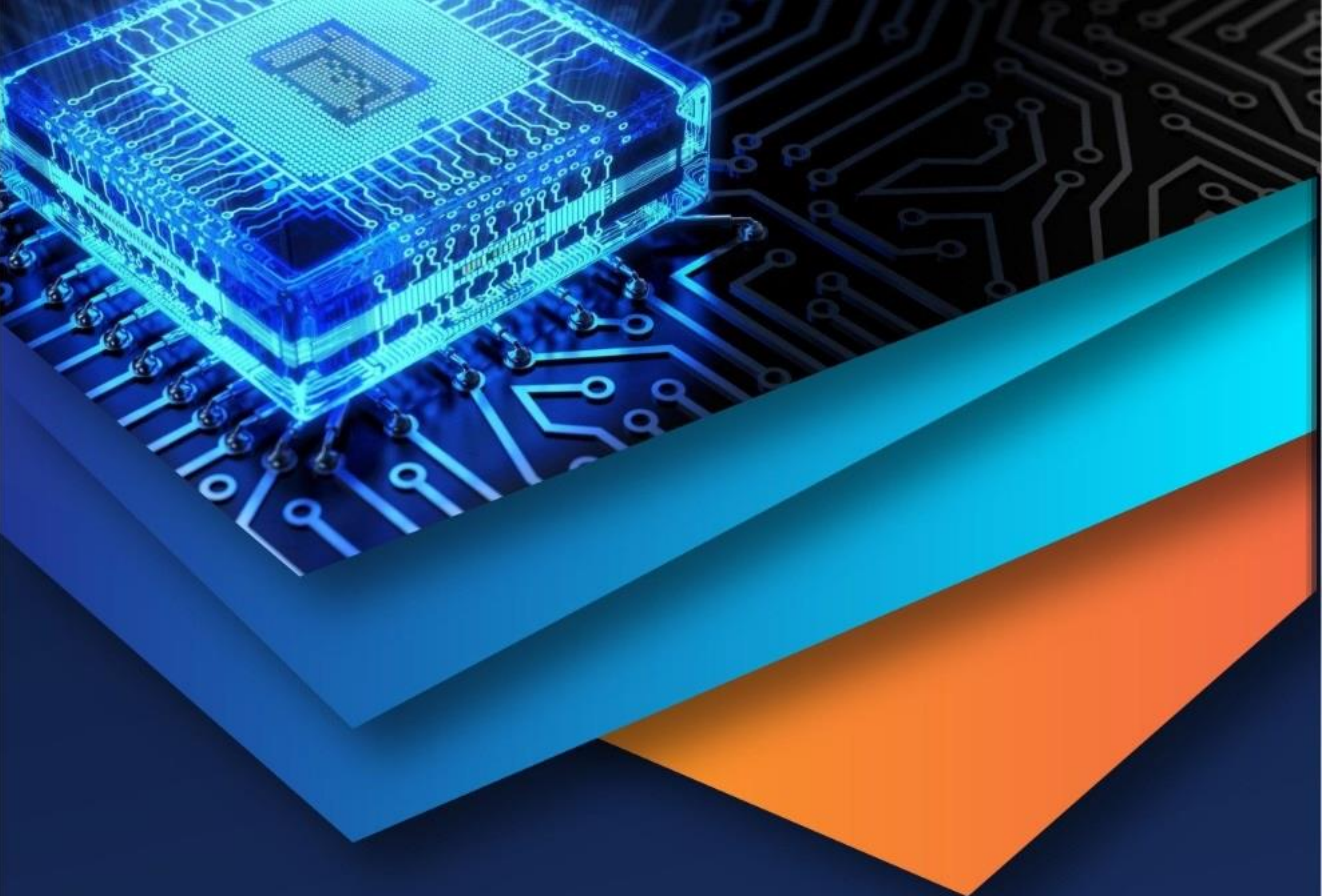

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