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# Design and Implementation of a Smart Parking System using IoT Technology

[1] Narayana Swamy J C, [2] Sahana Satyanarayana, [3] Lokesh Babu S, [4] Trishank Sharma
[1][2][3][4] Department of Electronics and Communication Engineering, Bangalore Institute of Technology, Bengaluru, Karnataka

*Abstract-* **With the rapid increase in the number of vehicles in urban areas, drivers waste a lot of time and fuel to find an appropriate parking spot in a commercial parking lot. Moreover, approximately 30% of urban congestion is created by drivers cruising for packing space. This paper aims at providing a low-cost solution to this problem by creating a Smart Parking Space using the technology of IoT and an inexpensive processor - NodeMCU. This amalgamation of embedded systems, connectivity and application will provide the user with the information of available parking spaces in a parking lot and also allows the user to reserve a parking space in the lot within the timestamp over the MQTT protocol. A Smart Parking Technology, as such, will help optimize space usage, improve the efficiency of the parking operations and help the smoother flow of vehicles. Further, this paper proposes a completely automated and smart parking space without much human intervention by including fire alarms, temperature and humidity sensors, water sensors for avoiding waterlogging and light sensors for automatic control of lights. On the whole, this paper focuses on designing smart parking system, beneficial to both the users and provider in terms of time, fuel and infrastructure.**

**Index Terms: - NodeMCU, smart-parking, IoT, fuel wastage.**

## I. INTRODUCTION

Internet of Things (IoT) is an ecosystem of physical devices that leverages the power of embedded systems, connectivity and software application to create an efficient, economic and automated society. With the advent of communication technology, connectivity is simplified and thus, IoT is gaining more importance day-by-day. This rapid development has engendered an increasing research in the field of IoT. One such exciting area of application of IoT is Smart Parking System. Traffic congestion has become one of the major problems in urban areas. It is characterized by excess fuel consumption, longer trip times, slower speeds, and increased vehicular queueing. This is a serious challenge for city planners, architects, and building owners. To resolve this, many IoT based Smart Parking Systems were proposed. But, those were found to be more expensive when they had to be deployed. To make the Smart Parking System more economical and available to everyone, an innovative, organized and automated parking system is presented. The proposed model uses an inexpensive processor, NodeMCU to gather data from each parking slot and transmit it to the Wise3 IoT Platform, from where the application derives each user information. Further, this project augments the existing Smart Parking System with maintenance and security features such as fire alarms, waterlogging indicators, etc. All buildings including malls, hospitals, government buildings, etc. can implement this technology. Consequently, this project is an on-site deployment of an IoT module that is used to monitor and signalize the state of availability of each parking space as well as notify the security personnel in case of emergency such as water leakage, fire, etc. The rest of the paper is organized as follows. The section II provides an overview of the related work done in the field of Smart Parking System. The section III elucidates the system design and the section IV proposes a mathematical model for the proposed design. The section V discusses the implementation and working of the system. Section VI concludes the paper and section VII gives the future scope.

## II. RELATED WORK

The parking system which exists today differs in vast proportions from the traditional parking systems. The flexibility provided to users has increased tremendously as they can choose their desired slots to park their vehicles

In [1], the paper focuses on the key issues of Space Optimisation. The System architecture was developed with IR sensor network and MCU. This architecture manages the traffic of the parking area by finding the shortest distance to park the vehicle and therefore helps the users to find the available parking space.

In [2], the authors mentioned about a smart, automated parking system which helps in delaying the car parking difficulties at various places such as railway stations, malls etc. that many people visit with their own vehicles. The drivers use the system to know the availability of slots of the parking area via website. Drivers also have the authority to choose or give their own slots in parking. The various reports of various kinds of management could be improved.

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Finally, lesser time of the car owner was an added advantage.

In [3], the design of the smart parking system was implemented using supported hardware's based on iot. These included raspberry pi, Arduino boards etc. Here the main focus is on less power consumption and more power device. Raspberry pi plays the role of a microcontroller. NOOBS installer is installed on the microcontroller. The installer internally comprises of various supportable operating systems such as Mac os, tiny os, Raspbian os etc. these operating systems consume less power.

In [4], the authors have proposed that they have to book the parking slot beforehand and then park their vehicle. Here, we are providing the facility for both the new users and pre-registered users. In [5], a smart parking system has been mentioned for commercial stretch in cities and which can be applied using different database storage systems like cloud, MySQL, python etc. wherein the vehicle is guided to the parking lot using the data which has been collected by sensors, image detectors etc. which is then processed and further sent to the mobile of the user.

## III. SYSTEM DESIGN

A high level description diagram of the proposed Smart Parking System is shown in Figure 1. The diagram illustrates the implementation of the system in a parking space with two lanes A and B with each lane consisting of 2 slots each. The system, composed of various interacting components, caters to the smart parking, safety and maintenance concerns of the user/driver and system owner. The diagram also gives the detailing of connectivity established between various components. The major components that comprise the system are discussed below:

- Sensors for parking and maintenance: Infrared (IR) sensors are placed in each parking slot to determine whether the particular parking slot is occupied or not. The sensors for maintenance include DHT11, MQ-135, LDR (Light-dependent resistor) module, and FC-37 raindrop sensor. DHT11 (Digital Humidity and Temperature sensor) is used to sense the humidity and temperature of the parking space. MQ-135, which is a gas sensor used to detect smoke in the parking space with the intention of alleviating the fire hazards in the parking space. LDR module is used for automatic switching of lights, based on the natural light available in the parking space to ON or OFF, if the natural light in the parking space is sufficient, then the LED lighting need not be used which saves power and if the natural light does not give enough visibility in the parking space, then the LED lighting is used. Waterlogging is highly undesirable in the parking space. In order to detect this condition, a raindrop sensor has been employed. The raindrop sensor detects the waterlogging in the parking slot.
- User identification: The users are identified via RFID cards, provided to each user on subscription to the Smart Parking System. When the RFID card is placed on an EM-18 RFID reader, the RFID reader generates a 12-digit hexadecimal code, unique for each user. The RFID reader, operating at 125kHz, sends the user ID to the NodeMCU on the UART communication pin.
- Slot status indicators: The status of each slot, whether occupied or free or waterlogged is indicated with the help of LEDs placed for each parking slot. The driver can look at the LED of each parking slot in the parking space to find the status of the slot so that he/she can easily decide whether to drive towards that slot or not. If the LED glowing is red in color, then it indicates that the slot is reserved or occupied. If the LED glowing is green in color, then it indicates that the slot is free to book or occupy. If the LED glowing is blue in color, then it indicates that there is waterlogging in the slot.
- Maintenance devices: The maintenance devices used in the proposed parking space comprise of the submersible water pump, buzzer, LEDs for automatic lighting and to indicate waterlogging. The output of the sensors are used to control these devices. If MQ 135 detects a considerable smoke density, the submersible water pump placed in a water tub will be switched on to put off the fire. The buzzer is used as an fire alarm to alert everyone in the parking space about the fire that broke out in the parking space. Automatic lighting is proposed with the intention of saving power, when the natural light is sufficient enough to provide the visibility in the parking space, LEDs are switched OFF and when the LDR senses poor visibility (less light) in the parking space, the LEDs are switched ON. As discussed above, if there is waterlogging in the slot, the slot status will be changed with the indication of blue LED.
- Processing unit: The processing hardware of the proposed model is the NodeMCU (Node Microcontroller Unit). It comprises the firmware which runs on the ESP8266 Wi-Fi SoC from Espressif Systems, and hardware which is based on the ESP-12 module [6]. It is comparatively an inexpensive microcontroller; the ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack. It supports the IEEE 802.11b/g/n agreement and operates in the 2.4 GHz ISM frequency band. NodeMCU provides access to the GPIO (General Purpose Input/Output) to which the sensors and devices are connected. The RFID is connected to the UART module on the NodeMCU. The NodeMCU gathers all the data from the sensor and connects to a nearby access point to upload the sensor data in the form of JSON to the Wise3 IoT Platform over the Mosquito MQTT broker. The

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NodeMCU further responds to the remote procedure calls; any call back made on the MQTT topic it has subscribed to will be taken care by the NodeMCU, say, switching on the slot status indicator LED if the available slot is booked. The communication between the NodeMCU and the Wise3 IoT platform is governed by the MQTT protocol, where the broker being Eclipse Mosquito and the NodeMCU and the Wise3 IoT platform are the Clients in the proposed system.

- Wise 3 IoT platform: The Wise3 IoT Platform has the provision of creating dashboards with the help of widgets. Each dashboard is derived from a device where the sensor data is published by the user and the responses for remote procedure calls are received; each device has its own access token to differentiate one device from the other. Each sensor data telemetry can be taken as a widget and displayed on the dashboard for better understanding of the reader. For the users to reserve a parking slot online, the dashboard includes control widgets which initiates a remote procedure call when an action is performed on the widget. Therefore, the system maintenance can get a good picture of the maintenance of the parking system by looking into the dashboard depicting the sensor data for maintenance. Also, the user of the Smart Parking System can look into his dashboard to find and to reserve the slots available.
- User: Each user of the parking system (or the driver) has to carry the RFID card along with him in order to use the parking system. The RFID card will be given to the user at the time of subscription to the parking system. The user need not reserve a parking space in order to use the parking system; the system is offline compatible with the RFID card, but the user gets updated on his dashboard about his entry, exit, bill and time spent irrespective of whether he is reserving a space or not. Each user is assigned a dashboard and can be accessed on any device using a web browser.

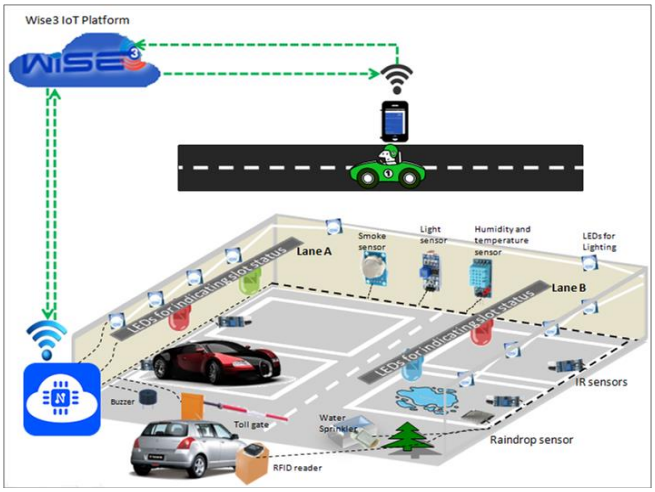


***Figure 1: High-level description diagram of the proposed model***

## IV. MATHEMATICAL MODELING OF THE PROPOSED SYSTEM

In this section, we propose a mathematical model of our Smart Parking System. The interplay of multiple factors determines the behaviour of the system. In order to analyse the system in a fine-grained fashion, we are leveraging the knowledge of Mathematics and representing the system using mathematical expressions and functions. Table 1 depicts the notations and Table 2 depicts the functions used in proposing mathematical model.

$T_{i\ entry}$, $T_{i\ exit}$,$P_{i,}$ N and S are the parameters subject to change by driver $D_i$'s actions.$R_{c\ i}$ remains constant for a driver $D_{i.}$

Value of $O_S$ parameter determines the value of B and W parameters.Value of $O_{IR}$ parameter determines the value of N and $S_j$.Value of $O_{RD}$ parameter determines the value of $S_j$.

$S_j$ = -1/0/+1; Status of the $j^{th}$ slot can be either -1 or 0 or +1 where
-1 indicates water logging in the slot (indicator LED is blue)
0 indicates that slot is free to occupy (indicator LED is green)
+1 indicates that slot is occupied or reserved (indicator LED is red )

| Notation | Parameters Denoted |
|---|---|
| i | Number of drivers |
| j | Number of slots in a parking space |
| $D_i$ | $i^{th}$ driver |
| $T_{i\ entry}$ | $D_i$'s entry time |
| $T_{i\ exit}$ | $D_i$'s exit time |
| $R_{ci}$ | $D_i$'s RFID card number |
| $P_i$ | Parking charges for $D_i$ |
| $S_j$ | Status of the $j^{th}$ slot |
| N | Number of slots available for parking |
| $P_{SM}$ | System maintenance charges |
| $O_S$ | Digital output of smoke sensor |
| $O_L$ | Digital output of light sensor |
| $O_{H,T}$ | Output of digital humidity and temperature sensor |
| $O_{IR}$ | Digital output of IR sensor |
| $O_{RD}$ | Digital output of raindrop sensor |
| B | Buzzer output |
| W | Water Sprinkler output |
| L | LEDs for lighting |

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*Table 1: Notations for proposing mathematical model*

$S_j$ = $WL(O_{RD})$ = -1; //has highest priority in assignment
= $IR(O_{IR})$ =0/1; //has 2nd highest priority in assignment
= R(N) =1; if i ≤ j or N>0

Also, N is never less than 0.If i > j or N = 0, then R (0) =" No available slots" which is not assigned to $S_j$, but displayed to the user.
Further,

$$P_i = C (R_{c\,i}, T_{i\,entry}, T_{i\,exit}, P_{SM})$$

is the amount paid for parking by $D_i$.
Maintenance action functions, $M_A (B, W, L) = X_M (O_S, OL)$
B = $X_{SB}(O_S)$ is the buzzer output function on smoke detection.
W= $X_{SW}(O_S)$ is the sprinkler action function on smoke detection.
L= $X_L(O_L)$ is the automatic lighting function of the parking space.

| Functions | Tasks Performed |
|---|---|
| WL() | Detects water logging in the parking space |
| IR() | Detects whether a particular slot is occupied or free based on IR sensor output |
| R() | Online reservation function |
| A() | Computes the availability of slots |
| C() | Computes the cost of parking |
| $M_A()$ | Output function for maintenance actions |
| $X_M()$ | Determines maintenance requirements |
| $X_{SB}()$ | Triggers the buzzer on smoke detection |
| $X_{SW}()$ | Triggers the water sprinkler on smoke detection |
| $X_L()$ | Determines the on-off condition of LEDs for lighting |

*Table 2: Functions for proposing mathematical model*

## V. IMPLEMENTATION & WORKING

In Figure 2, we observe the flow of the system. The system is divided into 3 sections (i) Embedded systems, here the data is collected from sensors and is uploaded to server through NodeMCU, (ii) User authentication, using RFID the system determines whether the user who wants to park is subscribed or not. (iii) Wise3 IoT Platform, with the help of user login credentials the user can book, search, cancel what he has booked etc. Each user is given an RFID card along with the unique login credentials when subscribed to this system. The user can use the login credentials to login to the Wise3 website in phone or portable devices and get the details on parking slots available, book parking space online, locations, etc. The system is working 24/7 throughout the year. Data from sensors are collected and by using NodeMCU we are uploading it to Wise3 IoT server. When the user wants to park, first the RFID swiped should be validated, upon valid user confirmation he can park the vehicle in the dedicated parking space provided/selected.

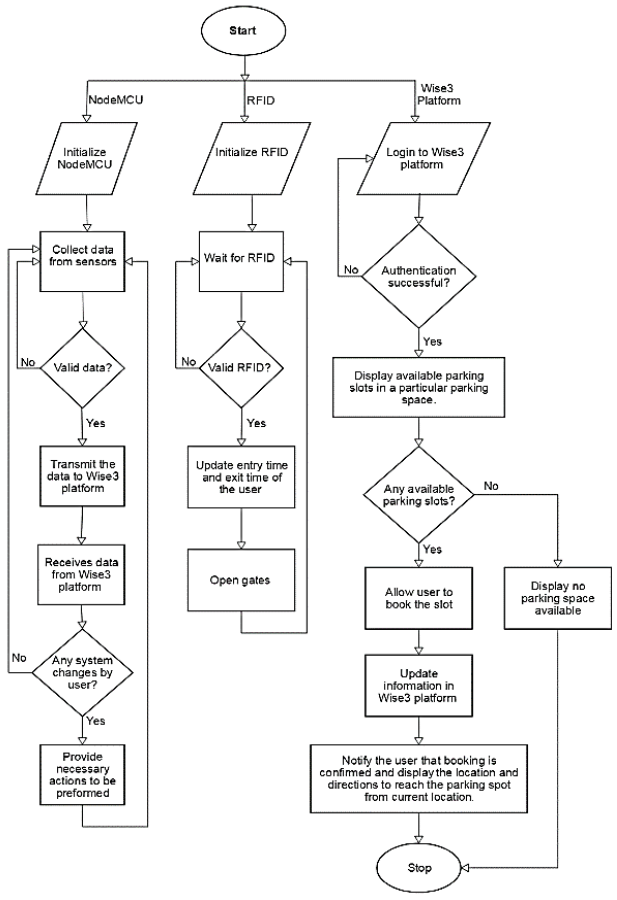


*Figure 2: Flowchart of the working of the system*

The system has very good safety measures included in it for cases such as fire accidents. We make use of smoke detectors for the detection of fire in the parking space and

sprinklers are activated automatically. Buzzers are activated as alarm during fire. In case of waterlogging, a high priority message is shown in Wise3 dashboard where the maintenance staff is notified to attend this issue, at the parking space a Blue LED is turned ON at the waterlogging spot. High temperature and humidity sensors are used to regulate the temperature of the space by turning ON the exhaust fans when required automatically. Lights are turned ON automatically. The parking slot is fitted with LED lights for easy identification like Green LED for free slot, Red LED for slot occupied and Blue LED for under maintenance (waterlogging).

## VI. CONCLUSION

An efficient, cost-effective and smart parking system has been designed which provides a viable solution to various problems such as traffic congestion, excessive fuel consumption etc. The various difficulties and concerns such as safety, security etc., are taken into account and their solutions are provided. The parking system can be implemented in almost all urban locations such as railway stations, police stations, malls etc. The proposed system abolishes the need of unnecessary travelling in parking slots and hence reduces the time as well as the effective cost. This system provides the actual and desired information about the availability of parking slots in the parking system. Users can book the available slots through the use of Wise 3 IoT platform. This paper desires to improve the parking facilities of the city, and hence reduce wastage of fuel, reduce traffic jams, decrease air pollution and noise pollution thereby improving quality of life.

## VII. FUTURE SCOPE

This parking system can be implemented in all of the major buildings in the cities such as malls, police stations, post offices etc. This would help us in reducing and managing the space congestion and fuel wastage problems which have become the major problems of the recent era. By including the smart parking system both the booking of parking space and the maintenance of parking slots can be managed through the dashboards provided by the online platform. Also in future, instead of manually creating dashboards for users, the entire process of creating a dashboard for the user can be automated. Further by the use of user friendly mobile applications the service can be used over smart phone and other portable smart devices for online booking, slots availability and many more features, etc.

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