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| RESEARCH ARTICLE

Design And Implementation of a Smart Wireless Parking System

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| ABSTRACT

Numerous people choose private vehicles over public transportation due to the fast growth of metropolitan populations and hectic work schedules. Finding parking spaces, particularly for cars, is a common challenge that sometime results traffic congestions too. Drivers frequently don't have the time to look for parking spots because of their busy schedules. A digital system that can automatically identify and give signals of available open parking spaces is therefore becoming more and more in demand. Such a method would save a great deal of time as the world is growing towards digitalisation, which is important in the fast-paced generation of today. In order to show available parking spaces in a certain region, this paper explains how data is gathered from several neighbouring parking lots and transmitted to a central unit. The nRF24L01 transceiver module provides full-duplex RF communication that is both economical and effective. These modules are reasonably priced and easy to control. The goal of this paper is to clearly indicate the exact location of available parking spots within a parking area. A list of empty slots will be displayed at the entrance. The system comprises a control unit, IR sensors, an LCD screen, antennas, and more. Implementing this system for car parking will significantly reduce the need for manpower.

| KEYWORDS

nRF24L01 transceiver module, Esp8266, Wireless Communication, IR module, TX-Unit, RX-Unit, Smart Parking.

| ARTICLE INFORMATION

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1. Intoduction

Optimizing parking slot management and utilizing is the main goal of "Design and Implementation of a Smart Wireless Parking System". Even though public transit has expanded significantly, middle-class households can now afford private cars because of the economic expansion, which has increased the number of cars in urban areas. As a result, parking infrastructure has undergone a discernible makeover, embracing ideas like multilevel parking, podium parking, multistorey parking, and multilane parking systems.

Vehicle parking systems and their associated technologies have grown and broadened throughout the years. The conventional parking system is mainly used for residences, offices, and other similar establishments. The layout of individual parking spots makes it simple to enter and exit, which eases traffic congestions. These systems, however, are controlled by humans and are manually operated. Drivers must personally look for an open parking spaces before parking their cars. Depending on how big or tiny the neighborhood is, finding an open parking space in a particular parking lane takes an average of five to ten minutes. In addition to using more time and gasoline, this pursuit of finding an open spot may cause traffic jams in the parking lot. Monitoring the overall number of vehicles in the parking lot, figuring out how many rooms are left for new vehicles, and keeping the parking spaces occupied are some of the difficulties that traditional parking systems confront. Moreover, vehicles use a lot of gasoline or fuel while they wait at the parking queue, and when they burn that fuel, they release the most harmful gasses into the atmosphere. In addition, a lot of waste is produced by the people while a car waits in the line, which essentially pollutes the environment [1]. An automated or digital parking system can operate with a smaller parking area infrastructure and takes up less space than a traditional parking system. More benefits than typical parking systems include time savings, cost and fuel savings, hassle-free navigation, less greenhouse effect, and more. This computerized system improves the driver's experience, reduces additional traffic on the road and inside parking lots, and makes better use of parking spaces [2].

2. Earlier Research

In 2020, Patil, M., Chakole, V., & Chetepawad, K. published a paper at the 3rd International Conference on Intelligent Sustainable Systems (ICISS) focusing on the rising challenge of car parking in densely populated cities by proposing an automated real-time parking system powered by the Internet of Things (IoT). The goal of this system was to address parking and traffic issues brought on by the growing number of cars. By using the Arduino Uno as the microcontroller to create a platform for engaging with digital devices and managing physical items, the Internet of Things-based framework made it possible for devices to communicate with each other seamlessly. The system made use of a Node MCU to link parking lots to the internet and an Arduino Uno board for parking management. To identify open spots, infrared sensors were placed in every parking space. With all required data stored on a server, this configuration enabled customers to reserve parking spaces in advance. To avoid abuse, each user was given a distinct username and password. The system was made to notify the appropriate staff in the event of misuse or illegal access. In terms of increasing parking efficiency and reducing urban traffic issues, this idea represented a major advancement [3].

In 2023, Sudhakar, M. V., Reddy, A. A., Mounika, K., Kumar, M. S., & Bharani, T. completed a study that examined the creation of a Smart Parking System as a solution to urban parking issues. By cutting down on the amount of time needed to locate parking, minimizing pollution from traffic, and making the best use of available parking spots, this method improved user convenience. The system's integration of cloud-based data storage allowed for push alerts and real-time updates to notify users of parking space openings. Future developments were anticipated to include the incorporation of machine learning (ML) and artificial intelligence (AI) to improve security with multi-layered protocols, expedite vehicle identification, and analyze parking patterns for more insightful suggestions, all of which would contribute to safe and sustainable parking solutions [4].

In 2023, Channamallu, S. S., Kermanshachi, S., Rosenberger, J. M., & Pamidimukkala, presented an analysis focused on the development and implementation of Smart Parking Systems (SPSs) and highlighted several key advancements. Significant advancements have been made in SPSs, especially with the use of Internet of Things (IoT) technology, which allows for effective parking spot management and real-time monitoring. This made parking more convenient by enabling consumers to check parking availability using mobile applications. These systems are now much more dependable and efficient because to advancements in sensor technology and data processing techniques [5].

In 2022, researchers Anusha T and M Pushpalatha studied the design of efficient communication models for Smart Parking Systems (SPS) in their research. In the context of smart cities, their research concentrated on how Internet of Things (IoT) technology may improve urban digital solutions. The researchers underlined the need for real-time parking space availability and occupancy of data. The use of IPv6 wireless mesh networks to develop low-power, secure communication systems for Internet of Things devices in parking systems is covered in the study. In order to reduce the need for continuous cloud data retrieval, it suggests a hybrid communication model with numerous data consumers for local data sharing [6].

Researchers IH Jung, JM Lee, and K. Hwang unveiled a cutting-edge smart parking lot management system in 2022 that improves parking space management and safety by utilizing artificial intelligence (AI) techniques and many cameras. In order to track parking space occupancy, identify car numbers as they enter the lot, and update parking space status in real-time, the system uses an embedded camera. The system also uses footage from surveillance cameras to identify possible collisions that might happen as cars travel around the parking lot. By giving each vehicle an Object ID, the vehicle number recognition system which is built on a Raspberry Pi system using Optical Character Recognition (OCR) techniques—allows for the tracking of automobiles as moving objects inside the parking space. This makes it possible for the system to accurately determine where the car is parked. The researchers used Convolutional Neural Networks (CNN) for deep learning and YOLO (You Only Look Once) for accident detection in order to increase safety [7].

In 2022, researchers Jemmali, M., Melhim, L. K. B., Alharbi, M. T., Bajahzar, A., & Omri, M. N sought to ensure fair parking lot distribution in smart cities in order to enhance traffic flow. Seven algorithms were introduced in the study to reduce the disparity between available parking places and people. The algorithms demonstrated outstanding performance in closing gaps and producing accurate time calculations when tested on 2430 examples. With an average gap of only 0.02 and an execution time of 0.007 seconds, the MR (Maximum Reduction) algorithm achieved an astounding 96.1% success rate, outperforming other algorithms. This framework shows how algorithm-based solutions can increase the effectiveness of parking management in smart cities [8].

Intelligent transportation systems (ITS) depend on effective vehicle management and traffic forecasts. The ability of Graph Neural Networks (GNNs) to anticipate traffic flow is explored in earlier research by Jonayet Miah et al. (2023). This is crucial for applications such as vehicle routing, road traffic control, and trip planning. In order to determine how well three well-known GNN architectures—Graph Convolutional Networks (GCNs), GraphSAGE, and Gated Graph Neural Networks (GGNNs)—minimize traffic prediction errors, this study compares them. With the lowest RMSE of 9.2 and an MAE of 7.0, the results show that GGNNs are the most successful model, highlighting the significance of sophisticated machine learning methods in traffic management. This investigation examines a supplementary component of ITS : resolving parking issues that vehicles encounter in metropolitan settings, whereas Miah et al.'s research focuses on traffic prediction using GNNs. Traffic congestion is made worse by the rapid urban population increase and hectic work schedules, which frequently make it impossible to find parking places. This research suggests a smart wireless parking system that automatically detects and communicates open parking spots in order to solve this problem[9].

In order to solve the persistent traffic management problems in Dhaka, a city beset by congestion and frequent infractions of traffic laws, in 2020 Fahad Faisal et al. suggested a low-cost automated traffic detection system that makes use of image processing. Their system uses live-streamed video to identify traffic infractions, allowing law enforcement to use stored data to take the necessary legal action. This strategy seeks to improve urban traffic flow and increase adherence to traffic laws[10].

Monowar Hossain Saikat et al. (2024) explored the use of deep learning, specifically a modified OverFeat Convolutional Neural Network (CNN), for real-time vehicle and lane detection in highway driving scenarios. Their research made use of a wide range of data, including inputs from GPS, radar, LIDAR, and cameras. On different GPU configurations, the researchers were able to recognize cars and 3D lane borders with high accuracy at functional rates higher than 10 Hz. High vehicle bounding box prediction accuracy, occlusion resistance, and effective lane border recognition are important results that demonstrate the great potential for applications involving autonomous driving. Although Saikat et al.'s research tackles dynamic vehicle navigation issues, our study concentrates on parking management, which is an essential aspect of urban transportation. In order to cut down on the amount of time drivers spend looking for parking, we suggest a smart wireless parking system that automatically recognizes and signals open spots [11].

In 2024 Zhizhong Wu presented a new method for predicting traffic flow by merging deep learning with bi-directional long short-term memory (BiLSTM) networks and the Revised Enhanced Extreme Gray Wolf Optimizer (REEGWO), which optimizes convolutional neural networks (CNNs). With notable gains in prediction parameters like RMSE and average absolute percentage error, the model outperformed traditional techniques in terms of accuracy and efficiency. This study offers a sophisticated way to deal with inaccurate traffic flow predictions [12].

3. Proposed System

3.1 Working System

Fig. 1 represents a basic block diagram for the proposed system, consisting of IR sensor modules, microcontrollers, antenna, and display. The transmitting unit and the reception unit are the two main components of the approach that this paper suggests. A microcontroller unit (MCU), an IR module (line sensor), and a nRF antenna module that serves as a transmitting antenna make up the transmission unit.

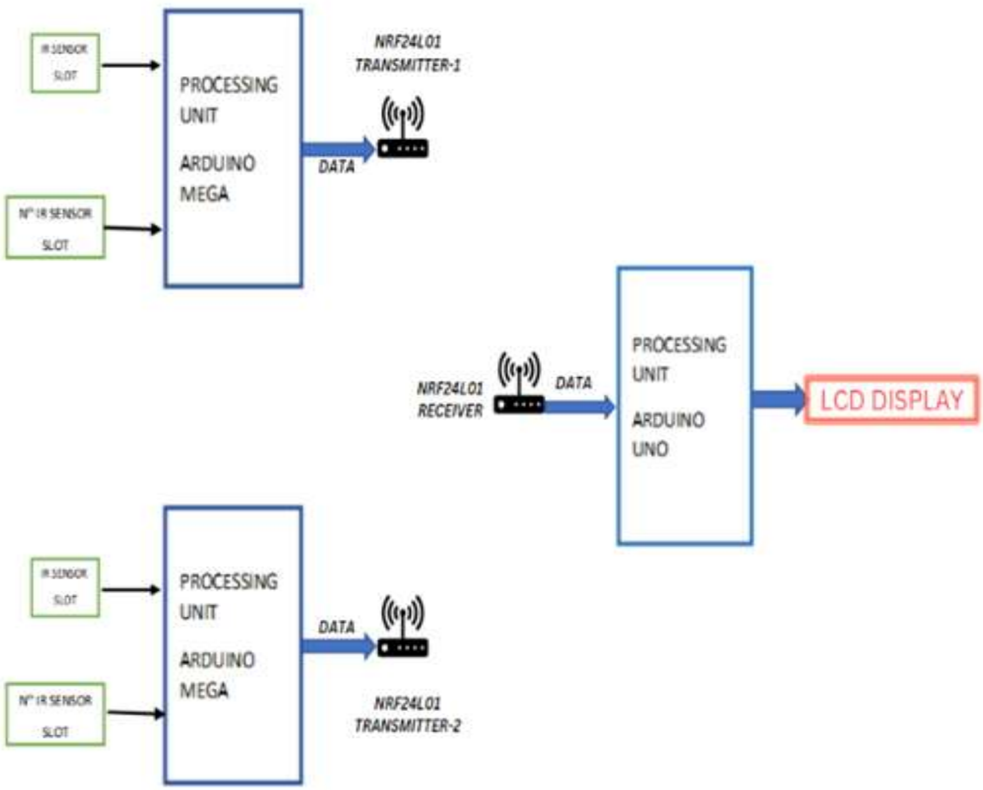

Fig. 1. Block Diagram of Proposed System

The components of the receiving antenna include the display unit, MCU, and nRF antenna module. The system's overall capacity can be increased by incorporating several transmitting units into the proposed strategy. The key idea of the suggested approach is to show the exact available spot at the main entrance from various parking lots, as shown in Figures 2(a) and 2(b) below.

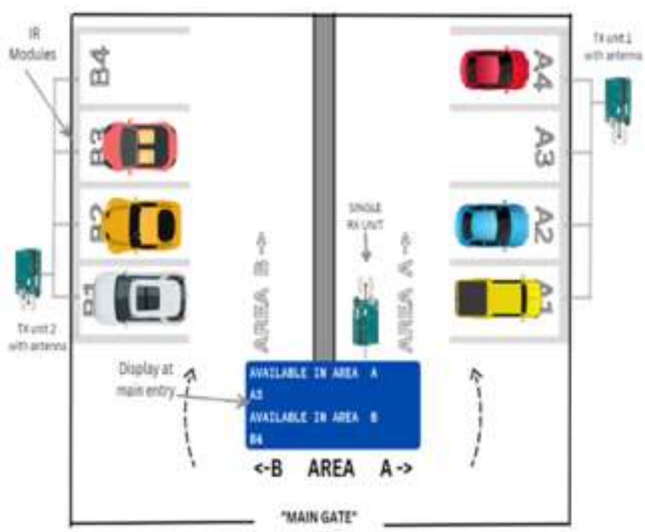

Fig. 2(a). Whole system

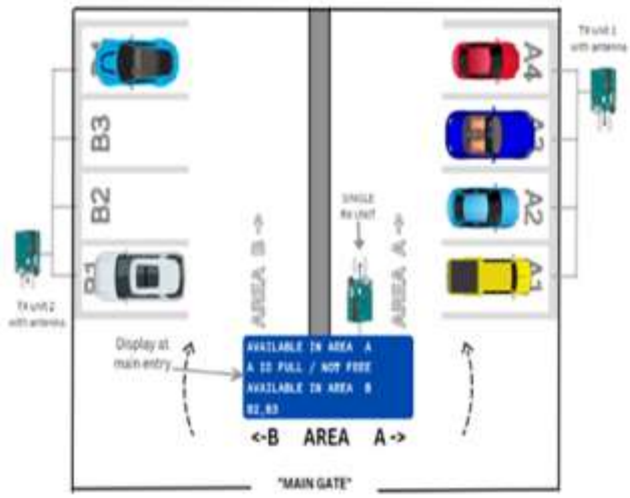

Fig. 2(b). Whole system

It can be seen in Fig. 2 (a) that two different parking areas, “A” and “B”, consist of slots “A1 to A4” and “B1 to B4” respectively. Each parking slot has been provided with individual IR detectors. IR LED in the IR sensor emits the IR light (ranges between 38 KHz to 57 KHz). This IR light gets reflected from the body of the car and IR sensitive photodiode on the IR module detects it. The IR modules detect the car on slots A1, A2, and A4 and give high input to connected pins of the MCU. The MCU creates the list of those slots for which there is no input to the assigned pin for slots, here “A3” is the available free space. This MCU is connected with the nRF24L01 antenna module forming a “TX-Unit-1” for the “Area A” as shown in Fig. 2. While encoding by the microcontroller, the same address is being provided for both the “TX-Unit” and “RX-Unit” over which transmitter and receiver will be communicating. A unique header is being added to the list of free slots so that it can identifies that this list is for “Area A”, and the list is being broadcasted on the air. The “TX-Unit-2”, which is placed in parking “Area B” follows the same process. In “Area B” when the IR sensors sense the absence of cars for the respective slots, it sends low input to the microcontroller. The microcontroller creates the list of free slots in “Area B”, in this case, “B4” is the available free space. A unique header is added to this list too so that the receiver can identify the list consists the information of “Area B”. Once again same address is being provided for “TX-Unit-2” and “RX-Unit” for communicating through the RF channel. Since the nRF24L01 module can behave as a transceiver in this system, the “TX-Unit-1” and “TX-Unit-2” antennas are configured to work only as transmitting antennas. It is to be noted that the data transmitted from “TX-Unit-1” does not affect the antenna and functionality of the “TX-Unit-2” antenna and vice versa. Hence there is no misplacement of messages on the air. The antenna at the “RX-Unit” is configured only for the reception of messages i.e., only as a receiving antenna. The message in the air transmitted by “TX-Unit-1” received by the “RX-Unit” and stored in the buffer. The antenna captures this messages and passes the required data to MCU for furthur processing. The MCU reads the data with the help of a header and this unit is trained/encoded to identify the message for a particular area. It comes to know that, this message consists of an information (list) of “Area A”, and sends this list to the display unit to show it on the desired location of the display. Simultaneously, “TX-Unit-2” transmits information about vacant slots of “Area B”. Similarly, the “RX-Unit” receives the message from “TX-Unit-2” and stores this message in the buffer. After processing this message, the MCU sends this information of free slots from “Area B” to display at the entry as shown in Fig. 2 (b). It is to note that the “TX-Unit-1” and “TX-Unit-2” transmits the updated list in every seconds in the entrance display so that there is no possibility of delaying vacant information transmission.

3.2 Flowchart

The program flowchart for the transmission unit's MCU is displayed in Fig. 3(a). The encoded function begins to run when the system boots up or the Arduino power supply is turned on. The MCU establishes the pins for the corresponding slots in the setup function. Next, it creates the radio object for nRF communication and specifies the address for communication between the "TX-Unit" and the "RX-Unit." "00001" is addressed here. If the payload and data rate are set to the same as the "RX- Unit," it can be any string of five characters, such as "node1". Next, invoke the procedure "radio.stoplistening()" to configure the radio for transmission only. nRF now only functions as a transmitter. When the Arduino (MCU) is configured as a setup function, the previously described procedure is carried out once.

The array for the list of available slots is created by the MCU. The MCU reads the inputs from all of the ports for designated slots after the array has been constructed as specified in the software. Slots are said to be occupied when every input from a particular slot is true or high.

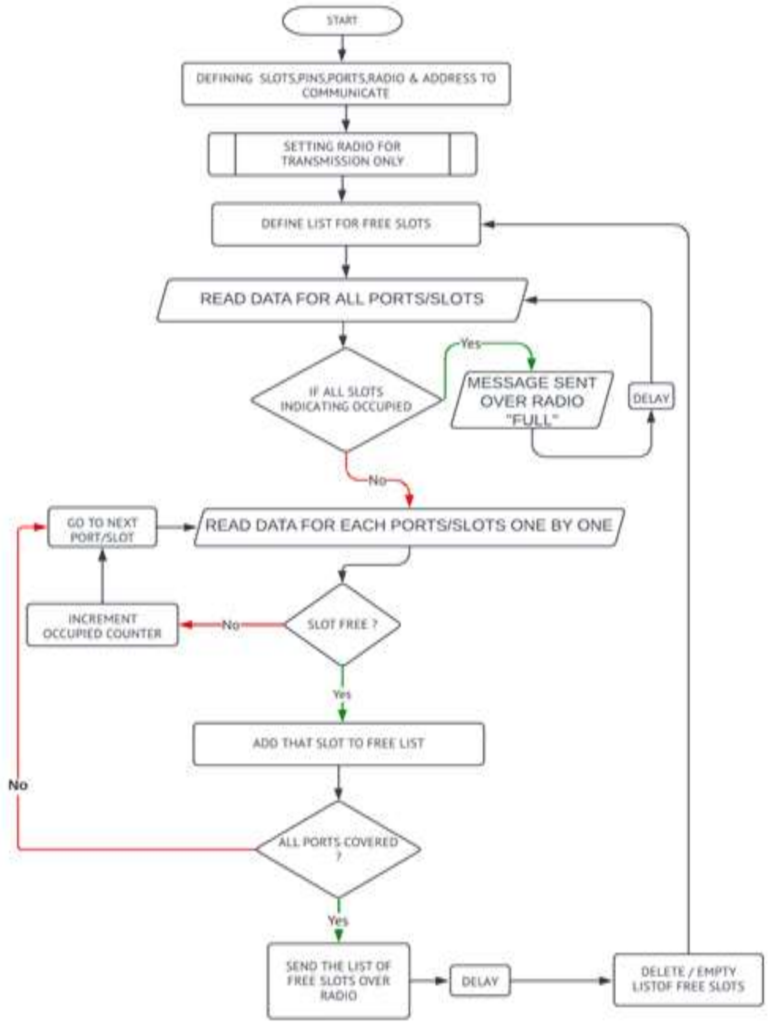

Fig. 3(a). Flowchart for "TX-Unit"

That means, cars are being detected by all IR modules, and the message "FULL", is sent from the "TX-Unit" to the main MCU. On the other hand, if the inputs are false/low, it indicates that there are some IR modules that are giving output as "0" which indicates no cars are detected. In this condition, inputs for each assigned pin, are read one after another. If the car is detected, MCU increments the counter of occupied numbers. If no car is detected, IR gives a '0' output at its data pin and No input signal is transferred to MCU indicating no car is detected and MCU adds this slot number to the array of free slots. Then it goes to the next pin, follows the same process, covers all the pins consecutively, and adds those to the free slot list. After all the pins are covered, the list of free slots is broadcasted via the nRF antenna module using radio waves. After transmitting the array of the list of free slots, MCU clears the elements in the array and all the other counters used in the program follows this same process in a loop again and again until the system is powered off.

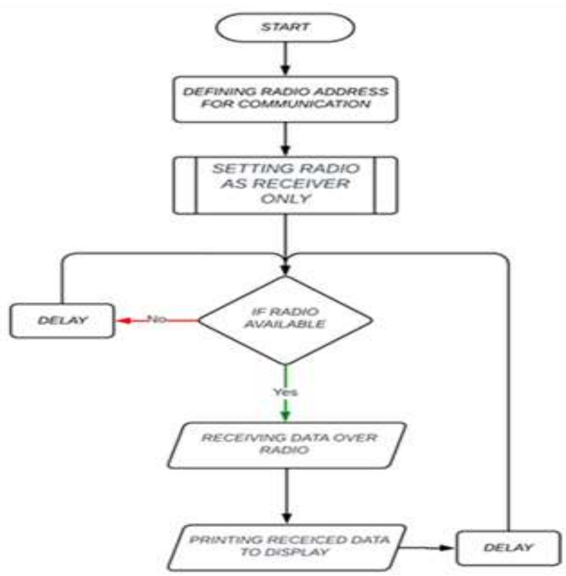

Fig. 3(b). Flowchart for “RX Unit”

The above flowchart Fig. 3(b) shows the program flow for the receiving unit. In the setup function, researcher define the radio object with CE and CSN pins for nRF module. After that, set the address as the transmitter ‘1’ at data pipe ‘0’ for communicating with the TX unit 1 address. 0 to 5 pipes are available for simultaneous communication with 6 different TX units, i.e., pipe ‘1’ is assigned to TX unit 2, and so on. By calling the function “radio.startlistening()”, the module is configured as a receiver only. By calling the method “radio.available()” in the loop, it checks if there is any data available to be read or not. If data is available, it returns “TRUE”, otherwise “FALSE”. In the “TRUE” condition, the data is retrieved from a radio. The same process is followed for all the pipelines in use. After retrieving the message, it is ready to be displayed on the screen. And the RX unit follows the above process in a loop until the system is powered off.

4. Results

In Figure 4 (a) and Figure 4 (b), the prototype model's results are displayed. We can observe that the single display at the main entrance successfully shows details of the available slots. With their own MCUs and antennas, "Area A" and "Area B" are isolated from one another. The image shows that the available place in lane A is A3, while in lane B, it is B2. The main screen always keeps updated to reflect the changes in the number of available spots.

Fig. 4 (a). System Model

Fig. 4(b). Empty slots detected on LCD display

5. Conclusion

The transport system significantly impacts a country's economy, and a well-developed system enhances the communication sector and overall economy [13]. People are increasingly facing the challenge of parking their own vehicles due to the significant population growth and the increase in personal vehicles, particularly autos. A straight forward computerized method for locating open slots in a specific parking location is required to solve this significant issue. The technique designed to identify and show the available space in a particular parking lane is described in this paper. An unoccupied parking space can easily be found by any individuals. As the proposed system offers flexibility and a digital way to show which parking spaces are available in a certain lane at the main entrance, it eventually helps people save more time and effort in their everyday lives. Since it is an electronic system there will be a certain delay across the system activation and signal transmission. In future, the system can be enhanced more by adding AI technology and IoT. To conclude, the system is comprised of a nRF module with transcribing functionality that facilitates the implementation of the system for N number parking slots, which may include podium parking, multilevel parking, numerous parking lanes, etc. To identify vacant spaces, a different infrared sensor module is utilized for every slot. This information is sent to the LCD screen at the parking lot's entrance to make the driver understand which space is free and which space is occupied. Thus, the system shows it's great adaptability which can be utilized in a variety of settings, including shopping centres, residences, business flats, etc.

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