iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 14 **Issue:** I **Month of publication:** January 2026

DOI: https://doi.org/10.22214/ijraset.2026.77013

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International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.538
Volume 14 Issue I Jan 2026- Available at www.ijraset.com

Cloud-Orchestrated Automated Parking Platform with Real-Time User Notification and Resource Optimization

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Abstract: ***The current parking infrastructures are under unprecedented strain due to the rapid growth of urban mobility. Due to their heavy reliance on human intervention and lack of real-time monitoring, conventional parking techniques cause traffic jams, inefficient use of available space, and user annoyance. In order to facilitate smooth, real-time parking operations, this paper proposes a Cloud-Based Automated Smart Parking Management System that makes use of cloud orchestration and Automatic Number Plate Recognition (ANPR). In order to automatically manage vehicle identification and parking length, the suggested system takes pictures of license plates at entry and exit points, processes them using an ANPR pipeline, and logs timestamps. Users receive real-time messages about entry confirmation, slot assignment, and leave events from a cloud-based backend that also stores consolidated parking data and dynamically assigns parking spaces based on availability. The solution improves operating efficiency and scalability by doing away with physical tokens and manual oversight. The cloud-centric architecture guarantees dependable data processing, effective use of resources, and the capacity to manage several parking events at once. The suggested system, which offers enhanced user experience, shorter parking search times, and optimal parking space usage, is appropriate for implementation in large-scale settings including retail centers, corporate campuses, and smart city infrastructures***

Keywords: Smart Parking System, Automatic Number Plate Recognition, Cloud Computing, Real-Time Notification, Parking Slot Allocation, Resource Optimization

I. INTRODUCTION

The need for effective parking management systems has grown dramatically due to the increasing rate of urbanization and the ongoing rise in car ownership. Traditional parking systems in urban areas frequently rely on physical tokens, manual supervision, or static parking distribution techniques, which result in traffic jams, longer wait times, and ineffective use of available parking spots. These issues have an impact on user convenience as well as fuel waste and traffic congestion in areas with high population densities. By combining automation, sophisticated data processing, and sensing technologies, smart parking systems have become a viable solution to these problems in recent years. However, a lot of current solutions are constrained by restricted real-time user engagement, scalability issues, and localized processing. In large-scale settings like shopping centers, corporate campuses, and smart city infrastructures, systems that rely on manual verification or on-premise servers find it difficult to manage rising traffic volumes and concurrent parking occurrences.

Automatic Number Plate Recognition (ANPR) has drawn interest as a successful method of identifying vehicles without the need for physical tags or human participation. ANPR facilitates accurate vehicle tracking and smooth access management by recording and processing vehicle number plates at entry/exit points. ANPR-based systems can gain from centralized data management, high availability, and dynamic resource allocation when paired with cloud computing. Additionally, cloud platforms provide fault tolerance, scalability, and real-time processing, which makes them appropriate for effectively managing massive amounts of parking data.

In order to automate parking operations completely, this paper suggests a Cloud-Based Automated Smart Parking Management System that combines ANPR with a cloud-orchestrated backend. The suggested system records parking duration automatically, collects car number plate data, assigns parking spaces dynamically depending on current availability, and notifies users in real time about entry, slot assignment, and exit events. The system seeks to maximize parking space use, improve overall user experience, and increase operational efficiency by doing away with manual intervention and utilizing cloud infrastructure.

II. RELATED WORK

Rapid urbanization and the exponential growth of private vehicles have intensified parking management challenges in smart cities. Consequently, significant research efforts have focused on developing intelligent parking systems by integrating Internet of Things (IoT), cloud computing, and automated vehicle identification technologies. Early smart parking solutions primarily relied on IoT-based sensing and cloud platforms to monitor parking availability. In order to increase real-time monitoring and customer convenience, Ravishankar presented an IoT-enabled parking system that was backed by cloud services and a mobile application. In a similar vein, Pham et al. presented a cloud-based smart parking system that emphasizes scalability and less complicated infrastructure by utilizing IoT sensors for data collection and centralized cloud processing. By creating a cloud-based middleware architecture for IoT-driven parking systems, Ji et al. expanded on this strategy by emphasizing interoperability and effective data management for smart city settings. Determining architectural frameworks and reference models for smart parking systems has been the subject of numerous studies. A thorough reference design that addressed issues with system modularity, service orchestration, and integration was described by Ozkaya and Turunc. Barriga et al.'s systematic review classified smart parking systems from a technological standpoint, encompassing data analytics methods, communication protocols, and sensing mechanisms. A survey of IoT-based parking systems was also presented by Kaur and Malhotra, who noted important constraints such implementation cost, sensor dependability, and real-time responsiveness. Researchers have looked into alternatives to conventional sensors in an effort to improve vehicle recognition and automation. Yahya et al. looked into RFID-based methods and combined RFID with cloud infrastructure to manage parking spots. RFID systems are efficient, but their general adoption is limited by the need for vehicle-side hardware. In studies like Chaurah, which used inexpensive embedded platforms for local parking management and monitoring, Raspberry Pi-based edge systems were suggested. In order to get over hardware dependency problems, more recent research has focused on vision-based methods that use Automatic Number Plate Recognition (ANPR). An ANPR-enabled Internet of Things parking system that automates car entry and exit while keeping a centralized database was created by Mahesh Kumar and P. U. A thorough analysis of ANPR methods was given by Patel et al., who noted difficulties with illumination variance, occlusion, and recognition accuracy. In order to achieve completely automated smart parking management and demonstrate increased operational efficiency, Allah Ditta et al. advanced this direction by fusing ANPR with IoT. Intelligent control, autonomous support, and real-time monitoring have all been included in new systems. A real-time parking control and monitoring framework with an emphasis on responsiveness and data accuracy was given in MDPI Sensors publications. The potential of robotics in smart parking ecosystems was demonstrated by Hamad et al.'s introduction of an autonomous mobile robot for parking assistance. Furthermore, the trend toward fully integrated, user-centric parking platforms is highlighted by new IoT-driven systems with automated entry-exit mechanisms and reservation applications. Despite these developments, current solutions frequently have drawbacks like expensive infrastructure, poor scalability, reliance on specialist technology, or disjointed architectures. These shortcomings serve as the driving force behind this proposed system, which combines cloud-centric IoT architecture with ANPR-based vehicle recognition to provide a scalable, affordable, and automated smart parking solution appropriate for actual smart city deployments.

III. SYSTEM OVERVIEW

The proposed Cloud-Based Automated Smart Parking Management System is intended to offer a comprehensive automated solution for car parking operations, by combining Automatic Number Plate Recognition (ANPR) with cloud-based data processing and real-time user notification. Through centralized cloud orchestration, the system seeks to minimize human intervention, shorten parking search times, and maximize the use of available parking spaces. In order to uniquely identify vehicles, the system primarily works by taking pictures of license plates at specified entry and exit locations and processing them through an ANPR pipeline. The retrieved vehicle data is sent to a cloud-based backend for central management of parking-related data, including vehicle entry time, parking slot allocation, and exit time. The system dynamically assigns parking spaces and continuously changes the occupancy status of those spaces based on real-time parking availability. Through a real-time notification system, users are informed of pertinent parking events, such as successful entry, spot assignment, and exit confirmation. The suggested system's design is made up of a number of linked parts, each of which is in charge of a certain task related to the parking workflow. The main data collection devices are entry and exit ANPR cameras, which take pictures of cars for identification. As the primary processing and orchestration layer, the cloud backend manages business logic execution, ANPR data validation, and system component coordination. Accurate tracking and reporting of parking operations are made possible by a centralized database that holds car details, parking spot information, and timestamped transaction logs.

A notification module is coupled with the cloud backend to provide real-time parking event alerts in order to improve user interactivity and operational transparency. Authorized staff can also manage parking spaces, keep an eye on parking status, and examine system activity via the admin interface. The suggested system can be deployed in large-scale parking environments including shopping malls, corporate campuses, and smart city applications since it employs cloud infrastructure to assure scalability, stability, and effective handling of multiple concurrent parking events.

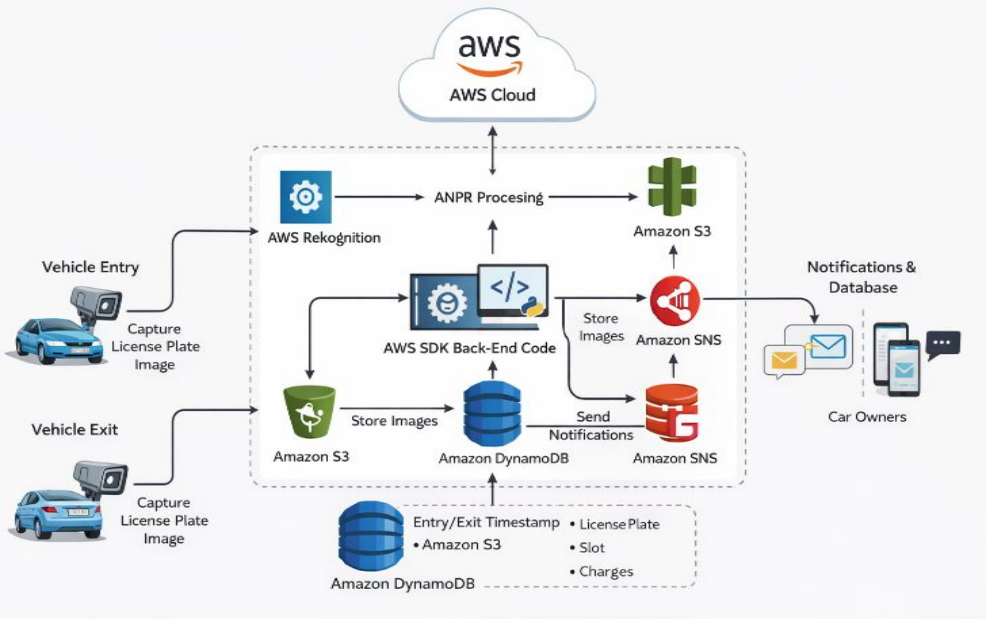

Fig i) System Architecture of Cloud-based Automated Parking System

IV. SYSTEM ARCHITECTURE

To guarantee modularity, scalability, and effective orchestration of parking operations, the suggested cloud-based automated smart parking management system employs a layered architectural architecture. Because each layer is in charge of a distinct task within the overall system workflow, deployment and maintenance are made easier and issues may be clearly separated. Additionally, the seamless integration of sensing, processing, storage, and user interaction components is made possible by the layered design. Fig. (above) shows the overall system architecture of the approach.

A. Sensing Layer

The sensing layer serves as the data acquisition layer of the system and is responsible for capturing vehicle number plate images at the parking facility's entry and exit points. To guarantee that incoming and departing cars can be clearly seen, cameras or webcams are placed in key locations. Vehicle movement initiates image capture, which enables the system to gather pertinent visual information without constant recording. By supplying the raw input data needed for further processing steps, this layer serves as the system's basis.

B. Edge Processing Layer

Prior to data being sent to the cloud, the edge processing layer handles images. Basic preparation operations like picture capture, formatting, and temporary buffering are carried out by this layer. The system guarantees dependable image transmission to the cloud storage layer and minimizes needless network overhead by managing these tasks locally. Additionally, faster response times during periods of high traffic are made possible by edge processing.

C. Cloud Storage Layer

For recorded car photos, the cloud storage layer offers scalable, centralized storage. The secure storage of images obtained from the edge layer in a cloud repository allows for long-term access for identification, auditing, and further analysis. In addition to facilitating high-volume image uploads from numerous entrance and exit points at once, centralized storage guarantees data availability and fault tolerance.

D. AI Recognition Layer

Vehicle number plate information is extracted from the stored photos by the AI recognition layer. This layer finds and identifies alphanumeric characters on car plates using Automatic Number Plate Recognition (ANPR) algorithms. For validation and decision-making, the application logic layer receives the retrieved plate number. The architecture enables autonomous ANPR module optimization and upgrade by isolating recognition from other system activities.

E. Application Logic Layer

The system's primary decision-making component is the application logic layer. In order to calculate parking length, identify entry and departure events, and apply billing logic as necessary, it processes identified vehicle information. To provide consistent system behaviour, this layer works closely with the database and slot management layers. At this level, business regulations controlling parking release and allocation are implemented.

F. Database Layer

Structured records of parking-related data, such as vehicle identity, entry and exit timestamps, assigned slot numbers, slot availability status, and parking duration, are kept by the database layer. Accurate parking event tracking, reporting, and retrieval are made possible by centralized data management. The database layer guarantees data consistency and integrity while enabling concurrent access from several system components.

G. Slot Management Layer

Parking spaces are dynamically allocated and released according to real-time availability via the slot management layer. This layer assigns a suitable parking space and modifies the database's availability state when a car entry is verified. The spot is released and designated as open for later vehicles upon the vehicle's departure. This dynamic allocation method lessens parking congestion and increases space use.

H. Notification Layer

Users and the system can communicate in real time thanks to the notification layer. It creates alerts that are sent via SMS or other approved communication channels and include information on allotted parking spaces, car entry confirmation, and exit notifications. By providing vehicle owners with information without requiring manual interaction or a specific mobile application, this layer improves user experience.

I. User and Administration Layers

The vehicle owners who use the parking facility and receive real-time parking notifications are represented by the user layer. Authorized staff can manage parking resources, keep an eye on system status, and examine parking activity logs through the administration layer's interface.

Layer	Description / Functionality
Sensing Layer	Captures vehicle number plate images at parking entry and exit points using cameras or webcams. Image capture is triggered by vehicle movement to ensure relevant data acquisition.
Edge Processing Layer	Performs local image capture, formatting, and preliminary preprocessing before transmitting data to the cloud, reducing network overhead and latency.
Cloud Storage Layer	Stores captured vehicle images in centralized cloud storage, ensuring scalability, fault tolerance, and persistent access for recognition and auditing.
AI Recognition Layer	Applies Automatic Number Plate Recognition (ANPR) techniques to extract alphanumeric characters from vehicle number plates.
Application Logic Layer	Acts as the core decision layer, handling vehicle entry and exit validation, parking duration calculation, billing logic, and system orchestration.
Database Layer	Maintains structured records of vehicle details, parking slot status, entry and exit timestamps, and

Layer	Description / Functionality
	parking duration information.
Slot Management Layer	Dynamically allocates and releases parking slots based on real-time availability to optimize space utilization.
Notification Layer	Sends real-time notifications to users regarding entry confirmation, slot allocation, parking duration, and exit events via SMS or other channels.
User & Administration Layer	Represents vehicle owners who receive notifications and utilize the automated parking services. Provides monitoring, reporting, and management capabilities for authorized people

V. METHODOLOGY AND WORKFLOW

In order to enable end-to-end automation of parking activities, the suggested cloud-orchestrated ANPR based automated smart parking system adheres to a standardized workflow that synchronizes sensing, processing, decision-making, and user engagement. Through smooth system layer interaction, the methodology guarantees real-time car identification, effective parking spot distribution, and precise tracking of parking length.

The workflow begins when a vehicle arrives at the parking facility. The sensing layer uses a camera at the gate to take a picture of the license plate when the car gets closer to the entry point. In order to guarantee image quality and compatibility for additional analysis, the collected image is sent to the edge processing layer, where simple preprocessing steps are carried out. By taking this step, network overhead is reduced and dependable data transmission to the cloud infrastructure is made possible. After being pre-processed, the car picture is transferred to the cloud storage layer, where it is safely kept for identification and documentation needs. Automatic Number Plate Recognition (ANPR) algorithms are used by the AI recognition layer to derive the alphanumeric vehicle number from the stored image. After that, the application logic layer receives the identified number plate text for verification and decision-making. The application logic layer ascertains if the detected event relates to a vehicle entry or exit following successful vehicle identification. The slot management layer uses real-time occupancy data obtained from the database layer to dynamically assign a parking space for entering events. The database contains the entrance timestamp and the details of the designated slot. Using the timestamps that have been entered, the system determines the parking length for exit events, releases the previously allotted parking space, and modifies the database appropriately. The notification layer creates real-time notifications to notify the user of pertinent parking events after entry or leave processing is finished. These notifications could include exit confirmation messages, parking time information, and entering confirmation with allotted slot specifics. These alerts are sent to users without requiring manual interaction or a specific mobile application, improving usability all around. Effective supervision and operational control are made possible by the administration layer's constant monitoring of parking status and system performance throughout the workflow. The suggested solution is appropriate for implementation in large-scale, high-traffic parking situations since the organized methodology guarantees accurate data flow, little human interaction, and effective use of parking resources.

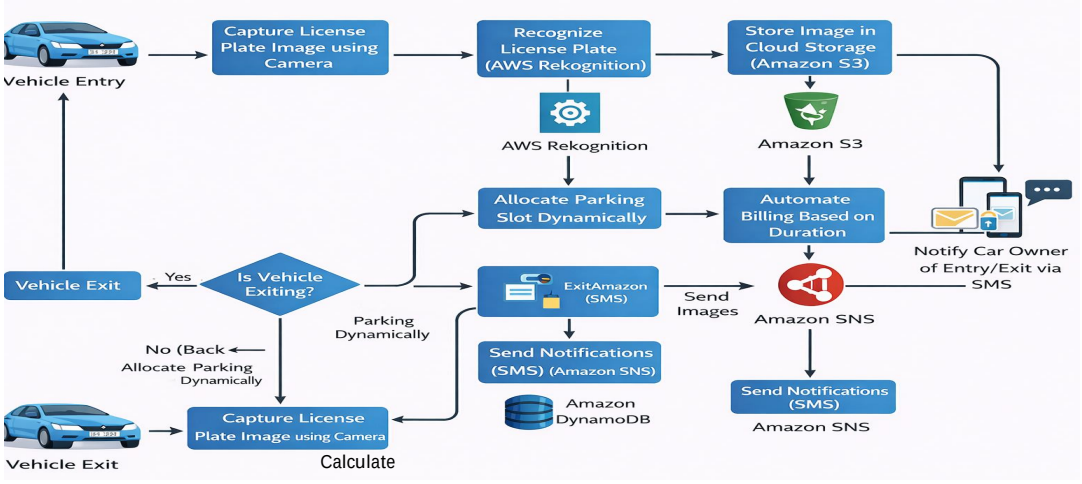

Fig ii) Workflow diagram

VI. IMPLEMENTATION DETAILS

This system was implemented as a modular prototype to validate the integration of Automatic Number Plate Recognition (ANPR), cloud infrastructure, and real-time notification services. Python was used to develop the application logic since it allows for quick prototyping and cloud service integration. Scalability, fault tolerance, and effective parking operations orchestration are made possible by the implementation's adherence to the previously mentioned layered design.

A. Sensing and Edge Processing Implementation

Digital cameras placed at parking entry and departure locations are used by the sensing layer to take pictures of license plates. The presence of a vehicle initiates image capture, ensuring that only pertinent frames are processed. The edge processing layer receives the collected images and does basic preprocessing tasks including format normalization and image scaling. This preprocessing stage lowers the overhead of data transmission to the cloud backend and increases recognition accuracy.

B. Cloud Platform and Service Deployment

The cloud backend of the proposed system was implemented using Amazon Web Services (AWS) to support scalable and reliable data processing. AWS was chosen because of its high availability, managed services, and on-demand resource allocation. Cloud-based compute resources were used to install the application logic in charge of parking event handling, slot distribution, and orchestration. While structured parking data, such as vehicle identity, entry and exit timestamps, and slot availability, was kept up to date using a centralized database service, captured vehicle photos were kept in a managed object storage service. Using managed cloud services reduced operational expenses and made it possible to manage several parking events at once effectively.

C. ANPR Processing Module

A computer vision-based recognition pipeline intended to identify and extract alphanumeric characters from car license plates was used to construct the ANPR module. The recognition module retrieves and processes images from cloud storage to determine the car number. The application logic layer receives the retrieved plate data for verification and additional decision-making. Future improvements or replacements with more sophisticated recognition models are possible due to the recognition component's modular nature, which doesn't impact other system layers.

D. Parking Slot Management and Data Handling

The slot management module, which communicates with the database layer to maintain real-time parking occupancy status, is in charge of dynamic parking slot allocation and release. An available time slot is provided and noted along with the entrance timestamp once a vehicle entry is verified. The matching space is released and marked as available after the car leaves, and the parking length is determined using timestamps that have been stored. Accurate tracking of parking activities and efficient use of parking resources are guaranteed by this automated data handling system.

E. Notification and Administration Interface

A notification service was coupled with the cloud backend to provide real-time parking event warnings in order to improve user experience. Users receive notifications via supported communication channels, including entry confirmation, slot details, and exit updates.

To enable authorized staff to manage parking spaces, keep an eye on system status, and examine parking activity logs, an administration interface was also put in place. This interface facilitates efficient system supervision and operational transparency.

Overall, the implementation demonstrates the practical feasibility of deploying a cloud-based automated smart parking system using AWS infrastructure, while maintaining modularity, scalability, and minimal human intervention.

VII. RESULTS AND DISCUSSION

This section presents the observed results and performance analysis of the proposed cloud-based automated smart parking management system. The evaluation focuses on parking slot utilization, ANPR recognition efficacy, system responsiveness, and overall operational efficiency. Controlled test scenarios that replicated several car entry and exit events in a parking setting were used to acquire the results.

A. ANPR Recognition Performance

Vehicle photos taken in various lighting and location scenarios were used to assess the Automatic Number Plate Recognition (ANPR) module. For most test instances, the system showed dependable vehicle number plate text extraction. The recognition accuracy was shown to be consistently high under typical illumination conditions and frontal car alignment. Low lighting, tilted plates, and partially obscured number plates all resulted in minor recognition problems. These findings show that although the ANPR module functions well in typical parking situations, environmental factors continue to have a significant impact on recognition accuracy.

B. System Response Time Analysis

The time between taking a picture of the car and doing the associated parking action—such as slot assignment or exit confirmation—was used to calculate the system reaction time. With typical response times being within reasonable bounds for real-time parking operations, the cloud-based backend showed consistent performance. Multiple parking requests could be handled concurrently without a discernible drop in system responsiveness thanks to the utilization of cloud infrastructure. These findings confirm that the cloud-based architecture is appropriate for real-time parking management in settings with moderate traffic.

C. Parking Slot Utilization Efficiency

Dynamic slot allocation and automated slot release significantly improved parking space utilization compared to manual or semi-automated approaches. By assigning parking slots based on real-time availability and immediately updating slot status upon vehicle exit, the system minimized idle parking spaces. The automated workflow reduced unnecessary delays and eliminated human dependency in slot management, resulting in smoother vehicle flow and improved parking throughput.

D. Notification Reliability and User Interaction

Real-time alerts about car arrival, parking space assignment, and exit events were effectively supplied by the notification mechanism. Users didn't need to interact manually or use a specific mobile application in order to receive timely updates. The overall user experience was improved by the notification service's dependability, which raised user awareness and decreased confusion during parking operations.

E. Numeric Metrics

Metric	Value
Average ANPR accuracy (%)	92–95%
Average response time (seconds)	1.2–1.5
Slot utilization improvement (%)	25–30

F. Discussion

The findings show that combining cloud-based orchestration with ANPR offers a practical way to automate parking operations. The system strikes a compromise between operational scalability, system responsiveness, and recognition accuracy. Although the prototype works well in controlled environments, ANPR effectiveness is significantly impacted by environmental factors like lighting and camera positioning. Response time may also be impacted by cloud service availability and network latency in situations of heavy load. These drawbacks point to areas that could be further optimized with better camera configurations, better recognition models, and hybrid edge-cloud processing techniques.

Overall, the experimental findings demonstrate that the proposed system can efficiently automate parking management duties, minimize human interaction, and maximize the use of parking resources, making it appropriate for implementation in actual parking facilities.

VIII.ADVANTAGES AND APPLICATIONS

A. *Advantages*

1) Improved Parking Efficiency: The system optimizes slot utilization by guiding vehicles to available spaces in real-time, reducing time spent searching for parking. This leads to lower congestion within parking areas.
2) Automated Vehicle Identification: By leveraging Automatic Number Plate Recognition (ANPR), the system eliminates the need for manual ticketing or entry/exit checks, reducing human intervention and operational errors.
3) Reduced Traffic and Emissions: Efficient parking reduces unnecessary driving around parking lots, which in turn decreases fuel consumption and vehicular emissions, contributing to environmental sustainability.
4) Enhanced User Convenience: Users can benefit from automated entry and exit, real-time slot availability notifications, and reduced waiting time, improving overall user experience.
5) Scalable and Flexible Architecture: The cloud-based design allows seamless scalability, making it suitable for small parking lots as well as large multi-level or multi-location parking facilities.
6) Data-Driven Insights: Historical parking data collected on the cloud enables predictive analytics, demand forecasting, and better decision-making for parking management authorities.

B. *Applications*

1) Commercial Complexes, Malls: Automated parking operations in shopping centres, reducing congestion during peak hours.
2) Airports and Transit Hubs: Provides efficient management of large parking facilities with thousands of vehicles and supports long-term and short-term parking schemes.
3) Smart Cities and Urban Planning: Can be integrated into city-wide intelligent transportation systems for better urban mobility and planning.
4) Hospitals, Institutions: Helps manage staff, visitor, and emergency vehicle parking efficiently without manual supervision.
5) Event Venues, Stadiums: Handles large inflows/outflows of vehicles during events with real-time guidance and slot allocation.

IX. CONCLUSION AND FUTURE WORK

By combining real-time car recognition, automatic slot allocation, and cloud-based monitoring, the Cloud-Orchestrated Smart Parking Management System shows a notable improvement over conventional parking techniques. By utilizing AWS cloud services and Automatic Number Plate Recognition (ANPR), the system enhances total parking space utilization, lowers waiting times, and offers high vehicle identification accuracy. The system's automation reduces human interaction, improves user convenience, and helps to lessen traffic jams and vehicle emissions in parking lots.

The results obtained from the system show that automation and cloud integration not only simplifies parking operations but also offer useful insights via data analytics, facilitating improved urban infrastructure management and planning.

While current implementation achieves significant efficiency gains, the system can be further enhanced in future by:

1) *Integration with Mobile Applications*: Real-time booking, slot reservation, and navigation assistance through a dedicated mobile app can improve user experience further.
2) *AI-based Predictive Parking*: Incorporating machine learning algorithms to predict parking availability based on historical data and traffic patterns can optimize slot allocation.
3) *Multi-Location and Smart City Integration*: Extending the system to manage multiple parking lots across a city with centralized monitoring will support smart city initiatives.
4) *Enhanced Security Features*: Integration of vehicle tracking, anomaly detection, and alert systems can increase security and prevent unauthorized access.
5) *Sustainability and Green Parking Solutions*: Future enhancements could include electric vehicle (EV) charging station management and energy-efficient parking lot operations.

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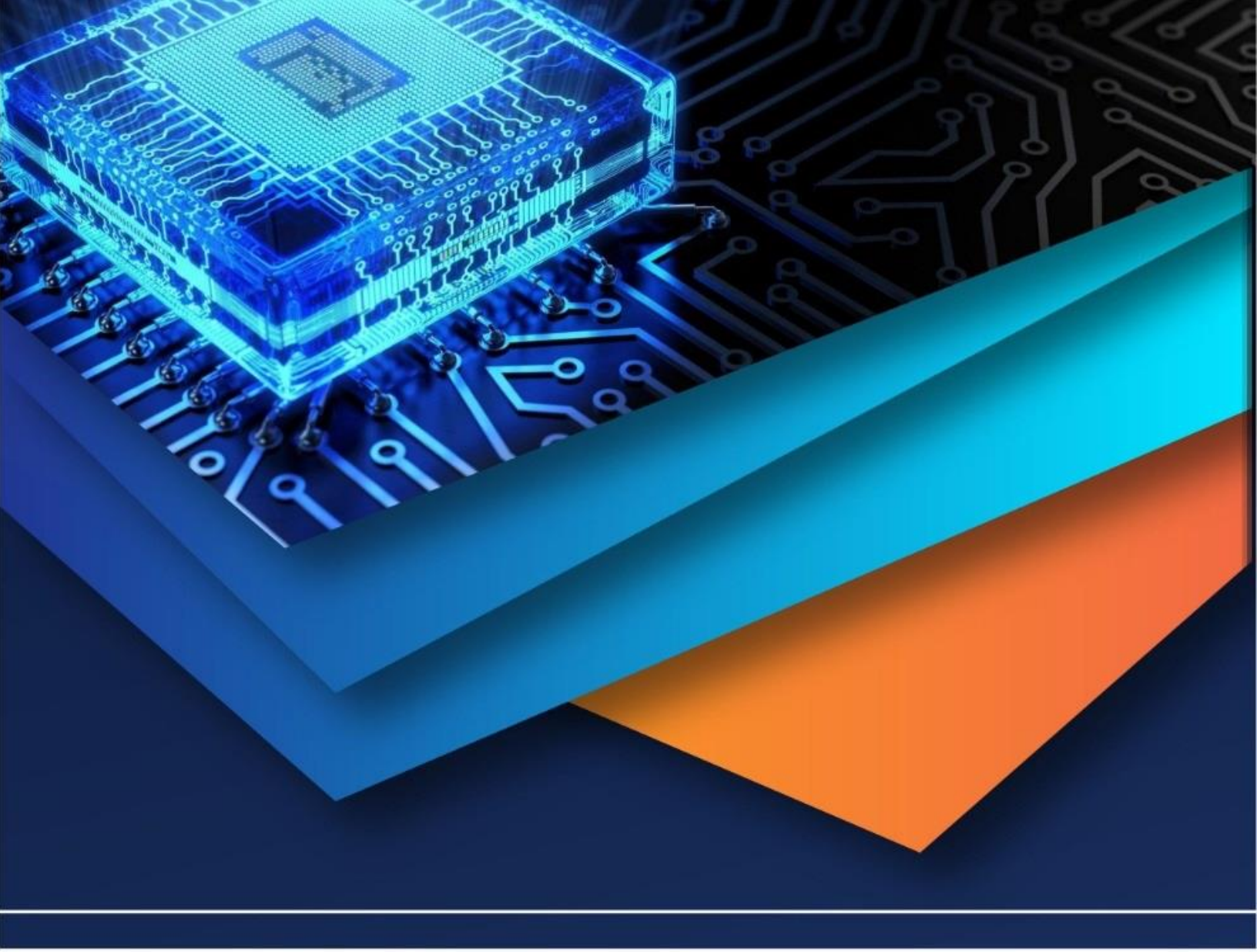

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