

Smart Parking Systems: A Review of Current Challenges and Emerging Solutions

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Abstract: *Urbanization has led to a rapid increase in the number of vehicles, creating serious challenges in parking management. The growing demand for parking spaces results in traffic congestion, excessive time spent searching for available slots, and inefficient use of parking infrastructure. Conventional parking systems rely heavily on manual processes, making them slow, unreliable, and unsuitable for modern urban needs.*

With the evolution of the Internet of Things (IoT), smart parking systems have emerged as an effective solution to these challenges. IoT-based parking systems integrate sensors, communication networks, and real-time data processing to provide accurate parking availability information. These systems help reduce traffic congestion, minimize fuel consumption, and lower carbon emissions. This paper focuses on analyzing smart parking systems from a technical perspective, emphasizing system architecture, sensor technologies, and solutions discussed in existing research.

Keywords: *Smart Parking Systems, IoT, Smart Cities, Architecture, Sensors*

Introduction

In metropolitan areas, parking management has become a major concern due to increasing vehicle density on roads. Drivers often face difficulties in locating available parking spaces, leading to frustration and time loss. In many cases, vehicles are parked along roadsides when designated parking spaces are unavailable, further worsening traffic congestion. During peak hours and festive seasons, the problem becomes more severe, with drivers sometimes failing to find parking altogether.

Smart parking systems aim to overcome these challenges by using low-cost sensors, real-time data, and mobile or web-based applications to monitor parking space availability. These systems automate the parking process and reduce the time required to search for suitable parking locations. Advanced smart parking solutions also provide additional features such as online reservations, digital payments, parking duration alerts, and vehicle location assistance in large parking areas. Such systems benefit both users and parking operators by improving efficiency, safety, and user satisfaction.

Advantages of Smart Parking Systems

- **Optimized Parking Usage:** Drivers can easily locate vacant parking spaces, ensuring better utilization of parking facilities.
- **Reduced Traffic Congestion:** Fewer vehicles circulate unnecessarily, improving overall traffic flow.
- **Lower Pollution Levels:** Reduced vehicle movement leads to decreased fuel consumption and emissions.
- **Enhanced Safety:** Real-time monitoring helps detect violations and suspicious activities, improving security.
- **Lower Operational Costs:** Automation reduces manpower requirements and management expenses.
- **Improved User Experience:** Integrated services such as navigation, payment, and notifications provide a seamless parking experience.

Literature Survey

Developing a Smart Parking Management System Using IoT

Searching for parking spaces consumes significant time and effort and results in financial losses for drivers. Smart cities adopt modern technologies to efficiently

manage urban resources, including parking infrastructure. A Smart Parking Management System (SPMS) provides a technology-driven solution to reduce congestion and improve parking efficiency.

The system enables users to search for available parking spaces, reserve slots in advance, and make payments digitally. It also supports advanced features such as notifications, usage statistics, and real-time parking status monitoring. Sensors are used to detect space occupancy, while Automatic Number Plate Recognition (ANPR) cameras regulate vehicle access.

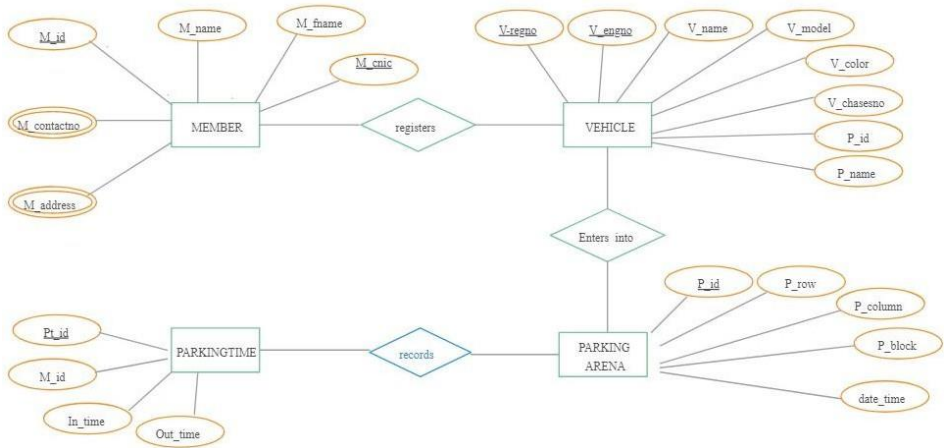


Fig 2.1 illustrates the Entity Relationship Diagram of the Smart Parking System, showing interactions between users, parking slots, sensors, and system components.

IoT-Based E-Parking System for Smart Cities

The rapid increase in vehicle numbers combined with inefficient parking management has intensified urban traffic congestion. Studies indicate that drivers spend an average of 15 minutes searching for parking, resulting in increased fuel consumption and air pollution. IoT-based E-parking systems aim to address these issues by offering automated parking management solutions.

These systems provide features such as real-time parking availability, slot reservation, vehicle occupancy detection, and navigation assistance. However, many existing solutions do not adequately address improper parking detection and automated billing. To overcome these limitations, a Parking Meter (PM)-based E-

parking system is proposed. This system supports real-time violation detection, accurate calculation of parking duration, and automatic fee collection.

The overall network architecture of the proposed system is shown in

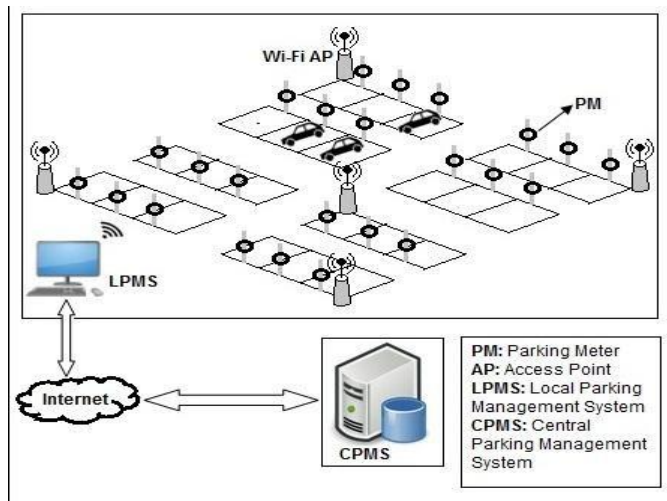


Fig 2.2, highlighting communication between sensors, gateways, and central servers.

Smart Parking System to Reduce Traffic Congestion

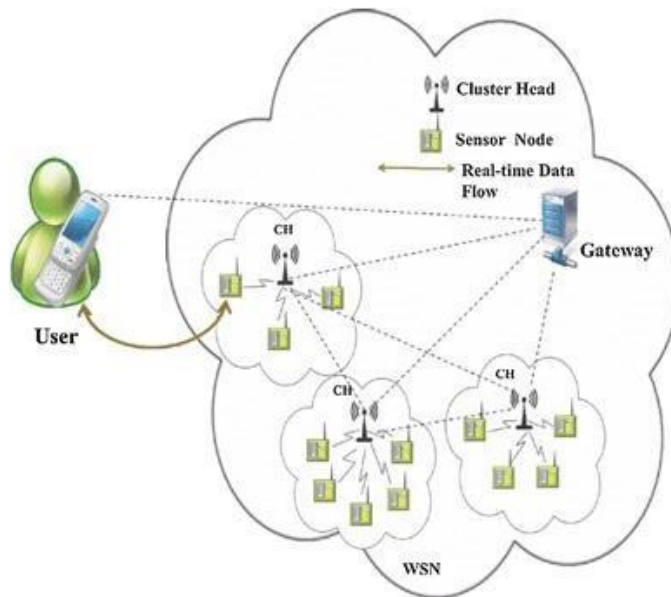
Transportation plays a crucial role in economic development, but increased dependence on private vehicles has made parking management more challenging. Traditional smart parking systems based on wireless sensor networks use infrared sensors to detect parking slot availability and display information on LED boards. Although these systems indicate vacant slots, they often fail to guide drivers efficiently to available parking areas.

Reservation-based smart parking systems address this issue by allowing users to pre-book parking spaces through mobile applications. These systems follow a client-server architecture, where users request slot reservations and the server responds with available options. Digital payment methods such as e-wallets, debit cards, and credit cards are integrated for convenience. Penalties are imposed for overstays, while refunds are provided for early exits or cancellations. This approach significantly reduces the time spent searching for parking and helps minimize traffic congestion.

IoT-Based Intelligent Parking Monitoring and Automatic Billing

Recent advancements in sensor technology have enabled real-time parking monitoring systems. Various detection methods such as inductive loops, ultrasonic sensors, infrared sensors, and video-based systems have been explored. While camera-based solutions offer wide coverage, they are expensive and sensitive to weather and lighting conditions.

Magneto-resistive sensors combined with wireless networks provide higher accuracy but are affected by electromagnetic interference and battery limitations. To improve efficiency, energy-optimized sensing mechanisms using hybrid detection techniques have been proposed. Despite progress in occupancy monitoring, automated parking payment systems have received limited attention. New solutions aim to integrate monitoring and billing without requiring user interaction, reducing system complexity, installation cost, and power consumption.



Proposed system architecture; wireless occupancy sensor; wireless gateway; data storage and processing unit.

Architecture of Smart Parking Systems

A smart parking system consists of multiple layers working together to provide real-time services.

Key Components

Physical Layer:

Includes sensors such as ultrasonic, magnetic, and camera-based devices to detect vehicle presence.

Network Layer:

Uses wireless technologies like Wi-Fi, cellular networks, XBee, and LoRa for data communication. Ethernet may be used for wired connections.

Processing and Control Layer:

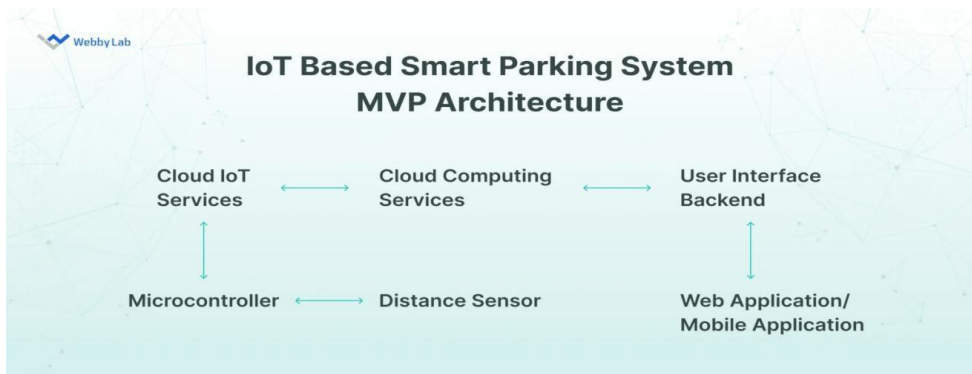
Gateways and microcontrollers collect sensor data and perform preliminary processing.

Cloud Layer:

Handles data storage, processing, analytics, and backend services.

Application Layer:

Provides mobile and web applications for users to check availability, reserve slots, navigate to parking areas, and make payments. Digital displays show real-time availability inside parking facilities.



The complete system architecture is illustrated in the **system architecture diagram**.

Conclusion

Smart parking systems provide an effective solution to the increasing parking challenges in urban environments. IoT-based technologies play a vital role in enabling automation, real-time monitoring, and efficient parking management.

Various system architectures and sensing techniques have been explored, each offering distinct advantages. The implementation of smart parking systems reduces traffic congestion, improves user convenience, and supports sustainable urban development by delivering cost-effective and real-time parking solutions. Despite these advances, several challenges continue to limit the large-scale adoption of smart parking systems. These include sensor reliability under varying environmental conditions, high installation and maintenance costs, network scalability, interoperability between heterogeneous devices, cyber security and data privacy concerns, energy consumption, and the difficulty of achieving reliable real-time performance. Furthermore, many existing solutions have been evaluated mainly through small-scale prototypes, creating a need for more extensive real-world testing and standardized performance evaluation

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