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# Finding the Spot: IoT enabled Smart Parking Technologies for Occupancy Monitoring – A Comprehensive Review

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## Abstract

Major cities in India have a significant number of vehicles, and the rate of ownership is increasing every day. However, the lack of proper parking infrastructure in these cities causes problems such as difficulty in finding parking spaces. According to the Urban Mobility Survey 2023 by Times Network, nearly 74% of vehicle owners in metropolitan cities struggle to find a parking slot. Various measures have been implemented to address this issue. One of the most promising measures is a smart parking management system. This system can use technologies like Radio Frequency Identification (RFID) and Automatic License Plate Recognition (ALPR) to make check-in and check-out easier. It can also include Wireless Sensor Networks (WSN), wired sensors, or visual occupancy detection to provide real-time occupancy status. The smart parking management system can offer useful services through mobile or web applications such as parking occupancy monitoring, reservation, payment gateway, occupancy prediction, automated check-in and check-out, and parking record management. The purpose of this review paper is to summarize the works undertaken in the field of smart IoT parking systems and educate the technological community about the technologies, features, and procedures for implementing the smart parking management system. In the paper, we aim to summarise the works on occupancy monitoring in smart IoT parking systems addressing the advantages and issues of the present occupancy monitoring methods, also suggesting future inclusions for smart IoT parking systems.

**Keywords:** Internet of Things, Smart Cities, Sensors, Occupancy monitoring, Wireless Sensor Networks, Radio Frequency Identification, Payment options.


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## 1. Introduction

Indian cities grapple with daily traffic issues, including speeding, signal jumping, accidents, and congestion due to illegal parking. Illegally parked vehicles exacerbate congestion and safety concerns. Efforts by municipalities and private entities have led to the development of sophisticated parking infrastructure, often incorporating smart management systems. These systems leverage the IoT for user convenience and administrative efficiency. While complexity enhances the user experience, cost optimization remains crucial for stakeholders. Features vary across systems but typically include user-friendly interfaces and administrative controls.

### 1.1 List of Functionalities of the Smart Parking Management System

The functionalities provided by the smart parking management system are as follows.

**1. Parking Occupancy Status Display:** Shows available and occupied slots, useful for staff and users.

**2. Improper Parking Detection:** Alerts if vehicle alignment disrupts others, for user and staff awareness.

**3. Automatic Vehicle Authentication:** For user convenience, plate number identification and automatic logging.

**4. Multifactor Authentication:** Prevents vehicular identity theft, ensuring parking record authenticity.

**5. Navigational Assistance to Nearest Parking:** Helps users find the closest available parking spots.

**6. Finding Parked Vehicle Location:** Users can locate their parked vehicle through the app.

**7. Reserving Parking Spaces:** The application allows Users to book spots in advance.

**8. Automated and Manual Payment Options:** Automatic deduction from e-wallet with manual payment backup.

**9. Remote Video Monitoring:** Staff can view real-time parking space streams for surveillance.

**10. Automated Report Generation:** Detailed reports on parking records for staff convenience.

**11. Notifications and Alerts:** Alerts users of occupancy density changes, aiding in spot reservation timing.

A realistic implementation of the smart parking management system comes with its disadvantages; hence, all the given features can't be fully seen in a single implementation. There are several methods to implement the system, including the combinations of RFID, ALPR, WSN, Global Positioning System (GPS), GSM (Global System for Mobile Communications), wired proximity sensors, cloud platforms, and mobile applications.

The goals of a smart parking management system are: to provide fast, easy, and automated entry and exit from the parking lot, automated fee deduction, real-time occupancy monitoring updates, parking space reservation, surveillance of parked vehicles, and improper parking detection.

This review analysis intends to do the following:

- Analyse parking occupancy monitoring methods that are used in smart parking lots.
- Draw the merits and limitations of the articles reviewed, aiming to improve the implemented works. This work aims to be a useful guide for engineers studying various technologies used in smart parking systems for parking space occupancy monitoring.
- Analyse and compile the outcomes of the reviewed publications.

Following diverse criteria, the technical papers on smart parking management systems were chosen with a primary focus on vehicle authentication and occupancy monitoring methods. Keywords about the Internet of Things were used with phrases such as "Smart + IoT + WSN + occupancy monitoring + parking system", "Smart + IoT + Camera + occupancy monitoring + parking system", and "Smart + IoT + sensors + occupancy monitoring + parking system". All the papers have been collected from the conference papers of IEEE Xplore, which is a mark indicating proof of exceptional work.

## 2. Methodology

This section covers the use of three parking occupancy monitoring methods for smart parking management systems. Occupancy monitoring can be achieved by ultrasonic sensors, IR sensors, and cameras, but this can be achieved through wired connections, or WSN. The standard methods are discussed in Table 2. Additionally, GPS and GSM technologies can be integrated with the system to provide navigational assistance and SMS-accessible services to users.

## 2.1 Occupancy Detection using Infrared or Ultrasonic Sensors

Each parking slot is equipped with an IR or ultrasonic sensor to monitor the occupancy status. The IR signal. or ultrasonic waves, are transmitted by the sensor and received based on the distance between the sensor and the obstacle. If the obstacle is near, then the signal is reflected back to the sensor, hence detecting an obstacle, which in this case is a vehicle. This data is sent to the microcontroller which displays the occupancy status on the LCD. Some implementations also send updates to users through web services. [1-15] Figure 1 is a smart parking system block diagram that uses TCRT 5000 proximity sensors to monitor parking spots interfaced with an Arduino.

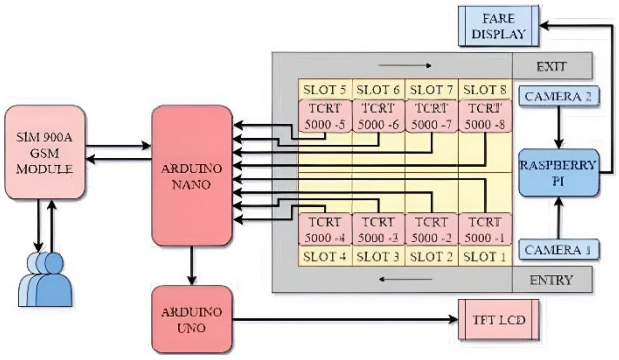


**Figure 1.** IR Sensor Occupancy Monitoring in Smart Parking System [13]

## 2.2 Occupancy Detection using a Mounted Camera

A camera is mounted at height in the parking space at a bird's eye angle to monitor the occupancy status of each slot. Deep learning algorithms use the footage to segment the videoorimage feed to individual slots and detect their status. The status of the individual parking spot is displayed on the user application. [16-18] Figure 2 depicts the use of a mounted camera and machine vision to detect the occupancy status of parking spots.

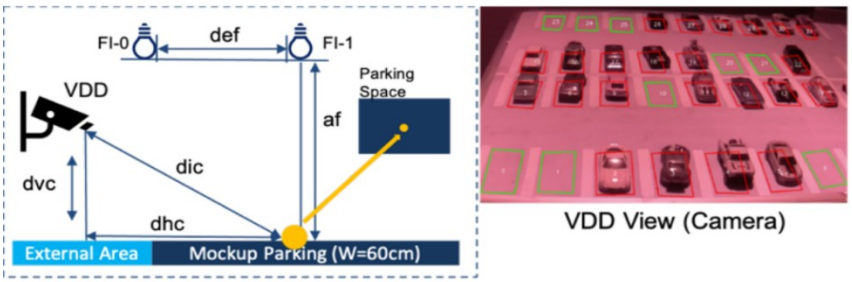


**Figure 2.** Parking Occupancy Monitoring Using Camera [17]

### 2.3 Occupancy Detection using WSN

Nodes are arranged in a hierarchy and have specific roles. Sensor nodes monitor occupancy using ultrasonic or IR proximity sensors and transmit data to group nodes, which then transmit it to coordinator nodes. The IEEE 802.15.4, or Zigbee protocol, is used to communicate within the network of nodes. [19-20]. Figure 3 depicts the hierarchy of wireless IoT nodes, which communicate the parking occupancy status to the web services, which can be accessed by mobile applications.

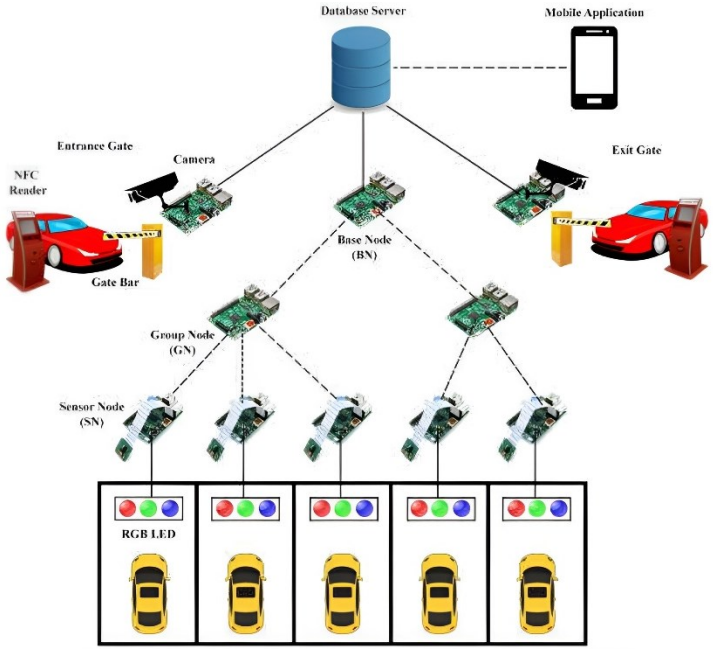


**Figure 3.** WSN for Parking Occupancy Monitoring [19]

## 3. Analysis of the Articles Reviewed

This section gives a detailed analysis of the implementation of the smart parking system given in each article. They are supported by the microcontroller, additional hardware, communication protocol, software technologies, method of occupancy monitoring, and the user application used by the different smart parking systems.

### 3.1 Comparative Study of Occupancy Detection using Infrared or Ultrasonic Sensors

The smart parking systems in [1-15] use either IR sensors or ultrasonic sensors to detect parking spot occupancy status. The additional hardware devices vary from LCD screens [1], camera modules [2], barcode scanners [3], and RFID scanners [4] to GSM modules [13]. In the

smart parking systems [1-15] most have provided a user-facing application except [8] and [15]. The communication protocols used in these are WiFi, HTTP(S), GSM, MQTT, and GPS. Table 1 details the aspects of implementation in [1-15].

**Table 1.** Parameters in the Smart Parking Management Systems with Occupancy Detection using Infrared or Ultrasonic Sensors

| Citation number | Micro-controller | Additional Hardware | Communication/ navigation protocol | Software tools | Occupancy monitoring method | User app |
|---|---|---|---|---|---|---|
| 1 | Arduino Nano, Raspberry Pi, ESP8266 board | Ultrasonic sensors, IR sensors, LCD | WiFi | - | Ultrasonic | Yes |
| 2 | Raspberry Pi 3 | HC-SR04 ultrasonic sensor, Camera module for Raspberry Pi | HTTP/ HTTPS | Cloud Vision API, firebase, android | Ultrasonic | Yes |
| 3 | ESP8266 (NodeMCU), Raspberry Pi | HC-SR04 Ultrasonic Sensors, Barcode Scanner, DC Motor, Display | - | - | Ultrasonic | Yes |
| 4 | NodeMCU, Arduino Uno | Power supply, RFID scanner, Servo motor, GSM module, IR sensors | GSM, Blynk | Blynk | IR sensors | Yes |
| 5 | NodeMCU, Arduino | RFID reader, IR sensors, LCD, GSM module, servo motor | HTTP/ HTTPS, GSM | - | IR sensors | Yes |
| 6 | Arduino MEGA 2560 | Ultrasonic sensor, LED, alarm IC | WiFi | - | Ultrasonic | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | module, camera module, solar cells, WiFi module | | | | |
| 7 | Generic controller | Camera, Generic parking sensors (Ultrasonic and IR) | - | - | Generic (IR/Ultrasonic) | Yes |
| 8 | PIC 16F887 | LEDs, LED Driver ULN2803, IR sensors, DC motor, Power supply, LDR sensors, Buzzer, LM358 op-amp | - | - | IR sensors | No |
| 9 | Raspberry Pi | RFID reader, boom gates, generic parking sensors | HTTP/ HTTPS | Android, JSP servlets, Python, Weka, Flask, REST API | Generic (IR/Ultrasonic) | Yes |
| 10 | Generic controller | IR sensors, transceivers. | HTTP/ HTTPS, Generic IoT protocol | Android, Google API | IR sensors | Yes |
| 11 | Arduino | Ultrasonic sensors, ethernet shields. | HTTP/ HTTPS | Google Maps | Ultrasonic sensors | Yes |
| 12 | Raspberry Pi | ESP 8266 WiFi modules, Ultrasonic sensors | MQTT | IBM MQTT server, Python, Angular JS, | Ultrasonic sensors | Yes |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | Apache Cordova | | |
| 13 | Arduino Uno, Arduino Nano, Raspberry Pi | SIM 900A GSM module, camera, LCD, TCRT5000 IR proximity sensor. | GSM | OpenCV EAST model | IR sensors | Yes |
| 14 | NodeMCU, Arduino mega | IR sensors (TCRT5000), camera, Barrier gates | HTTP/ HTTPS | Android Studio, PHP, MySQL, XAMPP, Java, HTML, CSS, JavaScript | IR sensors | Yes |
| 15 | Intel Atom Innovation Kit 3 | NI USB-6009 Data acquisition module, IR sensors, barrier gate, ticket printer | - | NI LabVIEW | IR sensors | No |

### 3.2 Comparative Study of Occupancy Detection using a Mounted Camera

The camera-based occupancy monitoring system is used in [16-18]. In [16] an image of the parking lot is taken, pre-processed, and segmented into blocks. Individual blocks are detected by Artificial Intelligence (AI) whether the spot is occupied or not. Similarly, [17] uses the camera as a Vehicle Detection Device (VDD) in parking spots to get the occupancy status of the parking spot. In [18], the parking system uses Machine Learning (ML) image recognition to detect vehicles in parking slots. Table 2 details the aspects of implementation in [16-18].

**Table 2.** Parameters in the Smart Parking Management Systems with Occupancy Detection using a Mounted Camera

| Citation number | Micro-controller | Additional Hardware | Communication/ navigation protocol | Software tools | Occupancy monitoring method | User app |
|---|---|---|---|---|---|---|
| 16 | Generic controller | Camera, LCD | - | Python, PyCharm, OpenCV, MediaPipe, NumPy, Pickle, CV Zone | Camera | Yes |
| 17 | Raspberry Pi 3 | OV5647 camera, networking devices. | WiFi | OpenCV, AWS Server/LightSail, SQLite, Python, Tolflex IoT platform | Camera | No |
| 18 | Raspberry Pi | Camera, WiFi module (ESP8266) | MQTT | OpenALPR, OpenCV, Python, Java, HTML, JavaScript, SQL | Camera | Yes |

### 3.3 Comparative Study of Occupancy Detection using WSN

The parking systems in [19-20] use WSN for parking occupancy monitoring. In [19] there are Sensor Nodes (SN), Group Nodes (GN), and Base Node (BN) which work hierarchically to communicate the occupancy data to the web services. In [20], each sensor node reports to the parking controller it is wirelessly connected with, and data is transmitted. Table 3 details the aspects of implementation in [19-20].

**Table 3.** Parameters in the Smart Parking Management Systems with Occupancy Detection using WSN

| Citation number | Micro-controller | Additional Hardware | Communication/ navigation protocol | Software tools | Occupancy monitoring method | User app |
|---|---|---|---|---|---|---|
| 19 | Raspberry Pi, ATmega 128 | PN532 RFID reader, Camera, RGB LED, NRF24L01 IEEE 802.15.4 Transceiver, Wireless sensor nodes | IEEE 802.15.4, HTTP/ HTTPS | - | WSN | Yes |
| 20 | Generic controller | IR sensors, LCD, servo motor, Lux sensors, LED lights (36W, 18W), RJ45 interface | Zigbee | - | WSN | Yes |

## 4. Discussions

The merits and limitations of the explored methods employed in parking occupancy monitoring are critically and briefly mentioned in this part. Table 4 details the advantages and limitations of occupancy monitoring methods.

**Table 4.** Advantages and Limitations of Parking Occupancy Monitoring Methods

| Number | Method | Advantages | Limitations |
|---|---|---|---|
| 1 | Ultrasonic sensors (wired)<br>IR sensors (wired) | The Ultrasonic sensors are not expensive and don't require complex installation procedures. It also detects improper parking with the support of more sensors.<br>The IR sensors can be easily integrated. These are inexpensive enough to scale up to hundreds of spaces. Easy to detect improper parking with more sensors. | Ultrasonic sensors are not suitable for big parking spaces with hundreds of parking spaces, because the cost multiplies,<br>and coverage is very low which is only one spot per sensor.<br>The failure rate of IR sensors is high. They cannot be used in the presence of sunlight which makes it not suitable for open spaces. Coverage is only one spot per sensor. |
| 2 | Camera (wired/ wireless) | A single camera can cover a large area of parking space. Bird's eye view image provides a real-time display of the parking lot to the user. | There are chances of false updates because of the limitations of algorithms. Mounting height must be sufficient to optimally cover large areas. Varying illumination levels can cause failures in detecting free or occupied spaces. |
| 3 | Wireless sensor network | Easy interfacing and wiring are not required. Easily scalable. | WSN nodes are expensive. Prone to cyber-attacks. |

Monitoring the occupancy of parking spaces in smart parking systems is a crucial feature. Utilizing sensors such as ultrasonic and IR sensors connected to a microcontroller is a straightforward approach to detecting vehicle presence. Ultrasonic sensors are suitable for both indoor and outdoor monitoring, while IR sensors are better suited for indoor areas due to their sensitivity to sunlight. For daytime and open parking lots, using cameras and image segmentation offers wide coverage but is limited by low light conditions and may be restricted by mounting height in enclosed spaces. WSN provides scalability and easy integration but comes with a cost for nodes. Another innovative approach involves RF NFC, requiring RF devices in cars and antennas embedded in parking spaces to detect occupancy.

## 4.1 Insights and Recommendations for Further Improvement from the Review

### 4.1.1 Insights from the Review

The review conducted on occupancy monitoring methods ultrasonic/IR sensor, Camera, and WSN in smart parking systems have given valuable insights concerning reliability and accuracy expectations, and implementation specificity of the occupancy monitoring method. The insights from the review are tabulated in Table 5, which covers modality, comments on reliability and accuracy, and implementation specificity.

**Table 5.** Insights from the Review

| Occupancy monitoring modality | Reliability and accuracy for occupancy monitoring | Implementation Specificity |
|---|---|---|
| Ultrasonic/IR sensors (wired) | Inexpensive, easy to maintain, reliable | Both open/closed parking spaces. |
| Camera | Provides large coverage, is easy to reconfigure, reliable, and flexible. | Open parking spaces (with good mounting height) |
| WSN | Accurate, easy to replace nodes, easily scalable. | Both open/closed parking spaces. |

### 4.1.2 Recommendations for Further Improvement

This subsection suggests adopting or practicing useful features in smart parking systems for future work in this field. Using the insights gained from the review, the features/practices are suggested based on the insufficiencies of the current implementations.

**1. Artificial Intelligence and Machine Learning:** Integration of AI algorithms for predictive analysis of parking occupancy duration, and occupancy percentage, aiding staff to take countermeasures to avoid improper parking.

**2. Integration with Smart City Initiatives:** Smart city initiatives primarily leverage IoT technology for user convenience. Integration of parking occupancy monitoring with such as traffic management, public transportation, and environmental monitoring.

**3. Enhanced Privacy and Security:** Use of state-of-the-art cryptographic algorithms, authentication mechanisms, countermeasures, and frequent security analysis.

**4. Scalability and Cost-Effectiveness:** Methods for scalability in different implementations of smart parking systems. The overall cost of the smart parking system should be optimal.

**5. User feedback and Iterative Improvement:** Feedback from the users for improvements in the features, and rating system for each parking lot.

**6. Energy Efficient Practices:** Integration of renewable energy to power the parking system devices. Replacing high power-consuming devices with energy-efficient alternatives.

**7. Environmental Sustainability Practices:** Use of e-tickets instead of parking receipts to save paper.

**8. Validation and Benchmarking:** Conduct rigorous validation and benchmarking studies to assess the performance of parking occupancy monitoring methods in real-world scenarios.

## 5. Conclusion

Various IoT-enabled technologies are available for implementing smart parking systems, each with its advantages and disadvantages. Occupancy monitoring of smart parking systems is a useful feature that can be achieved through various sensors, such as ultrasonic and IR sensors wired to microcontrollers. Ultrasonic sensors are suitable for both indoor and outdoor parking space monitoring, while IR sensors are optimal for indoor or closed space monitoring. The use of cameras and image segmentation is optimal for open parking spaces during the day but may not work in low illumination or closed parking spaces. The use of WSN offers easy scalability and hassle-free interfacing, but the cost of WSN nodes can be a disadvantage. The use of RF NFC with the parking spot antenna for detecting occupancy is an innovative idea, but requires cars to have installed RF devices and each parking space to be embedded with an RF antenna for receiving signals. From the review, recommendations for improvements in smart parking systems include integration with smart city initiatives, use of Artificial Intelligence and Machine Learning, enhanced privacy security, scalability and cost-effectiveness, and energy-efficient practices.

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