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IOT Based Smart Parking System

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ABSTRACT

The smart parking web application provides an advanced solution for advance reservation of parking slots, enhancing convenience and operational efficiency in urban parking management. This comprehensive platform enables users to access real-time data on available parking spaces, availability status, and pricing, allowing them to reserve slots ahead of time and specify the intended duration of use.

The system integrates a secure payment gateway for easy and seamless financial transactions, offering electronic confirmation in addition to a detailed parking ticket that contains reservation information. With the aid of advanced data syn- chronization technologies, the application automatically updates slot availability with regard to new reservations and cancellations.

The application also has auto-notifications and reminders, which help keep the users updated about their bookings. At arrival, users can easily verify their reservation, which makes them hassle-free to enter the reserved slots. Built using modern web technologies like HTML5, CSS3, and JavaScript, the system is user-friendly and powerful in functionality. With integration of advance reservations and real-time updates, this smart parking solution significantly enhances parking management efficiency and user satisfaction.

Keywords: Smart parking, Web application, Advanced reservation, Parking slots, Urban parking management, Slot availability, Reservation duration, Secure payment gateway, Electronic confirmation, Parking ticket, Notifications

1. Introduction

The Internet of Things has transformed the design and management of modern urban infrastructures, as smart parking systems are now one of the crucial components. Such systems try to address perennial problems in urban environments such as traffic congestion and inefficient parking space utilization by using IoT-enabled technolo- gies. Innovations such as First-Come-First-Serve (FCFS) scheduling mechanisms and Arduino-based models have been shown to be capable of enhancing parking efficiency and reducing waiting times for drivers [1]. Moreover, wireless sensor networks and real-time data analytics have enabled dynamic allocation of parking spaces, making smart parking systems an integral feature of smart city initiatives.

IoT-based smart parking systems employ a wide range of technologies to improve functionality. RFID tags, which can be inkjet-printed and thus cost-effective, have been used to allow accurate detection of vacant slots. This has streamlined the parking process [2]. Moreover, the advent of artificial intelligence and machine learning, such as deep long short-term memory (LSTM) networks, has revolutionized the predictive capabilities in parking systems, offering robust solutions for forecasting occupancy and optimizing the use of space [5]. These technological advancements enhance not just operational efficiency but also impact the environment positively in fuel consumption and emissions.

Technological advancements in IoT in further integrating with cloud computing and even mobile applications have enhanced smart parking systems. Middleware-based applications on cloud computing facilitate central management and real-time parking resource monitoring, making mobile access to parking availability possible by users [19]. Agents are being applied for modeling user behaviors under uncertainties like unpredictable arrival and departure times to maximize shared parking allocation while ensuring high overall reliability of the system, which makes these innovations smart with a dynamic and responsive feature against changing urban demands[24].

The adoption of IoT-enabled parking solutions is transforming the future of urban mobility, with convenience to the user and resource efficiency. The advanced sys- tems, including devices with edge AI integration and intelligent localization models, allow faster and more precise operations in large-scale parking lots [6, 8]. Smart park- ing systems represent a very crucial step in achieving sustainable and efficient urban ecosystems as cities all over the globe embrace IoT-driven technologies. Smart parking systems contribute to the better quality of life for city dwellers, while also represent- ing a vital component in lessening the environmental impact that is related to urban transportation.

1.1 Problem Statement

The fast rate of urban growth and car possession has made the management of parking spaces within cities a serious issue. The classical parking systems do not solve these problems: long search time for the available space, traffic jam, and additional fuel usage. These causes are not only frustrating drivers but also responsible for environ- mental pollution and an inefficient mobility pattern in towns. While IoT-based smart parking systems have been envisioned as a solution, it still has critical challenges with limited scalability, high cost of deployment, and inefficient detection of vacant parking slots. Technologies such as RFID-based systems [2], machine learning algorithms such as deep long short-term memory networks[5], and cloud-based management frame- works [19] have shown promises, but integration complexity, real-time data accuracy, and adaptability to a dynamic urban environment remain among the issues. Address- ing these limitations is critical to developing robust, scalable, and cost-effective smart parking systems that meet the needs of modern cities and their evolving demands.

1.2 Motivation

The rapid urbanization and increase in the number of vehicles on roads have resulted in an acute shortage of parking spaces, causing significant traffic congestion, fuel wastage, and environmental pollution. These issues need innovative approaches that integrate advanced technologies like the Internet of Things. This motivation has emerged from the critical need to develop a smart parking solution that can alleviate such issues by optimizing parking space utilization and enhancing user convenience. By employing IoT-enabled technologies, parking management systems can provide real-time parking slot availability, automate payment processes, and reduce time spent searching for parking.

[1] presented an IoT-based model that utilizes the Arduino UNO and incorporates a First-Come-First-Serve priority scheduling mechanism, indicating how the Internet of Things can revolutionize parking systems. It is also reflected in how [2] created a vacant parking slot detection system by utilizing inkjet-printed RFID tags; how cutting-edge technologies make it easier to handle the parking process. Besides, [3] presented an IoT-supported smart city intelligent parking system focusing on the scalability and integration of IoT frameworks. These systems reduce carbon emissions through the efficient use of parking space with reduced unnecessary movement of automobiles and fuel consumption. Other than that, IoT enabled parking solutions such as that dis- cussed by [4] which used LoRaWAN for communication purposes and[15] have applied deep long short term memory networks for data analytics purposes, thereby showing such systems' flexibility in many urban scenarios.

This project will build on these advancements by designing a comprehensive smart parking system that incorporates real-time monitoring, data-driven decision-making, and user-centric features. Such a system can not only improve urban mobility but also contribute to the sustainability goals of smart cities. By addressing these pressing challenges, the proposed project seeks to create a transformative impact on urban infrastructure management.

Fig 1,The photo shows an IoT-based intelligent parking system that demonstrates capabilities to transform traditional parking systems. It showcases real-time vehicle detection using IoT-empowered sensors, the monitor of parking space occupancy and guiding drivers through navigation to available slots. The marker has used geolocation services. It enables users to get easy access to parking spots and navigate their way through to the respective slots easily. It integrates with technologies that use RFID, ultrasonic sensors, cameras for proper data acquisition, and effective communication on different types of networks, thereby streamlining processes involving automatic payment computation of parking fees while leaving the tasks to technology in other

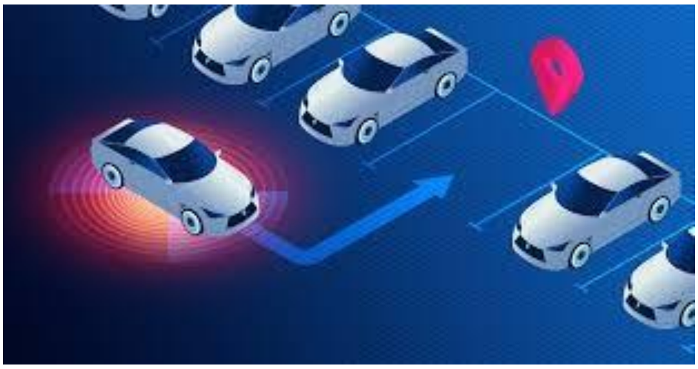

Fig. 1: smart parking

activities such as calculations for user convenience and avoidance of lengthy parking finding, a major time waster contributing to less traffic, saving on fuels, and minimizes exhausts thereby, facilitating eco-friendly transport. This innovative approach depicts how IoT can optimize the parking experience while addressing both environmental and operational challenges in urban areas.

1.3 Critical challenges in paking system

Despite the innovative and transformative nature of smart parking systems, several critical challenges hinder their large-scale adoption and efficient functioning. The main issue relates to the integration of various IoT devices and platforms. Veeramanickam et al. (2022) noted that the complexity of integrating hardware, such as sensors and controllers, with software platforms may cause implementation delays and increased costs. Similarly, the technical challenge to ensure the reliability of IoT-enabled RFID tags in different environmental conditions such as extreme weather was pointed out by [2].

Another challenge is scalability, especially in urban areas with high vehicle density. According to A[3], designing parking systems capable of managing large volumes of vehicles while maintaining performance is critical but challenging due to the limita- tions in current IoT frameworks.[5]discussed the difficulty of implementing long-range communication technologies like LoRaWAN in densely populated urban areas, where signal interference and network congestion can impact system efficiency.

The security and privacy issues in the user's data remain critical in IoT-based parking systems. According to [15], vast data that are collected using sensors, then processed at the cloud level, create chances for cyberattacks that raise potential dan- gers of privacy with regards to user data. The encryption protocol of data developed into this system must work against these sensitive pieces of user information while maintaining performance that guarantees the real time capability of the system [7].

The second major barrier is the cost, especially in developing countries. [11] identified that the high upfront cost involved in deploying IoT infrastructure and maintaining advanced parking solutions presents a significant limitation for many cities. Moreover, as Khanna and Anand (2016) identified, the reliance on steady internet connectivity raises questions over the reliability of the system in areas with less-than-stable network coverage.

Lastly, user adoption and awareness also present a challenge. [14] reported that many users are unaware of smart parking technologies, and this has resulted in low adoption rates and underutilization of such systems. Education and awareness cam- paigns and user-friendly interfaces are thus important to overcome these barriers and ensure the success of smart parking initiatives. The challenges must be addressed for the wide implementation of smart parking systems and their contribution to sustainable urban mobility.

1.4 Objective

The key goals of smart parking systems, based on literature, include overcoming the major issues in urban parking management using advanced IoT technologies. [1] pointed out the optimization of parking space utilization through the use of IoT- enabled sensors and First-Come-First-Serve priority scheduling system to provide efficient resource allocation of parking facilities, thus preventing traffic congestion and increasing the convenience of users. In the same line of action, [2] seek to improve the accuracy of reliability of parking slot detection through innovation: using RFID tags by bringing real-time updates for availability of parking for the user.

Another important goal is scalability and applicability to urban settings. Accord- ing to [3]), an intelligent parking system (IPS) has been designed that merges IoT frameworks for the control of high volumes of vehicles along with the preservation of the efficiency of the system in smart cities. [5] proposed the deployment of LoRaWAN to enable the extension of communication networks of parking systems to facilitate their applicability in diverse urban and suburban settings.

One of the critical objectives of modern parking systems is ensuring security and data privacy. [15] have addressed this issue by focusing on incorporating robust data encryption and cybersecurity measures to protect user data collected by IoT devices, thus enhancing trust and reliability in the system. Moreover, [7] pointed out the objec- tive of implementing resource allocation and reservation systems for optimizing the usage of parking space while maintaining user confidentiality.

Cost-effectiveness and affordability are also core goals. [11] developed IoT-based parking systems that are efficient but also cost-effective enough to be deployed in the urban environment at scale. [12] highlighted solutions that can work even in areas with low internet connectivity, thus making the technology more accessible to a wider audience.

Lastly, enhancing user experience and adoption is a pivotal objective. [12] aimed to create user-friendly interfaces and implement educational campaigns to familiarize users with smart parking technologies, thereby increasing adoption rates and ensuring the effective utilization of these systems. These objectives collectively aim to revo- lutionize parking management, contributing to smarter and more sustainable urban development.

1.5 Scope of the research

From this related literature, there were various research studies on the smart parking systems: from technological innovation to optimization and scalability, security and cost effectiveness, user adoption, unique issues and developments regarding a parking system..

- **Technological progress**:[1] explored the inclusion of IoT devices like Arduino UNO and sensors to develop a First-Come-First-Serve priority scheduling system to improve technological capacity in parking management systems.[2] continued from this by employing RFID tags to identify the vacant parking slots in real- time with novel applications of IoT in smart parking Important biomarkers are amyloid plaques, tau proteins, and neuroinflammatory markers. The development of such biomarkers is essential to diagnose Alzheimer's at the earliest stage because biomarkers detected in this case actually indicate progression, and on the other hand, brain-imaging techniques are invasive .
- **Optimization**: The research by [7] focuses on resource allocation and reservation systems that optimize parking space utilization, maximizing the efficient use of limited urban parking resources.[3] optimized by integrating IoT frameworks in intelligent parking systems to deal with the large volumes of vehicles in smart city environments.

- **Scalability**: [**?**] focused on the aspect of smart parking solutions when exploiting the capability of LoRaWAN technology. Coverage area through its deployment spans vast cities and suburbs but does not comprise efficiency in connectivity . [11]made deployments in parking system designs meant for gigantic areas but without making a tradeoff regarding the performance that such deployment brings in its wake.
- **Security**:[15] emphasized the importance of cybersecurity in smart parking systems and offered suggestions designed to protect user data through cyber attacks. This study underscored the fact that problems of privacy should be taken care of with the system integrity. Further, Khanna and Anand, in their 2016 study, applied the analysis of IoT of parking systems in areas of limited or intermittent network connections to ensure security and reliable processes in operation.
- **Cost-Efficiency**: [11] and [14] examined the economic feasibility of IoT-based parking systems. This approach strikes a balance between high-tech technology and cost-effectiveness. In that respect, smart parking systems could be feasible in both well-off and less well-off regions.
- **User Adoption**: [14] studied user-friendly interfaces and educational campaigns as the means to increase adoption rates of smart parking systems. In this case, focus- ing on user experience, their research ensures that the technology meets consumer expectations and will encourage wider usage.

2. Key Techniques and Models

2.1 IoT-Enabled Sensor Integration

[1] also proposed IoT-enabled sensors integrated with Arduino UNO, to monitor park- ing spaces and performed a First-Come-First-Serve (FCFS) scheduling mechanism. It aids in efficient parking space allocation and reduces congestion on roads of urban areas by conducting real-time slot monitoring and management.[2]enhanced this method by incorporating RFID technology for vacant slot identification purposes by utilizing inkjet-printed RFID tags in parking management for accuracy and cost reduction.

```
Initialize sensorArray[n]
Initialize serverConnection
Set parkingSlotStatus[n] = 'Vacant'

Function detectParkingStatus():
    For each sensor in sensorArray:
        if sensor.detectVehicle():
            parkingSlotStatus[sensor.index] = 'Occupied'
        else:
            parkingSlotStatus[sensor.index] = 'Vacant'

Function sendDataToServer():
    For each slot in parkingSlotStatus:
        serverConnection.send(slot.index, parkingSlotStatus[slot.
            index])

Function processServerData():
    Initialize availableSlots = []
    For each slot in parkingSlotStatus:
        if parkingSlotStatus[slot] == 'Vacant':
            availableSlots.append(slot.index)
    Return availableSlots

Function guideUserToSlot(userLocation):
    availableSlots = processServerData()
    nearestSlot = findNearestSlot(userLocation, availableSlots)
    sendNavigationInstructions(nearestSlot)

While True:
    detectParkingStatus()
    sendDataToServer()
    If newUserRequestReceived():
        userLocation = getUserLocation()
        guideUserToSlot(userLocation)
    Wait(interval)
```

- **Sensor Detection**: Each sensor monitors its assigned parking slot for the presence of a vehicle.

- **Data Communication**: The sensor sends the status of the slot (Vacant or Occupied) to a centralized server.
- **Centralized Processing**: The server processes all slot statuses and determines available slots.
- **User Guidance**: Based on the user's location, the nearest available slot is identified, and navigation instructions are sent to the user.

2.2 Resource Allocation and Reservation Systems

A new smart parking-specific resource allocation and reservation system was developed by [7],that enhances the usage of the parking space by making advanced reservations for slots. It helps to save time spent looking for parking and minimizes resource conflict so that parking systems become effective in a congested urban setting.

```
Initialize parkingSlots[n]
For each slot in parkingSlots:
    parkingSlots[slot].status = 'Vacant'
    parkingSlots[slot].reserved = False

Function allocateSlot(userID):
    For each slot in parkingSlots:
        if parkingSlots[slot].status == 'Vacant' and parkingSlots
            [slot].reserved == False:
            parkingSlots[slot].status = 'Occupied'
            parkingSlots[slot].userID = userID
            Return slot.index
    Return "No available slot"

Function reserveSlot(userID):
    For each slot in parkingSlots:
        if parking Slots[ slot ]. status ==' Vacant ' and parking Slots
            [slot].reserved == False:
            parking Slots [ slot ]. reserved = True
            parking Slots [ slot ]. userID = userID
            Return slot.index
    Return "No available slot to reserve"

Function checkAvailability():
    availableSlots = []
    For each slot in parkingSlots:
        if parkingSlots[slot].status == 'Vacant' and parkingSlots
            [ slot ]. reserved == False :
            availableSlots.append(slot.index)
    Return availableSlots

Function releaseSlot(slotIndex):
    if parkingSlots[slotIndex].status == 'Occupied' or
        parkingSlots[slotIndex].reserved == True:
        parkingSlots[slotIndex].status = 'Vacant'
```

```
        parkingSlots[slotIndex].reserved = False
        parkingSlots[slotIndex].userID = Null
        Return "Slot released"
    Else:
        Return "Slot is already vacant"

Function handleUserRequest(userID, requestType):
    If requestType == 'Reserve':
        reservedSlot = reserveSlot(userID)
        If reservedSlot != "No available slot to reserve":
            Return "Slot reserved: " + reservedSlot
        Else:
            Return "No slots available for reservation"
    Else If requestType == 'Allocate':
        allocatedSlot = allocateSlot(userID)
        If allocatedSlot != "No available slot":
            Return "Slot allocated: " + allocatedSlot
        Else:
            Return "No slots available"

While True:
    userRequest = getUserRequest()
    userID = userRequest.userID
    requestType = userRequest.type
    response = handleUserRequest(userID, requestType)
    sendResponseToUser(response)
    Wait(interval)
```

- **Slot Booking**:If a vacant slot is available, then users can reserve slots in advance. The slot are reserved and cannot be allotted to others unless they are freed and marked as reserved = True.
- **Dynamic Allocation**:If a user requests an instant parking, the system issues the nearest available slot identified as Vacant.
- **Availability Slot**:The system continuously monitors the status of all parking spots, keeping track of which ones are free or marked as reserved.
- **Slot Launch**: When a user leaves the parking lot, the slot will go back to Vacant so it will be free to accommodate other users. Real-Time User Interaction: The system processes user requests for reservation or allocation and gives instantaneous feedback concerning the availability of slots.

2.3 Long-Range Communication Using LoRaWAN

[4] incorporated LoRaWAN technology to enhance the scalability of intelligent parking systems. The communication technology allows for the operation of parking sys- tems over vast urban and suburban areas, enabling reliable, low-energy, long-distance connectivity.

```

Initialize  parkingSensors[n]
```

```
Initialize LoRaGateway
Initialize LoRaServer

Function monitorParkingSlots():
    For each sensor in parkingSensors:
        If sensor.detectVehicle():
            sensor.status = 'Occupied'
        Else:
            sensor.status = 'Vacant'

Function transmitDataToGateway():
    For each sensor in parkingSensors:
        Create message = {
            "sensorID": sensor.id,
            "status": sensor.status
        }
        LoRaGateway.receive(message)

Function gatewayToServer():
    While LoRaGateway.hasMessages():
        message = LoRaGateway.getMessage()
        LoRaServer.processMessage(message)
Function processServerData():
    Initialize parkingStatus = {}
    While LoRaServer.hasMessages():
        message = LoRaServer.getMessage()
        parkingStatus[message.sensorID] = message.status
    Return parkingStatus

Function guideUser(userLocation):
    parkingStatus = processServerData()
    availableSlots = []
    For each slot in parkingStatus:
        If parkingStatus[slot] == 'Vacant':
            availableSlots.append(slot)
    nearestSlot = findNearestSlot(userLocation, availableSlots)
    sendNavigationInstructions(nearestSlot)

While True:
    monitorParkingSlots()
    transmitDataToGateway()
    gatewayToServer()
    If newUserRequestReceived():
        userLocation = getUserLocation()
        guideUser(userLocation)
    Wait(interval)
```

- **sensor Monitoring**:Sensors placed in parking slots report if a vehicle is there or not and update the status as Occupied or Vacant.
- **Data Transmission**:These send status information to the LoRaWAN gateway by using LoRa communication, low power long range, very suitable for huge urban or suburban areas.
- **Gateway-to-Server Communication**:The LoRaWAN gateway retrieves the sensor data and sends it to the central server for further processing and management.
- **Data Processing**:The server processes the data to determine the number of available parking spaces and update the parking status database.

2.4 Optimization Through Heuristic Models

[6] developed the use of the Grey Wolf Optimization (GWO) model for the optimal deployment of sensor nodes with IoT in parking systems. This heuristic approach reduces costs for the deployment of the sensors and increases coverage by effective surveillance of vast parking space.

```

Initialize populationSize
Initialize maxIterations
Initialize searchSpace
Initialize parkingSlots[n]
Initialize sensorLocations[populationSize]
Initialize alpha, beta, delta
Initialize fitnessValues[populationSize]

Function calculateFitness(sensorPlacement):
    coverage = 0
    cost = 0
    For each slot in parkingSlots:
        If slot is covered by a sensor in sensorPlacement:
            coverage += 1
    cost = calculateDeploymentCost(sensorPlacement)
    Return (coverage / totalParkingSlots) - (cost / maxCost)

Function updatePositions(sensorLocations, alpha, beta, delta):
    For each wolf in sensorLocations:
        For each dimension (x, y):
            a = calculateParameterA()
            A1 = a * (2 * random() - 1)
            C1 = 2 * random()
            D_alpha = abs(C1 * alpha - wolf)
            X1 = alpha - A1 * D_alpha

            A2 = a * (2 * random() - 1)
            C2 = 2 * random()
            D_beta = abs(C2 * beta - wolf)
            X2 = beta - A2 * D_beta

            A3 = a * (2 * random() - 1)
            C3 = 2 * random()
            D_delta = abs(C3 * delta - wolf)
            X3 = delta - A3 * D_delta

            wolf[dimension] = (X1 + X2 + X3) / 3  # Update position based on alpha, beta, and delta

Function greyWolfOptimization():
    Initialize sensorLocations with random positions in searchSpace
    For each wolf in sensorLocations:
        fitnessValues[wolf] = calculateFitness(sensorLocations[wolf])

    For iteration in range(1, maxIterations + 1):
        Sort sensorLocations based on fitnessValues
        alpha = sensorLocations[0]   # Best solution
        beta = sensorLocations[1]    # Second-best solution
        delta = sensorLocations[2]   # Third-best solution

        updatePositions(sensorLocations, alpha, beta, delta)

        For each wolf in sensorLocations:
            fitnessValues[wolf] = calculateFitness(sensorLocations[wolf])

    Return alpha

Function deploySensors(optimalPlacement):
    For each sensor in optimalPlacement:
        Deploy sensor at sensor.location

optimalPlacement = greyWolfOptimization()
deploySensors(optimalPlacement)
```

- **Fitness Appraisal**:The sensor placements are evaluated on two objectives: maxi- mize parking slot coverage and minimize deployment costs.
- **Grey Wolf Optimization (GWO)**:Inspired by this predatorial behavior of gray wolves, the algorithm designates the best solution to ”alpha” wolf, then assigns sub-solutions to ”beta,” and ”delta.”

Fig. 2: Smart Parking System

3 Methodologies

The methodologies in IoT-based smart parking systems incorporate a range of innova- tive approaches to address urban parking challenges. IoT-enabled slot detection utilizes sensors like ultrasonic, RFID, or infrared to monitor parking spaces, transmitting real- time data to centralized systems for user access. For example, [1] used Arduino UNO for the low-cost slot detection with the implementation of the FCFS scheduling, and

[2] incorporated RFID tags for high precision and scalability. Predictive analysis based on AI models, like deep LSTM networks, provides a highly accurate forecast about slot availability. For instance, [15] reached more than 90 percent prediction accuracy. Optimization methods like GWO algorithm enhance sensor deployment in a way that is both cost-effective for deploying such sensors and saving the required energy, as utilized by [6]

Advanced communications like LoRaWAN and Zigbee ensure the efficiency of real- time data communication; the authors of [4] used LoRaWAN for huge parking, and [28] for zigbee-based energy-saving small structures. [23] presented energy-autonomous IoT devices, minimizing the maintenance required and promoting prolonged opera- tions. User-centric methods include mobile and web-based applications, such as those implemented by [16], in which real-time updates, bookings, and payments are all integrated.

Edge AI has also been implemented to facilitate the processing with low latency in real time, as highlighted by [8], hence providing immediate and accurate user response. Dynamic pricing models help optimize revenue and user satisfaction by changing rates based on demand and availability, according to [7]. Real-time syn- chronization mechanisms, such as those applied in [3], continuously update the status of parking slots, which improves reliability. Sustainability measures, such as using renewable energy sources and devices that consume less energy, further support eco- friendly urban infrastructure, as presented in [23]. These methodologies collectively enhance the efficiency, scalability, and sustainability of IoT-based smart parking systems while providing user-friendly and reliable solutions.

4 Literature Survey

The IoT-based smart parking system has emerged as a significant solution to the urban parking challenges, with considerable advances documented in recent literature. These systems integrate IoT, AI, and real-time data processing to enhance the efficiency of parking, user satisfaction, and sustainability. Different approaches and methodologies have been explored to optimize parking slot detection, energy efficiency, scalability, and communication reliability.

[1] proposed an IoT-based model using Arduino UNO with First-Come-First-Serve (FCFS) scheduling. The authors pointed out the simplicity and cost-effectiveness of the method, and it could be applied in small parking lots. Nevertheless, the scalability is poor for bigger urban environments. Therefore, a more complex solution needs to be addressed for widespread usage. [2]used RFID technology to detect slots correctly. The integration of RFID tags and readers permitted precise detection and scalable deployment. It significantly improved vacancy detection in larger parking areas.

[3] built on these developments by coming up with an IoT-assisted intelligent park- ing system, designed for smart cities. The system used ultrasonic sensors to detect slot availability in real time and was connected to cloud infrastructure to allow seam- less data synchronization. However, this system, while reducing users’ time taken to search and hence increase the efficiency of managing the parking system, could rely on a stable network connection, which can also sometimes be an issue due to heavy traffic in any place. In this scenario also, [4] selected LoRaWAN as the communication protocols because for the management of parking system at a large area. However, the need for high-end infrastructure to deploy LoRaWAN is a deterrent to its wide-scale adaptation.

Artificial intelligence has revolutionized modern smart parking systems, providing predictive functionalities and data-driven decision making.[15] have used deep LSTM networks in predicting the availability of parking slots using real-time as well as his- torical data. The model achieved an outstanding 90 percent prediction accuracy which enabled the users to plan in advance about parking and it reduced the time spent seek- ing slots. Another AI-inspired approach was demonstrated by [9]. They have applied Grey Wolf Optimization algorithms for optimal placement of sensors. This energy consumption technique minimized energy use while improving the localization of IoT sensors. However, the implementation of optimization algorithms such as GWO is highly complex and requires expertise and resources.

Energy efficiency is another recurring focus in IoT-based smart parking systems.

[23] introduced energy-autonomous IoT devices that can harvest renewable energy, thus reducing the dependency on external power sources. The devices have drastically reduced maintenance costs, making them a good choice for sustainable urban infras- tructure. As a contrary system, systems which are operating on external power, as [1] present, cost more in operations and lack scalability. [29] have worked with Zigbee for energy-efficient communication suitable for smaller installations but lacked the range of application, as with bigger applications as with technologies such as LoRaWAN. User interaction and accessibility are keys to success for smart parking systems. The studies [14] stressed on the significance of mobile and web applications, through

which people can book slots, obtain real-time updates, and pay securely. In such an approach, there is convenience and the uptake increases.[8] made use of edge AI in processing data in real-time to reduce latency. Therefore, the response for feedback would be instant for users. However, it increases complexity in the structure because edge com- puting has to be supported. [7] further improved resource allocation by introducing dynamic pricing models, which adjusted parking fees based on demand, maximizing revenue while maintaining user satisfaction.

[3] highlighted real-time synchronization mechanisms, which ensured that slot availability was updated seamlessly across their system. This feature ensured that data was accurate and reliable for both users and administrators. Sustainability measures included those by [22], who focused on deploying energy-efficient devices and renewable energy sources, which reduced the environmental impact of parking operations.

In summary, the literature highlights various methods of enhancing parking effi- ciency through IoT and AI. These studies focus on some critical points such as slot detection, real-time data processing, energy efficiency, scalability, and user satisfaction. Even though each solution has its strengths, the challenges associated with infras- tructure dependency, high initial costs, and complexities in implementation persist. Future advancements in IoT-based smart parking systems should be toward integrat- ing these innovations into holistic, scalable, and sustainable solutions for urban parking management

Table 1: Literature Survey

Sno	**Title**	**Author(s)**	**Journal & Year**	**Methodologies**	**Key Findings**	**Gaps**
1.	IoT based smart park- ing model using Arduino UNO with FCFS priority scheduling	Veeramanickam et al.	Measurement: Sensors, 2022	Used Arduino UNO with FCFS schedul- ing for slot management	Cost-effective and simple for small-scale parking	Limited scala- bility for large urban parking environments
2.	IoT-enabled vacant park- ing slot detection sys- tem using inkjet-printed RFID tags	Zahid et al.	*J IEEE Sen- sors Journal, 2023*	Integrated RFID tags for accurate slot detection	High detec- tion accuracy and scalable deployment	Higher ini- tial cost for large-scale implementa- tion
3.	An IoT assisted intel- ligent parking system (IPS) for smart cities	Aditya et al.	*IEEE Sensors Journal, 2023*	Used IoT frameworks and ultra- sonic sensors for real-time detection	Improved real-time updates, reduced park- ing search times	Dependent on stable network infrastructure
4.	IoT-enabled parking man- agement system using LoRaWAN	Jabbar et al.	*Internet of Things and Cyber- Physical Systems, 2024*	Used LoRaWAN for long- range data transmission	Reliable com- munication for large parking lots	Requires advanced infrastruc- ture.
5.	GWO model for optimal localization of IoT-enabled sensor nodes	Ghorpade et al.	*IEEE Trans- actions on Intelligent Transporta- tion Systems, 2020*	Utilized Grey Wolf Optimiza- tion (GWO) for sensor placement optimization	Improved localization accuracy and reduced energy consumption	Complex implementa- tion requiring specialized expertise.
6.	A smart, efficient, and reli- able parking surveillance system with edge AI	Ke et al	*IEEE Trans- actions on Intelligent Transporta- tion Systems, 2020*	Deployed edge AI for low- latency data processing.	Immediate and accu- rate real-time updates	Complex infrastructure required

5. Comparative Analysis

A comparative analysis of IoT-based smart parking systems reveals a wide variety of tech- nological frameworks, communication methods, and user-centric features, each designed to address specific challenges in urban parking management. [1] introduced a cost-effective solu- tion that utilizes Arduino UNO with FCFS scheduling, ideal for small-scale parking facilities. Though simple and efficient, the approach is limited in scalability for larger urban envi- ronments. On the contrary,[2] implemented an RFID-based detection system that is highly accurate and scalable but requires a higher initial investment. [3] further improved this by using ultrasonic sensors with IoT for real-time detection, which has significant advantages in urban applications but is dependent on stable network infrastructure.

In terms of communication technologies,[4] (2024) used LoRaWAN for long-range data transmission, which is reliable for large-scale urban implementations but requires advanced infrastructure. On the other hand, [28] used Zigbee for energy-efficient communication, which is suitable for smaller areas due to its low power consumption but has a limited range. These variations point out the trade-offs between energy efficiency and scalability.

Some systems transform fully with the involvement of AI. For example, [15] showed how deep LSTM networks can predict the availability of parking slots with an over 90 percent accuracy which is achieved with high degrees of operational efficiency but may require quite computational intensive setup. Likewise, [9] has used GWO for improving the optimization of placement IoT sensors and ensures less energy utilization and accuracy of localization for the IoT applications with possible complexity of its implementation.

Energy efficiency is the other key aspect. For instance, [22] proposed energy-autonomous IoT devices, which would automatically reduce maintenance needs and hence improve sus- tainability, making such devices perfect for long-term urban deployment. On the other hand, systems which rely on external power supply, like that of [1], are simpler but carry higher costs in terms of maintenance over time.

[16]focused on the perspective of user interaction while enhancing mobile and web applica- tions through real-time monitoring and updates to make accessibility convenient. [8] adopted edge AI for low-latency feedback, where real-time, accurate feedback can be received, but only if a complex infrastructure supports the function. All of these features underline the need for user-centric design in a smart parking system.

Regarding scalability, [30] developed IoT protocols for large networks, which enables their system to be suitable for urban environments but costly for implementation. On the other hand, localized solutions like those proposed by [26] are more affordable for certain areas but do not support scalability for larger applications.

From this comparative analysis, it is possible to see the diversity of methodologies and technologies in the use of IoT-based smart parking systems. Each approach has its merits, such as cost-efficiency, scalability, energy efficiency, and user convenience. However, there are associated challenges, including high implementation costs, computational requirements, and infrastructure dependency. These features must be integrated to create comprehensive solutions for efficient urban parking management.

Feature/Method	**Approach**	**Advantages**	**Challenges**	**References**
Technological Frameworks	Arduino UNO with FCFS scheduling	Cost-effective, simple for small-scale parking	Limited scala- bility for large environments	[1–3]
Communication Technologies	LoRaWAN for long-range communica- tion	Reliable for large urban parking	Requires advanced infrastruc- ture.	[4, 29]
Artificial Intelli- gence	Deep LSTM for predictive slot availabil- ity	High predic- tion accuracy (90 percent+)	Computationall intensive	[y6]
Energy Efficiency	Energy- autonomous IoT devices	Reduced maintenance, sustainability.	Initial setup cost.	[1, 23]
User Interaction	Mobile and web applica- tions	User-friendly, accessible, and conve- nient.	Requires con- sistent app and network performance	[8, 16]
Application Scala- bility	IoT protocols for large net- workss	Adaptable to urban envi- ronments.	Higher ini- tial costs for implementa- tion	[26]

Table 2: Comparative Analysis of Smart parking systems

5.1 Evaluation Metrics

Features	**Metrics**	**Description**
Slot Detection	Accuracy	Measures how accurately the sys- tem identifies the availability of parking slots.

	Prediction Accuracy	Evaluates the effectiveness of pre- dictive models in forecasting park- ing slot availability.
Scalability	Scalability	Assesses the system's ability to manage growing parking slots or expand to large urban areas.
Energy Efficiency	Energy Efficiency	Evaluates the system's ability to minimize power consumption, espe- cially for IoT devices.
Cost Management	Cost Management	Measures overall costs, includ- ing installation, maintenance, and operations.
Data Transmission	Latency	Assesses the time delay in pro- cessing and communicating data between devices and users.
System Reliability	Reliability	Evaluates the system's consistency in providing accurate data and han- dling disruptions.
User Experience	User Satisfaction	Measures user feedback on ease of use, accessibility, and overall expe- rience.

Table 3: Evaluation Metrics for Smart parking system

6 Limitations and Future Directions

- Integration Challenges: According to [1], integration challenges due to more than one IoT hardware and software platforms tend to increase the complexity as well as the cost of deployment. In that regard, [2]also mentioned reliability problems related to IoT-enabled RFID tags at challenging environmental conditions such as the scorching heat or precipitation that may result in a system inaccuracy.
- Scalability Issues: [3]also discussed the scalability problems of improving IoT- based parking systems to support huge numbers of vehicles in a large urban environment, where prevailing architectures face performance degradation. [4] also found interference and decreased efficiency of LoRaWAN-based long-range communication in dense populated areas.
- Data Security and Privacy:[15] have discussed vulnerabilities in IoT systems through which user data can get vulnerable to cyberattacks if appropriate encryption and security protocols are not maintained.[7] found challenges related to privacy while implementing resource allocation and reservation mechanisms.
- Higher Installation and Maintenance Costs: As per W[11], apart from con- stantly required maintenance costs, another significant constraint in developing countries is the large initial investment in IoT infrastructure.
- User Acceptance:[14] suggest that sometimes the infrequent usage of the system results due to ignorance and misunderstanding regarding smart parking technologies amongst the users.
- Integration with Advanced AI Models: Future smart parking systems can utilize advanced AI models in the form of deep learning, reinforcement learning, and more advanced models to optimize parking slot allotment, predict availability, or improve traffic flow. For example, the use of deep long short-term memory (LSTM) networks discussed by [15] highlights the potential use of AI in improving the IoT- based system.
- Adoption of Energy-Autonomous IoT Devices: IoT devices could be powered by renewable energy or energy-harvesting technologies, as proposed by[22]. in the year 2020. Maintenance cost would be reduced, and sustainable urban infrastructure would be supported .
- Scalability to Large Smart City Networks: The potential ability of smart parking systems, proposed by[5], in linking with larger smart city ecosystems while integrating with transportation, lighting, and energy systems can be leveraged to improve urban planning by developing interconnected parking systems.
- Enhanced Communication Protocols: Future research can focus on improving communication technologies such as LoRaWAN, Zigbee, and 5G to ensure faster, more reliable data transfer in large-scale deployments, as emphasized by [28].
- Development of Real-Time Analytics and Prediction Tools: Systems like those discussed by [2], which detect vacant parking slots in real time, could be enhanced with predictive analytics to forecast future parking demand based on historical and real-time data .
- Dynamic Pricing Models: Future systems can be integrated with dynamic pricing algorithms, where pricing is determined by the quantity of demand and occupancy. This concept aligns with resource allocation strategies, as discussed by [7].

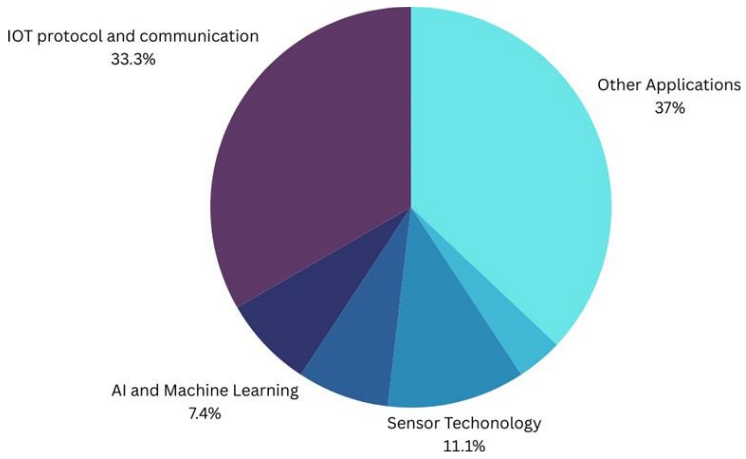

Fig. 3: limitations on smart system

7. Experimental Setup and Results

[18] developed an IoT-based smart parking system incorporating Arduino UNO with First- Come-First-Serve (FCFS) priority scheduling. Their experimental setup incorporated sensors used for detecting vehicle occupancy while having an Arduino-based unit controlling slot assignments. The analysis reflected a marked improvement towards parking slot utilization and shortened user waiting times, bringing about practical benefits of the whole system. Likewise, [30] designed a system using inkjet-printed RFID tags to detect empty parking slots. RFID readers and tags were mounted around the parking lots and conveyed real-time data to the central server. The article established excellent detection precision and cost effectiveness that makes it a viable competitor to existing systems.

[19] designed an IoT-assisted intelligent parking system tailored for smart cities by using ultrasonic sensors, microcontrollers, and a cloud-based server. The setup could efficiently detect and navigate urban users to the parking space, with significant reductions in parking search times and traffic congestion. Another research study proposes a LoRaWAN-enabled IoT parking system by [27] for real-time monitoring and data transmission over long distances. Experimental results demonstrated the system's scalability and reliability in large parking areas, maintaining low power consumption.

[15] proposed a deep learning-based smart parking system using long short-term memory (LSTM) networks. The experimental setup collected parking occupancy data via IoT sensors, which were processed by the LSTM model to predict parking availability. The system achieved over 90accuracy, and this shows the potential of AI in improving parking solutions. Ghorpade et al. (2020) proposed a Grey Wolf Optimization (GWO) model to optimize the placement of IoT-enabled sensors in smart parking systems. Experimental setup deployed sensor nodes and evaluated localization accuracy and energy efficiency with results showing enhanced coverage and reduced power consumption compared to traditional methods.

[22] designed an edge AI-based parking surveillance system for real-time video feeds and parking slot data processing. They adopted the edge devices in the architecture, ensuring low latency and better energy efficiency; they guaranteed high reliability in the management of parking space. This is indicative of how AI and IoT are gradually transforming the world of parking management. All of these studies together represent various advancements of experiments and practical applications of IoT-based smart parking systems for more efficient urban mobility solutions.

8. Conclusion

In conclusion, IoT-based smart parking systems are a transformative approach to addressing the growing challenges of urban mobility, including inefficient parking management, traffic congestion, and environmental degradation. Studies like those by [20] and Z[10] highlight the potential of integrating IoT technologies with cost-effective components, such as Arduino UNO and RFID tags, to improve parking slot utilization and detection accuracy. More com- plex solutions are the intelligent parking system (IPS) presented by[16]. in 2023 and the LoRaWAN-enabled parking management system proposed by[22]. These can be examples of the scalable and reliable IoT systems in big urban deployment. In addition, the use of artificial intelligence models such as deep LSTM networks, as developed by [26], and opti- mization techniques such as the GWO model developed by Ghorpade et al. (2020), can be used to predict analytics and efficient sensor localization for further improvement in parking operations.

These developments are supported by new technologies such as edge AI, which reduce latency and improve energy efficiency, as demonstrated by [30]. But ensuring the efficiency of energy use, the reliability of networks, and integration with other infrastructure does remain as a challenge. Thus, future work should emphasize on overcoming such limitations, considering new technologies like blockchain for secure data management, dynamic pricing models for efficient resource allocation, and others. In total, these contributions would provide smarter, sustainable urban parking solutions to enhance the overall efficiency of smart cities. These findings have called for the need to sustain innovation and collaboration in developing IoT-enabled parking systems.

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