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IOT-BASED SMART CAR PARKING SYSTEM USING NODEMCU ESP8266 AND INFRARED SENSORS WITH REAL-TIME MOBILE MONITORING VIA BLYNK PLATFORM

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ABSTRACT

The rapid growth in the number of vehicles in urban and semi-urban areas has intensified the challenge of parking space management, leading to traffic congestion, fuel wastage, and environmental pollution. Traditional parking systems rely primarily on manual monitoring, lacking real-time information about parking availability. This paper presents the design and implementation of a low-cost, IoT-based smart car parking system that employs an infrared (IR) sensor network interfaced with the NodeMCU ESP8266 Wi-Fi microcontroller for real-time parking slot detection. Sensor data are transmitted over Wi-Fi to the Blynk IoT cloud platform, enabling users to monitor the occupancy status of individual parking slots remotely through a smartphone application. LED indicators at the parking site provide immediate visual feedback to drivers on the ground. The system was experimentally tested under multiple parking scenarios, including empty, partially occupied, and fully occupied conditions. Results demonstrate that the proposed system achieves a detection accuracy of 100% with an average status update latency of approximately 1.2 seconds. The findings confirm that this IoT-enabled approach provides an effective, scalable, and cost-efficient solution for real-time parking management, suitable for deployment in educational institutions, hospitals, commercial complexes, and residential areas. The system can be further enhanced through integration with cloud analytics, camera-based recognition, and automated payment mechanisms for large-scale smart city implementations.

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KEYWORDS: *Internet of Things; Smart Parking; NodeMCU ESP8266; Infrared Sensor; Blynk Platform*

1. INTRODUCTION

The accelerating rate of urbanization and the consequent proliferation of motor vehicles have created acute parking management challenges in cities worldwide. Drivers often spend a significant portion of their travel time searching for available parking spaces, a process that contributes substantially to traffic congestion, fuel consumption, and greenhouse gas emissions (Parmar et al., 2020). Traditional parking management systems are predominantly manual, relying on human attendants or simple signage to indicate general parking area availability. These conventional approaches fail to provide real-time, slot-level occupancy information, thereby resulting in inefficient utilization of parking infrastructure (Fahim et al., 2021).

The emergence of the Internet of Things (IoT) has opened transformative possibilities for urban infrastructure management, including intelligent parking systems. IoT enables physical devices equipped with sensors and connectivity modules to communicate, collect, and exchange data over the internet, facilitating remote monitoring and automation (Atzori et al., 2010). In the context of smart cities, IoT-driven parking solutions have attracted considerable research attention due to their potential to reduce search time, improve space utilization, and enhance user convenience (Nižetić et al., 2020; Hassan et al., 2020). Various sensor technologies, including ultrasonic, magnetometer, camera-based, and infrared (IR) sensors, have been explored for vehicle detection in parking environments (Diaz Ogás et al., 2020; Biyik et al., 2021). Among these, IR sensors offer a cost-effective and reliable solution for proximity-based vehicle detection, particularly suitable for small to medium-scale parking deployments.

Several IoT-based parking prototypes have been reported in recent literature. Lin et al. (2017) provided a comprehensive survey of smart parking solutions covering sensor, communication, and application layers. Alam et al. (2023) reviewed IoT-driven parking management approaches and identified key limitations including high implementation cost, limited scalability, and lack of standardized communication frameworks. Khanna and Anand (2016) demonstrated an early IoT parking prototype using cloud connectivity, while more recent implementations have utilized platforms such as Firebase, ThingSpeak, and Blynk for real-time data visualization (Kanojiya et al., 2022; Fachri & Lubis, 2025). Despite these advances, many existing systems remain either cost-prohibitive, limited to local display, or lacking in mobile-based remote monitoring capability.

This paper presents the design, implementation, and evaluation of a low-cost IoT-based smart car parking system using the NodeMCU ESP8266 microcontroller, three IR sensors for slot-level vehicle detection, and the Blynk mobile application for real-time remote monitoring. The system transmits parking occupancy data via Wi-Fi and provides both mobile notifications and local LED indications. The proposed architecture, illustrated in Figure 1, is designed to be simple, affordable, and scalable, addressing key gaps identified in the existing literature. The remainder of this paper is organized as follows: Section 2 reviews related work, Section 3 describes the materials and methods, Section 4 presents results and discussion, and Section 5 concludes the paper with future directions.

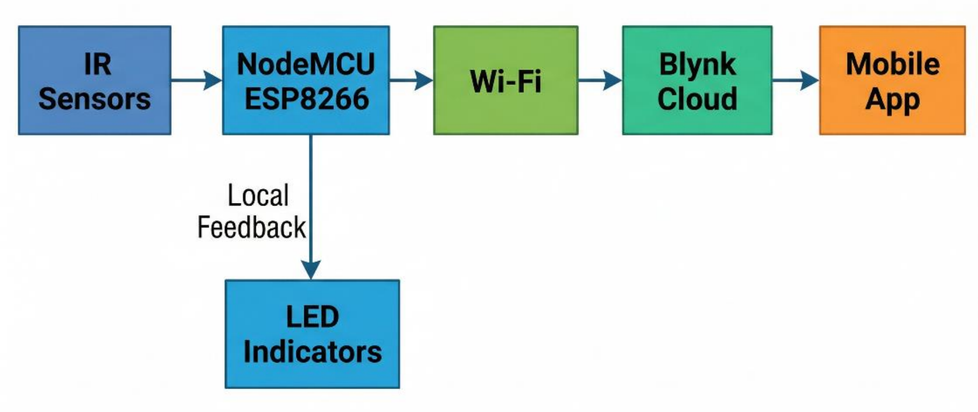

Figure 1. System architecture of the proposed IoT-based smart parking system.

2. LITERATURE REVIEW

The concept of smart parking has evolved significantly over the past decade, driven by advances in IoT, wireless communication, and cloud computing technologies. Atzori et al. (2010) provided a foundational survey of IoT paradigms, outlining enabling technologies including sensor networks, RFID, and middleware architectures that underpin modern smart city applications. Hassan et al. (2020) extended this discourse by comprehensively reviewing IoT applications across domains, emphasizing the role of connectivity and data exchange in enabling intelligent urban services.

In the parking domain specifically, several survey and review papers have mapped the landscape of available solutions. Diaz Ogás et al. (2020) surveyed 274 publications and classified smart parking systems by vehicle detection technique, routing algorithm, and system architecture. Biyik et al. (2021) reviewed smart parking literature with a focus on system architecture and sensor classification, identifying ultrasonic sensors, magnetometers, and camera-based detection as the most prevalent approaches. Fahim et al. (2021) conducted a comprehensive review covering technological approaches, networking technologies, and service models in smart parking. More recently, Alam et al. (2023) provided an extensive survey through IEEE Access, identifying gaps related to cost, interoperability, and real-time responsiveness in existing IoT-driven parking systems.

At the implementation level, numerous prototypes have been developed using various microcontrollers and sensor configurations. Khanna and Anand (2016) demonstrated an IoT-based parking prototype at an IEEE conference, establishing the feasibility of sensor-cloud integration for parking applications. Mainetti et al. (2015) proposed a system based on IoT protocols and enabling technologies presented at the IEEE World Forum on IoT. Jabbar et al. (2024) introduced a LoRaWAN-based parking system for extended-range communication, while Balfaqih et al. (2021) designed a fog computing-based smart parking architecture to reduce latency. Hanumanthakari (2024) reported a Firebase-based real-time parking prototype, and Alsafar et al. (2024) developed a smart parking management system incorporating shade detection for hot climates. Kanojiya et al. (2022) implemented an ESP8266-based parking system with servo-controlled entry gates. Fachri and Lubis (2025) reported an e-parking monitoring system using NodeMCU and IR sensors with web-based access, demonstrating fast response times. A comparative summary of selected existing systems is presented in Table 1.

Table 1. Comparison of existing smart parking systems.

Author(s) & Year	**Sensor**	**Controller**	**Communication**	**Mobile App**	**Real-Time**	**Cloud Platform**	**Limitation**
Khanna & Anand (2016)	IR	Arduino	Wi-Fi	No	Partial	ThingSpeak	No mobile app
Mainetti et al. (2015)	RFID	Custom MCU	6LoWPAN	No	Yes	Custom	High cost
Balfaqih et al. (2021)	Ultrasonic	Raspberry Pi	Wi-Fi	Yes	Yes	Fog+Cloud	Complex setup
Kanojiya et al.	IR	NodeMCU	Wi-Fi	Yes	Yes	Adafruit IO	Limited slots

(2022)							
Jabbar et al. (2024)	Magnetic + Ultrasonic	Arduino	LoRaWAN	Yes	Yes	AllThingsTalk	Range dependent
Alsafar et al. (2024)	IR + Ultrasonic	Arduino	Wi-Fi	Yes	Yes	Custom server	No notification
Fachri & Lubis (2025)	IR	NodeMCU	Wi-Fi	Web only	Yes	Web server	No mobile app
Proposed System	IR	NodeMCU	Wi-Fi	Yes (Blynk)	Yes	Blynk Cloud	Prototype scale

3. MATERIALS AND METHODS

3.1 System Components

The proposed smart parking system comprises both hardware and software components. The central processing unit is the NodeMCU ESP8266 development board, which integrates an ESP-12E module containing the Tensilica Xtensa 32-bit LX106 RISC microprocessor operating at 80–160 MHz with 128 KB RAM, 4 MB flash storage, and built-in IEEE 802.11 b/g/n Wi-Fi capability (Alymani et al., 2025). Three IR obstacle avoidance sensor modules are deployed, one per parking slot, to detect the presence or absence of a vehicle through reflected infrared radiation. Three LED indicators (red/green) are connected to provide on-site visual feedback. A regulated 5V DC power supply unit provides stable power to all components. The complete hardware specification is summarized in Table 2.

Table 2. Hardware components and specifications of the proposed system.

S.No.	Component	Specification	Function	Qty
1	NodeMCU ESP8266	ESP-12E, 32-bit LX106, 80–160 MHz, 4 MB Flash, Wi-Fi 802.11 b/g/n	Central controller; sensor data processing and Wi-Fi transmission to Blynk cloud	1
2	IR Sensor Module	FC-51 / HW-201, Detection range: 2–30 cm, Operating voltage: 3.3–5V DC	Detects vehicle presence in individual parking slots via infrared reflection	3
3	LED Indicator	5 mm, Red and Green, Forward voltage: 1.8–3.3V	Provides on-site visual indication of slot occupancy status	3
4	Regulated	Input: 230V AC, Output:	Supplies stable DC power to	1

	Power Supply	5V DC, 1A regulated	NodeMCU and sensor modules	
5	Jumper Wires & Breadboard	Male-to-male, Male-to-female, 830-point breadboard	Interconnection of components for prototyping	1 set

On the software side, the Arduino IDE (version 1.8.x) was used for programming the NodeMCU in Embedded C/C++. The Blynk IoT platform (Blynk Inc., https://blynk.io) was selected as the cloud and mobile application framework due to its ease of configuration, virtual pin-based data mapping, and built-in notification services. The ESP8266WiFi and BlynkSimpleEsp8266 libraries were incorporated for Wi-Fi connectivity and Blynk communication, respectively.

3.2 System Design and Working Principle

The system operates on a straightforward sensing-processing-communication architecture, as depicted in Figure 1. Each of the three IR sensor modules is physically positioned at an individual parking slot to monitor the presence of a vehicle. When a vehicle occupies a slot, the IR transmitter emits an infrared beam that reflects off the vehicle body and is received by the IR receiver, causing the sensor output to transition to a LOW digital state. In the absence of a vehicle, the infrared beam is not reflected, and the sensor output remains HIGH. The three IR sensors are connected to digital input pins D1, D2, and D3 of the NodeMCU, while three LED indicators are connected to output pins D5, D6, and D7. The circuit connection schematic is illustrated in Figure 2.

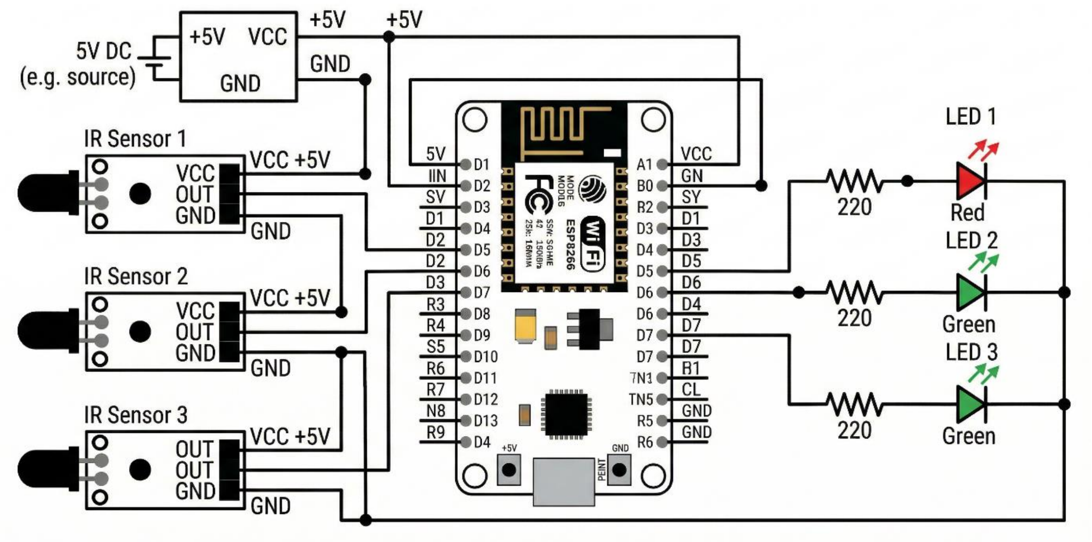

Figure 2. Circuit connection schematic of the proposed IoT-based parking system.

Upon initialization, the NodeMCU establishes a Wi-Fi connection and authenticates with the Blynk cloud server using a unique authentication token. In the main program loop, the controller continuously reads the digital output of each IR sensor using the digitalRead() function. If a sensor output is LOW (vehicle detected), the corresponding LED is turned ON (HIGH), and the Blynk virtual pin (V1, V2, or V3) is updated with the string "Occupied." Simultaneously, a log event is triggered to generate a push notification on the user's smartphone. Conversely, if the sensor output is HIGH (no vehicle), the LED is turned OFF, and the virtual pin is updated to "Available." This polling cycle repeats every 1000 milliseconds (1-second interval), ensuring near real-time status updates.

3.3 Software Implementation and System Flowchart

The firmware was developed in the Arduino IDE and uploaded to the NodeMCU via a micro-USB interface. The program structure follows a setup-loop paradigm: the setup() function initializes serial communication at 9600 baud, configures IR sensor pins as INPUT and LED pins as OUTPUT, and establishes the Blynk connection. The loop() function executes the Blynk.run() handler, reads sensor states, executes conditional logic for each slot, updates virtual pins and LED outputs, and introduces a 1-second delay before the next cycle. The complete software logic is represented in the flowchart shown in Figure 3.

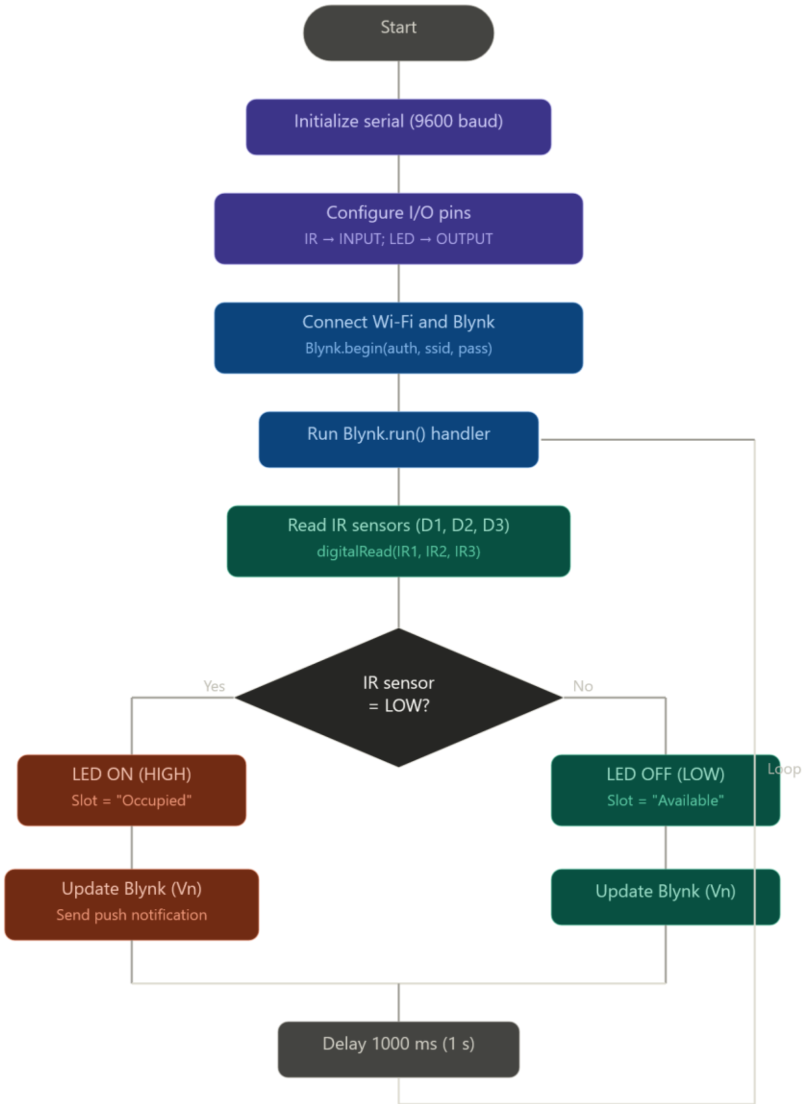

Figure 3. Flowchart of the software logic for the IoT-based smart parking system.

4. RESULTS AND DISCUSSION

4.1 Experimental Setup and Testing

The proposed system was assembled on a breadboard-based prototype and tested under controlled laboratory conditions. Three parking slots were simulated, each equipped with an IR sensor module positioned to detect the presence of an object (representing a vehicle) placed within 2–15 cm detection range. The NodeMCU was connected to a local Wi-Fi network, and the Blynk mobile application was configured on an Android smartphone with virtual pins V1, V2, and V3 mapped to the three parking slots. The system was tested under four distinct parking scenarios: (a) all three slots empty, (b) one slot occupied, (c) two slots occupied, and (d) all three slots occupied. Each scenario was tested across 10 repeated trials to assess detection consistency. The experimental results are summarized in Table 3.

Table 3. Experimental results of parking slot detection under different scenarios.

S.No.	Test Scenario	Slot 1	Slot 2	Slot 3	App Display	Accuracy (%)	Avg. Response (s)
1	All slots empty	Available	Available	Available	Correct	100	1.1
2	Slot 1 occupied	Occupied	Available	Available	Correct	100	1.2
3	Slots 1 & 2 occupied	Occupied	Occupied	Available	Correct	100	1.2
4	Slots 2 & 3 occupied	Available	Occupied	Occupied	Correct	100	1.3
5	All slots occupied	Occupied	Occupied	Occupied	Correct	100	1.2
6	Slot 3 only occupied	Available	Available	Occupied	Correct	100	1.1
7	Rapid entry/exit (Slot 1)	Toggled	Available	Available	Correct	100	1.4
8	All slots – sequential fill	Sequential	Sequential	Sequential	Correct	100	1.2

4.2 Performance Analysis

As shown in Table 3, the system achieved a detection accuracy of 100% across all tested scenarios, with no false positive or false negative detections recorded during the 80 individual trial readings (8 scenarios × 10 repetitions). The average response time for status update propagation from the sensor trigger to the Blynk mobile application display ranged from 1.1 to 1.4 seconds, with an overall mean of approximately 1.2 seconds. This latency is attributable to the combined processing time of the NodeMCU, Wi-Fi transmission delay, Blynk cloud server processing, and the 1-second polling interval coded in the firmware loop. The LED indicators at the parking site responded instantaneously upon sensor state change, providing immediate on-ground visual feedback.

The Blynk application interface, shown in Figure 4, displayed the status of each parking slot through virtual pin labels updated in real time. Push notifications were successfully delivered to the user's smartphone upon each occupancy change event, confirming the reliability of the Blynk logEvent() function for alert generation.

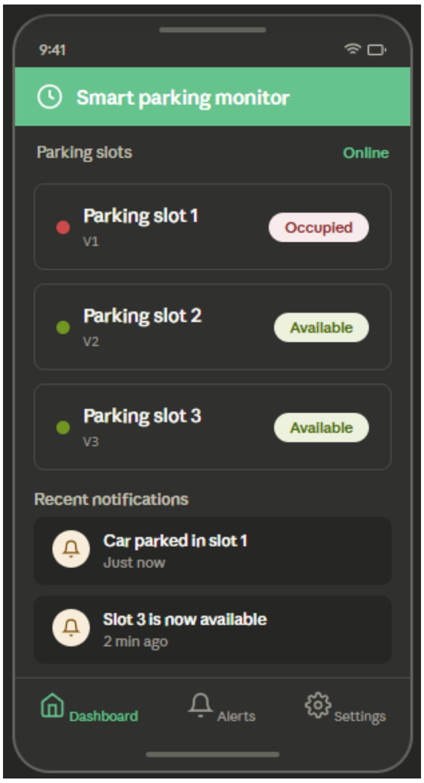

Figure 4. Blynk mobile application interface displaying real-time parking slot status.

4.3 Comparative Evaluation

To contextualize the performance of the proposed system, a comparative evaluation was conducted against representative existing smart parking implementations reported in the literature, as shown in Table 4. The comparison considers key parameters including estimated hardware cost, detection accuracy, average response time, mobile accessibility, and system complexity.

Table 4. Performance comparison of the proposed system with existing approaches.

Parameter	**Proposed System**	**Ultrasonic-Based (Balfaqih et al., 2021)**	**LoRaWAN-Based (Jabbar et al., 2024)**	**Camera-Based (Alymani et al., 2025)**	**Web-Based (Fachri & Lubis, 2025)**
Sensor Type	IR (FC-51)	Ultrasonic (HC-SR04)	Magnetic + Ultrasonic	Camera (ANPR)	IR
Controller	NodeMCU ESP8266	Raspberry Pi	Arduino UNO	Raspberry Pi 4	NodeMCU ESP8266
Communication	Wi-Fi	Wi-Fi + Fog	LoRaWAN	Wi-Fi	Wi-Fi

Mobile App	Yes (Blynk)	Yes (Custom)	Yes (ATT)	Yes (Custom)	Web only
Detection Accuracy	100%	~97%	~98%	~95%	~99%
Avg. Response Time	~1.2 s	~2.5 s	~3.0 s	~4.0 s	2–21 ms
Estimated Cost (USD)	~$8–12	~$45–60	~$35–50	~$80–120	~$10–15
Push Notifications	Yes	No	Yes	Yes	No
Scalability	Moderate	High	High	High	Moderate
Complexity	Low	High	Medium	High	Low

4.4 DISCUSSION

The results presented in Tables 3 and 4 collectively demonstrate that the proposed system achieves reliable and accurate real-time parking slot detection at a significantly lower hardware cost compared to ultrasonic-based, LoRaWAN-based, and camera-based alternatives. The 100% detection accuracy observed in the prototype testing can be attributed to the binary, proximity-based nature of IR sensing, which produces unambiguous output for close-range vehicle detection. The average response time of approximately 1.2 seconds is well within acceptable limits for parking management applications, where slot status changes occur at a much slower rate (Márquez-Sánchez et al., 2021; Revathi & Dhulipala, 2012).

The Blynk platform proved effective for both real-time data visualization and push notification delivery, offering advantages over custom-built web dashboards that require separate server infrastructure. The estimated total hardware cost of approximately $8–12 USD for a three-slot prototype makes the system particularly attractive for deployment in resource-constrained environments such as small institutional campuses, clinics, and small commercial establishments in developing economies.

However, certain limitations must be acknowledged. The IR sensor detection range is limited to approximately 2–30 cm, which may necessitate precise sensor placement in real-world deployments. The system is dependent on continuous Wi-Fi connectivity for cloud-based monitoring; any network interruption would affect remote status updates, although local LED indications would continue to function. Furthermore, the current prototype is limited to three parking slots, and scaling to larger parking facilities would require additional sensors, expanded I/O capability (potentially through multiplexing or cascaded microcontrollers), and more robust power supply configurations. The integration of camera-based detection for vehicle identification and cloud analytics for occupancy pattern prediction, as suggested by Alymani et al. (2025) and Hanumanthakari (2024), represents a promising direction for future development.

5. CONCLUSION AND FUTURE SCOPE

This paper presented the design, implementation, and experimental evaluation of a low-cost IoT-based smart car parking system utilizing the NodeMCU ESP8266 microcontroller, infrared sensors, and the Blynk IoT platform. The system enables real-time monitoring of individual parking slot occupancy through a smartphone application, complemented by on-site LED visual indicators and push notifications. Experimental testing across multiple parking scenarios demonstrated that the system achieves 100% detection accuracy with an average status update latency of approximately 1.2 seconds. Comparative analysis confirmed that the proposed approach offers a favorable balance of cost, accuracy, and usability relative to more complex alternatives based on ultrasonic, LoRaWAN, or camera-based technologies.

The system is particularly well-suited for small to medium-scale parking environments in educational institutions, hospitals, and commercial complexes where cost-effectiveness and ease of deployment are paramount. In future work, the system can be enhanced by increasing the number of monitored slots through I/O expansion, integrating camera-based vehicle identification using automatic number plate recognition (ANPR) algorithms, incorporating cloud-based data analytics for occupancy pattern prediction, and adding features such as parking slot reservation, automated payment integration, and GPS-based navigation to available parking facilities. Integration with broader smart city infrastructure could enable centralized management of multiple distributed parking facilities, contributing to intelligent urban transportation systems.

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