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# Smart IoT-Based Parking Assistance System

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## Abstract:

With the rapid increase in vehicles, parking management has become a major challenge in urban areas. Traditional parking systems lack real-time information, leading to congestion, time wastage, and inefficient space utilization. This project proposes a Smart IoT-Based Parking Assistance System that uses ultrasonic sensors and ESP32 microcontrollers to detect parking slot availability in real time. The system provides floor-wise dashboards and a QR-based mobile interface for users to check availability and select slots efficiently. The solution is low-cost, scalable, and designed to improve user convenience without relying on complex navigation systems.

*Keywords* — Smart Parking System, IoT, ESP32, Ultrasonic Sensor, QR Code Interface, Urban Parking Management, Real-Time Monitoring.

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## I. INTRODUCTION

In today's fast-growing urban environment, the number of vehicles on the road has increased drastically, making parking management one of the most common yet overlooked problems in public spaces such as shopping malls, colleges, and commercial complexes. Unlike traffic or road safety, parking congestion is rarely discussed seriously, yet it affects thousands of people on a daily basis. A person entering a busy mall or college campus often has no way of knowing which floor has available parking, forcing them to drive around aimlessly from one floor to another until they find an empty slot by chance. This not only wastes time and fuel but also adds to carbon emissions and causes unnecessary frustration for the user.

The root cause of this problem is simple — the lack of real-time information. Traditional parking systems are either fully manual, relying on security guards or physical indicators, or they are expensive automated systems that require heavy infrastructure and dedicated mobile applications that users must download and set up. Neither of these solutions is practical for everyday structured parking environments like college campuses or mid-sized malls.

To address this gap, we propose a Smart IoT-Based Parking Assistance System that is both low-cost and

easy to deploy. Our system uses ultrasonic sensors installed at each parking slot, connected to an ESP32 microcontroller, which continuously monitors whether a slot is occupied or free. This data is sent to a real-time database and reflected instantly on a web-based dashboard. What makes our approach unique is its simplicity from the user's perspective — there is no app to download, no registration required. A QR code placed at the parking entrance is all the user needs to scan, which directly opens a mobile-friendly website showing live, floor-wise parking availability. The user can see exactly which floor and which slot is free before even entering the parking area, saving time, reducing vehicle movement inside the premises, and improving the overall parking experience.

The proposed system is designed keeping cost-effectiveness and ease of installation in mind, making it a realistic and scalable solution for colleges, malls, and any structured parking facility looking to modernize without heavy investment.

## II. Motivation and Objective

### *A. Motivation*

The idea behind this project came from a very common and relatable experience. Anyone who has visited a busy shopping mall or a large college campus during peak hours knows how frustrating it can be to find a parking spot. You enter the parking area, go to the first floor — it is full. You go to the second floor — still full. By the time you finally find a spot, you have already wasted several minutes driving in circles, burning fuel, and adding to the stress of what should have been a simple task. This experience is not rare — it happens every day, to thousands of people, in malls and colleges across the country.

What made us think deeper about this problem was realizing that the parking slots themselves are not always full — the issue is that people have no way of knowing which ones are free without physically going there and checking. This information gap between the parking space and the person looking for it is exactly what motivated us to build this system. If a person could simply scan a QR code at the entrance and instantly see which floor and which slot is available, the entire experience changes. No more guessing, no more driving around, no more wasted time.

We were also motivated by the fact that most existing smart parking solutions are either too expensive for smaller setups or require users to download a dedicated application, which is an extra barrier many people avoid. We wanted to build something that is practical, affordable, and accessible to everyone without any technical effort on the user's side.

### *B. Objective*

The primary goal of this project is to build a smart, sensor-based parking system that solves the real problem of parking inefficiency in structured spaces like malls and college campuses. The following are the specific objectives of this work:

1. To detect the real-time occupancy of each parking slot using ultrasonic sensors connected to an ESP32 microcontroller, and reflect this data instantly on a web-based interface.
2. To develop a user-friendly, mobile-responsive website that displays floor-wise parking availability without requiring any app download or user registration.
3. To implement a QR code based entry point so that any user entering the parking area can instantly access live slot information by simply scanning the code with their phone camera.
4. To design a physical entrance dashboard that displays overall parking availability floor-wise, helping users make quick decisions before entering.
5. To build a system that is cost-effective and easy to install, making it a realistic solution for colleges, malls, and other structured parking environments that cannot afford heavy infrastructure.
6. To reduce unnecessary vehicle movement inside parking areas, which directly contributes to lower fuel consumption and reduced carbon emissions within enclosed spaces.

## III. RELATED WORK

The problem of parking inefficiency has attracted significant research attention in recent years, particularly with the rise of IoT and smart city initiatives. Researchers have explored various approaches to solve this problem, ranging from simple sensor-based detection to complex deep learning systems. This section reviews the most relevant existing work and identifies the gap that our proposed system aims to fill.

Early work by Revathi and Dhulipala [9] provided one of the foundational surveys on smart parking systems and sensors, establishing that real-time slot detection is the core requirement of any effective parking solution. Building on this, Fahim et al. [10] presented a comprehensive review of smart parking systems across multiple dimensions including technology, cost, and scalability, concluding that most existing systems struggle to balance accuracy with affordability.

IoT-based approaches have gained significant traction in recent years. Bhoyar, Avatade, and Gavhane [5] proposed a smart parking system combining IoT with cloud computing, demonstrating that cloud-connected sensors can effectively monitor slot availability remotely. Similarly, Alkhudhayr [4] extended this concept specifically for smart city traffic management, using IoT-based slot detection and occupancy classification to reduce urban congestion. Aditya [1] further explored intelligent parking systems for smart cities, highlighting the importance of real-time data in improving user decision-making before entering a parking facility.

A particularly relevant work to our project is by Sampath and Boggavarapu [6], who proposed an IoT-based smart parking system with QR code access and real-time navigation. Their system shares conceptual similarity with our approach, however it is designed for Industry 4.0 environments which typically involve heavier infrastructure and more complex deployment requirements. Our system adapts this idea for simpler, everyday structured spaces like colleges and malls with a focus on minimal setup cost.

Camera and vision-based systems represent another popular direction in this domain. Aswath et al. [3] proposed a smart car parking system using YOLOv8 and OCR for online reservation, achieving high detection accuracy through computer vision. Amato et al. [11] used smart camera networks combined with deep learning for parking occupancy detection, while Bura et al. [12] implemented an edge-based solution using camera networks for similar purposes. Sankareh [8] explored hybrid sensor and vision-based occupancy detection using an ESP32-CAM module, which is closely related to the hardware side of our work. While these vision-based systems offer high accuracy, they require significantly more computational resources, higher setup costs, and more complex maintenance compared to simple ultrasonic sensor-based approaches.

On the prediction and data side, Zheng, Rajasegarar, and Leckie [13] proposed parking availability prediction models for sensor-enabled car parks, showing that historical sensor data can be used to forecast availability patterns. Botta et al. [14] and Ballon et al. [15] discussed the integration of cloud computing with IoT systems and the potential of cloud platforms for smart city applications, providing the theoretical foundation for cloud-connected parking dashboards like the one in our system.

From a security perspective, Taylor and Francis [2] examined intelligent intrusion detection in VANET-enabled car parking systems, addressing vulnerabilities in networked parking infrastructure. Singh and Parihar [7] provided a comprehensive review of IoT technologies specifically in smart parking systems, summarizing the strengths and limitations of current approaches across different hardware and software stacks.

## IV. RESEARCH GAP

### *A. Missing in Existing Work*

After reviewing the existing literature on smart parking systems, it is clear that most of the proposed solutions are built with either very high accuracy or very low cost in mind, but rarely both at the same time. Vision-based systems using deep learning and camera networks achieve impressive

detection accuracy but come with significant hardware costs, complex setup requirements, and the constant need for computational resources. On the other hand, simpler sensor-based systems often lack a proper user-facing interface, meaning the detection happens at the backend but the information never reaches the actual user in a convenient way.

Another major gap observed is the dependency on dedicated mobile applications. Several existing systems require users to download and install an app before they can check parking availability, which creates an unnecessary barrier especially for first-time visitors to a mall or college campus. Not everyone is willing to install an app just to find a parking spot.

Additionally, most existing systems are designed keeping large-scale smart city infrastructure in mind, which makes them impractical and financially out of reach for smaller setups like college campuses or mid-sized shopping malls that still face the same parking problems on a daily basis.

### *B. Challenges Not Addressed by Prior Studies*

The particular challenges that prior studies have not fully addressed are as follows. First, the lack of a truly app-free user experience while some systems offer web interfaces, very few combine QR-based instant access with real-time floor-wise slot visibility in a single lightweight solution. Second, the cost and installation complexity of existing systems makes them unsuitable for everyday structured parking environments that do not have large budgets or dedicated technical teams for maintenance. Third, most reviewed systems do not address the experience of the user from the moment they enter the parking area the focus is mostly on detection, not on how that information actually reaches and helps the person looking for a slot in real time.

### *C. The Need for This Work*

This project addresses all of the above gaps by proposing a system that is simple to install, affordable, and genuinely useful from the user's perspective. By using ultrasonic sensors and an ESP32 microcontroller, the hardware cost is kept minimal without compromising on real-time detection capability. By choosing Firebase as the real-time database, the sensor data is instantly reflected on a web-based dashboard without requiring any complex backend infrastructure. Most importantly, by placing a QR code at the parking entrance, any user with a smartphone can instantly access live floor-wise parking availability without downloading any application or creating any account. This makes our system practical, scalable, and ready for real-world deployment in colleges, malls, and any structured parking facility looking for a simple and effective modernization solution.

## V. METHODOLOGY

### *A. Method Components and Workflow*

The proposed Smart IoT-Based Parking Assistance System is built using a combination of hardware components and a web-based software interface that work together to provide real-time parking slot availability to users. The system is divided into three main layers — the sensor and detection layer, the data transmission and storage layer, and the user interface layer.

The first layer consists of HC-SR04 ultrasonic sensors, one installed at each parking slot, connected to an ESP32 microcontroller. The HC-SR04 sensor works by emitting a high-frequency ultrasonic sound wave and measuring the time it takes for that wave to bounce back after hitting an object in front of it. Based on this echo time, the sensor calculates the distance between itself and whatever is present in the slot. During the installation of the system, a threshold distance value is defined for each slot. When a vehicle is parked in the slot, the measured distance drops below this threshold and the slot is detected as occupied. When no vehicle is present, the measured distance remains above the threshold and the slot is treated as available. This simple yet reliable mechanism ensures consistent and accurate detection without requiring any complex computation at the sensor level.

All sensors installed across the parking facility are connected to a single ESP32 microcontroller. The ESP32 is a low-cost microcontroller with built-in Wi-Fi capability, making it well-suited for IoT-

based applications. It continuously polls all connected sensors, reads their distance values, applies the threshold logic to determine the occupancy status of each slot, and prepares this data for transmission. Because the ESP32 handles all the processing locally, no additional server or gateway device is required between the sensors and the cloud.

The second layer is responsible for data transmission and storage. Once the ESP32 determines the status of each parking slot, it sends this information directly to a Firebase Realtime Database over Wi-Fi. Firebase is a cloud-hosted database service that stores and synchronises data in real time across all connected clients. The slot data is organised in a structured, floor-wise format inside the database, where each slot has a unique identifier based on its floor number and slot number, and its value is either "occupied" or "available." The ESP32 continuously updates this database at regular intervals, ensuring that the information stored always reflects the actual ground condition of the parking lot at that moment.

The third layer is the user-facing interface, which is a mobile-responsive website built using React. The website is directly connected to the Firebase Realtime Database and listens for any changes in slot status in real time. Whenever the ESP32 updates a slot value in the database, the change is immediately reflected on the website without requiring the user to manually refresh the page. The website is organised into a home view showing overall floor-wise availability, a floor detail view showing individual slot status with green for free and red for occupied, and a slot selection view where the user can identify the exact location of an available slot.

The entire user journey is designed to be as frictionless as possible. A QR code is placed at the entrance of the parking facility. When a user scans this QR code using their smartphone camera, it directly opens the website in their mobile browser. No application download, no account registration, and no login is required at any point, making the system instantly accessible to any user with a smartphone. This combination of affordable hardware, cloud-based real-time data, and a simple QR-accessible web interface makes the proposed system practical, scalable, and ready for deployment in any structured parking environment such as colleges, shopping malls, or office complexes.

### *B. Diagrams*

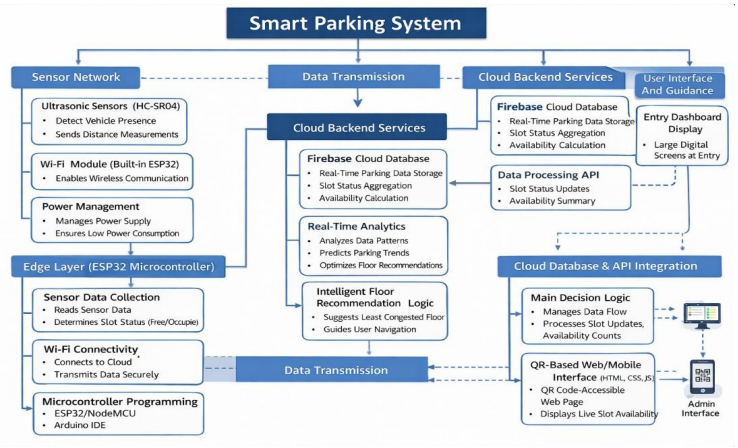


Fig. 1 Proposed system architecture of Smart IoT-Based Parking Assistance System

The Fig. 1 diagram shows the overall architecture of the Smart IoT-Based Parking Assistance System. The system begins at the hardware layer where HC-SR04 ultrasonic sensors detect vehicle presence in each slot and send the data to the ESP32 microcontroller. The ESP32 processes this data and transmits it to the Firebase Realtime Database over Wi-Fi. This data is then instantly reflected on the React-based website accessible to users via QR code scan, as well as on the entrance dashboard display.

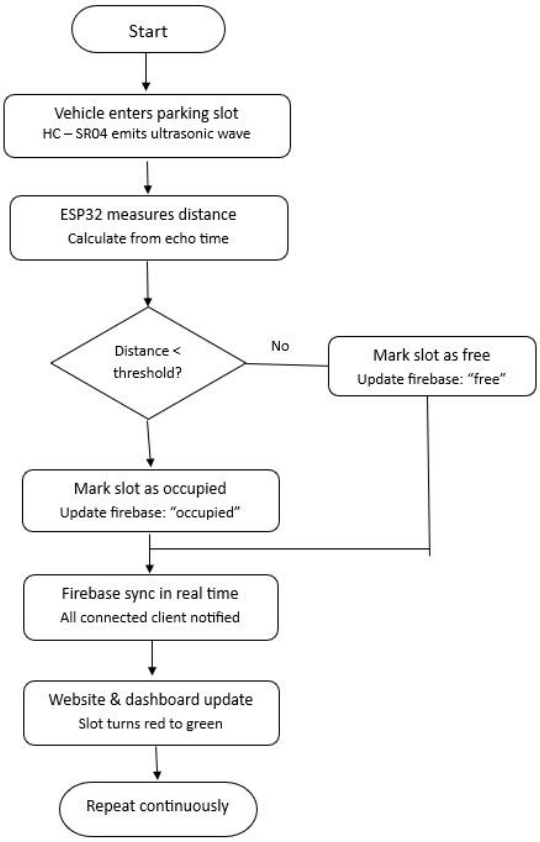


Fig. 2 — Flowchart

The Fig. 2 diagram shows the step-by-step operational flow of the system. The process begins when a vehicle enters a parking slot, triggering the HC-SR04 sensor to emit an ultrasonic wave. The ESP32 measures the returned echo and compares the distance against a predefined threshold. If the distance is below the threshold, the slot is marked as occupied and Firebase is updated accordingly. If the distance is above the threshold, the slot is marked as free. This updated status is then instantly reflected on the website and dashboard for the user to see.

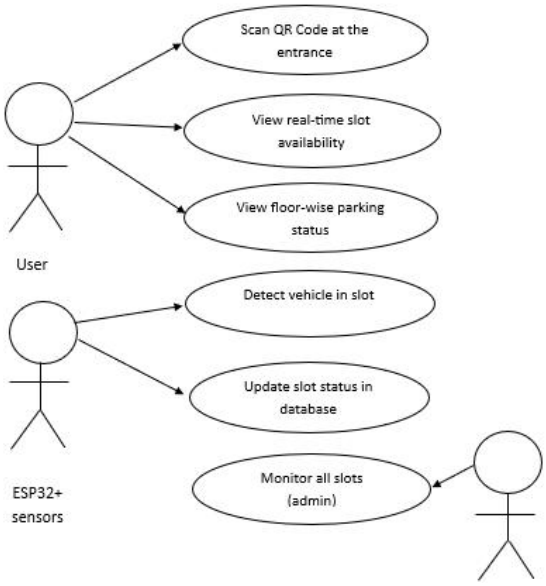


Fig. 3 — Use Case Diagram

The Fig. 3 diagram shows how the three main actors interact with the system. The User interacts with the system by scanning the QR code, viewing real-time slot availability, and checking floor-wise parking status. The ESP32 and sensor together act as a system-level actor responsible for detecting vehicle presence and updating the slot status in the database. The Admin has access to monitor all slots across floors for management purposes. The «include» relationships indicate that scanning the QR code automatically leads to viewing availability, and detecting a vehicle automatically triggers a database update.

## VI. ADVANTAGES

The proposed Smart IoT-Based Parking Assistance System offers several practical advantages over existing solutions that make it suitable for real-world deployment in everyday structured parking environments.

The most notable advantage of this system is its real-time slot detection capability. Since ultrasonic sensors continuously monitor each parking slot and instantly update the Firebase database, the information displayed on the dashboard and website always reflects the current ground reality without any delay. This ensures that users are never misled by outdated information.

The system is also completely app-free from the user's perspective. Unlike many existing smart parking solutions that require a dedicated mobile application, our system only requires the user to scan a QR code at the entrance, which directly opens a mobile-friendly website. This removes any technical barrier and makes the system accessible to all types of users regardless of their technical background.

Cost-effectiveness is another major strength of this system. By using ultrasonic sensors and ESP32 microcontrollers, which are both widely available and affordable components, the overall hardware cost is kept significantly lower than camera-based or deep learning-based alternatives. This makes the system a realistic option for colleges, mid-sized malls, and other structured parking facilities that cannot invest in expensive infrastructure.

The floor-wise display of parking availability further improves the user experience by helping people choose wisely before even entering the parking area, reducing unnecessary vehicle movement inside the facility and contributing to lower fuel consumption and carbon emissions.

Finally, the system is easy to install and maintain. The hardware setup is straightforward, and the web-based dashboard requires no complex server infrastructure, making it manageable even without a dedicated technical team.

## VII. APPLICATIONS

The proposed system has a wide range of practical applications across different types of structured parking environments.

The most direct application is in shopping malls, where parking congestion during weekends and holidays is a common problem. By displaying real-time floor-wise availability at the entrance, the system can significantly reduce the time visitors spend searching for a parking slot and improve their overall experience.

College campuses are another ideal setting for this system. With a fixed number of parking slots shared among students, faculty, and visitors, real-time availability information can help reduce morning rush congestion and make daily parking management much smoother.

The system can also be deployed in hospitals, where patients and visitors are often already stressed and finding parking quickly becomes an important need. Knowing exactly where a free slot is available before entering can make a meaningful difference in such situations.

Beyond these, any structured parking facility such as corporate office complexes, government buildings, railway stations, or bus terminals can benefit from this system. Since the setup cost is low and installation is straightforward, it is a scalable solution that can be adapted to parking lots of different sizes and layouts.

## VIII. CONCLUSION AND FUTURE SCOPE

### A. *Conclusion*

The proposed Smart IoT-Based Parking Assistance System successfully addresses one of the most common yet overlooked urban problems — the inefficiency of finding available parking in structured spaces. By combining affordable ultrasonic sensors, an ESP32 microcontroller, a real-time Firebase database, and a QR-accessible web interface, the system delivers a complete end-to-end solution that is practical, cost-effective, and genuinely easy to use.

Unlike complex existing systems that rely on expensive hardware or require users to install dedicated applications, our system keeps the user experience as simple as possible — scan a QR code and instantly see which floor and slot is available. This simplicity is not a limitation but a deliberate design choice, making the system accessible to everyone from tech-savvy students to elderly mall visitors.

Overall, this project demonstrates that solving real-world problems does not always require complex technology. Sometimes a well-thought-out combination of affordable components and a user-centered design approach can create a solution that is more practical and impactful than systems built with far greater resources.

### B. *Future Scope*

While the current system effectively solves the core problem of real-time parking availability, there are

several directions in which it can be improved and expanded in the future.

One important enhancement would be the integration of a slot reservation feature, allowing users to not just view but also reserve a specific parking slot in advance through the website. This would add another layer of convenience especially in high-demand parking facilities.

The system can also be extended to support automated entry and exit gates that open based on slot availability or reservation status, moving closer to a fully automated parking management solution.

In terms of hardware, replacing ultrasonic sensors with more advanced infrared or magnetic sensors in future versions could improve detection accuracy in challenging conditions such as rain or very bright outdoor lighting.

On the software side, adding data analytics to the dashboard could help parking facility managers understand usage patterns over time, identify peak hours, and plan resources accordingly.

Finally, the system can be scaled up and deployed on a cloud platform such as AWS or Google Cloud to support larger facilities with hundreds of parking slots across multiple floors, making it a genuinely enterprise-ready solution.

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