SPOT FINDER- SMART PARKING SYSTEM USING WIRELESS SENSOR NETWORK

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*Abstract*— In this project, we propose the development of an intelligent parking system that uses wireless sensor networks (WSN) to improve urban traffic management. This system uses sensors installed in each parking space to detect the availability of spaces. The sensors transmit wirelessly to a central office that processes the data and notifies drivers in real time of available parking spaces via a mobile app or mobile app. The goal of this solution is to reduce the time spent searching for a vehicle, reduce traffic congestion and improve mobility in the city. The system can be implemented using low-power protocols and the Internet of Things network to ensure reliable, scalable and cost-effective operation.

Keywords— Wireless Sensor Network, WSN, smart parking system, parking sensors, real-time parking availability, urban mobility, IoT, energy-efficient protocols, data transmission, central hub, parking management, traffic congestion, scalability, sensor communication, smart cities, parking space detection, vehicle parking, wireless communication, energy-saving strategies, urban infrastructure, parking data, simulation, Python libraries, Matplots, Grids.

# Introduction

The management of parking in urban regions has become more challenging as a result of the swift increase in vehicle ownership and the inadequate parking facilities available. In urban areas with high population density, the discrepancy between the need for parking spots and their availability poses considerable obstacles for both motorists and urban developers. Drivers often find themselves investing significant time in maneuvering through congested streets to locate available parking spaces, causing frustration and impacting the urban environment and economy on a larger scale. The extensive hunt for parking has various adverse effects, such as traffic congestion, more fuel being used, elevated air pollution levels, and time being wasted. Research has indicated that in certain urban zones, up to 30% of traffic congestion arises from vehicles circulating in pursuit of available parking spots. The existing inefficiencies highlight the increasing importance of adopting a smart and methodical parking management strategy.[1]

Conventional parking methods like manual ticketing, simple parking meters, or automated barriers frequently struggle to meet the requirements of today's bustling city settings. Most of these systems lack the capability to offer drivers current parking availability information or effective tools for maximizing the use of parking spaces. In traditional systems, imagine a driver arriving at a multi-story parking building with no clue about where to find open spaces, resulting in frustrating delays and traffic congestion. Furthermore, these systems frequently do not have functionalities to dynamically adapt to changing user requirements, like catering to priority customers, managing peak demand, or incorporating flexible pricing mechanisms. Traditional systems lack the ability to effectively address these challenges due to the absence of real-time monitoring and communication capabilities.

The project acknowledges these challenges and proposes the implementation of a Smart Parking Management System (SPMS) that utilizes cutting-edge technologies such as Wireless Sensor Networks (WSN) and the Internet of Things (IoT) to transform the management of parking spaces. The suggested system has been crafted to oversee parking spaces in real-time, offering users immediate updates regarding available spots via a mobile application. SPMS sets itself apart from traditional systems by incorporating sophisticated functionalities that address a wide range of user requirements. These include personalized pricing structures for regular and VIP customers, automatic penalty protocols for vehicles overstaying their time limit, and user-centered notifications for effortless management of parking durations. Drivers are kept informed of parking availability in real-time as they approach a parking lot, thereby reducing the time spent searching for spaces and enhancing overall efficiency.[5]

The innovative foundation of the SPMS is rooted in its advanced utilization of WSN nodes containing sensors like ultrasonic or infrared devices, which identify the parking status of individual spots effortlessly. The sensors transmit information to a centralized cloud server using lightweight IoT communication protocols such as MQTT, facilitating smooth data exchange. The information is processed by the cloud server in real-time, guaranteeing that drivers always have precise and actionable data readily available. The incorporation of IoT technologies not only provides instant updates but also enhances the system's flexibility to cater to larger parking spaces or multi-level parking structures.[3]

# literature survey

## Systems based on RFID technology:

The Utilization of RFID Technology for Smart Parking Systems RFID, which stands for Radio Frequency Identification, utilizes wireless technology by harnessing radio waves to effortlessly identify and track objects, which is why it is widely favored for automating parking systems. In a sophisticated parking system, vehicles come fitted with RFID tags that hold individualized identification details. The RFID readers at the parking lot entry and exit points scan these tags to record when vehicles arrive and leave. The gathered data is transmitted to a backend system for the purpose of determining parking durations and relevant fees. Passive RFID tags draw power from the reader's signal, while active tags are powered by an internal battery, offering enhanced range and reliability. This technology streamlines access control by enabling vehicles with valid RFID tags to enter parking lots smoothly, eliminating the need for manual intervention and vastly cutting down on wait times.[4]

Utilizing RFID technology for Smart Parking solutions. In order to set up an RFID-based parking system, RFID readers need to be placed at entry and exit gates for scanning vehicle tags. Every vehicle needs to have a distinctive RFID tag assigned to it, which can either be attached to the windshield or incorporated into the license plate. The backend system will link readers to a database responsible for monitoring entry and exit logs, computing parking charges, and issuing payment requests. In gated parking areas, the system can integrate with automated barriers to effortlessly open for authorized vehicles. This configuration is highly efficient in enclosed settings such as corporate offices or residential complexes, where vehicles are pre-registered. Nonetheless, ensuring that every vehicle in public parking lots is fitted with RFID tags can pose a challenge, as it necessitates extra infrastructure and user cooperation.

Challenges associated with RFID technology in Smart Parking. RFID systems streamline access control processes, yet they face various constraints that impede their efficiency within ever-changing urban settings. A notable limitation is the absence of real-time monitoring for each parking spot. After entering the parking lot, drivers may still need to navigate through the available spaces, causing delays and inefficiencies. Furthermore, the mandate for all vehicles to be equipped with an RFID tag presents a logistical hurdle, especially for individuals who are occasional users or visitors lacking the essential tools. External elements, like metal obstructions or inclement weather, have the potential to diminish the precision of RFID scanners, resulting in missed readings or inaccurate information. Moreover, RFID systems are susceptible to security flaws, as tags have the potential to be replicated or intercepted, allowing unauthorized entry into secure zones. These constraints underscore the necessity for more sophisticated solutions, like IoT-enabled systems, which can offer real-time updates, seamlessly integrate with mobile applications, and present a scalable method to address contemporary parking hurdles.

## Systems that utilize cameras:

Camera-based systems are increasingly preferred for parking management due to their utilization of image processing technologies to identify vacant parking spots, monitor vehicle movements, and enforce parking regulations effectively. Nevertheless, despite their sophisticated capabilities, these systems encounter various notable constraints that may impede their efficiency and efficacy in practical situations, especially in expansive urban settings.A significant drawback of camera-based systems lies in their expensive nature, which encompasses the initial setup costs as well as the continuous maintenance expenses. Placing cameras throughout an entire parking facility or multi-level parking structure involves a substantial amount of investment, particularly if high-resolution cameras are necessary for precise vehicle detection. Additionally, it is essential to conduct routine maintenance, cleaning, and replacement of any damaged equipment on these cameras, as they may be subject to wear and tear or vandalism. In the case of expansive parking lots, expenses can rise swiftly, rendering this method less financially feasible when compared to alternative parking management options.[8]

One other significant challenge is the vulnerability of camera-based systems to environmental factors. Insufficient lighting, like in the evening or in enclosed parking locations, may hinder the system's capability to effectively detect vehicles or empty spaces. In the same vein, unfavorable weather conditions such as rain, fog, or snow may interfere with camera lenses, leading to decreased accuracy. These factors may result in inaccurate alerts or overlooked notifications, causing inefficiencies and potentially disappointing users who depend on up-to-date parking availability information. In areas experiencing harsh weather, these systems may face challenges and may need extra support such as protective coverings, artificial lighting, or supplementary sensors to ensure they operate effectively

In addition, camera-based systems are constrained by limitations in scalability and processing capabilities. To effectively monitor expansive parking areas or multi-level structures, it is essential to have a sophisticated network of cameras paired with a reliable backend system equipped to manage large amounts of video data smoothly. The ongoing analysis of video streams to detect vehicles and spaces utilizes a considerable amount of computing resources, resulting in delays and higher operational expenses. The importance of incorporating complementary technologies like IoT-enabled sensors or hybrid methods is underscored by these limitations. They help tackle the issues of cost, environmental impact, and scalability that camera-centric systems encounter in contemporary parking management.

## Systems based on IoT sensors:

IoT-enabled sensors such as ultrasonic or infrared are placed in every parking space to accurately monitor vehicle occupancy in real-time. One of its key strengths lies in the ability to offer real-time updates, allowing drivers to effortlessly locate available parking spaces via user-friendly mobile or web interfaces.

Challenges include vulnerability to single-point failures, restricted fault tolerance, and absence of advanced functionalities like dynamic pricing and energy efficiency.[6][10]

## Suggested Framework:

The suggested framework addresses the shortcomings of conventional parking systems by incorporating cutting-edge technologies like Wireless Sensor Networks (WSN), Internet of Things (IoT), and cloud computing. At the heart of this model lie WSN nodes featuring ultrasonic or infrared sensors that keep track of the occupancy status of each parking spot. The sensors gather live data and effortlessly send it wirelessly to a centralized server through lightweight IoT communication protocols such as MQTT. This method guarantees reliable and energy-efficient data transmission, even in vast parking areas. The incorporation of WSN nodes removes the necessity for costly camera systems or RFID setups, thus providing a cost-efficient and easily adaptable solution. The system enhances the overall efficiency of parking operations by offering real-time updates on parking availability, ultimately reducing the time drivers need to search for parking spots.

One significant aspect of this framework is the distinction made between VIP and standard parking zones. VIP zones provide exclusive amenities, like convenient locations near entrances or exits, for a fixed fee, whereas standard zones follow a pricing structure that varies depending on the duration of parking. This sophisticated pricing system is designed to meet the varied requirements of users while also optimizing revenue generation from parking facilities. Moreover, the system seamlessly incorporates a cloud-based backend to handle and retain the gathered data, ensuring both scalability and fault tolerance. The cloud infrastructure offers sophisticated features like dynamic pricing adjustments, penalty enforcement for vehicles staying beyond the allotted time, and smooth integration with mobile applications. The sturdy backend allows the system to adjust to changes in demand smoothly and guarantee consistent performance, even when experiencing high usage levels.

The user interface has been crafted to revolve around a mobile application offering immediate updates and tailored notifications. Motorists have the ease of checking parking availability, estimated fees, and payment methods straight from their smartphones, thereby improving convenience and user contentment. The proposed system seamlessly integrates these features to tackle the primary limitations of current solutions while also prioritizing energy-efficient communication, scalability, and precision. This inclusive framework presents itself as a groundbreaking solution for effectively managing urban parking in today's cities, delivering substantial advantages for both drivers and parking facility operators.

# SYSTEM DESIGN

# The design of the Smart Parking Management System (SPMS) comprises cutting-edge technologies seamlessly integrated to enable real-time monitoring, effective communication, and flexible parking space management. The integration of parking sensors, IoT communication protocols, cloud-based infrastructure, and a user-friendly mobile application results in a smooth and scalable solution being delivered by the system. Here is a thorough breakdown of each component and its function within the system*.*

## Parking Sensors

# Parking sensors form the cornerstone of the system, crafted to monitor the availability of each parking space. Elegant ultrasonic or infrared sensors are placed at each parking spot to determine if a vehicle is parked or if the space is available. These sensors offer precise readings, guaranteeing consistent detection even in dimly lit or obstructed parking zones. The sensors are connected to nodes in the Wireless Sensor Network (WSN), creating a mesh network that efficiently transmits data throughout the parking lot. The mesh network structure in place guarantees the system's ability to expand smoothly and handle vast parking areas without the need for extra communication infrastructure.[5]

# Every parking sensor function with low power consumption, ensuring that the system is energy efficient. The mesh network established by the WSN nodes provides redundancy and fault tolerance by allowing data from a defective node to be redirected through adjacent nodes. The sturdy design allows for seamless data collection and transmission, even if there are minor network glitches. The parking sensors are finely tuned to prevent mistakenly detecting non-vehicle objects as parked, which strengthens the precision and dependability of the system.

## Communication using IOT

# Smoothly enabling effective communication between the parking sensors and the central server are IoT protocols like MQTT (Message Queuing Telemetry Transport) or CoAP (Constrained Application Protocol). These lightweight protocols have been intricately crafted for IoT environments, guaranteeing reliable and energy-saving data transmission.[9]

# **MQTT** is well-suited for parking systems because it ensures dependable communication, even when bandwidth is limited. It utilizes a publish-subscribe framework, in which the WSN nodes, acting as publishers, transmit occupancy data to a central broker. This broker subsequently disperses the data to the cloud server and other recipients, including the mobile application. This architectural design minimizes network congestion and decreases delays, guaranteeing that end-users receive real-time updates.

# **CoAP** is a protocol designed specifically for limited devices and networks. It runs on UDP (User Datagram Protocol), ensuring a streamlined and quicker performance compared to conventional TCP-based protocols. The simplicity and minimal resource demands of CoAP present a viable choice for smaller parking systems or locations with limited connectivity. The utilization of these IoT protocols facilitates a smooth integration of system components and guarantees effective data management, particularly in settings with constrained computational resources.

## Cloud based

# The cloud server serves as the system's central hub, taking charge of managing, processing, and storing parking data. This feature ensures that the system can easily handle various parking scenarios, whether it's in large parking lots or multi-level parking facilities. The cloud server gathers live data from the WSN nodes and carries out sophisticated processing to enhance the capabilities of the system. The cloud server is responsible for overseeing essential functionalities.[11]

# Dynamic Pricing is utilized by the server to determine parking charges by employing predefined pricing models, which include tiered rates for regular customers and fixed rates for VIP zones.

# Penalty Enforcement: When vehicles exceed their designated parking time, they are marked, and penalties are computed automatically.

# Scalability is a key feature of the cloud infrastructure as it can effortlessly accommodate a growing number of sensors and users without compromising performance, which makes it a perfect choice for scaling up parking facilities.

# Apart from handling data processing, the cloud server guarantees data security and redundancy using encryption and regular backups. This guarantees the system's continuous operation and security, even when faced with hardware malfunctions or cyberattacks.

## Mobile Application UI:

The mobile application serves as the main platform for users, delivering instant updates and engaging features. Crafted for iOS and Android platforms alike, the application prioritizes user experience and convenience. It provides essential details on parking availability, current rates, and estimated costs, allowing users to make well-informed choices on when and where to park.[8]

Noteworthy aspects of the mobile application encompass:

* Users can check real-time availability updates by viewing a map of the parking lot, which shows vacant spots in green, occupied spots in red, and VIP spots in blue. This helpful feature guides drivers straight to the closest available parking spot, reducing the time they spend searching for parking.
* The application conveniently sends notifications and alerts to remind users when their parking time is nearing expiration, thus helping to avoid penalties for overstaying. It additionally informs users about any accumulated penalties or alterations in pricing that may occur throughout their parking session.  
  Users have the option to access comprehensive cost breakdowns, which encompass base charges, extra hourly rates, and any incurred penalties. This feature enhances transparency and assists users in effectively planning their parking budgets.
* Smooth Rewritten Text: The application seamlessly incorporates secure payment methods, enabling users to conveniently pay for their parking within the app itself. This effectively removes the necessity for traditional payment methods, making the process of parking more efficient.

The mobile application effortlessly links to the cloud server using IoT protocols, guaranteeing users receive prompt updates and notifications. The user-friendly design and real-time functionality seamlessly integrate it into the Smart Parking Management System.

# SYSTEM IMPLEMENTATION

## Setting up the hardware:

Ultrasonic or infrared sensors have been placed at every parking spot to identify if a vehicle is parked there. Microcontrollers such as Arduino or Raspberry Pi are employed to gather sensor data and send it to WSN nodes. WSN nodes have been set up to establish a mesh network to ensure dependable data transmission.

## Setting up the software:

Back-end: Built with Flask/Django for handling sensor data and implementing pricing algorithms. It incorporates cloud services such as AWS IoT Core to store and analyze data.

## User Interface:

A mobile application developed with React Native showcases up-to-the-minute parking availability and estimates the associated costs. Provides a user-friendly interface suitable for both VIP and regular customers.

## Integration of cloud services:

A centralized cloud server efficiently handles and store’s parking data to guarantee scalability. The server is responsible for managing notifications, calculating costs, and enforcing penalties.

# COMPARISSION OF PROPOSED AND EXISTING SYSTEMS

|  |  |  |  |
| --- | --- | --- | --- |
| Feature | RFID based system | Camera based system | Proposed system |
| Real-time | No | Yes | Yes |
| Scalability | Medium | High | High |
| Cost efficiency | High | Low | High |
| Energy efficiency | Medium | Low | High |
| User differentiation | No | No | Yes |

**Table 1: Comparison Table [2][10]**

# RESULTS

The simulator created as part of this project serves an essential function in virtually evaluating and showcasing the capabilities of the proposed Smart Parking Management System (SPMS). Developed using Python and utilizing the Matplotlib library, the simulator constructs a virtual parking area that can hold up to 100 vehicles. This virtual setting replicates real-life situations by producing random car arrivals and departures, mimicking the interactions of a working parking lot.

The simulator computes vital metrics like arrival times, departure times, parking lengths, and the total fee for utilizing the parking facility. It also distinguishes between VIP and regular clients, offering specialized functionalities such as prioritizing VIP vehicles for premium parking slots while ensuring that non-VIP vehicles get assigned the closest available space.

* Payment System: The payment framework within the simulator mirrors the pricing scheme employed in the SPMS:

1. VIP Customers: Billed a standard rate of $2 each hour with no penalties for overextended durations. This guarantees clarity and predictability in charges for premium clientele while highlighting the system’s focus on user-friendly VIP services.
2. Regular Customers: A varied, tiered pricing framework is applied:
   1. The first hour costs $4.
   2. The second hour adds $3 to the total, totaling $7 for a maximum of two hours.
   3. From the third hour onwards, each extra hour incurs a cost of $2.
   4. If a vehicle exceeds five hours of parking, a penalty of $25 is added to the total charge.
3. This framework not only encourages short-term parking but also deters excessive use of parking areas by imposing a penalty for overstaying.

* Simulation Results: To confirm the proposed system, the simulator conducted several trials with randomized inputs. Presented below are the results of one such trial run:

1) System Performance

* 1. Total Cars Processed: 70 vehicles, including both VIP and regular customers.
  2. VIP Customers: Between 10 and 15 VIP vehicles were randomly allocated, occupying designated premium parking spaces.
  3. Regular Customers: The remaining 55–60 vehicles were classified as regular customers.
  4. Average Parking Time: Around 2.5 hours per vehicle, reflecting a combination of short and medium-duration parking sessions.

2) Statistical Analysis

The simulator monitored parking success rates and duration distributions:

a) Successful vs. Failed Parking:

Successful: 95% of vehicles managed to secure a parking spot.

b) Failed: 5% of vehicles could not park due to full capacity, emphasizing the necessity of dynamic

parking management in high-demand situations.

3) Parking Time Distribution:

a) 45% of vehicles parked for under 2 hours, indicating short-term usage trends.

b) 50% of vehicles parked for 2–5 hours, signifying medium-term parking durations.

c) 5% of vehicles surpassed 5 hours, incurring penalties for overstaying.

* Revenue Analysis: The simulator also assessed the revenue generated during the trial:

1) Total Revenue: Approximately $400, demonstrating the system’s capability to produce significant income even during limited operational periods.

2) VIP Contributions: VIP customers contributed about $80 through fixed-rate pricing, reinforcing the importance of premium services in generating revenue.

3) Regular Contributions: Regular customers comprised the remaining revenue, with dynamic pricing successfully balancing affordability and profitability

.

* Key Insights from Simulation-

1. Efficiency:

The simulator’s findings highlight the system’s effectiveness in managing high-demand parking situations while reducing failed parking attempts.

1. Scalability:

The design showcased its ability to accommodate a significant number of vehicles with minimal interruptions, providing scalability for larger parking facilities.

1. User Satisfaction: The layered pricing strategy, coupled with real-time space distribution, creates an equitable and clear system for regular customers while granting VIP users ease and predictability.
2. Penalty Effectiveness: The penalty system promotes effective use of parking resources by discouraging prolonged stays, thus maximizing space availability for new arrivals. By closely mimicking real-world parking behaviors, this simulator showcases the practicality and strength of the SPMS.

The statistical and financial data acquired confirm the system’s efficiency, scalability, and capability for generating revenue, establishing it as a feasible solution for contemporary urban parking issues. The simulator acts as a basis for future improvements, such as incorporating machine learning algorithms to forecast parking demand or executing dynamic pricing models based on real-time demand trends.

A green square with black squares

Description automatically generated with medium confidence

**Fig 1:** Display of the virtual parking space

A screenshot of a computer

Description automatically generated

Fig 2: Snap of the results of the simulator

# ADVANTAGES, LIMITATIONS AND FUTURE IMPLEMENTATION

* **Pros**:
  + Scalable and cost-effective solution for urban parking lots.
  + Energy-efficient WSN protocols ensure sustainability.[3]
  + Differentiated pricing improves user satisfaction.
  + Real-time updates reduce search times and traffic congestion.[8]
* **Cons:**
  + Initial setup cost for sensors and WSN nodes.
  + Dependence on network infrastructure for real-time updates.

**Future Enhancements**:

* + Dynamic Pricing: Adjust pricing based on demand and time of day.
  + Reservation System: Allow users to reserve parking spots in advance.
  + Machine Learning Integration: Predict parking availability based on historical data.
  + Solar-Powered Sensors: Reduce energy consumption and improve sustainability.
  + Integration with Smart Cities: Connect with traffic management systems to further optimize urban mobility.

# conclusion

The Smart Parking Management System utilizes WSN and IoT technologies to offer a streamlined, adaptable, and user-centric resolution to urban parking issues. The system enhances parking utilization, reduces congestion, and elevates the user experience by implementing VIP differentiation, tiered pricing, and real-time updates. Additional improvements in the future could enhance the system even more by integrating it with larger smart city projects.

##### References

1. IoT Enabled Smart Parking System, IEEE Internet of Things Journal, vol. 5, no. 6, pp. 4279–4288, Dec. 2018.
2. A Survey on IoT-Enabled Smart Parking Systems, IEEE Communications Surveys & Tutorials, vol. 22, no. 1, pp. 524–543, 2020.
3. Energy-Efficient Parking Management Using IoT, Proceedings of the IEEE International Conference on Green Computing and Communications (GreenCom),
4. pp. 218-224, 2020.
5. Smart Parking Management Using RFID and IoT Technologies, IEEE Transactions on Industrial Informatics, vol. 16, no. 8, pp. 5197–5206, Aug. 2020.
6. A WSN-Based Smart Parking System for Urban Areas, Proceedings of the IEEE International Conference on Smart Cities (ISC), pp. 142–147, 2019.
7. Dynamic Pricing for Smart Parking Systems Using IoT, IEEE Internet of Things Journal, vol. 8, no. 3, pp. 2452–2460, Feb. 2021.
8. Hybrid IoT Framework for Smart Parking Systems, Proceedings of the IEEE International Conference on Internet of Things (IoT), pp. 305–311, 2020.
9. Real-Time Smart Parking Systems Using Machine Learning and IoT, IEEE Transactions on Intelligent Transportation Systems, vol. 22, no. 4, pp. 2325–2335, Apr. 2021.
10. A Cloud-Based Smart Parking Solution Using MQTT, Proceedings of the IEEE International Conference on Cloud Computing (CLOUD), pp. 125–132, 2019.
11. IoT and WSN Integration for Efficient Smart Parking Systems, IEEE Sensors Journal, vol. 21, no. 10, pp. 11844–11855, May 2021.