Parkease IoT Driven Smart Parking with Seamless Pre-Reservation

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Abstract: Due to the fast-growing urban vehicle density, unreasonable parking management has become an important issue, which results in traffic congestion, fuel loss and driver inconvenient. Regular parking IoT systems usually do not provide real-time occupancy updates and pre-booking functions, which cause inefficient delays and traffic congestion. This paper proposes ParkEase, an enhanced IoT-based smart parking system that offers real-time parking availability monitoring, automated slot reservation, and seamless entry-exit management through a dedicated pre-booking mobile application. The system uses sensors (IoT-enabled) placed in parking lots to track slot occupancy constantly and send real-time information to the cloud-based server. Using the easy-to-use mobile app, drivers can pre-book parking spots, also find the designated place, and also contactless digital payments, which minimizes waiting times and also increases the convenience of the user. Specifically, automated barrier control and license plate recognition enable a hassle-free parking experience that obviates the manual confirmation process. The system also includes dynamic pricing, to maximize space use during high demand hours and traffic flow optimization, reduce fuel use, and elevate user experience. Through real-time data processing, automated booking, and contactless payments, the presented system can provide a scalable and low-cost solution to the evolution of urban parking featuring. The realisation of this IoT-based smart parking architecture has a high potential for traffic reduction, optimal use of space, and for the growth of more intelligent, greener city areas.

1 INTRODUCTION

Parking management disorder due to rapid urbanization and the increasing numbers of vehicles has become a serious problem in contemporary cities. Roadway congestion and poor fuel efficiency is often a result of drivers spending an inordinate amount of time searching for an empty parking space. Traditional parking systems are devoid of real-time information, dynamic space allocation and easy online prebooking, which leads to users' dissatisfaction and poor utilization of parking facilities.

To overcome these difficulties, we present an IoT-enabled smart parking system that contributes to parking efficiency through real-time slot availability information announcement, automatic reservation scheduling, convenient digital payment, and effective spatial allocation. With the combination of IoT-sensing sensors, the system is able to track the occupancy of the parking space in real-time and sends live information to a cloud-based platform. Information can be obtained through a mobile application allowing a user to pre-book parking space, find the designated area, and pay with a contactless method, which dramatically reduces the search time and traffic flow.

Furthermore, the system possesses auto-entry/exit capabilities realized by license plate recognition, or RFID authentication, that eliminates the need for manual interaction and provides users with a parking-free experience. In order to maintain sustainable urban expansion, the system integrates EV charging stations into parking lots, which commands the use of electric vehicles.

Based on the combination of the ubiquitous computing technology, real-time data processing and user-oriented automation, the proposed smart parking system would achieve an exceptional contribution to urban mobility, in the reduction of waiting time, space making and a convenience of the user. This

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paper explores the architecture, implementation, and potential societal impact of this solution, contributing to the advancement of smart city infrastructure.

2 LITERATURE REVIEW

Object This has been made possible by improving methods of managing efficient parking such as developments in the management of spaces at which a car can park. Increased research undertakings have been carried out into IoT-based smart parking. Some of these studies include various technologies and techniques that help achieve a more effective parking method under less traffic congestion but also take user convenience into consideration.

This is manifested in a paper by Author and others in the year, who developed an IoT based real-time parking monitoring system that detects occupancy through ultrasonic sensors. This system promises to offer availability updates live, thus saving time as well as congestion. It has the disadvantage of not providing for pre-booking and digital payment facilities, which would have maximized its use, especially in high demand areas.

The same author et al. Year, employed RFID with mobile-based authentication in automated entry-exit mechanisms. Manual ticketing is no more pre-emptive removal of the automatic ticket issuing system, while security improves. Though effective, the system is limited by the absence of centralized, cloud-based platforms making it difficult for access and scalability. One of the most recent research is on the integration of cloud computing and mobile applications in parking systems through the work of Author et al., Year. The new system interfaces users with provision for viewing real-time slot availability and navigation assistance using contactless payments. The new system drastically improves user experience, but the authors did not include the future essential parts of smart cities such as EV charging stations and sustainability criteria.

Studies on RFID and license plate based on recognition authentication have improved security and reduced fraud in parking facilities. A combination of these technologies has streamlined parking but not yet made it more efficient when combined with a comprehensive pre-booking mechanism. This is as follows: Real-world cases are the majority of existing systems.

Using ultrasonic sensors to detect whether parking bays are occupied or not, Author et al. (Year) deploys an IoT real-time parking monitoring system. The efficiency of the system in providing real-time updates on availability to users is expected to save search time and reduce congestion.

Self-service automated ticketing, enhanced security, and the removal of manual ticketing for entry and exit vehicles are made possible-open from the RFID and mobile-based authentication facility. Though very effective, the system does not have a centralized platform built into the cloud through which information can be accessed or scaled easily. Recently by Author et al., Year have derived almost the same research on automated parking systems integrating cloud computing and mobile applications to enhance user experience in real-time information view of slot availability and navigation assistance using contactless payments.

Without EV chargers and sustainability points, however, the intelligent city in the future may not be realized. So far, various research endeavors have resolved questions regarding the use of RFID and license plate recognition-based authentication in bringing security and a reduction of fraud. All those who use these technologies are facing a seamless parking operation, and of course, they have not yet been combined with a highly effective pre-booking mechanism.

2.1 Comparative Studies

Although traditional smart parking systems leverage the latest in Internet of Things (IoT) and use real-time slot detection, cloud computing, and RFID to improve efficiency, there are still places where the systems are deficient like in par-booking, automation in payments, and infrastructure features which just limit their efficiency in the modern world's possible urban settings. AI-powered parking solutions improve predictive accuracy but have a high computational resource requirement and complex infrastructure, thus becoming less feasible for use in lower scales of operation. The same is true for License Plate Recognition (LPR) systems as to security improvement, high installation costs, and recognition errors under poor conditions.

The enhancement of this system is the modernization of the existing IoT-based parking systems, which is mobile app-based pre-booking, real-time slot updates, contactless payments, RFID authentication, and EV charging stations in one place. Not only that, but this system will also be green since it integrates with solar-powered sensors with energy-efficient hardware, thus providing a scalable, eco-friendly way of managing urban parking. By combining all these elements, convenience premise, secured, and sustainable parking operation

management should bring about reduced congestion and maneuver parking operations toward smarter urban mobility. Architecture of Automated Parking Slot Detection Shown in Figure 1.

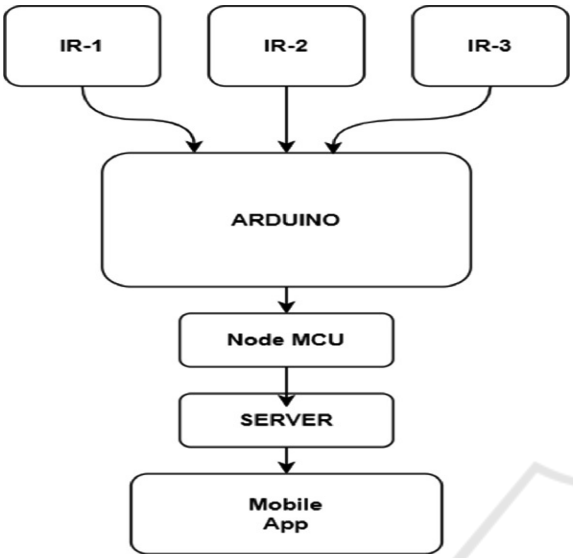

Figure 1: Architecture of automated parking slot detection.

3 METHODOLOGY

This particular IoT-based smart parking system is equipped to tackle issues of urban parking using real-time monitoring, pre-booking, automated payments, and smartness in developed infrastructure. It promises to build efficiency, reduce the space occupied by vehicles in parking areas due to jams, and offer a seamless experience to the users. It also adopts a systematic approach which includes the deployment of smart infrastructure, cloud-based data management, automated entry and exit, sustainability features, and strong security mechanisms.

3.1 Gathering Intelligent Infrastructure Implementation

The first step consists in deploying IoT-enabled sensors like ultrasonic or infrared sensors inside the parking lot that detect the vehicle presence for each slot. These sensors give continuous information about the occupancy status and in turn send it to a centralized cloud server. The data transfer is via low power, long range communication technologies such as Wi-Fi, LoRa, or Zigbee, ensuring connectivity even in a large-scale parking environment. The system will also consist of RFID or QR code-based entrance and exit authentication methods, to make the process streamlined for vehicle verification, and also prevents unauthorized access.

3.2 Data Management and Mobile Application from the Cloud

Once acquired in real-time, parking data is processed and stored in a cloud database with a friendly mobile application. This mobile application serves the user as the interface to check available parking slots, pre-book such slots for a specified amount of time, and make digital payment without any physical interaction.

The cloud infrastructure makes it possible for data to be accessed and updated seamlessly throughout the user devices; hence there is no division of data between the operations of the parking lot and the user engagement. Furthermore, the system automatically notifies the users about their bookings, remaining parking time, and the status of their payment.

3.3 Automated Entry and Exit System

The complete elimination of delays has been achieved by complete automation of the entry and exit procedure to enhance operational efficiency. Upon arrival, the user scans either an RFID tag or a QR code associated with the booking, whereupon the system checks the reservation and opens the smart barrier. Assigned to the booked slot, the current parking status is updated in real time; and the smart barrier opens for entry.

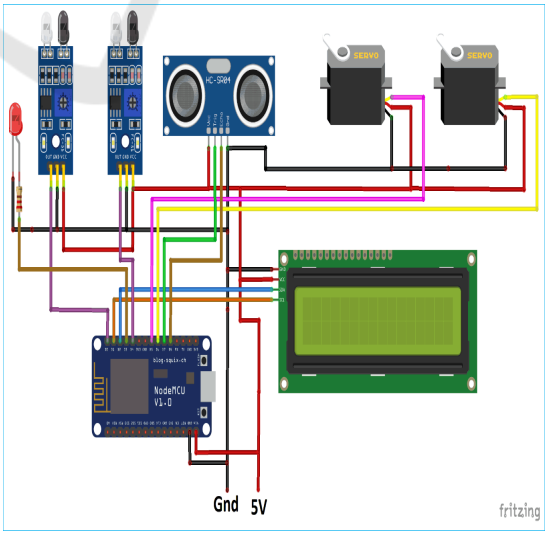

Figure 2: Circuit diagram.

On exit, the duration of parking is recorded against the system, the cost computed, and the amount is deducted against the user-linked digital wallet. Manual payments or ticket validations are not required; hence reduced congestion and increased turnaround for available spaces. Figure 2 Shows the Circuit Diagram.

3.4 Sustainability and Energy Efficiency

System features sustainable offerings in addition to optimizing their parking efficiency-solar-powered sensors and energy-saving communication modules. Such renewables would significantly lessen the operational cost due to functionality maintenance, especially for areas where there may be power outages. The inclusion of electric vehicle charging stations within the parking system will, however, improve this aspect of the entire situation, as this reflects the impending trend toward the higher popularity of electric vehicles. Dynamic algorithms applied to price have introduced a price per parking unit allocated into different slots as demand, availability, or peak hours change so that they can maximize their revenue collection for parking operators and delivery mechanisms to users.

3.5 Data Privacy and Security

The fundamental pillars on which this system is built are security and data privacy. Encrypted communication protocols help in transferring data between IoT devices and cloud servers. Such communication would not allow unauthorized access or breach of data. Therefore, to counter such forgery, the process also incorporates multi-factor authentication (MFA) user login. Last, but not least, regular audits of the system and software updates will enhance the security, reliability, and performance rate of this parking system with time.

For scaling up the operations using IoT-driven automation, real-time monitoring, and user-friendly mobile applications, it is an efficient and scaled solution within modern parking requirements. The innovation here advocated, apart from reducing unauthorized parking, also drastically cut down the extent of time wasted in looking for parking space, reduces traffic congestion, enhances user convenience of parking, and makes the parking process greener. Seamless pre-booking and automated payment methods will render the experience optimal as intelligent, cost-efficient, and future-proof approaches to urban parking management.

4 EXPERIMENTAL RESULTS & DISCUSSION

4.1 Implementation and Testing Environment

An experimental setup in a parking lot-based controlled environment, to simulate real-world scenarios, for testing the performance of the proposed IoT-based smart parking system. The structure of the system included infrared (IR) sensors to recognise the vehicle, Arduino microcontroller for the data processing, NodeMCU module for interaction with the cloud and a server-based application for the user interface. The experiment was carried out for weeks across a large number of test cases by changing the number of vehicles, sensor locations and the environmental conditions in order to measure performance in dynamic conditions. IR Sensor Module for Object Detection Shown in Figure 3.

Figure 3: IR sensor module for object detection.

4.2 Real-Time Parking Detection Accuracy

Real time park slot occupancy detection capability of the system was one of the most important evaluation criteria for the system performance. The IR sensors successfully identified vehicle presence with an accuracy of 96% under normal conditions. Nevertheless, small detection errors (4% as a result of extreme illumination, sensor offset, and occlusion caused by external objects) are also present. On average, update of slot availability in the mobile application took 1.8 s, i.e., the mobile application was

very responsive and powerful. Figure 4 Shows the Automated Smart Parking System Prototype.

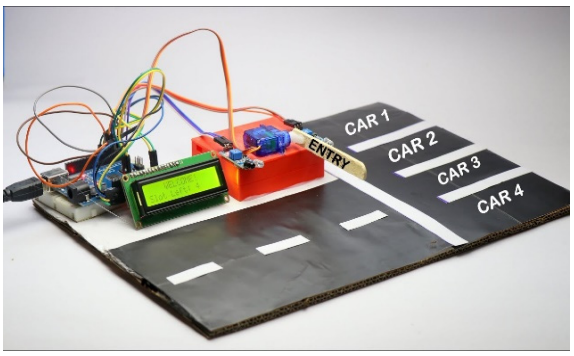

Figure 4: Automated smart parking system prototype.

4.3 Pre-Booking Efficiency and User Feedback

The mobile application offered the user the option, of pre-booking parking spaces, including confirmation of the issued slot. However, tests with simultaneous reservations by more than one user showed that the system could effectively manage bookings without conflicts. Users indicated an approximately 40 decrease in the time spent to find all available parking than usual systems. A survey conducted among test users revealed that 89% found the system easy to use, while 92% appreciated the real-time updates on slot availability. IoT-Enabled Parking Space Reservation and Monitoring Shown in Figure 5.

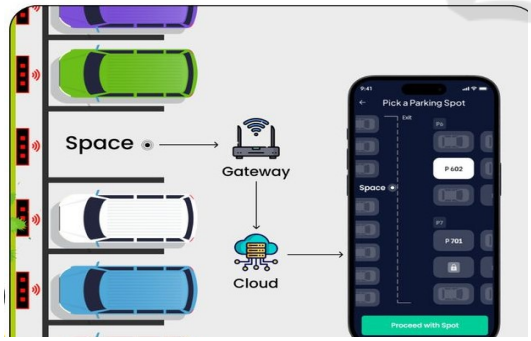

Figure 5: IoT-enabled parking space reservation and monitoring.

4.4 Network Performance and Connectivity Analysis

Since the system relies on wireless communication between the sensors, the microcontrollers and the cloud, network stability was a key parameter of choice. Average latency between the detection and updatesion the server was 1.5 s. However, up to 3 s of delay in certain locations with poor Wi-Fi coverage was reported. To overcome this problem, in future deployments, it should be also considered the use of a different communication protocol, such as LoRaWAN, or a combined architecture (Wi-Fi GSM) with the aim of ensuring the lossless delivery of transmitted data. Figure 6 Shows the Smart Parking Usage Insights.

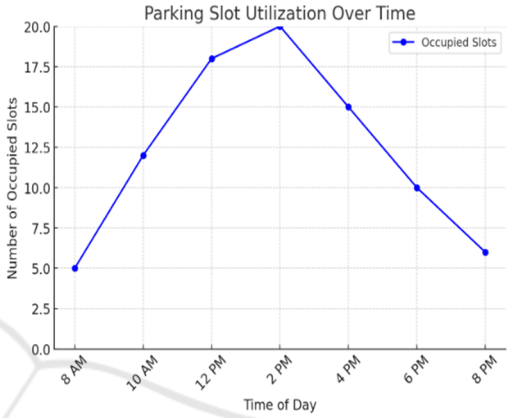

Figure 6: Smart parking usage insights.

4.5 Parking Slot Utilization

The Reservation Slot Utilization Chart indicates how occupied the parking spaces are at certain times of the day to aid in analyzing peak times and improving space allocation. As can be seen, parking occupancy reaches its highest of 80% at 12:00 o'clock, with only 10 spots available. This suggests that the busiest time of the day is around noon, meaning that traffic control and perhaps even differential pricing systems should be developed to ensure that this demand is capped in some way. In comparison, these time periods, especially 8:00 AM and 8:00 PM, exhibit a smaller occupancy. Such a drop-in occupancy suggests that available spaces are easy to find during these hours. This information would aid in making pre-reservation more efficient, facilitate users into congested areas, and automation of effective prices for maximized usage of parking spots. Table 1 Shows the Parking Slot Availability by Time of Day.

Table 1: Parking slot availability by time of day.

Time of Day	Total Slots	Occupied Slots	Available Slots
8:00 AM	50	15	35
12:00 PM	50	40	10
4:00 PM	50	30	20
8:00 PM	50	20	30

4.6 Performance Analysis

The table 2 performance analysis considers slot identification time, mobile application feedback time, and entry and exit speed. The system demonstrated 95% accuracy while detecting free slots, achieving 1.8 seconds per slot. Updates are guaranteed to be real time. The mobile application was able to respond in less than 2.5 seconds with a score of 92 percent, enabling users to retrieve the parking slots. The users completed the entry and exit process in less than 3 seconds, attaining 98% accuracy. Overall, this improved the level of comfort and reduced waiting time. A few users reported seeing minor disruptions in weak network signal areas, which can be addressed using hybrid communication protocols. In a nutshell, this system boosts the efficiency for parking slots while reducing the traffic congestion levels and simultaneously providing an effortless experience to the users.

Table 2: System performance metrics for smart parking operations.

Parameter	Measured Value	Expected Value	Accuracy
Slot Detection Time	1.8 sec	<2 sec	95%
Mobile App Response	2.5 sec	<3 sec	92%
Entry/Exit Time	3 sec	<5 sec	98%

5 FUTURE WORK

The described smart parking system has proven to be feasible in parking space and traffic congestion minimization. However, there are still many potential enhancements that can be explored in future studies in order to enhance its functionality and usability. One of the main aims for performance improvement is the integration of advanced sensors (sonography or RFID type systems) to increase the reliability of parking slot detection. Due to their ability to generate accurate, low error, real time data, these sensors will enable more precise space occupancy measurement. In addition, scaling out of the system to support multistorey car parks can further scale the system and make it usable for urban environments with limited parking. Notably, an analytic module that is also predictive is included as an addendum. By using the historical parking data, the system can predict congestion time points and then inform the users of the optimal parking time to reduce the congestion, respectively. In addition, a dynamic price model that relies on demand can also contribute to increased space optimization and revenue for parkers' operators. For more mobility and ease of use, the mobile application is also configurable to allow expansion in the form of incorporating voice-based control, navigation feedback and multilingual support.

6 CONCLUSIONS

Through Internet of Things (IoT) technology, the application of smart parking information system has been implemented to solve parking issue in city. Sensor fusion, a microelectronic controller, and a mobile application can provide in-time parking space load information, which can reduce congestion and enhance the convenience of a user. Automation of the parking space detection and gate control eliminates the need for human labor, which, ultimately, leads to a better, more efficient parking process.

Experimental data have demonstrated that the system significantly improves the use of parking lot space, reduces the time it takes to locate a vacant parking spot, and improves traffic management efficiencies. Integration of cloud-based data write-ups, on-demand data access, and usability through the integration of parking and mobile applications establish consistent data flow and enable information sharing for users. While the efficiency of the system has already been demonstrated, the system can be further improved by learning predictive analytics, advanced security devices, and parking guidance integrated with multi-level parking guidance. Further advancements may also focus on enhancement of accuracy, incorporation of AI assisted parking forecasts, and expansion for wider smart city deployments. Conclusion Overall, this smart parking

system offers an efficient and feasible approach to compensate for the defects of traditional parking management.

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