

PARKEASE: SMART PARKING SYSTEM

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Abstract - Urban areas across Kerala are increasingly burdened by disorganized parking, resulting in driver frustration, wasted fuel, traffic congestion, and environmental pollution. This project proposes a Smart Parking System that operates entirely without GPS, making it ideal for indoor or multi-level parking structures such as shopping complexes, hospitals, or campuses. The system utilizes IR or ultrasonic sensors integrated with ESP32 microcontrollers to monitor the occupancy of each parking slot in real-time. The collected data is transmitted over Wi-Fi to a cloud-based dashboard. A mobile or web-based application allows users to check live availability, book slots in advance, and receive indoor navigation guidance to their allotted slot. Since GPS is not applicable indoors, the system employs visual maps in the app showing user's location and path to assigned slot Optional audio/visual directions in the app. The project also includes an admin dashboard to monitor occupancy, issue time alerts, and optimize space usage. Optional features like license plate recognition and automatic entry logging can enhance security and control. This Smart Parking System significantly reduces the time and stress involved in finding a parking space, helping minimize fuel usage, CO₂ emissions, and mental fatigue. It promotes urban order, social convenience, and psychological comfort, especially in densely populated regions. Designed to be modular, affordable, and scalable, this project demonstrates how IoT, automation, and real-time analytics can collectively solve real-world urban problems with direct environmental and societal impact.

Key Words: Smart parking system, GPS, IR sensors, Ultrasonic sensors, Cloud-based dashboard, ESP32 microcontrollers, Real-time monitoring, IoT.

1. INTRODUCTION (Size 11, Times New roman)

With rapid urbanization, parking has become a significant challenge in indoor and multi-level facilities such as shopping complexes, hospitals, offices, and campuses. Traditional parking systems often lead to traffic congestion, driver frustration, wasted fuel, and environmental pollution due to the time spent searching for available parking slots. Moreover, indoor environments render GPS-based navigation unreliable, making it difficult for drivers to locate free parking spaces efficiently.

To address these challenges, this project proposes a Smart Parking System with Indoor Slot Navigation. The system leverages IoT-based sensors, ESP32 microcontrollers, and BLE beacons to provide real-time monitoring and guidance for parking slots. Users can check slot availability, reserve slots in advance, and navigate to their allocated parking spot using a mobile application that provides interactive maps and OLED-based zone guidance.

Additionally, an admin dashboard facilitates efficient parking space management, allowing administrators to monitor occupancy, optimize space usage, and enhance security through optional features such as automatic entry logging and license plate recognition.

By integrating automation, real-time analytics, and indoor navigation, this system aims to reduce parking-related congestion, minimize fuel consumption and CO₂ emissions, and improve user convenience and urban parking efficiency. Designed to be modular, scalable, and

cost-effective, the project demonstrates how modern technologies can provide practical solutions to everyday urban challenges.

2. PARKEASE

The Smart Parking System with Indoor Slot Navigation is designed to help drivers efficiently locate and reserve parking spaces in indoor or multi-level facilities where GPS signals are unreliable. The system uses IR sensors and ESP32 microcontrollers to monitor slot occupancy in real-time, while BLE beacons and OLED displays guide users to their assigned parking spots. A mobile application allows users to check slot availability, make reservations, and receive interactive, zone-based navigation, while an admin dashboard enables monitoring, booking management, and optimization of parking space usage. By automating the parking process, the system reduces traffic congestion, time spent searching for parking, fuel consumption, and CO₂ emissions, while optional features like automatic entry logging and license plate recognition enhance security and control. Designed to be modular, scalable, and cost-effective, this project demonstrates how IoT, real-time analytics, and automation can collectively improve urban parking efficiency, user convenience, and overall quality of life in densely populated areas.

3. LITERATURE REVIEW

[1] The paper “Evaluating the Impact of Smart Parking Systems on Parking Violations” (2024) by Atusa Javaheri et al. investigates how Smart Parking Systems (SPS) influence parking compliance at the University of Texas at Arlington. Using five years of parking citation data (2018–2023), the researchers developed an LSTM-based predictive model to estimate violations that would have occurred without the system and compared them with the actual post-SPS data. The study revealed a significant reduction in parking violations after SPS implementation, proving that real-time monitoring and guidance improve user behavior and compliance. The model also incorporated academic schedules, holidays, and exam periods as influential features. While the system demonstrates strong potential for scalability and sustainability, limitations include the study’s restriction to a single university setting, exclusion of external factors like weather, and a short post-implementation period that may not capture long-term behavioral changes.

[2] The paper “Method of Increasing the Security of Smart Parking System” (2023) by Tetiana Hovorushchenko, Olga Pavlova, and Mariia Kostiuik focuses on improving the security of Smart Parking Systems by identifying potential vulnerabilities and proposing a middleware-

based protection mechanism. Instead of using experimental data, the study conceptually analyzes existing methods such as blockchain, RFID, IoT, cloud, and 5G technologies, highlighting their limitations in ensuring full system security. The authors identify common threats like data breaches, unauthorized access, and DDoS attacks that can affect the client, API, and server levels. To address these issues, they propose a middleware layer that intercepts all client requests, filters malicious or suspicious ones, and forwards only safe requests to the main server, thereby reducing the risk of attacks and improving overall system reliability. However, the paper remains theoretical, lacking practical implementation and performance evaluation, and may require customization for different smart parking architectures.

[3] This paper highlights the limitations of purely cloud-centric smart parking systems and introduces a three-tiered architectural model designed to enhance performance and scalability. Proposed by Md. Mahmud Hossain, Samee U. Khan, Niamat Ullah, Sazzad Hossain, and Muhammad Atiquzzaman in 2023, the model is structured into a Sensing layer, a Fog layer, and a Cloud layer. The Sensing layer is responsible for the foundational task of data collection, utilizing physical sensors to detect parking slot occupancy. The innovative Fog layer consists of computing nodes, like gateways or local servers, deployed at the edge of the network, near the parking facilities themselves. This layer processes data locally, handling time-sensitive tasks such as immediate slot detection, real-time reservation requests, and dynamic pricing calculations. The Cloud layer, in turn, manages long-term data storage, complex analytics, and system-wide management functions. By leveraging fog computing, this design directly addresses the high latency problems that can plague cloud-only systems, where data must travel long distances to a remote data center and back. This architecture also significantly reduces the bandwidth consumption on the core network, as only summarized or non-time-critical data is sent to the cloud. The authors demonstrate through simulation that their model is highly scalable and particularly suitable for the demanding environment of large, dense metropolitan areas. The system supports a wide array of services, including user guidance and automated payments, creating a comprehensive parking solution. However, the study’s limitations are rooted in its methodological approach, as the model’s performance was validated only through software simulation without the construction of a physical prototype. This absence of real-world testing leaves questions about its performance under unpredictable environmental conditions and real-user load. Additionally, the paper does not provide a detailed assessment of the potential deployment costs associated with installing and maintaining the fog computing infrastructure across a city. A further limitation is the

relatively limited analysis of the security implications and potential vulnerabilities introduced by the distributed fog nodes themselves, which become new targets for cyber-attacks. The paper successfully outlines a promising future direction but identifies a clear need for practical implementation and more thorough cost-benefit and security analyses.

[4] This paper highlights the specific challenges associated with indoor parking navigation and presents a practical, hardware-oriented solution to guide drivers efficiently. Developed by Deepak Bhatnagar, Vaibhav Soni, and Pragati Agrawal in 2024, the system is designed for complex environments like basement parking garages and shopping malls where GPS signals are unavailable. The core of their system relies on a network of infrared (IR) sensors installed in each parking space to detect the presence of a vehicle. These sensors are connected to a central ESP32 microcontroller, a low-cost, programmable device that acts as the system's brain. The ESP32 gathers data from all the sensors and processes it to determine the real-time status of every slot. It then communicates this information to a user's smartphone via the Blynk IoT platform, which provides a user-friendly mobile application interface. A key innovative feature is the use of simple LEDs or on-screen instructions to provide guided visual or textual navigation, directing the driver from the entrance to the specific location of a vacant spot. This direct guidance is the system's primary advantage, as it drastically reduces the time and frustration spent circling in search of a space. The authors successfully developed a low-cost and functional prototype that demonstrates the core concept's viability. The system is praised for its real-time slot monitoring capability and its intuitive interface that requires minimal user learning. However, the authors are transparent about the system's limitations, noting that its precision is limited in very large, multi-story, or multi-zone parking facilities where more sophisticated tracking is needed. The implementation lacks zone-based tracking or integration with more advanced indoor positioning technologies like beacons. Furthermore, the current prototype represents a basic implementation, and scaling it to a large, commercial-grade facility would present engineering challenges related to sensor network stability and wireless communication robustness. The paper concludes that while the system effectively proves the concept for low-cost indoor navigation, it requires further development for widespread commercial deployment.

[5] This paper highlights an innovative approach to user interaction within smart parking systems by integrating a conversational AI to reduce driver stress and improve accessibility. Proposed by Hanozi Albaiali, Sherren Meer, Farris Aiharbi, Mashaal Aljohani, and Reema Abehise in 2025, the "Quick Park" system is built around a standard IoT sensor network that monitors parking space

availability. Its distinctive and central feature, however, is the incorporation of a chatbot interface, allowing users to communicate with the system using natural language. Drivers can interact with this chatbot via a messaging platform or an in-app feature to ask questions, check for available spots in a specific area, or even make a reservation through a conversational dialogue. This model aims to make the technology more accessible to a broader range of users, including those who may not be comfortable with complex mobile application interfaces. The authors argue that this interactive and communicative approach can significantly reduce the mental strain and anxiety associated with searching for parking in congested areas. Providing instant, conversational updates empowers the driver and creates a more seamless experience. The system promises real-time updates and interactive communication as its core advantages. However, this innovative approach introduces its own set of complexities and limitations. The integration of a chatbot significantly increases the overall system complexity, requiring sophisticated natural language processing (NLP) algorithms and constant training to understand user intents accurately. This complexity also introduces new potential points of failure in both the software and the conversation logic. Furthermore, the paper notes that the system, in its proposed form, lacks indoor guidance capabilities, so while a user can reserve a spot, the system may not be able to guide them to it inside a large garage. Another critical limitation is the question of scalability; the chatbot backend may struggle to maintain performance and provide instant responses during peak hours when thousands of users are simultaneously requesting information, potentially leading to delays and user frustration. The paper presents a forward-looking concept but identifies key technical hurdles that must be overcome for practical realization.

[6] This paper highlights the role of smart parking systems in mitigating broader urban issues like traffic congestion and environmental pollution by combining IoT with predictive machine learning. Presented by Narinder Yadav, Sandeep Singh Kang, Rajneesh Verma, Varun Garg, and Ishdeep Singla in 2024, their proposed system utilizes a network of sensors, often based on Arduino modules, to gather real-time data on parking slot occupancy across a city. This raw data is then fed into machine learning algorithms which are designed to identify patterns, predict future space availability, and potentially optimize pricing based on demand. The processed information is delivered to users through a mobile application, which provides real-time slot updates and allows for reservation options, enabling drivers to plan their parking in advance. The authors emphasize that by reducing the time drivers spend circling city blocks in search of a parking space, the system contributes to lower vehicular emissions and less overall traffic congestion. The key advantages they promote include fully

automated slot detection, the promotion of an eco-friendly urban environment, and the convenience of real-time reservations for users. The system is positioned as a comprehensive solution for managing growing urban parking demand more efficiently. However, the design has several specific limitations that are acknowledged in the paper. Firstly, the system is primarily designed for outdoor parking lots and on-street parking, lacking the precision required for effective indoor parking garage navigation. The sensors and algorithms are not optimized for the GPS-denied environments of multi-story structures. Secondly, the system's accuracy is noted to be dependent on careful and periodic calibration of its sensor network, an ongoing maintenance requirement that, if neglected, would degrade performance. Finally, while machine learning is incorporated, the paper suggests the implementation may be basic, and the system lacks more advanced features like deep integration with city-wide traffic management systems for holistic urban mobility planning. The paper concludes that the integration of IoT and ML is a powerful step forward, but the solution requires further refinement to become a universal parking management tool.

[7] This paper highlights the application of advanced deep learning techniques to predict parking availability, directly tackling the issues of long waiting times and unnecessary fuel consumption. Authored by H. Canli and S. Toklu in 2021, the research focuses on the development of a predictive mobile application rather than a hardware-based detection system. The core of their application uses a Long Short-Term Memory (LSTM) network, a specialized type of recurrent neural network known for its effectiveness in analyzing and forecasting time-series data. The model was trained and validated using large datasets of historical and real-time parking data from a real-world urban environment: Istanbul. This approach allowed the system to learn complex temporal patterns, such as rush hour demand and weekly cycles, to achieve a high degree of prediction accuracy for space availability. The application is cloud-based, meaning all the heavy computational work of the LSTM model is handled on a server, and the results are simply delivered to the user's smartphone. This architecture allows for widespread accessibility without demanding high processing power from the user's device. The primary advantages are the system's ability to provide drivers with a reliable forecast, enabling them to plan their trip and destination with greater confidence, thereby saving time and reducing energy use. The high prediction accuracy demonstrated in the study is a significant strength. However, the authors clearly outline the limitations of their design. The application itself lacks any form of indoor navigation, as it is purely a predictive information tool. Its entire functionality is fundamentally dependent on a stable and continuous internet connection for both data input and output delivery. Perhaps the most

significant limitation is the lack of direct integration with physical hardware; the system relies on external data sources and does not include its own sensor network for real-time validation, which could lead to inaccuracies if the data source is unreliable. The paper presents a powerful software solution but shows that its effectiveness is contingent on the infrastructure and data sources it depends upon.

[8] This paper highlights the critical security and privacy flaws of centralized smart parking systems and proposes a radical shift towards a decentralized architecture using blockchain. Written by Wesam Al Amiri, Mohamed Baza, Karim Banawan, Mohamed Mahmoud, Waleed Alasmay, and Kemal Akkaya in 2020, the research argues that traditional systems, with their single points of control, are vulnerable to data breaches, server hacking, and single points of failure. Their proposed framework uses blockchain as a distributed ledger to record all parking transactions, such as reservations and payments, in a transparent and tamper-proof manner. Because the data is replicated across many nodes in the network, it becomes extremely resilient to manipulation or corruption. A particularly innovative feature of their model is the use of a cloaking method, which deliberately obfuscates a driver's exact location and identity during the booking process to prevent tracking and protect personal privacy. The authors conducted a formal evaluation of their scheme, demonstrating that it is both practical to implement and provides strong security guarantees against various attack vectors. The advantages are profound: enhanced data privacy for users, fully transparent and auditable operations for operators and city authorities, and a resilient decentralized structure that eliminates central points of attack. However, the authors are careful to detail the significant trade-offs involved in adopting blockchain technology. The consensus mechanisms required to validate transactions on a blockchain inherently introduce higher latency compared to a fast centralized database, which could slow down the reservation process. The initial system setup is also far more complex, requiring the establishment and maintenance of a distributed network of nodes. Finally, the computational and energy overhead of running a blockchain leads to a potentially costly implementation, raising questions about its economic feasibility for widespread public use. The paper makes a compelling case for blockchain's security benefits but acknowledges that these performance and cost challenges must be addressed for mainstream adoption.

[9] This paper highlights a foundational model for a cloud-based IoT parking system that focuses on the core functions of detection and notification to address user difficulty in finding available slots. Designed by Vaani Rajvanshi, Swasti Chaturvedi, Dinesh Yadav, and Lokesh Sharma in 2020, the system employs a network

of sensors, likely ultrasonic or magnetic, to detect the real-time status of each parking space. This occupancy data is transmitted wirelessly to a cloud platform, such as IBM Watson or a similar service, where it is aggregated and processed. The cloud server then makes this information available for display on public dashboards or mobile applications, giving users a clear view of available spots. A notable advanced feature included in their model is an alert system designed to identify and report instances of improper parking, such as vehicles occupying multiple spots or parking in unauthorized areas. The authors conducted tests focused on user convenience, which indicated that the system successfully reduced the time spent searching for parking. The advantages of this design are its straightforward cloud integration, which allows for remote monitoring, and its accurate real-time detection capability. The driver alert system adds a layer of management that goes beyond simple availability monitoring. However, the limitations outlined reveal it as an early-stage or foundational design. Crucially, the system lacks any form of navigation support; it can tell a user that a spot is available but cannot guide them to its specific location, which is a significant shortfall in large or complex lots. The architecture also has limited scalability, potentially struggling with the data load from hundreds of parking lots simultaneously. Furthermore, the system does not include a user reservation feature, meaning spots are available on a first-come, first-served basis, which does not fully guarantee a spot for a user. The paper presents a solid base model but identifies clear avenues for future enhancement in navigation, scalability, and user guarantees.

[10] This paper highlights the development of a practical sensing and software platform to address the common problem of locating vacant spaces within large parking complexes, a key component of smart city initiatives. Developed by Paul Melnyk, Souliene Djahel, and Farid Naik-Abdesselam in 2020, the research involved the creation of a functional prototype system comprising both hardware sensors and a mobile application. The sensing platform is deployed in the parking area to detect space occupancy, and this data is used to guide drivers through the mobile app interface. The authors subjected their prototype to testing under various conditions to rigorously validate its reliability and performance in a realistic setting. The results from these tests demonstrated that the system could indeed provide a faster and more efficient parking experience by significantly reducing the time drivers spend in a futile search for an available spot. The primary advantages of this system are its mobile-based accessibility, allowing users to access information directly on their personal devices, and its efficient slot detection mechanism. By cutting down search time, the system also contributes to lower fuel consumption and reduced localized congestion around parking facilities. However, the authors acknowledge several important

limitations that constrain the system's immediate applicability. A major drawback is the lack of indoor position tracking; the system is effective for outdoor lots but cannot provide precise guidance within multi-story parking garages where GPS is ineffective. The testing was also conducted on a small scale, leaving the system's scalability and performance under the load of a city-wide deployment unproven and potentially problematic. Finally, the system lacks advanced data analytics capabilities; it collects raw occupancy data but does not employ machine learning or other techniques to predict future demand, optimize pricing, or provide deeper insights for urban planners. The paper successfully demonstrates a working prototype but positions it as an initial step towards a more comprehensive and intelligent city-wide management system.[10]

4. ARCHITECTURE

The main components of smart parking system architecture are:

1. Embedded Hardware Layer – Parking Area

This is the base layer where all physical devices and sensors are deployed.

ESP32 Microcontrollers: Act as the core processing unit that connects all sensors and devices, enabling communication with the cloud.

BLE Beacons: Used for indoor positioning to guide users to available parking slots.

IR Sensors for Slot Occupancy: Detect whether a parking slot is occupied or vacant.

Servo Motor for Gate Control: Controls the opening and closing of the gate based on booking or authentication.

OLED Displays: Show real-time navigation information to help users locate their slots easily.

This layer ensures real-time data collection from the parking area.

2. Cloud & Middleware Layer

This layer acts as the brain of the system where data is processed and managed.

Authentication & Booking Service: Handles user verification and parking slot booking operations.

Navigation & Slot Management Logic: Manages slot allocation, real-time navigation, and path guidance.

Firestore Realtime Database: Stores and updates all parking and user data in real-time, ensuring smooth communication between hardware and user interface

This layer ensures data processing, storage, and real-time updates.

3. Application Layer (User & Admin Interfaces)

This is the front-end layer that interacts with the end users and administrators.

Admin Dashboard: Allows administrators to monitor slot availability, gate operations, and overall system status.

User & Admin Interfaces: Provide different functionalities based on access levels—for example, booking slots for users and system monitoring for admins.

Mobile App (Flutter): A cross-platform mobile application that enables users to view available slots, book parking, and navigate to their assigned slot.

This layer ensures user interaction, control, and monitoring.

Overall Working Flow

1. Sensors and microcontrollers at the hardware layer collect parking data (slot occupancy, gate control, navigation signals).
2. This data is sent to the Firebase cloud through ESP32 for processing and storage.
3. The middleware layer manages authentication, booking, and navigation logic.
4. Finally, the user or admin accesses the processed information via a mobile application or dashboard interface to monitor or control parking activities.

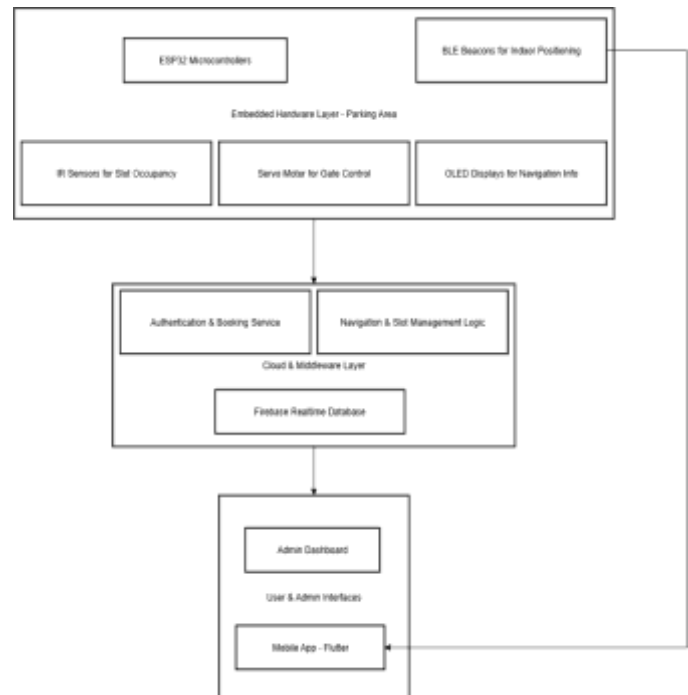


Fig -1: Architecture design

5. COMPARISON WITH EXISTING SYSTEMS

Existing smart parking systems mainly focus on outdoor GPS technology and simple IoT-based slot detection, which limits their effectiveness in covered or multi-level parking areas. These traditional solutions typically focus on identifying whether a parking slot is free or occupied, but they lack accurate real-time navigation within enclosed environments where GPS signals are unavailable. As a result, users often face difficulties in locating their reserved slots indoors, leading to wasted time, congestion, and frustration. The most conventional systems provide only basic functionality—slot detection and booking—without offering navigation and many advanced user interaction features.

In contrast, the proposed Smart Parking System with Indoor Slot Navigation addresses these challenges with an innovative, user-centric design. By integrating BLE beacons for accurate indoor positioning and OLED displays for visual navigation, the system ensures accurate guidance to the exact reserved slot, even in multi-level or underground facilities. ESP32 microcontrollers paired with IR sensors enable reliable real-time slot monitoring, while Firebase cloud support ensures live updates and data synchronization. A mobile

application developed in Flutter allows users to view availability, reserve slots, make payments, and receive in-app navigation, while an admin dashboard offers advanced management and analytics. Together, these components deliver a comprehensive, energy-efficient, and intelligent solution that improves user convenience and operational efficiency compared to existing GPS-based or manually managed systems.

6. CONCLUSION

In simple terms, this smart parking system is designed to make parking less stressful and more convenient, especially in indoor or multi-level areas where GPS doesn't really help. Instead of driving around aimlessly or struggling to find your reserved spot, the system guides you directly using BLE beacons and OLED displays, while also keeping you updated through a mobile app. At the same time, it helps administrators manage slots better and reduces unnecessary congestion and energy use. Beyond just saving time, it also improves the overall parking experience by ensuring reliability, safety, and smooth traffic flow inside parking facilities. By combining real-time monitoring, user-friendly navigation, and cloud integration, the system represents a step towards smarter and more sustainable urban infrastructure.

More importantly, this solution is built with scalability and adaptability in mind. It can be easily expanded to handle larger parking spaces, integrated with payment gateways, or even connected to smart city platforms in the future. For users, it adds a sense of convenience and confidence while parking, while for administrators, it offers powerful tools for analytics, planning, and efficient resource utilization. With urban areas becoming more crowded and the demand for smarter infrastructure increasing, such a system is not just useful—it is necessary. Overall, the proposed smart parking system bridges the gap between technology and everyday life, making parking a simpler, faster, and more intelligent experience for everyone.

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