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# Smart Parking: An IoT-Enabled Solution for Efficient Vehicle Management

**Dr. Soumitra Das**
Department of Computer Engineering, Indira College of Engineering and Management
Pune, India
soumitra.das@indiraicem.ac.in

## Abstract

A significant challenge facing modern cities is maximizing the efficiency and sustainability of their urban infrastructure, including reducing road congestion by utilizing limited parking facilities to their full potential. With the growing number of vehicles on the road, especially during peak hours, it becomes difficult for drivers to find a parking spot. To address this challenge, there is increasing interest in the capabilities of the Internet of Things (IoT) which allows for the detailed monitoring of physical objects and environments through low-cost, low-power sensors and communication technologies. This paper presents a Smart Parking Management System based on wireless sensor network technology that offers advanced features such as remote parking monitoring, automated guidance, and parking reservation. The system utilizes IEEE 802.15.4 Wireless Sensor Network and IoT technology, and employs an efficient shortest path algorithm (haversine formula) to find the minimum distance between the user and each parking lot. This reduces the waiting time for the user. The system also uses RFID technology to minimize cost and minimize human intervention. The system is capable of collecting data on the occupancy status of parking areas and directing drivers to the nearest available spot through a custom software application.

**Keywords:** Urban infrastructure, Internet of Things (IoT),Wireless Sensor Network,Parking Management System,Shortest path algorithm

## Introduction

By 2050, it is estimated that 70% of the global population will reside in cities and nearby regions. To ensure their economic, social, and environmental sustainability, these cities must be efficiently managed. One of the biggest challenges faced by city dwellers is finding a parking spot during peak hours. Studies show that 30% of downtown traffic congestion is caused by drivers searching for a parking space, and they can spend 5 to 10 minutes on average looking for a spot. This not only leads to a waste of time and fuel but also contributes to air pollution and driver frustration. The advancements in Internet of Things (IoT) technology have created opportunities to develop innovative smart parking systems that can alleviate traffic congestion and improve the quality of life for citizens.

Two of the most promising wireless technologies for smart environments are Radio Frequency Identification (RFID) and the IEEE 802.15.4 Wireless Sensor Network (WSN). RFID is a low-cost, low-power technology that uses passive devices called tags to transmit data when powered by an interrogator, called a reader. Since passive RFID tags do not require a power source, their lifetime can be measured in decades.

In this paper, a prototype of a smart parking system is designed and implemented. The system is intended to provide real-time parking information to drivers as well as a reservation service. An RFID reader is used to read the RFID tag and authenticate user information. All the parking spaces in the designated area are connected to form a parking network, which uses WSN nodes equipped with various sensing, computation, and communication units to

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collect, process, and transmit information to a central point. This proposed smart parking solution is cost-efficient, automatic, real-time, and easy to use, and can manage individual parking areas while providing automatic guidance and advanced reservation services.

**Literature Survey**

This paper [1] presents a new algorithm for improving the efficiency of a cloud-based smart parking system using IoT technology. The system helps users find a free parking space at the lowest cost by considering distance and the number of available spots in each parking lot. The cost is used to provide a solution for finding a parking space upon request or suggesting an alternative if the current lot is full. The algorithm was shown to improve the chances of successful parking and minimize wait time through simulation and real-world implementation.

This paper [2] proposes an IoT-based solution to automate parking management and allocate efficient parking spaces. The system provides wireless access and allows the user to track parking availability. The solution aims to reduce road congestion in metropolitan cities caused by the growing population of vehicles. The system sends notifications to the user to minimize the wait time for a parking space. RFID technology is also used to prevent car theft.

This paper [3] proposes a "smart parking" system for urban areas that assigns and reserves the optimal parking space for drivers based on a cost function that takes into account proximity to their destination and parking cost. The system solves a mixed-integer linear programming problem at each time-driven decision point to allocate resources optimally and updates the solution at each decision point to prevent conflicts and ensure that drivers are never assigned a space with a higher cost than their current cost. The system was shown to reduce average wait time, parking cost, and improve parking utilization compared to uncontrolled parking processes or guidance-based systems. The implementation of the system was tested in a garage and a new lighting system was proposed to support user reservations.

This paper [4] presents a method for parking planning in the context of smart parking systems. The increasing number of vehicles in the world has led to parking problems and the development of smart parking systems. Effective parking planning is essential to make the best use of parking resources. The parking planning problem is transformed into a linear assignment problem, where vehicles are considered as jobs and parking spaces as agents. The distances between vehicles and parking spaces are used as costs for agents doing jobs. An algorithm is designed to solve this assignment problem and provide timely and efficient guidance information to vehicles in real-time. The effectiveness of the method is demonstrated through experiments using data that simulates real-world parking planning situations.

This paper [5] discusses the issue of traffic bottlenecks caused by the rapid growth in population and the need for smart parking solutions in the age of IoT and smart city ecosystems. Smart parking, using sensors embedded in cars and city infrastructure, can help alleviate parking problems and provide better quality of service and profits to citizens. The paper classifies smart parking systems while considering design factors and overviews the commonly used enabling technologies and sensors. It highlights the importance of data reliability, security, privacy, and other critical design factors in such systems and investigates emerging parking trends in the ecosystem. The paper also outlines open research issues in the current state of smart parking systems and recommends a conceptual hybrid-parking model.

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The paper [6] presents a Smart Parking Energy Management solution for multi-storied office parking areas. The system uses IoT technology and advanced Honeywell sensors and controllers to provide a systematic parking experience for users. Unoccupied spaces are indicated with lamps and occupied spaces are stored virtually in the cloud to be accessed by the central system. The automatically controlled lighting helps reduce energy usage and improves the aesthetics of the parking area. The fully automatic system leads to reduced manpower and improved user convenience and time value in the parking process.

The proposed solution in the paper [7] is an innovative approach to tackle the issue of finding parking spaces in populated cities. The system combines IoT technology and an Android application to guide users to the nearest available parking slots and manage the parking space. The system allows pre-booking and tracking of parking, reducing human dependency and errors. The results of the implementation show a reduction of time by 70\% and the number of workers by 40\%, leading to a lower cost for the system compared to existing ones.

The proposed solution in the paper [8] is an intelligent parking system using IoT and mobile technology to tackle the issue of locating parking spots in crowded cities. The system aims to assist users in finding the best parking spot and reducing congestion, using cloud-based storage for all data related to vehicles and parking space. The 5G network will be utilized for better connectivity and efficient data transfer and storage. The design will enhance the overall smart parking system and simplify vehicle management through the physical connection to the 5G network.

## System Architecture

### A. Proposed System

In this section, we aim to describe the design of a Smart Parking Management System that includes WSN, Sink, Parking Management, Automatic Steering, Entrance Display, and Customer Reservation subsystems. The proposed system is shown in fig.1.

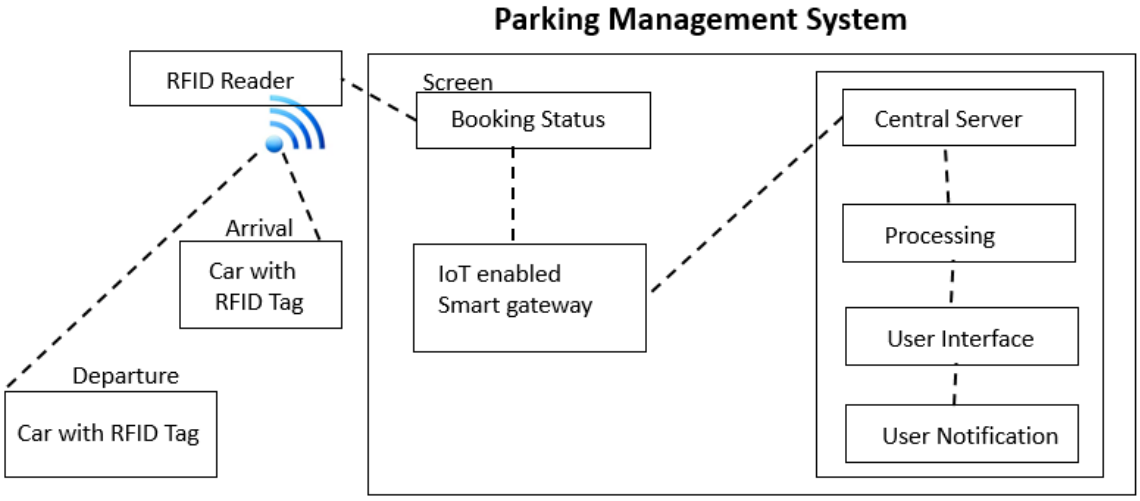


Fig.1: System architecture of parking management system

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The system will be capable of visually displaying real-time data related to the availability of car parking spaces to users and will also allow users to reserve parking spaces from remote locations. The system will also be capable of efficiently guiding users to vacant parking spaces so they can quickly and safely park their cars.

### B. Subsystems Description

The design is divided into six major subsystems as mentioned. The functions of each subsystem are as follows:

- **WSN Subsystem:** The primary function of the WSN system is to monitor the availability of parking spaces. This is achieved through the use of a hybrid sensing technique that detects the presence of vehicles in parking spaces. The status information is then transmitted wirelessly using RF technology. The system can also receive commands from the Parking Management Subsystem to carry out specific actions. In this system, Zigbee communication protocol is utilized, as depicted in Fig.2.

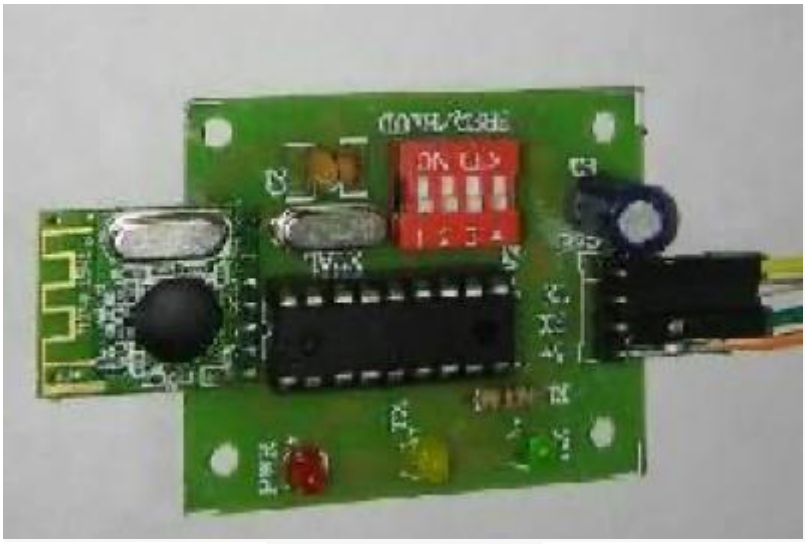

Fig. 2. Zigbee Circuit

- **Sink Subsystem:** The sink system serves as the intermediary between the WSN system and the Parking Management System. It gathers the parking status reports from the WSN system and conveys them to the Parking Management System. The sink system operates as a bridge between the wireless sensor network and external networks, as depicted in Fig.3. Additionally, the sink system transmits data regarding changes in parking status received from the management system to the guidance system through RF interfaces.

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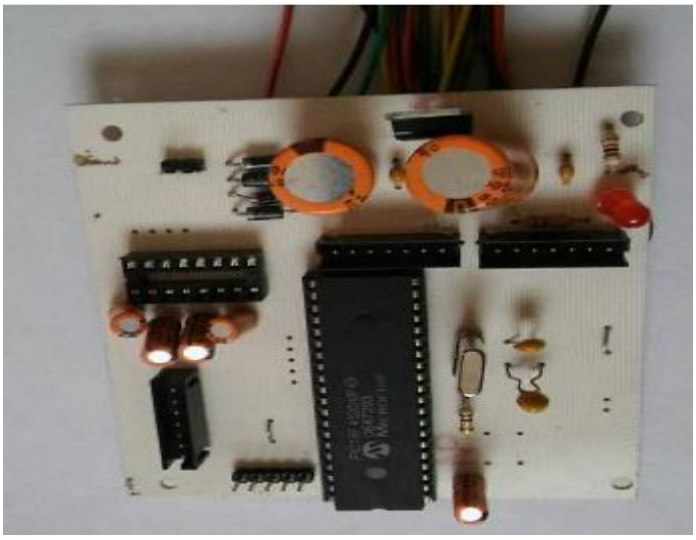

Fig. 3. Components assembled on PCB board

- **Parking Management Subsystem:** The Parking Management Subsystem serves as the central component of the entire SPS system. When the sink subsystem sends information to the Parking Management Subsystem, the entrance transceiver module associated with the subsystem receives the information, processes it, and forwards it to the information module. Conversely, information can also be sent from the information module to the entrance transceiver module. The information module stores sensor information and the health status of sensor nodes, which is collected by the Parking Steering Module and displayed on the car parking space graphical user interface. This module also displays the health information of the sensor nodes, which is retrieved from the sensor health monitoring module. The Parking Entrance Display module in the subsystem receives consolidated status information from the information module, processes the data, and sends it to the Parking Entrance Display. When a customer reserves a parking space, the reservation message is forwarded to the Parking Reservation Module running on the Parking Management Subsystem. The module retrieves information from the sensor information module to determine the availability of parking spaces and sends an acknowledgment to the customer based on that information.

- **Entrance Display Subsystem**: This system is designed to help drivers find an available parking spot quickly and efficiently. It is placed at the entrance of the parking facility, allowing drivers to view the current availability of parking spaces before they enter the parking lot. The system displays real-time information about the number of open spots and where they are located within the parking facility.

By using this system as shown in Fig.4, drivers can avoid driving around aimlessly looking for a spot, saving time and reducing traffic congestion. This is especially useful in busy areas where finding a parking spot can be a challenge. Additionally, the system provides valuable information to the parking facility operator, allowing them to monitor the utilization of their parking spaces and make informed decisions about managing their resources.

Overall, the system at the entrance of the parking facility helps drivers find parking spots more efficiently, reduces traffic congestion, and provides valuable information to the parking facility operator.

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Fig. 4. Screen using LCD Display

- **Client Subsystem:** The client subsystem is a crucial component of the SPARK (Smart Parking) system, as it allows users to remotely interact with the system and reserve a parking spot. The client subsystem consists of a Parking Reservation interface, which is a user-friendly front-end application that runs on the users' devices (such as smartphones or laptops). Through the Parking Reservation interface, users can provide their parking details, such as their license plate number and the time they plan to park, to reserve a parking spot. This information is then processed by the client application and sent to the parking management system for processing. The parking management system uses this information to allocate a suitable parking space for the user's vehicle. The client subsystem offers a convenient and efficient way for users to reserve a parking spot, as they can do so from the comfort of their own devices. This eliminates the need for users to physically be present at the parking facility to secure a spot. It also reduces the waiting time and frustration associated with finding a suitable parking spot, as users can reserve their spot in advance.

- **Subsystem Interactions:**The Wireless Sensor Network (WSN) system plays a crucial role in monitoring the status of a car parking zone. The WSN subsystem is equipped with sensors that can determine if a particular parking spot is occupied or vacant. Once it has this information, it sends updates to the sink subsystem through the RF communication unit. These updates trigger a change in the status display, which shows the availability of each parking spot. The sink subsystem is responsible for receiving messages from the WSN and processing the information before sending it to the management system. This processed information is then stored in the information module of the status display. This ensures that the information is easily accessible and up to date at all times.The client subsystem allows users to reserve a parking spot by submitting their details. The management system can then access the information module of the status display to check the availability of parking spots. If a spot is available, the reservation can be confirmed, and the information updated accordingly.

**Experimental Result**

The experiment outcomes demonstrate the effectiveness and practicality of the suggested IoT-based smart car parking system in an economical manner. The proposed complete system is depicted in Fig.5.

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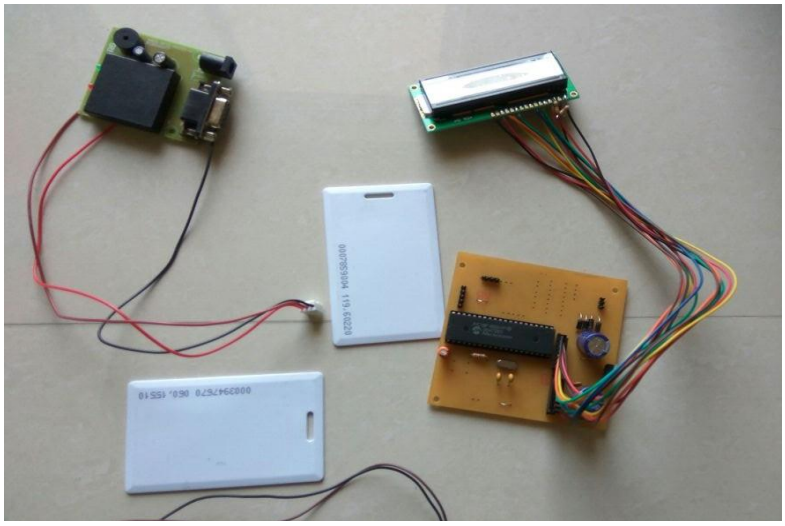

Fig. 5. Proposed complete system

The Parking Reservation and Management System is designed to provide a convenient and efficient way for users to find and reserve parking spots. With the ability to book a spot from a remote location, users can plan ahead and be assured of having a spot available when they arrive at the parking lot. The visual interface makes it easy to see which spots are currently available and which have been occupied, reducing the frustration of driving around a lot looking for an open spot.

| Parking Reservation Status | | | | |
|---|---|---|---|---|
| PL001 | PL002 | PL003 | PL004 | PL005 |
| PL006 | PL007 | PL008 | PL009 | PL010 |
| -- | -- | -- | -- | -- |
| PL100 | PL101 | PL102 | PL103 | PL104 |

Reserved / Occupied

Available

Fig. 6. Parking lot status

In Fig.6, the green colour areas represent available parking spaces while the red colour ones indicate parking spaces that have already been reserved or are occupied.

In addition to making parking more convenient, the system also provides an enhanced level of security. By using blacklisted RFID tags to detect stolen vehicles, the system can alert the authorities and assist in the recovery of stolen vehicles. This added level of security can provide peace of mind to users and parking lot operators alike.

Overall, the Parking Reservation and Management System can improve the experience of parking in busy areas and make it more efficient, convenient, and secure. It can benefit both users and parking lot operators by providing a more streamlined and controlled parking experience.

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## Conclusion

In this paper, we detail the design and implementation of a Smart Parking Management System using wireless sensor networks. The aim was to address the limitations of current car parking management systems through a comprehensive analysis of their requirements. This led to the development of a system architecture and its various subsystem-level components. To demonstrate the feasibility of the proposed system, we created a fully functional prototype model. Our results showed that the system architecture is capable of effectively managing car parks and fulfilling the needs of users. We believe that the use of wireless sensor networks in this manner holds significant potential for solving future parking issues and improving the overall parking experience.

## Future Work

In future work, we aim to expand the implementation of this technique beyond the current application in car parks to other platforms such as railway stations, airports, and mall parking lots. By doing so, we hope to streamline the management of these parking areas, reducing the need for manual labour and increasing efficiency.

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