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Recent advances and emerging trends in smart parking technologies from sensor based to next generation parking system: a review

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ABSTRACT

Rapid urbanization, growing vehicle ownership, and limited parking infrastructure have made parking allocation a major challenge in modern cities. To address this issue, numerous smart parking systems (SPSs) have been proposed to improve parking efficiency, reduce congestion, and enhance user convenience. This paper presents a comprehensive review and comparative analysis of SPSs in terms of technological approaches, sensing methods, networking technologies, computational models, user interfaces, and service capabilities. It also addresses an important research gap by evaluating the suitability of different SPS approaches under diverse environmental conditions and highlighting their key advantages and limitations. The review emphasizes the growing role of internet of things (IoT)-based, multi-approach architectures in enabling real-time monitoring, reservation, payment integration, and vehicle guidance for smart city applications. Furthermore, it discusses the potential of integrating reconfigurable systems with IoT to improve adaptability, scalability, and responsiveness through dynamic resource allocation and efficient local decision-making. Despite these benefits, challenges related to interoperability, security, energy management, design complexity, and deployment cost remain significant. Future SPSs are expected to incorporate artificial intelligence, predictive analytics, dynamic pricing, autonomous vehicle support, and digital twin technologies to achieve more adaptive, intelligent, and sustainable parking management.

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1. INTRODUCTION

Urban mobility issues in contemporary cities have greatly increased due to rapid urbanization and the exponential rise in private automobile ownership. Finding parking spots is one of the most enduring problems with urban transportation, which exacerbates traffic jams, raises fuel consumption, and pollutes the environment. According to studies, a significant amount of urban traffic congestion is brought on by drivers looking for parking spots, which wastes time and produces needless emissions [1]. Smart parking systems (SPSs), which use internet of things (IoT) technologies, sensors, and intelligent data analytics to monitor parking availability and direct drivers to available spaces in real time, have emerged as a promising solution to these problems within the larger context of smart city initiatives [2].

Urban parking challenges and limitations of conventional systems: traditional parking management systems rely on manual monitoring or static infrastructure, offering limited automation and little real-time visibility of parking availability. Studies indicate that drivers spend an average of 7.8 minutes searching for parking, with nearly 30% of urban traffic caused by vehicles looking for available spaces [3]. This contributes to traffic congestion, fuel waste, driver frustration, and increased emissions, including carbon monoxide (CO), carbon dioxide (CO_2), volatile organic compounds (VOCs), hydrocarbons (HCs), and nitrogen oxides (NOx) which negatively impact air quality and public health [4]–[7]. SPS address these challenges by using sensors, communication networks, and cloud platforms to detect and share real-time parking availability. Occupancy data is collected through sensors and delivered to users via mobile applications or navigation systems, enabling faster parking searches. However, current SPS solutions still face challenges related to scalability, deployment and maintenance costs, energy consumption, and data privacy [8].

Recent research has explored sensor-based, IoT-enabled, and machine learning (ML)-driven parking solutions. These technologies support real-time monitoring, parking reservations, and occupancy prediction using historical and live data [9], [10]. Nevertheless, most studies focus on individual components rather than integrating sensing, communication, computation, and user services into a unified architecture suitable for large-scale smart city deployments [11]. Although substantial research has been conducted on smart parking technologies, several important gaps remain. Many existing studies emphasize individual components-such as sensing devices, wireless communication technologies, or predictive algorithms-rather than examining the end-to-end architecture required for real-world deployments. Moreover, scalability, energy efficiency, interoperability, and privacy-preserving mechanisms are often insufficiently addressed in current systems. As smart cities continue to expand, future parking infrastructures must support large-scale deployments while maintaining low energy consumption, secure communication, and seamless integration with other urban services. To address this gap, the paper presents a comprehensive review of SPS by organizing the literature into key technological dimensions, including sensing technologies, networking frameworks, computation and data-processing methods, and service-layer applications. It also identifies the major research gaps and deployment challenges that must be solved for next-generation SPS development. The significance of this review lies in its relevance to embedded IoT platforms, reconfigurable system architectures for smart cities, and very large-scale integration (VLSI)-based low-power design approaches, making it useful for both researchers and practitioners working on scalable, energy-efficient, and intelligent urban parking solutions. Some of the advantages of SPS are shown in Figure 1.



Figure 1. Overall organization of the paper as a block diagram

The subsequent outlines the organization of the paper. Section 1 provides motivation and introduction. The literature review procedure is outlined in section 2. A comprehensive review of the literature is provided in section 3. Section 4 provides an implemented sensors technology in the SPS. Section 5 discussed SPS networking technologies. Section 6 discussed computational approaches. Interfaces for user interaction are detailed in section 7. Hardware embedded technology and IoT are discussed in section 8. SPS services are classified under section 9. Section 10 discuss the compressive review. The research gap and future direction of the paper is presented in section 11, while conclusion is provided in section 12.

2. METHODOLOGY USED FOR LITERATURE REVIEW

This study identified current technology trends, highlighted future research opportunities, and used an organized literature review process to investigate the evolution of SPS. Figure 2 illustrates the three main stages of the review process: planning, review, and outcome synthesis. The review's scope, data sources, and search criteria were established during the preparation phase. A methodical filtering procedure was used to obtain and screen the literature throughout the review step. In order to provide a comprehensive understanding of SPS architectures, technologies, and implementation techniques, the chosen studies were finally examined and categorized. Major academic databases such as Google Scholar, Springer, Web of Science, ScienceDirect, Scopus, IEEE Xplore, and ProQuest were used for the literature search. The search method used terms like "SPS," "IoT," "sensor network," "parking occupancy prediction," and "e-parking" to guarantee a wide retrieval of pertinent papers. Since this time frame reflects the development and expansion of contemporary SPS research, only publications published after 2015 were considered. A preferred reporting items for systematic reviews and meta-analyses (PRISMA)-style screening logic was applied to improve transparency and reproducibility. The initial database search identified 487 records. After quality screening, 261 peer-reviewed studies were retained. A further relevance assessment was then performed, resulting in a final set of 81 studies directly related to SPS design, methodologies, sensors, prediction models, and e-parking systems. To support the analysis, both qualitative and quantitative synthesis were used. Quantitative assessment included publication trends from 2015 to 2025, showing a strong increase in SPS research, particularly after 2014 and more sharply during 2022–2025.

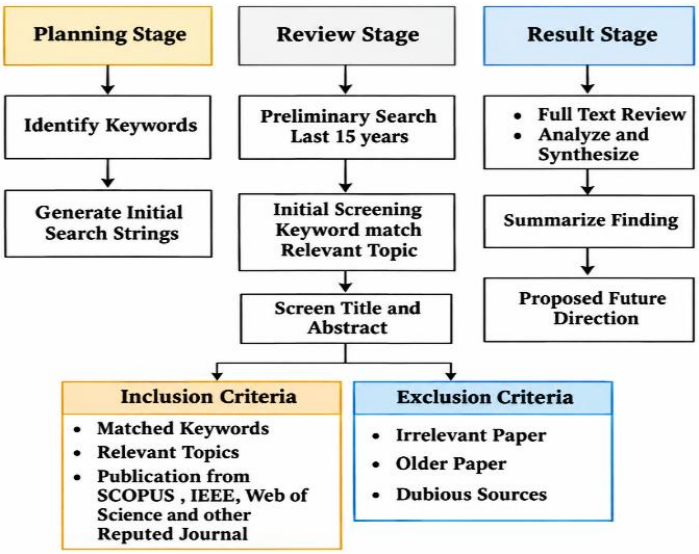


Figure 2. Methodology for literature review

The review also analyzed the distribution of technologies used in SPS, including camera, radar, infrared, ultrasonic, and magnetometer sensors; communication methods such as ZigBee, Wi-Fi, dedicated short-range communications (DSRC), constrained application protocol (CoAP), and cellular networks; data management techniques including hybrid models, ML, deep learning (DL), and neural networks. User interfaces such as web-based, smartphone-based, and VICS-supported platforms. We also explore methodologies in embedded/IoT systems focusing on SPS and how technology map to hardware and software codesign strategies for energy efficient, edge enabled IoT systems. The search for the keyword "smart parking" resulted in a compilation showing the distribution of indexed scholarly publications across various academic publishers as shown in Figure 3. This data indicates the concentration of research materials available on the topic across different platforms. The largest number of indexed results were found on Elsevier ScienceDirect (55), followed closely by Springer Nature (44) and IEEE (41). Other substantial publication venues included Sage Publishing (37), Wiley Blackwell Publishing (33), and Emerald Publishing (19). The remaining counts diminish across other publishers, such as Institute of Physics (13), Taylor and Francis (10), Association of Computing Machinery (ACM) Digital Library (9), and various smaller venues, illustrating the broad, yet unequally distributed, scholarly footprint associated with the search results. The main goal of this paper is to

take a closer look at existing smart parking solutions and understand how they work. We focus on four main areas:

- Approaches and methods: how SPS are designed, from centralized and decentralized setups to sensor-based and intelligent decision-making systems.
- Sensors: the types of sensors used to detect vehicles, monitor parking spaces, and track environmental conditions, which provide the real-time data these systems rely on.
- Hardware interface: embedded IoT platforms, reconfigurable system architectures for smart cities, and VLSI-based low-power design approaches, making it useful for both researchers and practitioners working on scalable, energy-efficient, and intelligent urban parking solutions.
- Services: the features SPS offer, such as reserving spaces, guiding drivers to available spots, handling payments, managing gates, and supervising parking operations to make the experience smoother for users.

3. OVERVIEW OF SMART PARKING SYSTEM

We have divided the SPSs into 12 groups, as seen in Figure 3. Wireless sensor networks (WSN), multi agent systems (MAS), computer vision (CV)/image processing (IM), vehicular ad-hoc network (VANET), IoT, ML, DL, neural network, fuzzy logic, global positioning system (GPS), global system for mobile (GSM), and Bluetooth-based SPS are these categories. The key strategies used in SPS are shown in Figure 4. The technological approaches used by various SPS implementations are thoroughly examined and contrasted in this section. Subsections 3.1 through 3.12 address the twelve categories into which SPS solutions are divided based on their fundamental methods.

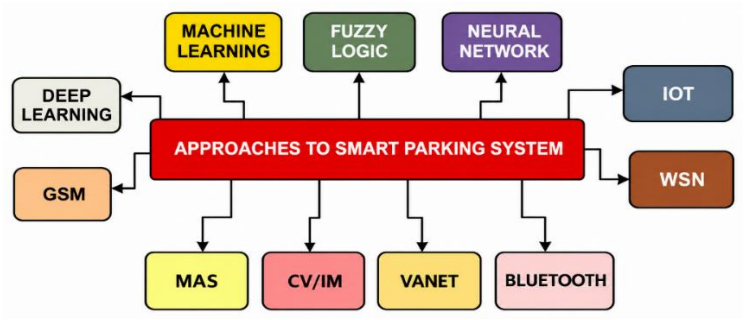


Figure 3. Methods for intelligent parking systems

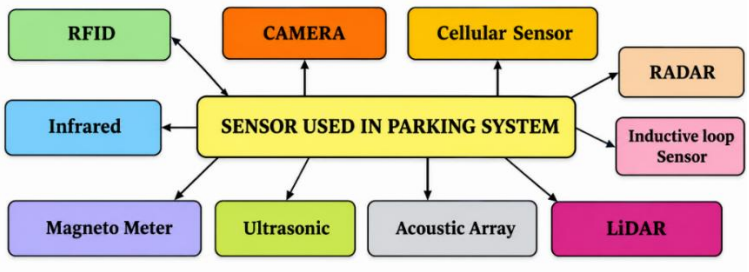


Figure 4. Sensor used in parking system

3.1. Wireless sensor network

Based SPS use distributed sensor nodes equipped with ultrasonic, magnetic, infrared, or pressure sensors to detect vehicle occupancy. These nodes transmit data wirelessly to a gateway, which forwards it to a central server for processing and user display [12]. WSN-based systems are widely adopted due to their low cost, scalability, and ease of deployment, particularly in large parking facilities. However, challenges such as battery maintenance, sensor calibration, network congestion, and environmental interference can affect reliability. Energy-efficient communication protocols and sleep scheduling techniques are commonly used to extend sensor lifetime [13].

3.2. Multi agent system

Based SPS use autonomous agents to manage tasks such as occupancy monitoring, reservations, vehicle guidance, and payments. These agents communicate and make distributed decisions without a central controller, improving system robustness and fault tolerance. MAS-based systems are suitable for complex parking environments, such as multi-level and city-wide parking networks, but challenges remain in agent coordination and real-time decision-making [14].

3.3. Smart parking system

That use CV use networks of cameras to get information like parking occupancy status, license plate recognition, and, in some cases, facial recognition for billing, security, and traffic analysis. These systems depend on real-time video or image streams, which means that the cameras and processing units need to send a lot of data back and forth. Vision-based methods work best in open parking lots because one camera can cover a lot of spaces [15].

3.4. Vehicular ad-hoc network

Based SPS enable wireless communication between vehicles and roadside infrastructure. They typically consist of parking space units (PSUs), roadside units (RSUs), and vehicle on-board units (OBUs). Occupancy information is transmitted from PSUs to RSUs and then shared with nearby vehicles, providing real-time parking availability updates [16]. While VANET-based systems support efficient parking guidance, their adoption is limited by high deployment costs and dependence on OBUs, particularly when vehicles without OBUs use the parking facility [17].

3.5. Internet of things

Based SPS integrate sensors, communication networks, cloud platforms, and mobile applications into a unified framework. Parking data collected by sensors is transmitted through technologies such as Wi-Fi, long range wide area network (LoRaWAN), narrowband (NB)-IoT, or ZigBee for real-time monitoring and management [18]. These systems offer high scalability and interoperability, but face challenges related to data security, network reliability, and energy consumption [19].

3.6. Machine learning

Based SPS analyze historical and real-time parking data to predict occupancy and optimize space utilization. Techniques such as decision trees, support vector machines, and regression models improve parking management in dynamic environments [20]. However, their performance depends on data quality, model selection, and regular retraining to adapt to changing conditions.

3.7. Deep learning

Based SPS use neural networks, particularly convolutional neural networks (CNNs), to analyze images and video streams for vehicle detection and occupancy estimation [21]. These methods provide higher accuracy and automation than traditional IM techniques but require large, labeled datasets, significant computational resources, and careful model optimization for real-time performance [22].

3.8. Neural network

Based SPS employ artificial neural networks to recognize patterns in parking-related data. These systems are commonly used for license plate recognition, vehicle classification, and occupancy detection. CNNs and recurrent neural networks (RNNs) are particularly effective in processing visual and temporal data. Neural network-based systems offer high adaptability and can handle complex, nonlinear relationships. Their limitations include high training costs, sensitivity to data imbalance, and challenges in interpretability [23].

3.9. Fuzzy logic

Based SPS model deals with uncertainty and inaccuracy in parking situations by using language variables and rule-based reasoning [24]. These systems guess how many parking spaces are available based on things like the time of day, how many cars are on the road, and how many people have used the space in the past. Fuzzy logic is easy to understand and doesn't take up a lot of computer time. But its accuracy depends on having clear rule sets, and it often needs to be combined with real-time sensor or vision data to be more reliable [25].

3.10. Global positioning system

Technology is widely used in SPS for navigation and parking guidance. While GPS cannot directly detect parking occupancy, it can support occupancy prediction and traffic analysis when combined with CNN

or DL techniques [26]. GPS accuracy depends on the receiver type and is generally more effective in open parking areas, as signal errors increase in enclosed environments [27].

3.11. Global system for mobile communications

Is standard for 2G digital cellular networks. Short message service (SMS) is a service that is part of the GSM standard. SPS is based on GSM and lets you book parking spots at several lots using SMS. Some systems also give users special codes when they make a reservation. These codes are used to check the reservation and make sure that only the right people can park [28].

3.12. Bluetooth is a short

Range wireless communication technology commonly used in SPS for applications such as automated valet parking. However, additional sensors and technologies are required to support broader parking management [29]. Crowd-sensing approaches use smartphone sensors, including GPS, accelerometers, gyroscopes, and magnetometers, to collect parking data and identify available parking spaces [30].

4. SENSORS IMPLEMENTED IN SMART PARKING SYSTEM

As illustrated in Figure 4, SPSs can be categorized as infrared ray (IR), cellular sensor, magneto-resistive, acoustic array, light detection and ranging (LiDAR), radio detection and ranging (RADAR), magneto meter, agent, radio frequency identification (RFID), ultrasonic, camera, and inductor loop sensor-based systems. Table 1 discussed the comparative analysis of various sensors utilized in SPS system [31]–[37].

Table 1. Review of comparative analysis sensor technologies

Sensor type	Accuracy (%)	Environment	Cost	Advantages	Disadvantages	Study
Infrared	90	Every weather	Moderate	Works in low-light conditions	Susceptible to interference	31
Ultrasonic	85–90	Every weather	Low	Reliable and inexpensive	Affected by severe weather	32
Camera	80–95	It depends on lighting	Moderate-high	Detailed visual data, license plate recognition	impacted by low light levels	33
Magnetometer sensor	85	Indoor and outdoor	Low	Affordable and easy to install	Electromagnetic interference sensitivity	34
Inductive loop sensor	98	Indoor, ideal for garages	High	High accuracy, reliable	Expensive installation	35
Radar	95	Every weather	High	Reliable under all conditions	High cost	36
Cellular	90	Wide network coverage	Moderate	Integration with parking systems and real-time communication	Ongoing subscription costs	37

5. COMMUNICATION NETWORKING

Table 2 highlights that different networking technologies exhibit distinct advantages and limitations depending on their inherent characteristics. Overall, each networking solution is tailored to specific application requirements, and its suitability depends on the intended operational context of the SPS [38]–[44].

Table 2. Review of comparative analysis communication networking technologies

Network type	Advantages	Disadvantages	Latency	Data transfer rate	Study
Wired	Secure and high dependable	Expensive, less flexibility	<1 ms	Up to 10 Gbps	38
Wireless ZigBee	Low power, cost-effective	Low data rate, short range	~30–50 ms	250 Kbps	39
Wi-Fi	Fast and adaptable	High power and limited coverage	~1–5 ms	Up to 1 Gbps	40
DSRC	For vehicle-to-vehicle communication	Short range, interference	~50 ms	Up to 27 Mbps	41
CoAP	Effective and economical	Restricted network	~100 ms	Up to 10 Mbps	42
Cellular Networks	wide-ranging coverage in real time	High cost, privacy issues	<1 ms (5G)	Up to 10 Gbps (5G)	43
GPRS	Easily accessible	Slower compared to 4G/5G	~500 ms	Up to 100 Kbps	44

6. COMPUTATIONAL APPROACHES IN SMART PARKING SYSTEM

The computational unit in SPS can be implemented either on cloud platforms or through local processing units deployed within parking facilities. Big data techniques are commonly used to process the large volumes of structured and unstructured data generated by sensor networks, enabling efficient analysis and

decision-making in large-scale parking environments [45]. Cloud computing provides on-demand storage and processing resources, allowing IoT-based SPS to manage parking data remotely without requiring local infrastructure [46]. In contrast, fog computing brings processing, storage, and communication capabilities closer to edge devices, enabling local data processing [47]. This reduces dependence on centralized cloud servers, lowers network traffic, improves response time, and enhances energy efficiency.

7. USER INTERFACE IN SMART PARKING SYSTEM

Table 3 compares web-based, smartphone-based, and vehicle-integrated interfaces used in SPSs. Web-based platforms offer wide accessibility and support reservations and availability monitoring. Smartphone applications provide real-time updates, mobile payments, and high user convenience, making them the most practical solution. Vehicle-integrated systems enable seamless in-car navigation and parking updates but are limited to compatible vehicles and require more complex implementation [47]–[49].

Table 3. A comparison of user interfaces

User interface type	Advantages	Limitation	Key features	Quantitative metrics	Study
Web-based application	Access by internet devices	It might not be mobile-friendly	Reservations and parking availability	Load time: ~2-5 seconds, accessibility: high	[47]
Smart phone-based application	Simple, mobile-friendly, and real-time reports	Installing an app is necessary	Data in real time and mobile payments	Load time: ~1-3 seconds, user ratings: 4.5/5	[48]
Vehicle integrated camera system	Included into automobile navigation systems	Limited to select vehicles, complicated setup	Real-time updates and in-car navigation	Data transfer rate: ~5 Mbps, accuracy: 90 95%	[49]

8. EMBEDDED TECHNOLOGY AND INTERNET OF THING INTERFACE

This literature review highlights the evolution of SPSs through the integration of IoT technologies and hardware/software co-design. As shown in Table 4, recent studies emphasize edge/fog computing and AI-based models such as TinyML to reduce latency and improve vehicle detection. Low-power communication protocols, including long range access (LoRa) and message queuing telemetry transport (MQTT), play a key role in enhancing energy efficiency and scalability. However, challenges related to interoperability and security remain. Overall, the review underscores the need for unified and flexible architecture to support sustainable urban mobility [49]–[54].

Table 4. Methodologies and co-design in smart parking

Architectural model complexity	Energy efficiency	Communication protocol integration	Scalability and flexibility	Real-time performance	Study
IoT-based system with online interface and sensor network	Energy efficiency through contactless entry and reservation	Real-time sensor data via IoT network	Flexible for urban parking infrastructure	Real-time availability and reservation updates	[49]
Systematic literature review of AI and IoT smart parking methods	Energy-efficient automated solutions discussed	WSNs and ultrasonic sensors	Scalability challenges and interoperability issues	Real-time data analytics and demand forecasting	[50]
Embedded STM32 and LoRa for low-power parking system	Low power consumption via LoRa communication	LoRa protocol for long-range sensor communication	Scalable for large parking areas	Real-time parking availability via mobile app	[51]
Separate hardware/software parts for parking system	Energy savings via RFID and ultrasonic sensors	RFID and ultrasonic sensor communication	Scalable with modular hardware/software	Real-time parking zone determination	[52]
Blockchain-IoT integration for parking counters	Energy efficiency via decentralized data handling	IoT nodes with LED and web communication	Scalable with blockchain-based asset tracking	Real-time parking space counting	[53]
RFID-enabled SPS	Energy savings through RFID sensor use	RFID communication with mobile app	Scalable for urban parking environments	Real-time parking space detection	[54]

9. SERVICES PROVIDED BY DIFFERENT TYPES OF SMART PARKING SYSTEMS

Figure 5 summarizes the six fundamental services offered by different SPSs. The parking reservation feature allows users to use the SPSs graphical user interface to reserve parking spots in advance within a

specified area [55]–[59]. Drivers are assisted by vehicle guidance, which points them in the direction of allocated or currently open parking spots within the building [56]–[58]. By enabling customers to electronically pay parking fees, online payment reduces the need for manual transactions [55]–[58].

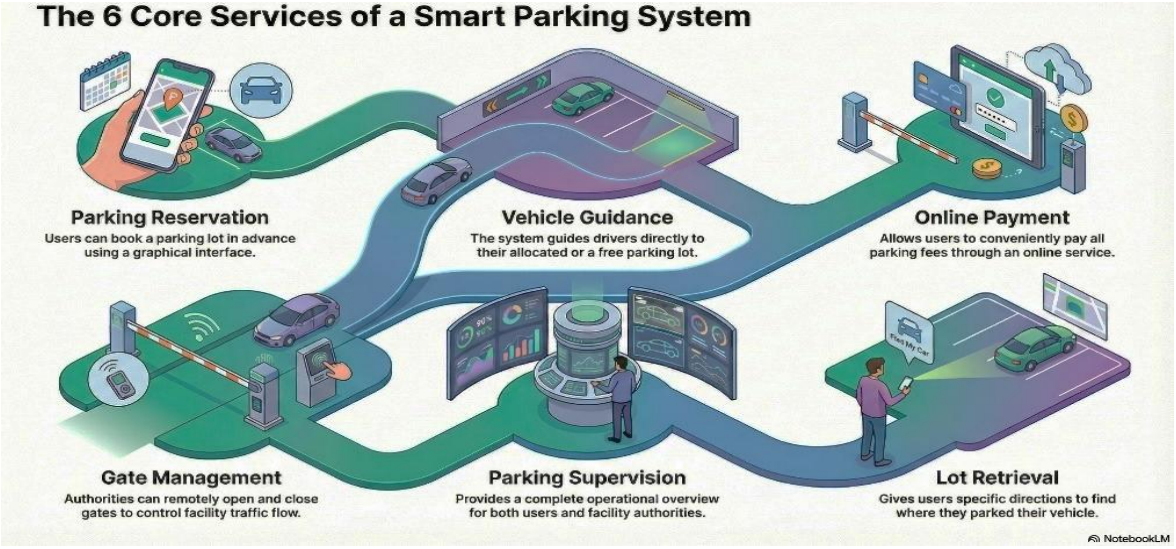


Figure 5. Services provided by different parking systems

Gate management encompasses the regulation and coordination of various entry and departure points within a parking facility, enabling operators to efficiently manage vehicle access and traffic flow [55]–[57]. Parking supervision involves oversight and administration of parking operations from user and administrative viewpoints, facilitating regulation enforcement and system performance assessment [38].

10. DISCUSSION AND COMPARATIVE ANALYSIS OF SMART PARKING SYSTEMS

10.1. Discussion on smart parking system approaches

IoT-based SPSs are widely preferred due to their low deployment and maintenance costs. WSN-based systems are the second most common, benefiting from minimal wiring requirements. Although camera-based systems require fewer sensors for vehicle detection, their installation costs are high, despite generally requiring less maintenance.

10.2. Discussion on sensor technology

The comparative analysis in Table 1 shows that no single sensor technology satisfies all SPS requirements. Camera-based systems provide high accuracy and enhanced security through surveillance and license plate recognition but incur high energy and processing costs. Magnetometer-based systems are scalable and energy-efficient but may be affected by interference. RFID and ultrasonic sensors are also widely used, with ultrasonic sensors primarily employed for real-time vehicle detection and parking occupancy monitoring.

10.3. Discussion on networking technologies, computational approaches, and interfaces used in smart parking system

The analysis shows that no single communication technology meets all smart parking requirements. Wired networks offer high reliability, while ZigBee and CoAP are energy-efficient and cost-effective. Wi-Fi and 5G enable real-time applications but require higher power and infrastructure costs. Hybrid network architectures and fog–cloud frameworks provide an effective balance between scalability, responsiveness, and data processing. Among user interfaces, mobile applications are the most practical due to their accessibility and real-time functionality.

10.4. Discussion on embedded technology and internet of thing interface

The review highlights the growing adoption of hardware–software co-design, modular architectures, and edge/fog computing to improve real-time performance and reduce latency in SPSs. Energy-efficient communication technologies such as LoRa, MQTT, and BLE, combined with sensors and AI-based edge

analytics, enable accurate and intelligent parking management. However, key challenges remain, including the lack of standardized architecture, limited validation through large-scale real-world deployments, and insufficient focus on security, privacy, and sustainability.

10.5. Discussion on various services in smart parking system

Parking supervision has been given top importance. Parking reservations, security, and vehicle guidance have received a moderate amount of attention. In SPSs, gate management is given the lowest importance. Even though there aren't many SPS that offer online payment options, the demand for these services is probably going to rise in the next days due to the current advancements in internet transactions.

11. FUTURE RESEARCH DIRECTIONS

11.1. Next-gen parking features

Parking 4.0 as shown in Figure 6, integrates IoT and cloud technologies to provide real-time parking monitoring, reservations, and status updates, improving the utilization of available parking resources. These systems enhance driver convenience through real-time space search, reservation services, and automated valet parking. They also support integrated mobility services such as electric vehicle (EV) charging, bicycle parking, ridesharing, and pick-up/drop-off zones, creating a more connected and efficient parking ecosystem. For parking operators, the system offers predictive analytics to forecast parking demand and optimize resource allocation. It includes automated violation detection and traffic monitoring to improve enforcement and parking compliance. Furthermore, space-optimization techniques maximize parking capacity and utilization, while data-driven insights support operational efficiency, revenue generation, and smarter parking management. Parking 4.0 represents the digital transformation of the parking industry into a value-driven ecosystem. This framework emphasizes the integration of parking with other urban services, such as EV charging and multimodal transit. Research focuses on "Uberization 2.0" of parking, where dynamic pricing and shared parking resources (e.g., private driveways) are managed through automated platforms. This ecosystem approach requires not just technical integration but also new business models and regulatory frameworks [60].

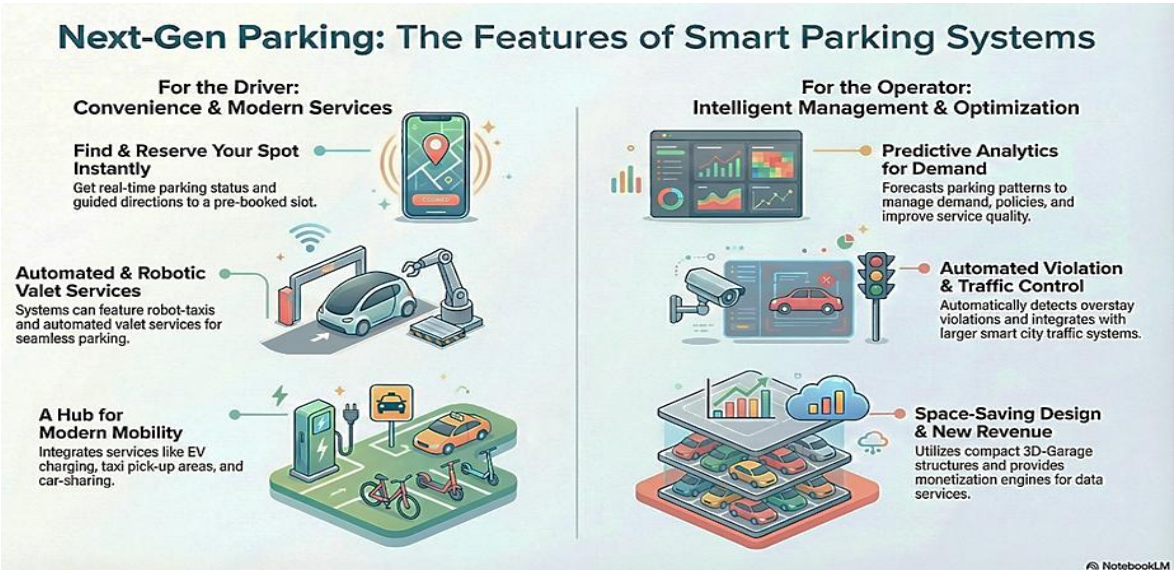


Figure 6. Next-gen parking system

11.2. Connectivity: 5G and vehicle-to-everything integration

The adoption of 5G and vehicle-to-everything (V2X) communication enhances real-time parking guidance by providing low-latency, high-bandwidth connectivity and enabling direct vehicle-to-infrastructure communication for services such as automated valet parking and in-car reservations [61]. Additionally, blockchain technology improves security, trust, and privacy by creating tamper-proof parking transactions, supporting secure data sharing, and preventing fraudulent activities in smart parking ecosystems.

11.3. Advanced analytics

Edge AI, digital twins, and federated learning (FL): to overcome the latency and bandwidth costs of centralized cloud computing, research is shifting toward Edge AI. By processing data on localized smart border control (SBC) clusters or edge gateways, systems can provide near-instantaneous feedback for occupancy detection.

11.4. Digital twins

Are being proposed to simulate and optimize real-time traffic flow and parking allocation at a city scale. To protect driver privacy while still benefiting from artificial intelligence insights, FL is emerging as a critical research direction. FL allows artificial intelligence models to be trained across multiple devices without ever sharing raw location or identity data.

11.5. Artificial intelligence enabled parking violations detection mechanism

It is hard and easy to make mistakes to enforce parking rules by hand. Automated systems that use cameras and smart infrastructure to find violations can make enforcement more effective and encourage people to follow the rules.

12. CONCLUSION

This review presents a comprehensive overview of SPSs and highlights their growing importance in addressing urban traffic congestion, parking inefficiency, and limited space availability caused by rapid urbanization. By examining a wide range of studies, the paper classifies smart parking approaches into major categories and compares them in terms of sensing methods, networking technologies, computational models, user interfaces, and service capabilities. The analysis shows that no single approach is sufficient for all parking scenarios, and the effectiveness of an SPS depends on the proper combination of sensors, communication protocols, processing techniques, and user-oriented services. The study further indicates that IoT-based multi-approach smart parking architectures are likely to play a central role in future smart cities. Smartphone-based platforms, real-time monitoring, reservation, payment integration, and vehicle guidance are becoming standard features, while security, privacy, installation complexity, and sensor suitability remain key concerns.

Reconfigurable systems combined with IoT can significantly improve the adaptability, scalability, and efficiency of SPSs. IoT provides real-time communication between sensors, gateways, cloud platforms, and user applications, while reconfigurable architectures enable processing resources to be adjusted according to traffic conditions, sensing demands, and service requirements. This integration supports better responsiveness, efficient sensor coordination, and faster local decision-making in dynamic parking environments. At the same time, this combination also introduces practical challenges. The use of reconfigurable platforms can increase design complexity and implementation cost, while interoperability among heterogeneous IoT devices, communication security, and energy management remain key concerns. Therefore, although reconfigurable IoT-enabled parking systems offer strong potential for next-generation smart city applications, further work is needed to make them more secure, cost-effective, and easier to deploy at scale. In the future, next-generation SPSs are expected to integrate artificial intelligence, predictive analytics, dynamic pricing, autonomous vehicle support, and digital twin technology to enable more adaptive, efficient, and sustainable parking management. Overall, this review provides a useful foundation for researchers and practitioners to design smarter, scalable, and more intelligent parking solutions.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

We have obtained informed consent from all individuals included in this study.

DATA AVAILABILITY

The data that supports the findings of this study are available from the corresponding author, upon reasonable request.

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