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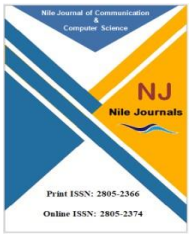

Effective Smart parking systems: A review

Shymaa.G.Eladl

Nile Higher Institute for Engineering and Technology , Mansoura, Egypt

Abstract

Traditional parking techniques frequently lead to inefficiencies like traffic jams from cars vying for spots and poor parking operators' revenue management. By providing simple payment alternatives, optimizing parking spot utilization, and giving real-time parking availability data, smart parking systems seek to address these issues. In terms of sensors used, technological method, user interface, networking technologies, computational methodologies, and service offered, this paper attempts to present thorough research, comparison, and in-depth analysis of smart parking systems. The research aims to provide a more thorough grasp of the state of a lot academic research in this area by thoroughly analyzing the scholarly work done on smart parking systems. The results of this study will assist city planners in incorporating smart parking systems with their broader smart city projects and help researchers pinpoint areas that need more research. Additionally, the study closes the research gap by clearly illustrating the advantages and drawbacks of smart parking systems and their appropriateness in various environmental situations. Researchers, designers, and policymakers able to choose the most appropriate smart parking space system and understand the present trends in this industry by thoroughly contrasting various smart parking system elements.

Keywords: Smart parking systems, Internet of Things, Image processing, Sensor network, Web application, Smartphone application, Neural networks.

1.Introduction

The contemporary world is evolving quickly due to technical advancements and scientific discoveries that make it easier to create a wide range of intelligent appliances, systems, and gadgets. Home appliances, robotics, intelligent cars, smart sensor networks, smart transportation systems, communication systems, automation, and other gadgets are examples of these intelligent devices, appliances, and systems. A new dimension has been added to the concept of developing smart cities because of the internet of things (IoTs) and cloud-based smart systems' rapid expansion and development. The goals of smart cities include lower operational costs, better local administration, greater efficiency, and higher output[1].

The idea of a smart city encompasses intelligent transportation systems, buildings, and infrastructure that are systematically monitored and managed [2], healthcare [3,4], Public security, energy use, and education [5]. The IoTs has fundamentally altered human behavior recently by giving people a plethora of comforts and amenities to make daily living more comfortably. IoTs technology connects electronic devices in the digital world that are outfitted with sensor networks and an Internet connection [6,7,8,9,10].

Finding a parking spot may seem straightforward, but it actually involves a number of difficulties that demand a lot of patience, time, and focus. About 30% of cars on a large city roads are manually looking for

empty parking spaces, and it takes about 7.8 minutes to find a spot, according to the authors in [11]. Additionally, it results in air pollution, driver frustration, and fuel waste [12,13,14,15]. According to [16,17], the rate of fuel use is impacted by traffic congestion. Air pollution is the result of increased emissions of carbon dioxide (CO2), volatile organic compounds (VOCs), nitrogen oxides (NOx), hydrocarbons (HCs), and carbon monoxide (CO). The United Nations Environment Program (UNEP) estimates that air pollution kills more than 7 million people before their time each year[18,19,20].

In the United States, traffic congestion is estimated $13 billion cost in health care expenses in 2020, and by 2030, that amount is expected to rise to $17 billion [21]. However, the Australian Infrastructure Audit 2019 [22] estimates that the entire cost of traffic congestion in Australia was approximately $19 billion in 2016 and is projected to increase to $39 billion by 2031. It should be mentioned that parking issues cannot be resolved by expanding the parking supply. Transport planners will be able to create a sustainable parking ecosystem with the aid of improved parking performance and sustainability considerations [23]. Smart parking systems have the potential to be a good way to ease traffic congestion, which will lessen air pollution and the health hazards that come with it.

Over time, smart parking technologies have been developed to meet the increasing difficulties of traditional parking management. A major turning point Throughout parking management's history was reached in the 1930s when mechanical ticketing systems and simple parking meters were first implemented to control parking spaces [24,25]. By enabling time-based parking and charge collection, these meters created a controlled parking space system [26]. Electronic parking meters first appeared in the 1980s, bringing with them enhanced enforcement capabilities and automated charge collecting [27]. The development of sensor technology in the latter half of the 20th century led to the creation of sensor-based parking systems that provided real-time information on parking spot availability [28,29].

It is impossible not to overstate the significance of the technical advancements of the last ten years on a worldwide scale. Continuous innovations like the IoTs, big data, artificial intelligence (AI), machine learning, and others are profoundly changing entire living areas. This change is especially apparent in the parking industry, where the use of digital solutions is opening the door for smart cities to develop [30]. Rapid developments in information technology, communication, and the internet have made it possible to create effective smart parking systems at comparatively lower costs. With the introduction of mobile applications that provide navigation, parking information, and reservation options, integrating wireless communication technologies, such as cellular networks and Wi-Fi, allowed for the real-time transfer of parking information to drivers [31,32].

IoTs-based designs transformed smart parking systems by improving data collecting and administration capabilities and enabling smooth connection between sensors, devices, and infrastructure [33]. Advanced parking optimization, predictive analytics, and driver-specific services are now possible thanks to the growing use of data analytics and artificial intelligence techniques in smart parking systems [34,35,36].As a result, numerous studies have used a variety of smart parking spots systems rely on distinct methodologies and sensors. In light of the aforementioned facts, the writers in [37] analyzed some smart parking solutions created by researchers and gave brief summaries of their sophisticated solutions. The continuous development of intelligent parking solutions is being propelled by increasing awareness of the drawbacks of conventional parking lots, which find it difficult to adjust to the needs of traffic and population increase [38,39].

Research published in 2023 by Markets projects that the global smart parking market will develop at a compound yearly growth rate of 18.47% between 2022 and 2030, reaching a market size of USD 21 billion

at the conclusion of the forecast period [40]. They presented a brief explanation of the smart parking systems and contrasted them to emphasize their strengths and limitations.

The study listed appropriate parking lot sensors and discussed the benefits and limitations of each. Nonetheless, this work aims to overcome the shortcomings noted in earlier research, which frequently lacked a thorough methodology and left out crucial examples. By compiling and evaluating the literature on the many forms of smart parking systems that have been established and exploring different facets of them, the ultimate objective is to contribute to a fuller comprehension of the subject. The findings will allow for well-informed decision-making throughout the development process, and the insights offered in this study will be a useful resource for scholars working in the sector. it also adds to the larger Intelligent Transport Systems (ITS) architecture by improving urban mobility and transport effectiveness.

2. Research Methodology

To achieve the study's goals, a search was carried out using a variety of databases, such as Google Scholar, Hindawi, Springer,IEEE Xplore, ProQuest, Scopus,MDPI, Science Direct, and Web of Science, to become acquainted with the body of current body of literature on the topic. Many studies were extracted and thoroughly reviewed after a rigorous review procedure. We were able to make well-informed conclusions on the state of the field and smart parking improvements thanks to this analysis, and combining these results gave us important new information about the field's advantages, disadvantages, and possible areas for development.

3.Smart parking system literature review

Finding parking spaces for residents at the busiest times of the day is a terrible issue in many big towns. People consequently waste a great deal of time looking for the ideal parking spot or standing in queue to get one. This, in turn, creates traffic congestion. Because of its many benefits, smart parking has attracted a lot of attention in recent decades. Considering the issues, to solve this problem, many researchers have put forth a variety of smart parking system strategies and technological advancements. Researchers have been actively involved in tackling the problems related to smart parking systems and generating innovative solutions.

A range of surveys and research devoted to smart parking are included in the body of existing literature, each having unique advantages and disadvantages. For example,[41] carried out a survey on parking lot reservations, providing illustrations and justifications of reservation methods; yet, their survey lacked a thorough methodology. In a similar vein, [42] provided a survey on the subject but left out literature samples. [43] summarized approaches and shared goals while concentrating on the emergence and the creation of smart parking.[44] In Delhi, research has been conducted to examine parking features and gauge compliance with parking regulations. In Delhi, parking surveys have been conducted at nine locations, mostly in business and retail districts. Parking information, On-street and off-street parking features were analyzed by taking into account factors including parking accumulation, occupancy, load, average parking time, and parking index/efficiency. Some places, although they have enough parking spaces, experienced traffic jams due to inadequate administration, a deficiency of essential signage, bay marking, and other clever strategies.

Although [45] reviewed a thorough analysis of a number of smart parking systems in-depth, they did not analyze a detailed examination of the system's design. [46] identified usage trends and identified components in smart parking systems that are commonly used. Similarly, Vehicle parking systems built on the latest smart parking technologies were also described by [47]. In [48] the appropriateness of open parking lots in smart parking systems has been reviewed. The writers discussed a variety of smart parking technologies, sensors, and methods for developing smart parking systems in this research.

A cloud-based platform as a service (PaaS) might be adapted to create an IoTs-based smart parking systems, according to the authors in [49]. A front-end data platform and a back-end dashboard platform are the two components that make up PaaS. The back-end data platform offers facilities for processing, managing, and storing data. The front-end dashboard platform, on the other hand, handles data visualization and reporting. A Multi-Agent System (MAS) based smart parking systems was designed in [50]. The technology uses agent networks to make it easier for the driver and smart parking devices to coordinate. Using a negotiation algorithm, it offers a parking price that may be negotiated based on a number of elements. Furthermore, the system offers parking reservation services for the quickest path and shortest path to the parking lot.

In [51], a proposal for an IoTs-based Car Parking Framework was made. The framework integrates Radio Frequency Identification (RFID), networked sensors, and actuators with an automated parking management system. The Car Parking Framework provides security, retrieval of the parking lot, payment facilities, and vehicle direction. Instead of using traditional nodal communication, the system uses a hybrid communication method. Because of this, the system is cheap to build and utilizes minimal energy. A smart parking systems rely on Wireless Sensor Network (WSN) was created by the authors of [52] . WSN technology, the system makes use of a hybrid self-organization algorithm. The system is meant to use less energy to be more energy efficient when communicating wirelessly. As a result, it extends the lifespan of WSN nodes and the WSN overall. This type of smart parking system helps users by directing them to the closest parking space and the location where they can make a reservation. The system gives consumers access to smart parking systems features through both web and smartphone applications.

Rahayu and Mustapa [53] suggested a secure system for parking reservations that makes use of the Global System for Mobile (GSM). The system consists of two modules: one for security reservations and the other for parking spot monitoring. Parking lot reservations are managed via the security reservation module. To book the parking lot, the customer must submit a Short Message Service (SMS) with detailed instructions. The module for monitoring parking lots allows the user to select a parking lot for reservation by displaying a layout animation of the occupancy status of parking spaces. The system generates a password, which is required at points of entry and departure.

The availability of a parking lot prediction system based on sample parking lots was proposed by the authors in [54]. The prediction system forecasts available parking spots using fuzzy logic. Park-and-ride (PnR) commuters are the focus of the system, which suggests that the sample parking spots are close to public transportation hubs. A visual method for detecting the occupancy of parking spaces approach using a deep Convolutional Neural Network (CNN) was proposed in a study conducted in [55]. Using smart cameras, the decentralized system can identify Real-time parking lot occupancy. Visual datasets are compared to the solution datasets.

In [56], a vision-based technique for detecting empty parking spaces was created. The outdoor parking service offered by the system may identify parking lot openings in real time and give the motorist with the lot's location for vehicle guiding. Additionally, the system uses the Adaptive Background Subtraction method to address light variations and shadow effects. A real-time parking space occupancy detection system based on CNN was the main topic of the authors' study in [57]. The CNN classifier requires relatively little power to operate on a smart camera. The system is quite resilient to partial occlusions, shadow effects, and changes in illumination. The system's results are contrasted with those of the current parking lot detecting smart parking systems.

In [58], a fusion-based sensor system for tracking and detecting vacant parking spaces was proposed. The data generated by the Around View Monitor (AVM) system's sensors is fused by the system using a sensor fusion technique. Parking space occupancy is tracked using data produced by ultrasonic sensors. The three

steps of the system are parking lot marking detection, parking lot occupancy classification, and parking lot marking tracking. A WSN-based smart parking systems with an ultrasonic sensor was proposed in [59]. To give the user the quickest way to the empty area, the system has applied the shortest path algorithm. Users are also given access to parking lot occupancy data.

In [60], A smart parking system that runs on the cloud was suggested. The system monitored a parking area's parking lots using the WSN technique. The cloud server then receives the parking space status wirelessly. An Android app on a smartphone allows the user to view the parking space's current status in real time. An IoTs-based smart parking system was suggested by the authors in[61]. Through IoTs applications, smart parking systems can keep track of and notify the user of parking lot availability. Three components make up the system: the user-side platform, cloud platform, and on-field network. Parking lot occupancy is detected via the vehicle detection sensors that make up the on-filed network. After that, a cloud platform is used to move the sensor data to the user side platform. Any user is capable to quickly view the specific parking area's space status via the user-side platform.

In [62], an IoTs-based smart parking systems framework for urban was created, with parking reservations serving as the primary criterion. This smart parking system offers a key-based parking reservation system that guarantees the right Parking space distribution space to The right individual. In order to provide two-way security, the system also uses facial recognition and License plate reading with optical character recognition. [63] used WSN and IoTs to create a smart parking system. The system makes use of RFID tags for car identification and payment capabilities, as well as an ultrasonic sensor to determine parking space occupancy. Three different types of sensor nodes are implemented by the system: anchor nodes, also known as repeaters; master nodes, also known as transmitters; and slave nodes, also known as receivers. To ascertain if a parking lot is filled, slave nodes are positioned on parking spots. Data from slave nodes is collected by the master nodes and send data to the cloud. To expand WSN's coverage area, inside the parking structure, the repeaters are placed at strategic locations. Both wired and wireless connectivity are used by sensor nodes.

A low-cost, energy-efficient smart parking systems rely on WSN was proposed by the author in [64] . Instead of identifying the presence of cars in each parking lot, the smart parking systems is made to track how many cars are entering and leaving a parking area. The system's energy efficiency rises because it communicates via 6LoWPAN rather than IEEE802.15.4, which uses less power. FID and infrared sensors have been used to construct IoTs-based smart parking systems for smart cities in [65]. Infrared sensors are used by the system to identify parking lots that are occupied and those that are not. WiFi is then utilized to transmit sensor information to the cloud. A web application makes it simple for users to access data. RFID tags are used by smart parking systems to manage gates. Additionally, smart parking systems offer vehicle theft protection, online payment processing, and parking reservations.

An IoTs-based automatic intelligent parking system has been presented in [66] . The closest parking lots receive parking lot status in real time updates from smart parking systems. Through a web application, the data is accessible to the user. The smart parking system has utilized a centralized server for data processing and storage.
A smart parking system based on WSN was introduced by [67]. Wireless sensors and smartphone app make up the system. WiFi and a low-power RF transceiver are used to connect the system's wireless sensor nodes. With the help of the smartphone app, a user can quickly find the locations of empty parking lots. Additionally, the system offers a payment option based on RFID. Bluetooth connectivity has been used to create an automated smart parking system. The system makes use of a mechanized valet parking service that operates automatically, moving cars to vacant spots and retrieving them from those spots without the need for human assistance.This system uses Bluetooth connectivity to authenticate users before initiating

processes. A wireless technology-based parking space vacancy monitoring prototype was constructed by the authors in [68].
The The master module and the parking lot occupancy monitoring module are the two separate modules that make up the system. The laptop Graphical User Interface (GUI) that displays data from the infrared sensor is part of the master module. Using a PIC microcontroller and the Zigbee transceiver interface, the data is sent to the laptop. Digital infrared sensors make up the parking space occupancy checking module, which determines whether or not a parking space is occupied. A liquid crystal display LCD placed at the parking area's entrance allows the user to view the information. An image-processing-based smart parking system was given by [69] to identify vacant parking spots. To ascertain if a parking lot is filled, the system uses cameras as sensors. The system's central processing unit gets data from the camera via radio frequency (RF) transmission.

Researchers in [70] used an RFID-based smart parking systems and a modified WSN. The parking lot occupancy real-time status for a particular location can be obtained from smart parking systems. For wireless communication amongst the wireless sensor nodes, the system makes use of ZigBee technology. The sink node and the monitoring node are the two different kinds of nodes in the system. Every parking space possesses a monitoring node that gathers data and uses ZigBee communication technology to transmits the data to the sink or gateway sensor nodes. The RS-232 interface is used to connect the Sink node to the monitoring room.

In [71] , a smart parking systems built on WSN, IoTs, and RFID technology was created. The system makes use of a lightweight cryptographic algorithm in consideration of the cybersecurity of the IoTs devices. Additionally, the system processes and manipulates the network edge's sensitive sensor node data by employing fog or edge computing methods. Techniques like fog or edge computing lessen the system's energy usage and the computational strain on the central server. The user can access real-time parking space occupancy data from the system. Additionally, Parking fees can be paid online. and reserve a parking space. An optical WSN-based smart parking system was introduced in [72]. The system can direct users to the parking spaces that are available and notify them of the parking spaces that are available in various parking lots. To connect with wireless sensor nodes, the system uses a polling Medium Access Control (MAC) protocol in conjunction with a star-based tropology.

A WSN-based smart parking systems prototype was provided by the authors in [73] WSN nodes, an embedded web server, a central web server, and a mobile phone application are all included in the system. The user can locate parking spots for free using the smart parking systems. Additionally, it uses wireless sensor nodes to offer real-time parking lot status information. A web server implanted in the parking lot receives the data. The information is then transmitted once more to the central web server, where it is accessible by the user through a mobile application. In [74], a smart parking system based on intelligent image processing was implemented. Webcams are used by this smart parking systems to identify whether a parking lot is occupied. An ARM8-based microcontroller processes picture data. After that, the data is posted to a web server. Users can check the parking lot's condition via a web application. Additionally, an LCD screen at the entrance gate displays the information for them to observe. Any user can utilise SMS to book a parking spot. Through the GSM module, the SMS is sent to the system's controller.

In [75], A smart parking system based on a smartphone application with Bluetooth connectivity and smartphone embedded sensors (such an accelerometer or gyroscope) was developed. The information spread throughout the target situation by combining WiFi communication between devices and internet access to a distant server after vehicle parking has begun at the parking lot. A smart parking system for the metropolitan area that allocates and holds user parking spots was proposed by work done in [76]. By combining information like parking fee and the distance of the car to the destination, this smart parking system suggests

parking lots to the user. Additionally, the system has parking lot identification, Infrastructure to Vehicle (I2V) communication, Vehicle to Infrastructure (V2I), and reservation guarantee.

To determine parking lot availability in real time, the researchers in [77] suggested a crowdsourcing-based smart parking systems that makes use of integrated smartphone sensors. To identify whether a parking lot is occupied, the system follows the driver's path. To track the driver's path, the system uses Position Dead Reckoning (PDR), which is installed on the waist. In addition, the smart parking systems calibrates directional inaccuracies in an interior environment using a map-matching technique. An essential component of the smart city and smart parking systems concepts is the autonomous vehicle (AV). A scheduling system for Long-range Autonomous Vehicle Parking (LAVP) was proposed by the authors in [78]. The plan takes into account the AV's fuel consumption rate as well as its travel duration. To improve public safety and lessen traffic congestion, the AVs' Car Parks (CP) are located outside of the city. The AV drivers in this study had the ability to choose where to drop off and pick up their vehicles. The AVs must use these points to travel to the closest CPs and return to the CPs' pick-up points to retrieve their drivers.

To lessen the substantial power loss brought on by sensor nodes and the expensive nature of sensor connectivity, a smart parking systems based on Narrow Band (NB-IoTs) technology was presented in [79]. A novel cellular technology for low-power wide-area (LPWA) applications is called NB-IoTs. This smart parking system offers the user a smartphone application and incorporates a third-party payment platform. Additionally, it offers charge, information management, and surveillance through a cloud platform. In [80], the authors developed a WSN prototype for vehicle occupancy monitoring. Through smartphone applications, technology gives the user access to real-time parking lot changes. The system's sensor placement is made simple by the use of WSN.

An IoTs-based smart parking systems that is connected to a smartphone app was proposed by [81]. Infrared (IR) sensors are used by the method to ascertain if a parking lot is occupied. The cloud platform receives data from the infrared sensors. The data is accessible to the user through a smartphone application. Furthermore, depending on the size of the car, smart parking systems allows the user to find the closest parking lot location. Additionally, a user can utilize the integrated smartphone application of the system to reserve a parking lot. Parking reservations have been authenticated using RFID tags. The person who owns the parking space can determine the parking fee and monitor the lot's occupancy level.

In [82], an IoTs-based smart parking application called I_SPARK was created. Information about parking spot occupancy for a certain parking area can be obtained through the application. Users can use smartphone apps and the web to access the data. For IoTs connectivity, the system makes use of the Message Queuing Telemetry Transport (MQTT) protocol. In [83], researchers suggested a new smart parking solution that uses a smartphone app to tell drivers about parking lots that are available. The quantity of vehicles arriving and leaving the parking place is taken into account by the system using ultrasonic sensors. Data from the sensor is processed by a Raspberry Pi board before being sent to the client-server for storage. Users' smartphone apps provide entry to the data. Additionally, the system directs cars to the closest parking space, where there are free spaces. In [84] researchers presented a novel smart parking system that recognizes a car's license plate using an image processing technology. It also offers an autonomous door that opens and closes when it recognizes a car approaching the parking lot's entry. Information about available parking spots, parking lot security and safety measures like fire and gas leak alerts are all provided by smartphone applications. The control device that manages and processes the system's whole functioning is the Raspberry Pi. A LCD that shows The accessibility of parking lots is situated at the parking lot's entrance. IR proximity sensors are used to detect the presence of a car near the parking lot's entrance gate. A smart parking system based on WSN that gives the parking lot status of a particular parking facility was provided by the authors in [85].

Ultrasonic sensors installed on each parking lot are used by the system to determine whether a space is occupied. Arduino Mega 2560 processes the information produced by the sensors. After processing, the data is sent to the system's sink node. Users can view the monitors' parking occupancy status positioned throughout the parking area from the washbasin node. IoTs and computer vision-based smart parking system was proposed by Baroffio et al. [86]. Several cameras are used as visual sensors in the computer vision-based visual sensor network to record video footage of various parking lots. This data is then analyzed to determine whether the lot is occupied. An Ad Hoc network is used to collect content and send data to the central controller because of numerous cameras.

In order to offer a privacy-and security-conscious solution known as Parking data as a solution (PIaaS), the authors of [87] suggested a cloud infrastructure based on Vehicle Ad Hoc Networks (VANETs). PIaaS securely and privately transmits smart parking systems information from VANET-oriented cloud infrastructure to vehicle nodes. Through cloud infrastructures, VANET-enabled cars and Park Side Units (PSUs) exchange parking data with Roadside Units (RSUs) in the form of Parking Mobility Vectors (PMVs). Another name for the RSUs is Communication Terminals (CTs). Location privacy is provided via the geolocation-oriented parking lock encryption that the smart parking systems use. The system also has features for preventing vehicle theft, detecting malevolent vehicles, and reporting traffic congestion on various routes.

In [88] , a cloud-based smart parking systems built on IoTs technologies was created. By using RFID tags and offering a parking reservation service, the smart parking system makes sure that only the authorized individual enters the parking lot. Additionally, for vehicle security, the system makes use of Number Plate Recognition (NPR). Additionally, it can identify overweight and large cars and prevent them from parking in the lot. Smart parking systems based on smart car presence sensors and IoTs was proposed in [89]. A single-board computer, sensors, an LED indication, a beeper, and a battery pack make up the smart car existence sensor. The occupancy of the parking lot is detected by car presence sensors. Data is monitored, controlled, and processed by the system's monitoring center, smart car presence sensors, and smartphone applications. IoTs technology forms the basis of the smart parking systems created in [90] . The device lessens the driver's search effort by helping them locate empty parking spots in the nearest parking area. Additionally, the method offers information about traffic jams on several roads that could lead to the smart parking systems site. To reduce the volume of data that must be transmitted to the cloud for processing and evaluation using a machine learning algorithm, the smart parking systems also uses fog computational techniques.

An IoTs-based cloud platform was integrated into a smart parking solution that was proposed by researchers in [91] . On-site IoTs devices are used by the system to track and identify parking space vacancies. The end user can obtain the parking lot status by utilising the smartphone application. Additionally, the customer can use the smartphone application to book a parking lot. In [92], the authors introduced an smart parking systems that detects empty parking spots in a parking complex using IEEE 802.15.4 technology and Ultra High Frequency (UHF) RFID. Through a specially designed smartphone application, the technology assists the driver by guiding the vehicle to the closest parking spot. The parking fee payment method uses an e-wallet based on Near Field Communication (NFC). Additionally, the system uses the Google Cloud Messaging (GCM) platform to notify both the user and the system administrator when the allotted parking time has expired. Additionally, the system can use a customized smartphone application to notify any discrepancies in the parking lot to the local police department.

In [93]. A novel smart parking systems built on the IoTs and MAS was implemented. It makes it possible for parking space suppliers to charge for their spots. Additionally, it offers parking space providers a dynamic price structure. Drivers can access real-time parking lot information thanks to the smart parking technology and vehicle navigation to parking spaces. A smart parking system that offers pricing, reservations, and dynamic resource allocation was provided by the authors in [94]. In the shortest length of time, the system guarantees the user parking at the lowest cost. Additionally, optimal parking resource utilization is guaranteed, giving parking lot owners the highest potential income. Mixed Integer Linear Programming (MILP) is used by the system to optimize resource use and reduce financial costs. An Internet of Things-based privacy-preserving smart parking systems platform was proposed by researchers in [95].Instead of using traditional public key cryptography, it used Elliptic Curve Cryptography (ECC). Devices with constrained memory and processing power are the primary platforms on which ECC is used. To further improve the system's anonymity, Zero-Knowledge Proofs (ZKP) are also implemented.

In [96], AI and image processing were used to construct a smart parking system. The system uses cameras to recognize license plates, which is utilized for vehicle security and billing, and ultrasonic sensors to determine parking lot occupancy. Additionally, the system makes parking recommendations depending on the user's position, parking area distance, and parking prices. In [97], a distributed camera network, sophisticated deep learning algorithms, and fog computing techniques were used to offer a flexible and reasonably priced smart parking platform. The system's cameras have telescopic lenses and motorized heads, which enable precise and effective vehicle tracking. In order to assure car security and calculate accurate parking fees for the user, the system also takes a picture of the license plate. Distributed intelligence and a decentralized decision-providing architecture form the foundation of smart parking systems in [98]. The system is scalable as a result of its architecture. The system offers features like car guiding to empty parking spots and real-time parking lot vacant monitoring. A smart parking system using loop detectors as a sensor was proposed by the authors in [99]. The loop detector detects the vehicle in the parking lot. The system displays the parking lot occupancy status on the LCD monitor based on that data. Both open and closed parking lots can use the system.

In [100], a smart parking surveillance system based on a network of cameras and acoustic sensors was put into place. Low-cost microphones were used by the smart parking systems to listen for any acoustic activity occurring within the parking lot. The acoustic sensor network promptly locates the incident's location and modifies the cameras to capture the event when it detects any acoustic events. The system made use of an acoustic source localization system, a server system, and a camera system. Maps can be used to determine the approximate location of the acoustic event. A smart parking system with a mobile application-based user interface that made use of Bluetooth connectivity and embedded sensors in smartphones was described by [101] Following the car's parking, the system used Wi-Fi to link devices and sent data to a distant server over a network. A smart parking system built on IoTs and smart car presence sensors was presented by [102]. The occupancy status of parking lots was determined by the smart sensors, This had a power pack, LED indicator, sensor, single-board microprocessor, and beeper. The data was monitored, controlled, and processed by a monitoring center, a smartphone application, and smart vehicle presence sensors In a study by [103] parking place occupancy was measured using cars fitted with Global Positioning System (GPS) receivers and ultrasonic rangefinders. A map displaying parking availability was created by combining the data acquired from these cars at a central server. However, this system's drawback was that all users saw the same information, which resulted in several automobiles squeezing into already-occupied spots and clogged traffic if there was a greater demand for parking than there was availability.

According to [104], the local administration has made an investment in installing a sensor system to direct drivers to e-parking spaces. Six hundred wireless parking sensors were placed around Barcelona's Les Cortes neighborhood. After the embedded components were positioned beneath the asphalt, the sensors were utilized to detect open parking spots and alert drivers. By giving drivers in real-time guidance on the location and availability of open parking spaces, the program aimed to reduce emissions and traffic. The proprietary application programming interface (API) of various technology providers operating in the smart parking area was used to access sensor data. Another example is the first smart city pilot project enabled by IoTs in Busan, South Korea, which made use of IoTs technology [105]. From 2015 to 2017, the suggested intelligent parking services were improved every year. In order to offer real-time parking service data, parking sensors were installed in public parking lots in 2015. To better understand the occupancy data, closed-circuit television (CCTV)-based image recognition technology was used the following year. Lastly, parking spots equipped with electric vehicle charging stations were added in the last year (2017). In the wise IoTs project for 2014 intelligent parking sensors, six indoor ones were chosen to be used in smart parking. They offer occupancy data in real time for each parking spot. Another example is the city of Riga, which provides paid parking. The city has about 167 underground parking spaces that are controlled by an automated parking ticket machine that is placed near the parking lot's entrance and exit. Using a QR code with time stamps, drivers can get a ticket [106]. Because of the system's effectiveness, a car that stays in the parking lot longer than allowed will not be able to park without incurring additional fees. A smart parking solution was also tested in the Spanish city of Santander, where parking lots were equipped with inductive sensors. In order to determine whether parking spaces are available, The city's major parking lots already have over 250 outdoor parking sensors installed [107].

Using GPS, [108] developed a cloud-based smart parking system. The goal of this application is to coordinate and supply data on things like the quantity of cars, the amount of free parking spots available in different places, and the separation between parking spaces. The app might also be useful for figuring out how much drivers' parking requests will cost. Another example is the research of [92], who used RFID and an integrated ultra-high frequency (UHF) ,WSN to map out a smart parking system. Software characteristics that put together the parking slot occupancy make up their system. They were developed into an application that directs cars to the closest parking space. Through a wallet system based on NFC, the app also enables users to pay for parking. In order to manage warnings (such the expiration of the purchased time and the condition of the reserved space), it uses Google Cloud messaging, Java REST, and APIs. These are installed via a main server and are used to alert traffic cops.

An IoTs framework for cloud-based parking was developed by [109] to guarantee that various evolving parking systems are designed to accomplish the desired goals. Three layers make up this framework: the application layer, the communication layer, and the sensor layer. The OSGi-based Web application that gives drivers information about The greatest parking system available is used by the system's proponents. The system uses a number of protocols, which are thought to have made it cumbersome and complex.

The deployment of a smart parking system was suggested by [110] as a solution to the problem of urban parking. Their suggested method was created using Another server's advancement is ZigBee technology information over a gateway, with the server being the end outcome of database changes.

Researchers like [111] to have created and put into use a parking system rely on the ZigBee wireless sensor network. Communication between the parking monitoring system and the microcontrollers in the parking lot is primarily accomplished through the use of the ZigBee wireless network protocol, these researchers suggested a smart parking system.

In their study,[112] suggested a parking system that uses a CCTV camera to monitor certain park spaces by sending the video to a networked system that uses a computer vision algorithm to determine the automobile parked in the slot. Free consideration would be available that would be occupied if there were no vehicles parked there. The status would then be sent to every server place by the system. Thus, the driver can use the smartphone to check the status and then locate a free spot.
The benefits, drawbacks, and services utilized by the different smart parking system architectures examined in this analysis are compiled in Table 1.

Table 1Comparison between Different Smart Parking Techniques

Paper Ref	Technology	Advantages	Disadvantages
[114] (2007)	-RFID readers, labels, computers, barriers, software, and other components make up this unmanned, safe automation technology. -The program is used to manage parking lot data, report transactions, and govern operations.	- RFID Workloads that are accomplished manually are significantly reduced. - RFID is an effective technology for tracking inventories. - RFID Simple setup and use, automated reporting and data collection	- Pricey, internet disconnection, application-specific tags, no one-size-fits-all tag, and several tags that can respond simultaneously. -The system will not read or process either of the two vehicles' identifying information if they enter the parking lot next to each other and are in the RFID reader's field of view. - When energy is applied at the correct frequency, it is relatively straightforward to jam communications in the electromagnetic spectrum.
[115] (2011)	- Using an application to broadcast real-time parking information to drivers is the aim of a reservation-based smart parking system. -It will offer the ability to reserve parking spaces in advance.	- less time wasted searching for a parking space. - Traffic congestion has significantly decreased. - Cut down on pollution and energy use.	- This system's deployment uses Bluetooth-enabled modules and Zigbee sensors for every vehicle parking place. Naturally, this raises the system's cost and causes maintenance issues. - Due to its small range, the Bluetooth module's transmission is less reliable, which is unacceptable in many situations. - When there is a lot of traffic, the bottleneck issue is probably
[116] (2010)	-Suggests a method that would allow customers to make parking reservations by sending an SMS. - Users will receive their assigned space number and password to access the parking lot after their reservation has been confirmed.	Ease of usage and More Secure.	- Instead of being a centralized system that permits bookings for every parking space in an area, the system is designed for individual parking places. - It is not allowed to Scalability – Since parking information is stored in CMOS flash memory,
[117] (2010)	- The ParkNet automobile has a GPS receiver and an ultrasonic rangefinder on the passenger side, which is a mobile system that uses driving to gather data on parking space occupancy. - A real-time parking availability map is created by integrating the gathered data at the central server.		- If the speed restrictions are not adhered to, the ultrasonic sensors might not be able to detect distances. - When unregistered spaces are used for parking or storage, the locations and occupancy may not be accurate. - To convert many taxicabs into ParkNet-equipped vehicles, the system would require a significant financial investment, which might not be practical on a wide scale.

[118] (2012)	The Android app is utilized. Although it lacks a reservation feature, it offers a nicer interface.	Using the Android platform offers an improved user interface. Simple to use.	-The presence of the car can be detected by sensitive light sensors. -The method is only appropriate for private outdoor parking lots, not public ones. -There is no navigation system to the city's parking lots. - The driver is unable to make remote payments.
[70] (2013)	Parking is made possible by the use of wireless sensors and RFID, which let the driver locate their position.	-It directs the driver and gives the slot information. -It can be parked in the current lot. -The system is less expensive, it can be used in indoor parking lots, and it is based on LCDs.	-Longer implementation time. -There is no program designed to facilitate drivers' search for open spots.
[162] (2010)	-Bluetooth is utilized for network or communication purposes.	-Bluetooth is utilized for identification or registration. -Find out if a new car is parked by its unique registration number.	Costly and A time-consuming affair.
[69] (2014)	-Image processing as a concept is applied. To help determine if parking spaces are available or not, the sensor camera takes photographs. However, the system may be impacted by weather conditions such as snow, fog, rain , etc. when it comes to visibility.	-Easily identify the existence of vehicles. As a sensor, the camera is employed.	-Some meteorological circumstances, such rain and fog, make it incompatible. -There is no GPS available.
[119] (2012)	-The parking area's vacancy is checked using ZigBee. -It adds a security feature that requires a password to be put in order for a user to Go out of the parking lot. The user will open the gate after entering the right exit password.	Secure, using a password-protected system, GSM, and SMS	This method's issue is network congestion, which stops users from obtaining SMS messages. and costly.
[120] (2015)	It presented object ad-hoc networks, RFID, WSN, and information systems that allow traffic items to be automatically monitored and managed over a network.	WSN use increased the system's dependability.	Networking congestion.
[121] (2013)	An innovative technology that lowers installation costs and time is RFID.	Cut down on installation expenses and time.	GPS is not used.
[122] (2016)	-The smart, high-definition image is created with the Raspberry Pi 2. - The traffic problem is managed by the RASPBERRY PI 2, receives a signal from certain ultrasonic sensors that measure the intensity of the vehicles.	-Automatically identify the cars. -Regulates issues relating to transportation.	Costly.
[123] (2012)	-Makes use of A broad -angle camera as a sensor to record or locate empty lot. - The purpose of these records is to ensure that space is used appropriately.		-The technique is unreliable when a camera is used.
[66] (2015)	-IoT is employed in this automatic smart parking system, which is economical and environmentally benign because it reduces carbon dioxide emissions.	Cost effective and Eco-friendly.	Not address the issues caused by congestion.
[124] (2017)	-A automobile parking detecting system that uses an ultrasonic sensor and the Internet of Things to broadcast the parking slot's status to the Internet allows users to	-The user benefits from having a distinct identity. -An internet connection is not necessary for this system to function.	Needs a QRScanner app on the user's smartphone.

	see which parking spaces are empty and where to park from anywhere in the world. - QRcode:AllocatingaQRcodetoeveryparking space	-Assists in determining the best route for an automobile search.	
[125] (2016)	-An add-on system that works with a range of vehicles. - It locates open, authorized parking spaces and securely directs the car into the designated space. - Both interior parking lots and roadside locations can be used for detection.	-Giving the user verbal and visual directions and warning them if there are any obstructions in the parking lot	-These directions may cause disruptions and be misinterpreted, increasing the likelihood of misunderstanding and, consequently, traffic.
[126] (2014)	-It talks about a project that shows a miniature version of an automated parking system with control and management capabilities how many automobiles can be parked in a specific area at any given moment depending on parking spot availability. -Using sensing devices, an Android-based application controls entry and exit from the parking lot.	-It is low-cost and effective, and they can detect in environments that are dark, dusty, and moist.	-Their detection range is limited. Temperature variations may have an impact on the sensors' functioning, rendering them unreliable.
[127] (2017)	-With the help of their automated real-time parking system, ParkUs 2.0, they hope to shorten the time it takes to find a spot. - Their approach makes use of sensor and location data gathered from smartphones that drivers carry, applies machine learning to identify cruising behaviour, automatically annotates road segments with parking availability information based on the classified data, and shows the data on the user's smartphone as a heatmap.	- By eliminating the need to search for open areas, the user can save time, particularly in an emergency. -It conserves fuel.	-If it takes the user longer to reach their destination, the location would be empty and inconvenient for other users.
[49] (2014)	An IoT-based SPS could be developed by adapting a cloud-based PaaS. PaaS consists of two parts: a front-end data platform and a back-end dashboard platform.	using a PaaS development environment, the smart parking system was created much more quickly than it would have been, with less time, money, and maintenance required. It is also more flexible.	
[50] (2008)	-To truly assist drivers and parking lot operators, It is recommended to use an agent-based coordination network.	-These contemporary intelligent agents are capable of coordination, execution monitoring, planning, and mobility. - The integrated parking assistant system can be built using these qualities.	
[51] (2015)	-An IoT-based framework for parking cars was proposed. - The framework integrates networked sensors with an automated parking management system, actuators, and RFID.	-The technology is affordable to install and consumes little electricity. -RFID system for predefined parking, RFID and wireless sensor hybrid system that can withstand many nodes' communication interference.	-It does not have an application for remote free space monitoring. -Nonaviation system extra services to make the latter more scalable, and the system's scalability and interoperability are limited by the wired bus topology.

[52] (2018)	-A WSN-based SPS was developed. For WSN technology, the system employs a hybrid self-organization algorithm. - In order to communicate wirelessly, the system is designed to consume minimal energy.	-This type of SPS helps users by directing them to the closest parking slot and reservation location. - Clients can access SPS features through the online and mobile applications of the system.	
[53] (2013)	-GSM technology has been used to create a safe parking reservation system. -Two modules, such as those for security reservations and parking lot monitoring, have been developed.	-Flexible and easy to implement, private with spaces reserved via GSM prior to movement, less expensive, and secure with a password that the GSM provides.	- During mass system access, the GSM system is prohibited, and no navigational aids or guidance are utilized. -No application is developed for remote monitoring, and access is restricted to the driver who made the reservation in advance.
[68] (2014)	-To ease traffic issues, a wireless technology-based Parking Space Vacancy System Monitoring prototype is unveiled. - The master module and the parking lot vacancy monitoring module are the two components that make up the system. - A PIC microcontroller interfaces with the digital infrared sensor, LCD, and Zigbee module that comprise the parking lot vacancy monitoring module. The result is a master module with a Graphical User Interface (GUI).	- The sensor nodes are attached to one other, and the system is straightforward and adaptable, it is less expensive, and it is valid for internal use.	-It uses linear networking. The system makes use of a display with a restricted web application. -The technology fails to provide remote monitoring of the parking lot's available slots.
[128] (2024)	-Suggests a wireless sensor network-based smart parking management system that can track the occupancy status of parking spaces and notify end users when they become available. - Each participating node in the route has its trust score determined by The trust-based routing method that considers energy. - The artificial neural network classifier is utilized in conjunction with the firefly method.	-The suggested plan to improve QoS metrics.	
[92] (2014)	-Present a Smart Parking System that combines WSN and Ultra-High Frequency (UHF) RFID technology.	-Mobile applications are managed by a cloud system built on Google, NFC payments are used, The Google API serves as the foundation for outdoor navigation, reservations are set up, and spaces are managed effectively.	-Only linear parking lots and not for mass parking lots can use the outdoor parking system. -The money is not examined, and RFID is only used in specific parking spaces.
[129] (2011)	-Wireless sensor-based information system. - Parking advice displays, sink nodes, routing nodes, parking space monitoring nodes, and an information and management center make up this system.	-System that transmits detected data using ZigBee technology. -A guidance system based on internal LCD. -It is a large parking lot that employs the cluster architecture for WSN self-organization. -Adaptable and affordable system	-It is not able to adjust to linear parking. -It lacks an external guidance system and navigation mechanisms. -This system is a no-payment system.

[130] (2016)	- RFID is used to identify the automobile's features, an infrared sensor is used to determine whether the car is present, and all information is accessible remotely via the Internet of Things.	-The system relies on data transmission via IPv6. -The RFID system is in place. An anti-theft system that relies on sending police GSM messages. -Using barriers to control inputs and outputs, hybrid sensors are used in indoor parking.	- No guidance or navigation system is in operation, there are sensors that are sensitive to car lights, and there is no security system at the exit.
[131] (2015)	- Utilizing a network of sensors and Zigbee-based wireless technology, it featured the construction of a smart parking system, which was based on the existing "Sistema integrado de Estacionamiento (SIMERT)" system and the mobility in Loja, Ecuador.	-It deploys sensors in outdoor parking lots using the tree topology. -A mobile app for drivers and agents. -The agents play a crucial part in keeping an eye on the parking spots in each region. - LEDs are used to show the number of empty slots in each section.	The technique is only appropriate for linear outdoor parking lots.
[67] (2015)	-Offers a wireless sensor node to determine if parking places are available and a wireless system that allows users to locate parking spots remotely with a smartphone.	-The use of outdoor navigation. -The RFID-based payment and security system. -The use of a Google Maps-based program to find every parking space that is available	-The application is restricted to visualizing the free spots within interior parking lots, and the technique is only applicable to indoor parking lots.
[132] (2017)	-A Smart Parking Management System (SPMS) is introduced that combines WSN, RFID (Radio Frequency Identification), and Automatic License Plate Recognition (ALPR) technologies. Information on parking space occupancy status is gathered by the system and sent to a database server via ALPR and WSN. - Users can access this data and get real-time updates by using a mobile application.	-For security and identification, they use ALPR and RFID. -The use a smartphone application to locate available spaces and navigate to parking areas. -The NFC is used for online payments.	-The system is only valid for mass sparking. The network's topology is fixed.
[133](2017)	-An Arduino Uno, an ESP8266-01 Wi-Fi module, an ultrasonic sensor, and a cloud server are all used in smart parking. - Smart parking is made feasible by an IOT-based new parking platform that connects, analyses, and automates data collected from devices.	-The use of strong sensors, the navigation of parking spaces via a mobile application (ParkX), and the implementation of parking fee payment.	-The sensors are costly,there is no security system in place, making reservations in advance may result in parking issues.
[134](2017)	-It is recommended that a smart parking system use the passive RFID tag-to-tag communication paradigm in order to increase operational effectiveness and energy efficiency.	- Parking entrance and exit control is implemented using RFID technology. - Additionally, it serves as the cornerstone for space management and security.	-They use a lot of Wi-Fi multi-hop communication. - No navigation or guidance system is used, and no mobile applications are used.

4. Smart parking systems Architecture

A smart parking system is an architectural framework that incorporates several application platforms incorporated into embedded systems. A smart parking system is made up of several interrelated components that work together to improve user happiness and parking management. These components include a communication network for smooth data transfer, a data management system for processing and analyzing data, occupancy sensors placed in parking spots to determine whether there are any vehicles present, and a user application that offers real-time updates. [42]. For example, users can request reserved parking spaces at the network layer, and the application layer will handle the request right away. According to the explanation, parking providers are supposed to use the network layer to execute the interaction with the transaction layer in order to handle the user request. Lastly, the distributed ledger is updated by the specific parking provider and the consensus mechanism protocol of the transaction layer [135]. the layered architecture is illustrated in Fig. 1.

This section offers a thorough examination and comparison of the technological strategies or tactics employed by different smart parking systems.

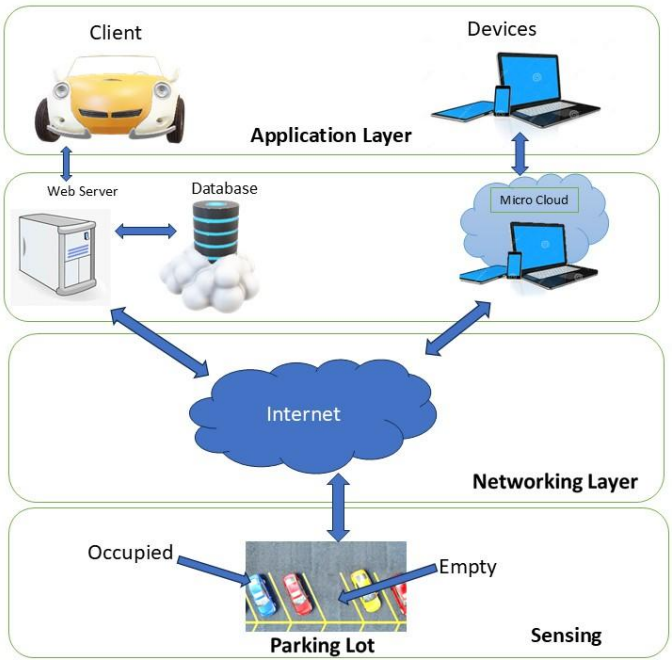

Fig. 1 Smart parking system architecture [135].

4.1. Network Layer

The network layer makes sure that users, integrated systems, and different parking centers can communicate with one other without any problems. Through a layer, the integrated system receives the user and parking center data. Layer comprises several communication technologies, such as LAN and WAN, which are utilized by parking service providers, users, and IoTs devices associated with parking systems (such as security cameras and parking sensors). They might have several wireless technologies, such as Bluetooth, WI-FI, and others, which, in addition to the current GSM technologies, come in 4G and 5G versions [135].

4.1.1 Wired Network-based Smart Parking Systems

A smart parking system that used loop detectors as sensors to identify cars in parking lots was presented in a study by [136]. The data gathered was then utilized to show the parking slot's state of occupancy in real time on an LCD panel. The design of this intelligent parking system was flexible enough to be effectively installed in both closed and open parking lots. Loop detectors or other wired sensors are used by wired network-based smart parking systems to identify cars in parking lots. Real-time occupancy data is provided by this method, which can be shown on LCD screens or other user interfaces. Although wired networks are

less prone to interference and provide dependable communication, installing wired infrastructure can be more difficult and expensive, particularly in parking slots that are already in place.

4.1.2. Smart Parking Systems based on wireless sensor networks (WSNs)

A WSN is a spatially distributed network of wirelessly connected sensor nodes. Every sensor node in a WSN is wirelessly coupled to a sink node [137,138]. These days, WSN has gained a lot of interest with smart parking systems developers due to its inexpensive deployment costs, scalability, and flexibility. Numerous research articles examined in this paper used WSN as the main strategy for constructing smart parking systems because of these advantages. In order to identify and track parking lot occupancy, [139] introduced a parking management system that made use of WSN by installing wireless sensors strategically throughout parking spaces. Regular transmission of the gathered sensor data to a database allowed for a number of administrative tasks, such as identifying empty parking spots, maintaining security, and producing statistical reports. A smart parking systems that employed optical WSN to notify users of parking spaces that were available and give them directions was presented by [140]. In addition to being easier to install and maintain, optical WSNs had even higher occupancy detection accuracy. [141although a control computer that monitored available spots and wireless transceivers that relayed parking and reservation information was part of the parking lot infrastructure, cars were equipped with basic processors and short-range wireless transceivers. Drivers were only able to book a spot when they were close to the parking slot, and they received messages on their terminals.

A WSN-based smart parking systems prototype comprising WSN nodes, a central web server, a mobile phone application-based user interface, and an embedded web server was presented by [142]. Its goal was to give customers access to real-time parking availability information and the ability to find available parking spots. Users could access the central web server through a smartphone application after the data from the parking lot was sent to an embedded web server. By combining WSN and RFID technology, [70] created a modified smart parking systems that enabled real-time parking lot occupancy monitoring. Wireless communication between the sensor nodes was made possible by the use of ZigBee communication technology. Using a smartphone application, [143] developed a WSN system for car occupancy monitoring that gave customers real-time parking lot availability updates. [144] presented an application-based user interface that was combined with an IoTs-based smart parking system. Parking lot occupancy was detected by infrared sensors, and the gathered data was sent to a cloud platform. Through a smartphone application, users could access the data and locate the closest parking spot that could hold a car their size. Although WSN-based smart parking systems demonstrates encouraging results in real-time parking lot occupancy monitoring and providing drivers with the most recent information on available parking spaces, issues like sensor accuracy, network dependability, and scalability must be taken into account. By combining WSN technology with web servers and mobile applications, parking information can be accessed more easily, improving user comfort and providing advantages such as real-time updates, accurate detection, and simple installation and maintenance. All things considered, WSN-based smart parking systems provide a practical way to manage parking effectively since it gives precise data on parking lot occupancy and assists cars in finding open spots instantly.

4.1.2. 1.Sensor in Smart Parking Systems

The following subsections provide specifics about the sensors utilized in the design, development, and implementation of smart parking systems [46].

4.1.2.1.1. Infrared (IR) sensor

An electrical device known as an infrared sensor measure and detects the infrared radiation that an object emits. Infrared radiation is released by any item with a temperature of five degrees or above. The primary applications of infrared sensors are temperature measurement and motion detection. There are Two types of infrared sensors are active and passive. [47,48,145,146].

4.1.2.1.2. Cellular Sensor

The sensors found inside smartphones are called cellular sensors. While a smartphone may have many sensors, most utilized ones are the smart parking systems, magnetometer, accelerometer, and gyroscope. These sensors are employed to determine the direction, orientation, and motion of the user [75,77].

4.1.2.1.3. Magneto-Resistive (MR) sensor

Magneto-Resistive sensors don't require any electrical connections to identify the applied magnetic field. It works on a very simple basis. Any electrical conductor that permeates undergoes a change in resistance when a magnetic field is applied. The direction of the magnetic field lines determines changes in resistance. In parking lots, MR is mostly utilized for vehicle detection.
[49].

4.1.2.1.4. Acoustic array sensor

To ascertain the direction and distance of the sound source or reflector that produced the sound, an acoustic array sensor listens for sound or vibration at particular frequencies. It's called the passive acoustic locating approach given to this kind of localization technique [100] . Acoustic array sensors are employed in smart parking systems for monitoring and parking lot vacancy detection.

4.1.2.1.5. Ultrasonic sensor

An ultrasonic sensor uses acoustic waves in the 25–50 kHz range to detect any nearby item that reflects the acoustic wave [42,47,48,147]. Due to its inability to function in adverse weather conditions like rain and snow, this sensor is most appropriate for interior applications. Consequently, ultrasonic sensors are utilized in indoor and closed parking facilities, where they are often installed on the ceiling. Vehicles can be detected via ultrasonic sensors. Furthermore, this kind of sensor can distinguish between a car and a bystander when used correctly. They are inexpensive and require little upkeep. It require little upkeep and are inexpensive.

4.1.2.1.6. Camera

Many smart parking systems researchers use cameras or a network of cameras for parking lot surveillance and vehicle detection. For the purposes of billing, reservations, and authentication, numerous Scholars have employed cameras and various computational tools (such as image processing, computer vision, etc.) to identify car license plates. Smart parking systems offers users a reliable parking solution by utilizing network of cameras. However, the deployment and maintenance costs of camera-based smart parking systems are frequently high [55,56,57,58].

4.1.2.1.7. Inductive Loop detector

The electromagnetic induction concept is used by an inductive loop detector, sometimes referred to as a vehicle loop detector or an inductive loop traffic detector. To find cars above the road, this kind of detector is placed beneath it. These detectors can categorize various vehicle types when combined with certain computational methods [99 ,148]. Loop detectors for cars are costly and need a lot of installation work. Parking lots that are open and closed can use this kind of sensor.

4.1.2.1.8. Light Detection and Ranging (LIDAR)

By illuminating the item of interest and using a sensor to measure the reflected light, LIDAR employs laser light to determine distance. A three-dimensional model of the object of interest can be produced by timing the acquisition of the reflected light and measuring the light's wavelength [97]. LIDAR is mostly utilized for vehicle identification in smart parking systems.

4.1.2.1.9. Microwave Radio Detection and Ranging (RADAR)

Microwave Radio Detection and Ranging measures the velocity, angle , and distance of a target object using electromagnetic waves in the microwave band. However, only moving objects can be detected by microwave radar [149]. It is possible to recognize both moving and stationary objects using Doppler Microwave Radar [150]. A smart parking system can replace a video camera by producing 2D images using AI and radar sensors. Additionally, a CNN can be taught to forecast the occupancy status of a parking lot using the

information gathered by microwave radar. This kind of sensor is not impacted by changes in the surroundings. As a result, both open and closed parking lots can use them. Nevertheless, it is costly to implement and maintain this kind of sensing method.

4.1.2.1.10. Magnetometer

By detecting changes in the electromagnetic fields surrounding a vehicle, a magnetometer may detect its presence. Each parking lot has magnetometers placed underneath it to detect the presence of any cars [42] [98]. Due to their insensitivity to environmental changes, Open-space and closed-space smart parking systems can both make use of magnetometers.

4.1.2.1.11. Agent

A multi-agent system includes processors, sensors, and additional tools is made up of agents. An agent is a little system that is a part of a larger network of systems that can produce, process, and send data in order to get a more complete view of the environment [50, 93].

4.1.2.1.12. Radio Frequency Identification (RFID) sensor

RFID tracks and identifies objects using electromagnetic waves. RFID technology makes use of a radio transponder that consists of an RFID tag and an RFID receiver. Digital data stored within the RFID tag is transmitted when it is read by the RFID receiver. The recipient receives the information needed to identify the object. Smart parking systems frequently use RFID technology to identify users and vehicles [47,51,59,151,152,41].

4.1.3. Multi-agent system (MAS) based Smart Parking Systems

A self-organizing computer system called MAS gathers several intelligent agents to address issues that are challenging for a single system to handle [153,154,155]. Numerous researchers have used MAS to create smart parking systems because of its efficacy in both enclosed or indoor and open or outdoor parking lot settings. An important part of MAS-based smart parking systems lowers the system's overall data transmission head by giving the agents access to computational resources. The rate of electricity consumption decreases as a result.

4.1.4. Computer vision/image processing based Smart Parking Systems

Using a range of camera networks, smart parking systems that are based on image processing and computer vision are able to extract information from image data, including the occupancy status of parking lots[86], Face recognition and license plate recognition (LPR) are used for security concerns, billing, and providing reports on traffic congestion [156,157]. Because they use real-time parking lot video data to extract features, computer vision/image processing systems usually have a high data transmission rate between the processing units and the camera network.

Since a single camera can catch a sizable portion of the parking lot, these smart parking systems are typically appropriate for open parking areas. These systems are vulnerable to distortion, light changes, shadow effects, and occlusion, though. In order to determine whether parking lots are occupied,[158] devised a smart parking system that made use of cameras and clever image processing.

Users could verify the occupancy or emptiness of parking spaces using an LCD panel at the entrance gate or through a web-based application once the acquired picture was processed and uploaded to a web server. It was easy to reserve parking spaces via SMS, which sent the reservation through a GSM module to the system's controller. A platform that made use of fog computing ,camera networks methods, and sophisticated deep learning algorithms was presented by [159]. The system had telescopic lenses and motorized camera heads to enable effective vehicle tracking, take pictures of license plates to compute fines, and improve security. A smart parking systems that used AI image processing techniques to recommend parking spots based on parameters including costs and the parking lot's proximity to the user's location was created by[160] .

Ultrasonic sensors were used to detect parking slot occupancy, and license plate identification, billing, and vehicle security were improved by cameras. Using IoTs technology, [161] developed a cloud-based smart

parking system that offered a parking reservation service and integrated RFID tags to guarantee that only those with permission could enter the parking lot. By using license plate recognition technology, the system also improved vehicle security by identifying large and overweight cars and blocking their entry into the parking lot. To identify parking lot occupancy, image processing-based smart parking systems uses cameras and image recognition techniques. This method is quite accurate and offers additional appealing features like improved security and identification of license plates for billing.

System's drawbacks include the need for higher initial investment because of the expense of the cameras and processing infrastructure, as well as the requirement that the image processing algorithms handle a range of lighting conditions, occlusions, and camera angles in order to provide accurate findings. The integration of intelligent image processing techniques into smart parking systems has also demonstrated efficacy in improving parking management.

Research has shown that distributed camera networks and sophisticated deep learning algorithms can be used to precisely determine number plates, detect parking slot occupancy, and provide real-time monitoring, fee computation, and enhanced security. Furthermore, incorporating fog computing approaches minimizes the need for in-depth cloud-based analysis while optimizing data processing.

4.1.5. Vehicular Ad-Hoc network (VANET) based Smart Parking Systems

Using a wireless network of mobile devices, VANET is modelled after the Mobile Ad Hoc Network (MANET). The three primary parts of smart parking systems using VANET are the On-Board Unit (OBU), Road Side Unit (RSU), and Parking Side Unit (PSU) [162,163,164]. PSUs are placed on parking lots, RSUs are placed alongside the roadways close to the parking lots, and OBUs are mounted on the cars. For this kind of system to authorize the vehicle's OBU, a reliable authentication authority is needed. The OBU of the car notifies the PSU that the parking lot is reserved if the vehicle is parked in a smart parking structure. After then, this data is sent from the PSU to the RSU. Through their OBUs, the cars that pass the road where the RSU is located can obtain information about parking lot occupancy. Both open and closed parking lots can use VANET-based smart parking systems. But when a vehicle pulls into the smart parking structure without an OBU, the system is expensive and gives false information.

Based on vehicle-to-vehicle communication,[165] presented a smart parking system that provided intelligent anti-theft protection, real-time parking information, and parking information distribution tailored for big parking lots. Using roadside units that made use of VANET technology, their system allowed for the effective management of the entire parking lot. In order to locate and reserve preferable parking places, [166] suggested the Eparking idea, which included an on-board unit put in vehicles. Additionally, the system offered value-added services to investigate possible business opportunities and partially offset operating costs. A smart parking system with an urban focus was provided by [167] Their system provided parking lot recommendations based on variables including parking costs and closeness to the destination, as well as parking space assignment and reservation services.

This smart parking system was notable for its parking lot identification, communication between vehicles and the infrastructure, and assured reservation. Vehicle-to-vehicle communication is used by VANET-based smart parking systems to distribute parking information and offer real-time parking navigation functions. This method works especially well in cities and big parking lots. Implementation challenges arise from the synchronisation of communication protocols and the deployment of the VANET infrastructure, VANET technology enables effective parking lot management because vehicles communicate with the infrastructure and each other [47].

4.1.6. IoTs based Smart Parking Systems

IoTs is the newest and most popular technology, in which every gadget is connected to every other device over the internet. Each internet-connected gadget has its own unique identity (UID). These gadgets may be digital, mechanical, or computational in nature. They are able to transmit data without requiring interaction between people or between computers [168,169,170]. One of the main essential technologies that developers

utilize for smart parking systems is IoTs technology. Every sensor and computing device in an IoTs-based smart parking systems is internet-connected and capable of data transfer without the need for human involvement. Both wired and wireless connections are possible for the internet connection between sensors, computing devices, and storage units. In a study published in [171] presented a smart parking solution that included an Internet of Things-based cloud platform. On-site IoTs modules were used by the system to track and determine availability of parking spots in real time.

Through a smartphone application, users could easily reserve a parking spot and check the condition of parking lots. An IoTs and multi-agent system-based smart parking systems was put into place by [172]. It offered real-time data on empty parking slots, guided cars to available parking spaces, and created a dynamic price structure for management who wished to rent out their places. An IoTs-based smart parking systems with a privacy protection focus was proposed by [173]. The technique was appropriate for devices with low processing power since it used elliptic curve cryptography rather than traditional public key cryptography. Zero-knowledge proof was also included in the system to further improve privacy protection. In order to help vehicles identify the nearest parking spots, provide real-time traffic congestion updates, and provide substitute routes to the smart parking systems facility, [174] built a smart parking systems that included IoTs technologies. The amount of data required for cloud-based analysis was reduced by using fog computing methods to increase the efficiency of data processing and transportation.

4.1.7. Machine learning (ML) based Smart Parking Systems

A subset of artificial intelligence called machine learning (ML) enables a system to learn from datasets or experiences and get better at a given activity without requiring explicit programming [175]. To determine the parking slot status, a machine learning-based smart parking systems analyses the data. Additionally, parking slot occupancy status for the next few days, weeks, or even months can be predicted using ML and AI-based smart parking systems, which can also offer a dynamic pricing plan.ML-based systems are able to track traffic on specific roadways and provide a clever solution for smart parking spots [176].

4.1.8. Deep learning (DL) based Smart Parking Systems

Deep learning is a subset of ML and an AI function that processes data and extracts features to make judgements similarly to the human brain [177,178]. The system needs fewer sensors and cameras because DL algorithms, rather than conventional sensors, identify special and vacant parking spots in a smart parking systems. Parking lot occupancy is predicted using DL as well.

4.1.9. Neural Network (NN) based Smart Parking Systems

Neural Network is a collection of algorithms that, by simulating how the human brain works, pulls features and underlying relationships from data sets [57]. NN is utilized in smart parking systems to distinguish license plates from real-time video data. Smart parking system uses NN to identify license plates from live video footage. Additionally, CNNs can display the traffic situation on several routes [179].

4.1.10. Fuzzy logic based Smart Parking Systems

One type of thinking that mimics human reasoning is fuzzy logic. Since fuzzy logic employs multi-valued logic, neither absolute truth nor absolute false value exists [180]. Smart parking system predicts the occupancy state of parking lots using fuzzy logic [1]. However, without verifying the predicted outcome using real-time data, There would be little accuracy in the fuzzy logic-based prediction model[181]. As a result, fuzzy logic increases the system's overall accuracy when combined with sensors or machine vision.

4.1.11. Global Positioning System based Smart Parking Systems

GPS is a crucial part of various smart parking strategies. However, parking slot occupancy status and other smart parking facilities cannot be obtained with GPS alone. On the other hand, GPS can introduce a car navigation feature that allows the user to drive in the direction of empty parking lots. Numerous systems use CNN or DL algorithms to predict traffic congestion and parking lot occupancy based on GPS data [182]. The quantity of GPS receivers determines its accuracy. GPS accuracy for a single frequency receiver is

around 7.8 meters. However, a two-frequency receiver offers an accuracy of about 0.715 meters. Additionally, if the GPS data is used inside a closed parking area, it may have errors. Therefore, GPS-based smart parking systems are appropriate for open parking lots [48,76,77] .

4.1.12. Global System for Mobile based Smart Parking Systems

Second-generation (2G) digital cellular networks use the GSM standard. SMS is a subsidiary service offered by the GSM standard. Based on GSM, smart parking systems makes reservations for parking spaces at various locations via SMS service. During the reservation process, some systems also provide users with unique codes that are used to validate the reservation and guarantee that only the people who are supposed to be there can park [53].

4.1.13. Bluetooth based Smart Parking Systems

The Bluetooth technology standard enables data transfer across short distances. Automated valet parking is typically included in smart parking systems that are fully Bluetooth-based. To obtain various smart parking services, regular smart parking system — Their automatic valet parking facility is not used —needs extra sensors and methods [183,75,150]. The crowd-sensing technique is used by many smart parking systems to collect data about nearby parking spaces. The technique collects parking lot data using smartphone sensors (magnetometer, gyroscope, accelerometer, and GPS) and apps [184]. It is evident that the most often used methods for putting smart parking systems into practice are WSN and IoTs. Another commonly employed method in smart parking systems is computer vision/image processing. In smart parking systems, the remaining technological approaches are used essentially in the same way.

4.2. Transaction Layer (Networking technologies)

This layer is required to conduct transactions between the network's nodes. With the help of consensus processes and smart contracts, users and various parking facilities may share data in a more secure manner. Networking is among the most crucial components of smart parking systems. Through networking, the processing units receive the data produced by the sensors, or the end users receive the information that has been processed by the processing units. Stated differently, it establishes connections between sensors, processors, and end users.

The Sensor Network and User Network are the two components that make up the smart parking systems network [46][135].

4.2.1. Sensor network

The component that transmits data between the sensors and the processing unit is called a sensor network. There are two types of sensor networks: wired and wireless. Local Area Networks (LAN), WiFi, Direct Short-Range Communication (DSRC), ZigBee, Constrained Application Protocol (CoAP), 3G/4G cellular networks, General Packet Radio Services (GPRS), Improved Information for IPv6 over Low Power Wireless Personal Area Networks (6LoWPAN), and GSM Evolution (EDGE), and other common wireless technologies are among the many that smart parking systems can use for wireless communication [46][135].

4.2.2. User network

For data visualization, parking reservations, billing, and other associated tasks, the user network links end users to the smart parking systems. Wireless connectivity such as 3G/4G cellular networks, WiFi, Device to Device (D2D) via WiFi, GPRS, GSM, Wide Local Area Network (WLAN), etc.—is the primary foundation of user networks [46][136].

4.3. Application Layer (User interfaces)

Users can use a variety of interfaces (including online applications, Vehicle Information and Communication System, and smartphone applications) to communicate with smart parking systems. It is clear that VICS-based smart parking systems are the least used type of smart parking systems, whereas smartphone application-based smart parking systems are the most popular [43].

4.3.1.Web application based Smart Parking Systems

Many smart parking systems use web applications built on the Transmission Protocol (TCP)/Internet Protocol (IP) and Hyper Text Transfer Protocol (HTTP) protocols to give end users remote access. PS web applications often give the user a graphical user interface (GUI).The online application presents features like parking spot reservations, online payment options, real-time parking slot status updates, and directions to the closest parking slot or parking location.

4.3.2.Smart phone application based Smart Parking Systems

In order to inform end customers about smart parking facilities, a sizable portion of smart parking systems uses Android or iOS applications. Similar to web-based apps, smartphone apps let users interact with the system through a graphical user interface. Additionally, using web services or cellphones' Near Field Communication (NFC) technology, one can pay parking costs, reserve a parking space, get parking lot information, and get real-time parking lot status updates.

4.3.3.Vehicle information and communication (VICS) based Smart Parking Systems

Through a monitor installed on the dashboard of the car, VICS technology provides the driver with traffic and trip information. The VICS uses wireless technology to send and receive data such Radio Data System (RDS), IR, Data Radio Channel (DRC), FM, and microwaves in the Industrial Scientific and Medical (ISM) band. VICSs are used smart parking systems to obtain data on traffic congestion and the closest parking lot. They can occasionally be used to make parking reservations as well.

4.4.Computational approaches in Smart Parking Systems

One essential component of a smart parking system is the computing unit. Either a physical device situated within the parking area, or a cloud platform can serve as the computational unit. The following computational techniques were used by the smart parking systems under review.

4.4.1. Big Data

Massive amounts of data are produced by large-scale smart parking systems, and Big Data is typically employed as its computing approach. Generally speaking, "big data" refers to enormous volumes of both organized and unstructured data that are far too large and complicated for conventional data processing application software to handle. It offers a method for managing the enormous volume of data and producing insights. Big Data can be implemented on-premises or through cloud services by large smart parking systems [185,186,187,188].

4.4.2. Cloud computing

Smart parking systems typically uses cloud computing since it necessitates off-site sensor data processing and storage devices. Cloud computing gives the system on-demand cloud storage and data processing power without requiring user oversight [189]. The IoTs-based system often makes use of cloud computing [47,65,66].

4.4.3. Fog computing

Fog computing refers to an architecture that optimizes the edge device's ability to process, store, and link with the end route via internet technologies. This architecture can be seen in big data and cloud computing. Decentralized smart parking system tends to use fog computing for data processing and storage [190,191,192]. Smart parking systems can lower the volume of data that needs to be sent by using fog computing, which increases the system’s energy efficiency.

5.Discussion

The literature now in publication offers a variety of smart parking systems approaches based on cutting-edge techniques including wired networks, VANET, image processing, WSN, and others. Every strategy has pros and cons, and the selection of technology is influenced by elements like precision, affordability, scalability, and simplicity of use. IoTs-based smart parking systems has been shown in numerous studies to

be successful in improving parking management and user experience. To implement dynamic pricing techniques, enable reservation services, and give real-time information on parking spot availability, these systems make use of a variety of IoTs technologies, such as cloud platforms, sensors, smartphone applications, and sophisticated algorithms. These systems also include features for car security, privacy protection, and navigation system integration.

6.Conclusion

There are fewer urban parking spots and more traffic congestion as a result of the unplanned urbanization and fast urban population growth. Consequently, smart parking becomes a topic of interest for both urban planners and researchers. To precisely identify real-time parking occupancy and effectively manage parking spots, smart parking systems have experienced substantial development and have adopted a range of methodologies and technology developments.

Improvements in sensor technology and data processing have increased their efficacy and dependability, and the incorporation of IoTs technology has made it easier to monitor and identify available parking spaces. Users can now conveniently access the information through smartphone applications. The potential of IoTs-based smart parking systems to improve user experience and make data-driven decisions is what has led to their broad acceptance in urban settings. Due to its wireless networking feature, which eliminates the need for significant wiring and lowers deployment costs overall, WSN is a preferred option for smart parking systems installation. Vehicle detection systems that use computer vision or image processing use fewer sensors, but because camera networks are required, installation costs are high. However, they usually require less upkeep after installation. The poor acceptance rate of VANET-based smart parking systems is mostly caused by the expensive cost of installation and the need for on-board units in cars. An overview of smart parking systems implemented by various researchers is given in this publication. The study methodically discusses the various strategies the researchers used to create their smart parking system and how well they work with various parking lots. Additionally, the article discusses several smart parking sensors and how to use them in various scenarios.

Additionally, smart parking systems has been categorized according to services, networking technologies, user interfaces, and computational methods. These categories offer a comprehensive understanding of smart parking systems from a variety of perspectives. Additionally, the study offers a thorough analysis of the benefits and drawbacks of various smart parking system types in resolving a range of issues that are presented to the systems. According to the thorough examination and analysis carried out in this study, multi-approach based smart parking systems will predominate in future smart cities where the IoTs will serve as the backbone. Services including parking surveillance, online payment, parking reservations, and vehicle navigation will be standard smart parking systems features, and the user interface will be based on a smartphone application. In conclusion, a number of studies have investigated the application of smart parking systems and have presented creative solutions to the problems associated with parking space management and availability. Because it lays the groundwork for future investigation and development of novel ideas, technologies, and approaches pertaining to smart parking and IoTs-based solutions, Researchers, academics, and professionals working in the transportation sector, smart cities, IoTs, and urban planning will find this study to be a priceless resource.

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