Designing of RFID-based IoT model for Automated Parking System with Mobile Communication

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ABSTRACT
Automated parking systems (APS) have emerged as an innovative solution to address the growing demand for parking spaces in urban environments, where land scarcity and congestion are major concerns. This review explores the evolution, benefits, and challenges of implementing APS. The primary objective of automated parking is to enhance space utilization and reduce human intervention by relying on advanced technologies such as sensors, robotics, and artificial intelligence. However, it also introduced challenges such as environmental degradation, increased emissions, and road accidents. Among these issues, parking congestion in cities has become a significant concern. The difficulty of finding parking spots contributes to time wastage, fuel consumption, and increased pollution. SPS have emerged as a solution, leveraging technologies like RFID, IoT, and computer vision to optimize parking management. These systems enhance parking efficiency, reduce traffic congestion, and minimize environmental impact through real-time data and predictive analytics. Various SPS approaches—such as Wireless Sensor Networks (WSN), machine learning, and deep learning—aid in parking lot monitoring and occupancy prediction, improving both user experience and urban traffic flow. The integration of such smart systems is crucial in mitigating the parking challenges of modern cities.

Keywords: Automated parking systems (APS), Machine Learning, RFID, IoT

1. INTRODUCTION

The emergence of automobiles in the transportation sector brought about unprecedented changes, including increased flexibility in travel and the movement of goods, as well as the growth of various economic sectors. However, automobiles have also given rise to some notable challenges that have gradually reached a level requiring urgent solutions. Such challenges include environmental degradation, emissions, and noise. Additionally, people and animals are exposed to harm, with increased road accidents as more cars are introduced onto the roads[1]. Furthermore, automobiles have also contributed to economic issues associated with traffic jams that are now rampant in most cities. Automobiles have gradually come to pose a challenge to city planners, especially in terms of ensuring that the increasing influx of automobiles may be accommodated, through both the construction of roads and the creation of enough parking spaces[2, 3].

The challenge of parking is particularly important, as most people prefer private car ownership, something that is deeply ingrained in the daily routines of many of us[4]. For this reason, the search for a parking spot in busy towns and cities is a daunting endeavor, leading to time wastage and unwarranted consumption of fuel, and, importantly, contributing to climate change[5,6]. The issue of parking is significant to the point that it has been raised in discussions of climate change mitigation as well as in political arenas[7,8].

In the new era, where technology has been accepted as one of the most critical tools for solving some of the challenges faced in the 21st century, especially in urban areas, the issue of parking has not been left behind. With the adoption of the Smart City model in most urban areas, smart digital solutions have emerged. RFID today is the popular wireless induction system. Each RFID tag in the RFID system is given a unique ID (UID). When an independent RFID tag approaches the RFID antenna, the induction between the tag and the antenna happens[9]. The information and content recorded in the tag are transmitted to the RFID antenna and translated into the computational data. Following up the data translation, the tag recognition can be completed and related applications are provided.

RFID solutions have a decreased operating spectrum (up to 10 m) inside of boundaries to object to detection and quantification in relatively small areas[10,11]. The consumers go through a once-in-a-time registration process when one ‘s personal information has been questioned to ever be filled out and an account is generated with them this account does have information about them and money they can recharge at local kiosks[12]. In this technique, the customers were also guided to an unfilled parking space using video displays entrance of the parking structure. With empty and occupied slots, these displays show a visual representation of the parking lot, which are green and red respectively[13]. The customer has been furnished with such a tag that he gets because once he registers, this tag has been connected with his prepaid account as well as contains confidential information, this tag uses an RFID system and has been mounted on the surface of the windshield of the customer. A parking fee has been instantly deducted from the user's account based on the period consumed inside the parking area[14]. RFID has been used to register every other customer for once, and an RFID tag has been attached to his vehicle instead of repetitively creating a token. There is no wait time in the RFID system, which would be distinctive to him (as if Aadhar number).These same consumers transfer via the entrance easily and park everyone's vehicles[15]. When a vehicle has opted to stay, the IR sensor releases the database and moves via the entrance door to see a big display with stay-living parking spaces. It is noticed that a large number of people waste fuel for free parking space. Utilizing IoT, messages can be transmitted to the website on the free or used slot [16,17].

2. The Architecture of Smart Parking Systems

Various application platforms are incorporated with embedded systems to provide an architectural framework that is known as a smart parking system. Users can send application-layer requests for reserved parking spots, and those requests are promptly handled via a network layer[18]. Parking providers are anticipated to execute user requests by interacting with the transaction layer via the network layer, as described by Kayal and Perros[19]. Lastly, the distributed ledger is updated by the protocol of the transaction layer's consensus mechanism and each parking provider individually.

Ahmed et al., [20] described the four primary layers that make up the architecture of a smart parking solution: application, network, transaction, and physical. In Figure 1, the systems' instrumental components are shown, and the layered architecture is also shown. Here are the specifics of the smart parking subsystems.

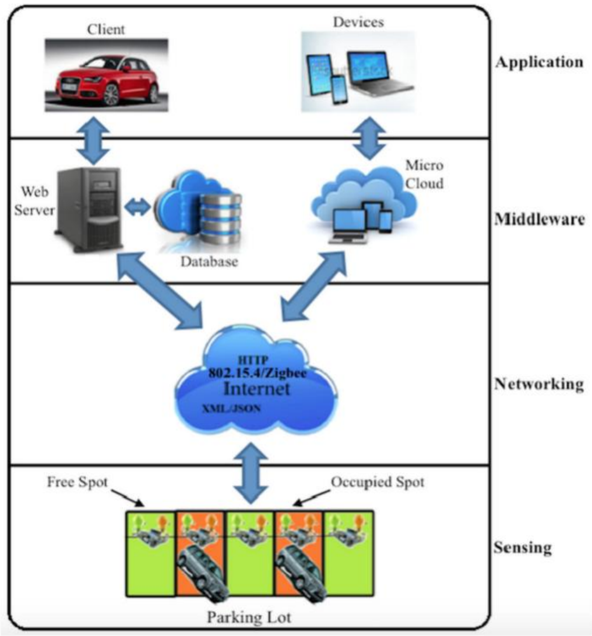

Figure 1: Layer architecture for integrated smart parking system[21].

2.1 Application Layer

The application layer is the uppermost tier of the architectural stack that facilitates user interaction with the system, whether via mobile applications (i.e., Android and iOS) or web applications. According to Yang et al., [22], users could look for their desired parking places and make reservations. Likewise, the parking services provider can send parking-related information, such as parking space availability, to the providers and offers to the linked systems. The layer provides the ultimate service to end-users because they interact directly with the integrated system.

2.2 Network Layer

The network layer facilitates uninterrupted communication between the several parking facilities, integrated systems, and users. User and parking center data are sent to the integrated system via a layer. The layer comprises several communication technologies, including LAN and WAN, used by users, parking service providers, and IoT devices associated with parking systems, such as parking sensors and security cameras. They could involve several wireless technologies, including Bluetooth and Wi-Fi, in conjunction with current GSM technologies, manifesting as 4G and 5G[23].

2.3 Transaction Layer

This layer is required to facilitate transactions among the nodes in the network. The users and the diverse parking facilities safely communicate data via the smart contract and consensus procedures. The parking facility further updates the public ledger via the layer. The transaction layer maintains the transparency of the transaction and the security of data transfer without the need for trusted third parties, particularly when using immutable Blockchain systems[24].

2.4 Physical Layers

The physical layers explicitly address the mechanics and electronic anchoring of the system. The physical layer relies on a collection of physical sensors and the data obtained from entities, which are processed and used for entity management. The many kinds of sensors constitute the essential components of the layer. The utilization of IoT device sensors could be acknowledged by their availability, discernible from the physical layers as articulated by[25].

3. Approaches to Smart Parking System

This section presents a comprehensive examination and comparison of the technological processes or approaches used by different SPSs.

3.1 Wireless Sensor Network (WSN) based SPS

A WSN is characterized as a network of geographically distributed sensor nodes that are wirelessly interconnected and specifically tasked with monitoring various environmental parameters, including sound, temperature, and pressure. A WSN-based sensor node consists of many sensors linked to observe various environmental parameters. In a WSN, all sensor nodes are linked to a sink node over a wireless connection[26,27]. Currently, WSN has garnered significant interest among SPS developers because of its flexibility, scalability, and inexpensive implementation costs. Owing to these advantages, several research studies examined in this work used WSN as the principal methodology for constructing SPS.

3.2 Multi-agent system (MAS) based SPS

A MAS is a self-organizing, computer-based system that comprises several intelligent agents designed to address complex issues that are challenging for any one system to resolve[28-30]. Researchers have used Multi-Agent Systems (MAS) to construct SPS because of their efficacy in both indoor and outdoor parking environments. A substantial segment of MAS-based SPS offers computational resources to the agents, therefore reducing the data transmission burden of the whole system. Consequently, the power consumption rate decreases.

3.3 Computer vision/image processing-based SPS

Based on computer vision and image processing SPS uses several camera networks to utilize image data for extracting information[31], including parking lot occupancy status, license plate recognition (LPR), facial identification for charging, security concerns, and reporting road traffic congestion[32,33].Systems using computer vision and image processing technologies often exhibit a high data transfer rate from the camera network to the processing units, since they rely on real-time video data from parking lots for feature extraction. Such SPSs are often appropriate for open parking spaces since a single camera could cover a substantial area inside the lot. Nonetheless, these systems are susceptible to occlusion, shadow effects, distortion, and variations in lighting.

3.4 Vehicular Ad-Hoc network (VANET) based SPS

VANET is founded on the Mobile Ad Hoc Network (MANET), using a wireless network of mobile devices. The SPS using VANET has three primary components: Parking Side Unit (PSU), Road Side Unit (RSU), and On-Board Unit (OBU)[34-36]. The OBUs are affixed to the cars, PSUs are positioned in parking areas, and RSUs are situated next to the roadways near the parking zones. This method necessitates a reliable authentication authority to validate the vehicle's OBU. When a car is stationed inside a smart parking facility, the OBU of the vehicle communicates to the PSU that the parking space is reserved. Subsequently, this information is sent from the PSU to the RSU. Vehicles traversing the road next to the RSU could obtain information on parking lot occupancy via their OBUs. VANET-based smart parking systems could be implemented in both enclosed and open parking facilities. However, the technology is expensive and delivers inaccurate information when a car without an OBU enters the smart parking lot.

3.5 Internet of Things (IoT) based SPS

The IoT is the prominent technology of the present period, characterized by the interconnection of all things over the Internet. Each internet-connected gadget has a unique identity (UID). These devices could be classified as computational, mechanical, or digital. They can send data autonomously, without human-to-human or human-to-computer contact[37-39]. IoT technology serves as a fundamental core technology used by developers for SPS. In IoT-based SPS, all sensors and computational equipment are interconnected over the internet, enabling data flow without human involvement. The connectivity among sensors, computational devices, and storage units could be established by either a wired or wireless link.

3.6 Machine learning (ML) based SPS

ML is a subset of Artificial Intelligence (AI) that enables a system to learn and enhance its performance on a specific task via datasets or experiences, without the need for explicit programming[40]. An ML-based SPS analyzes data from the parking lot to determine its state. Furthermore, ML and artificial intelligence-based smart parking systems may forecast parking lot occupancy for forthcoming days, weeks, or even months, and provide a dynamic pricing model. ML-based systems can assess traffic congestion on specific roadways and provide intelligent solutions for smart parking spots[41].

Dahiya et al., (2024)[42] offered an extensive analysis of machine learning (ML) models inside IoT-enabled contexts, emphasizing the development of an ML-based model for forecasting available parking spaces. The research assesses the efficacy of many models, including K-nearest neighbors (KNN), support vector machines (SVM), random forest (RF), decision tree (DT), logistic regression (LR), and Naïve Bayes (NB), using precision, recall, accuracy, and F1-score as performance indicators. The outcomes derived from the application of ML models on data with threshold values of 65% and 85% are analyzed to extract significant insights about their efficacy in forecasting parking spot availability.

Safran et al., (2024)[43] proposed a multistage learning-centric methodology that utilizes pre-existing security cameras in the parking facility and a self-assembled dataset of Saudi license plates. The methodology integrates YOLOv5 for license plate identification, YOLOv8 for character identification, and a novel Convolutional Neural Network (CNN) architecture for enhanced character recognition. Our method surpasses the single-stage strategy, with an overall accuracy of 96.1% compared to 83.9% for the single-stage method.

Canli et al., (2021)[44] created a deep-learning and cloud-based mobile smart parking application to alleviate the issue of locating parking spots. A service using deep learning with Long Short-Term Memory (LSTM) has been built inside the application to estimate parking availability. High-accuracy findings were achieved using real-time automobile parking data acquired in Istanbul, Turkey. The efficacy of the suggested model was evaluated against the SVM, RF, and ARIMA methodologies. The findings have validated the anticipated high accuracy and dependability.

Awan et al., (2020)[45] performed a comparative examination of prominent ML/DL algorithms, including Multilayer Perceptron (MLP), KNN, DT, RF, and Voting Classifier (or Ensemble Learning Approach) for predicting parking spot availability. This comparison used Santander's parking dataset, which was begun under the H2020 WISE-IoT project. This investigation indicates that irrespective of data set size, simpler algorithms such as DT, RF, and KNN surpass more sophisticated algorithms like MLP in prediction accuracy while offering similar insights for forecasting parking spot availability.

Hasan et al., (2019)[46] offered an intelligent parking model designed to minimize time wasting by allocating available parking places and assisting drivers in navigating the parking area. Utilizing the IoT and Google Cloud, we can efficiently identify available spaces. A DL algorithm has been used for user authentication, while a navigation bot has been constructed using Deep Reinforcement Learning (RL) for navigating inside the parking area. TensorFlow, a DL framework, is used for the development of the navigation bot and the implementation of the DL algorithm. The experimental methodology achieved a 98% accuracy rate in license plate identification, and the suggested model can cut time wastage by 50%, outperforming previous approaches. Figure 2 illustrates the accuracy graph.

Table 1: Comparison of Previous Work.

Author [Reference]	Year	Methodology	Outcomes
Dahiya et al., [42]	2024	KNN, RF, SVM, DR, LR, and NB	RF has exceptional performance with precision (92.13%), recall (90.39%), accuracy (93.16%), and F1-score (91.70%).
Safran et al., [43]	2024	CNN	The suggested technique attained a standard accuracy of 97%, general precision of 98.5%, standard recall of 98.5%, and standard F1-score of 98.2%.
Canli et al., [44]	2021	LSTM	The suggested model had the best accuracy (99.57%) by the integration of Capacity, Density, Time, Day, and Holiday.
Awan et al., [45]	2020	EL	EL demonstrated average precision, recall, F1-Score, and accuracy of 89.02%, 82.52%, 85.64%, and 88.70%, respectively.
Hasan et al., [46]	2019	DL	The algorithm achieves 98% accuracy in license plate detection and has decreased time wasted by 50% compared to older methods.

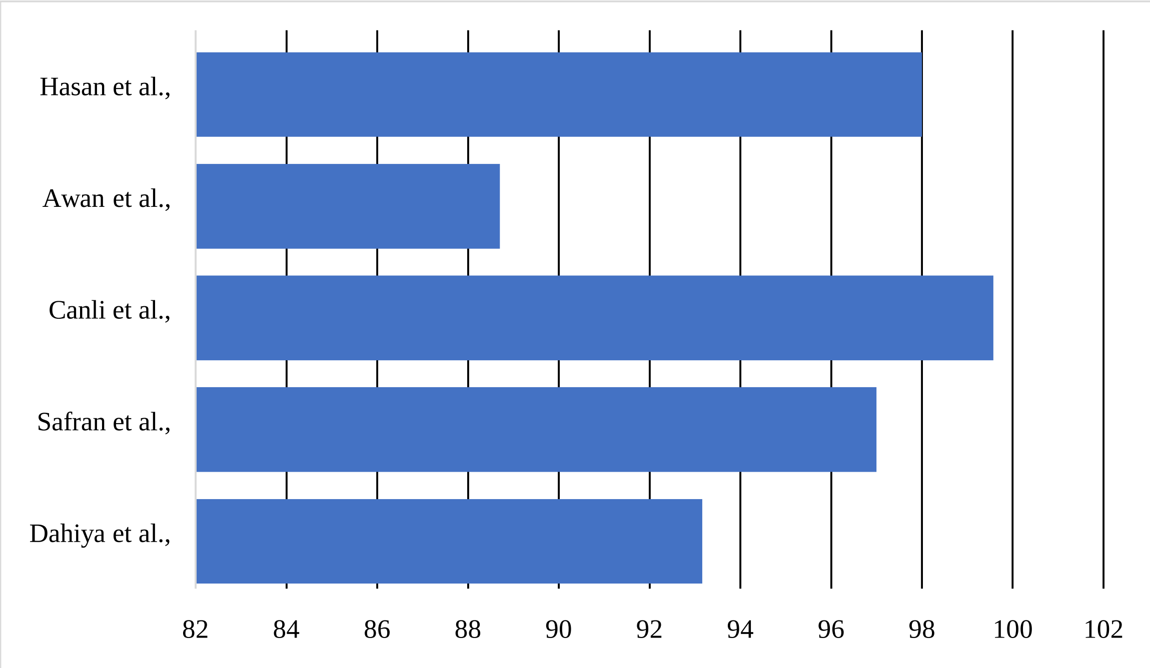

Figure 2: Graph of Accuracy

3.7 Deep learning (DL) based SPS

DL is a subset of ML and a function of AI that emulates human brain processes for data processing and feature extraction to facilitate decision-making[47,48]. DL algorithms identify both unoccupied and designated parking spaces in a Smart Parking System, hence minimizing the number of sensors and cameras needed for the system. DL is used to forecast parking lot occupancy.

3.8 Neural Network (NN) based SPS

NN is a synthesis of algorithms that derive characteristics and intrinsic correlations from data sets by emulating human brain activity[49]. In SPS, NN is used for license plate identification with real-time video data. CNN and machine vision are used to ascertain parking lot occupancy status. CNNs can also provide information on road traffic conditions for various routes[50].

3.9 Fuzzy logic-based SPS

Fuzzy logic is a reasoning approach that parallels human cognition. It employs multi-valued logic, indicating the absence of absolute truth or falsehood in fuzzy logic[51]. Fuzzy logic is used in SPS to forecast parking lot occupancy status[52]. The accuracy of the prediction model using Fuzzy logic would be significantly diminished without validation against real-time data[53]. Consequently, fuzzy logic, in conjunction with machine vision or sensors, enhances the precision of the whole system.

3.10 Global Positioning System (GPS) based SPS

GPS is a crucial element of several smart parking strategies. However, GPS alone cannot ascertain parking lot occupancy status or provide further smart parking features. GPS may provide a car navigation feature to direct the user to available parking spaces. Numerous methods may predict parking lot occupancy and road traffic congestion via CNN or DL algorithms based on GPS data[54]. The precision of GPS is dependent upon the quantity of receivers available. The accuracy of a single-frequency GPS receiver is around 7.8 meters. A two-frequency receiver offers an accuracy of around 0.715 meters. The GPS data is susceptible to inaccuracies when used inside an enclosed parking facility. Consequently, GPS-enabled smart parking systems are appropriate for open parking facilities[55,56].

3.11 Global System for Mobile (GSM) based SPS

GSM is a standard for 2G digital mobile networks. The GSM standard offers a supplementary service known as SMS. SPS, via GSM, employs SMS services to book parking spaces at various locations. Certain systems create unique codes for users throughout the reservation process, which are used to validate the reservation and guarantee that only authorized individuals are permitted to park[57].

3.12 Bluetooth-based SPS

Bluetooth is a wireless communication technology standard for short-range data transmission. A Bluetooth-based smart parking system often incorporates automatic valet parking. Conventional SPS, without an automated valet parking system, need supplementary sensors and methodologies to implement various smart parking solutions[58-60].

Numerous intelligent parking systems use the crowd-sensing approach to collect data on available parking spaces in a given area. The approach employs smartphone sensors, including the accelerometer, gyroscope, magnetometer, and GPS, with apps to collect parking lot data[61].

4. Implemented sensors in SPS

The specifics of sensors used in the design, development, and implementation of SPSs are detailed in the following sub-sections.

4.1 Infrared (IR) sensor

An IR sensor is an electronic device that identifies and quantifies infrared radiation produced by an object. Any item with a temperature over 5° produces infrared radiation. Infrared sensors are mostly used for motion detection and temperature monitoring. Infrared sensors may be classified into two categories: Active Infrared Sensor and Passive Infrared Sensor.

4.2 Active IR sensor

The Active IR (AIR) Sensor generates infrared radiation and detects the radiation reflected from nearby objects. This sort of infrared sensor has two components: a Light-emitting diode (LED) and a receiver. The LED emits radiation, while the receiver detects the reflected infrared radiation. An operational IR sensor is responsive to precipitation and snowfall. Consequently, it is more appropriate for object identification in enclosed areas, such as indoor parking facilities. The substantial expense of deployment and maintenance is a critical challenge for Active IR Sensors[62,63].

4.3 Passive IR (PIR) sensor

The PIR Sensor does not emit infrared light. Rather, it identifies variations in radiation from its environment. PIR sensors are mostly used for object detection. In SPS, it is mostly used for detecting parking lot occupancy. Similar to the AIR sensor, the PIR sensor exhibits sensitivity to environmental changes, including precipitation and snowfall. Consequently, it is inappropriate for open parking areas. Furthermore, PIR sensors are costly to install and maintain.

4.4 Cellular Sensor

Cellular sensors are the sensors included in a smartphone. Despite a smartphone having several sensors, the primary sensors used are the SPS, accelerometer, gyroscope, and magnetometer. These sensors are used for the detection of the user's motion, orientation, and direction.

4.5 Magneto-Resistive (MR) sensor

MR sensors are designed to sense the applied magnetic field without the need for electrical contact. The idea of the MR sensor is rather simple. When a magnetic field is introduced, a change in resistance happens in any permeating electrical conductor. The variation in resistance is contingent upon the alignment of the magnetic field lines. MR is mostly used for car identification in parking facilities[64].

4.6 Acoustic array sensor

An acoustic array sensor identifies sound or vibration at various frequencies to ascertain the distance and direction of the originating sound source or the reflecting surface. This localization method is referred to as the passive acoustic location technique[65]. In SPS, the Acoustic Array Sensor is used to ascertain parking lot availability and for surveillance applications.

4.7 Ultrasonic sensor

An ultrasonic sensor employs acoustic waves within the frequency range of 25 kHz to 50 kHz to identify adjacent objects that reflect these signals[66]. This sensor is optimally designed for interior applications because it is not susceptible to environmental variations such as snow and rain. Consequently, ultrasonic sensors are used in enclosed and indoor parking spaces, often affixed to the ceiling. Ultrasonic sensors are capable of detecting automobiles. Furthermore, with appropriate installation, this kind of sensor can distinguish between a vehicle and a pedestrian. Ultrasonic sensors are economical and need little maintenance expenses.

4.8 Camera

The utilization of a camera or a network of cameras for vehicle identification and parking lot monitoring is commonly embraced by several SPS researchers. Numerous researchers have used cameras and other computational tools, including computer vision and image processing methods, to identify car license plates for invoicing, reservation, and verification purposes. SPS using a camera or a network of cameras offers a reliable parking option for consumers. Nonetheless, camera-based SPS often proves to be costly in terms of both implementation and upkeep.

4.9 Inductive Loop Detector

An inductive loop detector, sometimes referred to as an inductive loop traffic detector or vehicle loop detector, is a vehicle detection technique that employs the idea of electromagnetic induction. This detector is embedded under the roadway to identify cars traversing above it. These detectors, in conjunction with other computational algorithms, can categorize distinct types of vehicles[67,68]. Vehicle loop detectors are costly and entail significant installation expenses. This kind of sensor is appropriate for both open and enclosed parking facilities.

4.10 Light Detection and Ranging (LIDAR)

LIDAR is a method that uses LASER light to determine distance by lighting the target object and detecting the reflected light with a sensor. A three-dimensional representation of the item of interest may be created by measuring the time taken for the reflected light to return and the wavelength of the light[69]. In SPS, LIDAR is mostly used for vehicle detection.

4.11 Microwave Radio Detection and Ranging (RADAR)

Microwave RADAR employs electromagnetic radiation within the microwave spectrum to ascertain the velocity, distance, and angle of a target object. Microwave RADAR is capable of detecting just moving things[70]. Doppler Microwave RADAR could be used to identify both fixed and moving objects. An SPS could substitute a video camera using 2D pictures produced by radar sensors and AI. Additionally, by using data acquired from Microwave RADAR, a CNN may be trained to forecast parking lot occupancy status. This sort of sensor is unaffected by environmental changes. Consequently, they are appropriate for both open and enclosed parking facilities. Nonetheless, this kind of sensor technology is costly to implement and maintain.

4.12 Magnetometer

A magnetometer detects the presence of any vehicle by measuring changes in the surrounding electromagnetic fields. Magnetometers are embedded underneath each parking lot to detect the presence of vehicles. Magnetometers exhibit insensitivity to environmental fluctuations, making them appropriate for both enclosed and open environments. SPS.

4.13 Agent
An agent constitutes a component of a multi-agent system that includes sensors, processors, and other tools. An agent may be seen as a little component within a broader network of systems capable of generating, processing, and transmitting data to get a thorough understanding of the environment[71].

4.14 Radio Frequency Identification (RFID) sensor
RFID technology employs electromagnetic fields for the identification and tracking of objects. RFID technology employs a radio transponder that includes an RFID receiver and an RFID tag. Upon scanning by the RFID receiver, the RFID tag sends the digital data contained inside it. The receiver acquires the data for object identification. RFID technology is often used in smart parking systems for the identification of vehicles and users[72,73].

5. Application Smart Parking
The importance of smart parking is:
- Precisely detect and forecast real-time spot/vehicle occupancy.
- Directs residents and guests to available parking spaces.
- Enhance Parking Space Utilization.
- Streamlines the parking experience and enhances value for parking stakeholders, including retailers and drivers.
- Facilitates the unobstructed movement of transportation inside the city by using IoT technologies.
- Facilitates informed decision-making using data, including real-time status apps and historical analytics reports[74].
- Smart Parking significantly contributes to the enhancement of urban environments by reducing CO_2 emissions and other pollutants.
- Smart Parking facilitates enhanced real-time oversight and administration of available parking spaces, leading to substantial income production.
- Offers instruments to enhance staff management efficiency.

6. CONCLUSION
An APS is a technology-driven solution designed to optimize parking efficiency by automating the parking and retrieval of vehicles without human intervention. These systems are commonly used in urban environments where space is limited, offering a smart alternative to traditional parking methods. APS integrates various technologies such as sensors, cameras, robotics, and software algorithms to maneuver vehicles into available parking spaces. The introduction of automobiles revolutionized transportation, offering flexibility and economic growth but also presenting challenges such as environmental degradation, traffic congestion, and parking shortages. As cities struggle with increasing vehicle numbers, parking becomes a critical issue, affecting time, and fuel usage, and contributing to climate change. In response, SPS is being developed using advanced technologies like RFID, WSN, ML, and the IoT. These systems streamline parking management by offering real-time information, optimizing space usage, and reducing emissions. By utilizing sensors, computer vision, and AI, SPS improves urban mobility and generates revenue, promoting sustainability and efficiency in modern cities.

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