Smart Parking System with PlacePod, LoRaWAn IoT sensors and Android app

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***Abstract*—Rapid population growth, increased wealth and adaptation to new urban environment norms led to a significant increase in car traffic. This caused significant challenges associated with higher emissions, diminished road safety, and limited parking facilities. Smart parking solutions aim to contribute to this challenge. This paper describes a small-scale smart parking implementation at the University of Oulu parking site using IoT sensors and a mobile app to provide real-time parking information on parking availability. Testing has been conducted to demonstrate the feasibility and soundness of the developed implementation.**

***Index Terms*—Smart Parking system, Internet of Things, Smart Cities, Intelligent Sensor.**

I. Introduction

Nowadays, car-parking has become a critical component of the modern transportation ecosystem, which impacts users' mobility patterns, business, and well-being. Recent studies revealed that vehicles seeking parking spots account for 30% of the city's congested traffic due to limited parking spots combined with usual road traffic. This increases emissions, air pollution and causes traffic safety concerns as well as business downscale [1, 2, 3]. It is acknowledged that in the overwhelmed majority, passenger carsThis creates a constant need for new parking infrastructures whose development is halted by urban and environmental constraints as well as deficiency of space in metropolitan areas. This motivated the development of smart car-parking solutions that enable drivers to minimize their search for free parking lots and better plan their trip to the destination. For this purpose, several technologies have been proposed and promoted in smart city pilots. Such solutions aim to guide drivers to nearby available car park locations while accommodating driver's preferences. Technologies such as Radio frequency identification (RFID), wireless sensor networks (WSN), Bluetooth, Wi-Fi, ZigBee, and image processing were employed to design a smart car parking system. For instance, [4] proposed a prototype of an intelligent car parking system that uses a wireless sensor network. The suggested system is based on low-cost sensor nodes that identify and monitor each parking lot's condition, whose statute is then employed to quantify the overall parking status and communicates the information to the PostgreSQL database via the implemented wireless sensor network and the associated gateways. However, the system does not perform in real-time, which causes drivers' frustration to some extent. Authors in [5] demonstrated a smart parking system incorporating ultrasonic sensor technology where a sensor was installed in the ceiling above each parking slot. Therefore, the ultrasonic waves were produced from the head of an ultrasonic vehicle detection sensor, while timing differences between the emitted and the received signals identify the presence or absence of vehicles. This provides the basis for updating lot status, which is then communicated to a user via other wireless sensors. The weakness of the system is that it only provides information about the location of parking areas and the number of vacant spaces in that parking area. Most of the provided parking systems are considered "informative parking systems (IPS)" rather than "smart parking systems (SPS)" because they cannot locate the exact location of the vacant parking slot. Ultra-High Frequency (UHF) Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN) are two other promising technologies used for the creation of innovative parking systems among all IoT-enabling technologies[6]. RFID is a low-cost, low-power technology that employs a set of (mainly) passive tags transmitting data when energized by an electromagnetic field created by a reader. Although the prolonged lifetime of tags makes this technology suitable for a wide range of application scenarios, their limited operational range (i.e., up to 10 m) often restricts the usage of RFID-based solutions for item identification and tracking in relatively small regions [7]. WSNs, on the other hand, are self-organizing networks of tiny, low-cost devices that interact via multi-hop communication to offer monitoring and control functions [8, 9]. WSN sensors typically include an IEEE 802.15.4 radio [10] with a range of up to 100 meters in the open air (single hop). As a result of these considerations, RFID and WSN are seen as two complimentary technologies whose physical integration might open up new possibilities for a wide range of novel smart parking applications [11, 12].

Besides, in order to use the above technology efficiently to accommodate driver's parking choices, several algorithmic challenges hold to yield a flexible and scalable solution. WSN nodes with a light sensor were used in [13] to identify the condition of each parking lot in an indoor space and transmit the collected data to a Web server. The data was transferred through a Wi-Fi network to a centralized server and made available to drivers via a mobile app.

In [14], a new reservation-based smart parking system was suggested, which broadcasts real-time parking information to the user and offers reservation services. The authors of [15] proposed a RFID-based technology to control street parking spots. The suggested method also allows users to reserve the needed parking place. One of the most widely used communication protocols in the IoT is Message Queue Telemetry Transport (MQTT)[16]. MQTT is an OASIS standard messaging protocol for the Internet of Things (IoT). Built as an extremely lightweight publish/subscribe message transport that is ideal for integrating remote devices with minimum code and network resources. MQTT is now utilized in many industries, including automotive, manufacturing, telecommunications, oil and gas, and so on. Furthermore, REST-style IoT systems provide smooth interchange with cloud services, ensuring the construction of scalable solutions that can readily connect with a complex Smart City infrastructure. Taking these factors into account, it may well be feasible to design and develop scalable smart parking systems directing the users towards available parking lots while accommodating up to some extent their preferences. In Finland, many existing mobile applications, such as ParkMan [17] and EasyPark [18], are restricted to assisting users with online parking tickets solely, without any information about parking availability. This motivated the current work in this paper, which investigates the design and implementation of a novel IoT aware Smart Parking System (SPS), providing the users with real-time parking lot availability and a possibility to accommodate some user's preferences.

Considering the earlier literature and implementations, two main research questions are addressed in this paper. First, How to overcome the limitations of ultrasonic and/or IR-based sensors used in Smart Parking deployment? The second important question is, What are crucial factors to be considered in a smart parking system? How to achieve scalability and reliability using the existing technologies such as MQTT protocol, Restful services, cloud platforms, etc.? The technical contributions of this work include 'the use of intelligent low-cost magnetic sensors, instead of the primitive IR-based sensors, to overcome the issues like temperature sensitivity, air turbulence effects, and limited system functionalities due to smoke, dust, fog or other harsh environmental conditions.The proposed solution ensures the context of scalability and reliability by using local gateways, MQTT protocol, and Restful service architecture. They are highly counted to provide smooth working of the systems and can easily be integrated with new resources. Furthermore, the new functionalities i.e. real-time parking lots information and predicting parking state ahead of time of mobile application has been introduced.

The remaining part of the paper is organized as follows. Section II provides an overview of the architecture design of the proposed solution. Section III provides a detailed description of the system components. Section IV presents the small-scale study analysis. Concluding remarks are drawn in Section V.

II. System Architecture

The design and functional components of the complete smart parking system are detailed in Fig. 1. As presented, the system is composed of five main components (1) Placepod Sensor, (2) Data Communication module, (3) Cloud Message Broker, (4) Cloud platform and, and (5) Mobile Application.

To detect the presence or absence of a car in a parking area, Place pod sensors were positioned in ten distinct positions. The primary purpose of these sensors is to communicate data packets containing parking spot information into the network. The messages exchanged between the PNI PlacePod and the LoRa Network follow the standard Cayenne Low Power Payload (LPP) Format to deliver all packets across the LoRa network. The proposed system only uses the downlink packet once to configure the sensor. On the other hand, the parking status information is transmitted to the network through the uplink packets periodically after each minute. Furthermore, the communication is handled by the gateways (capable of accepting LPP), which in turn are responsible for forwarding the packets to the next destination termed as "endpoint." The endpoint in our scenario is a cloud message broker. Cloud Message Broker (CMB) retrieves the packet information and delivers it to the cloud server, which interacts with users through the Internet. The CBM is a mediator that enables the communication between the cloud server and the gateway. The CBM, in turn, allows communication with the gateway and cloud server using the MQTT pub/sub. At the same time, packets from the parking sensor to user interaction are transmitted through one-way communication. CBM acts as a subscriber, on the one hand, when receiving packets from the gateway and, on the other hand, as a publisher when transmitting packets to a cloud server.

The cloud platform is equipped with the following different modules: (i) Data Server Module, which includes a) Data fetching script where a script running on the cloud server was used to fetch data packets, decrypt, and pre-process them into meaningful form before storing them to Database; b) RESTful server-side script, which is designed to handle the request initiated by the mobile client's application. (ii) Data Storage Module is responsible for storing the parking sensor information. As stated earlier, RESTful services have been implemented to make an easily accessible interface for the users. For this purpose, an android application was developed. It allows users to find information related to parking spots and areas.

III. In-Depth description of System Components

A. Parking Sensor's deployment

In this small-scale study, 10 in-ground PlacePod sensors were installed in the premises of University Oulu parking area. The actual position of the all the sensors can be seen in Fig 2. The green circles represents the sensor deployment positions, accompanied by the number labels, which in turns, are associated to their parking positions (see Fig 2b). PlacePod

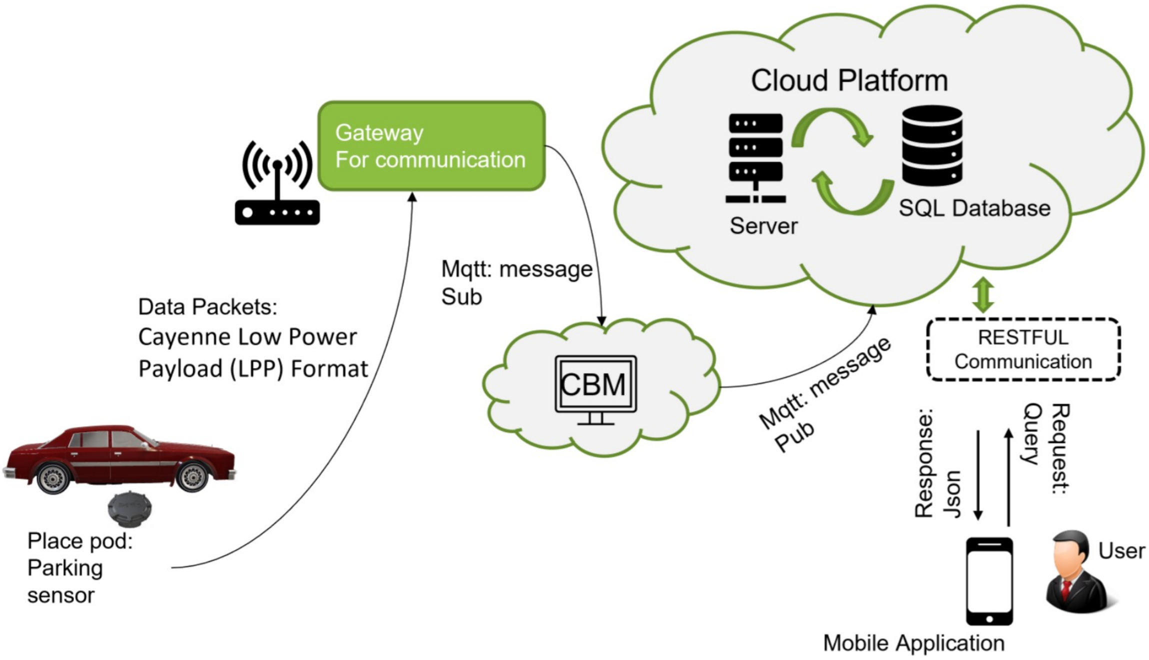

Fig. 1. Overall Smart Parking System Representation.

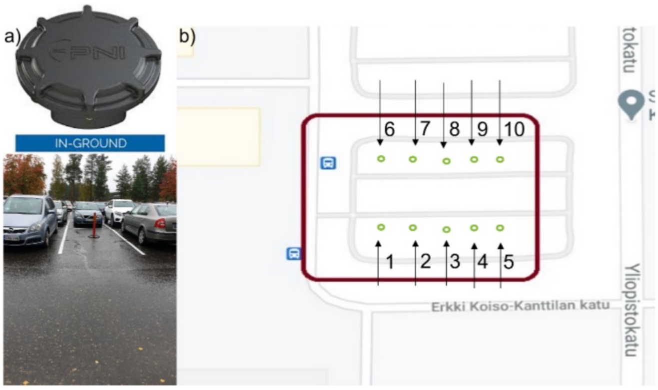

Fig. 2. a) In-ground sensor and actual parking location; b) geo-locations area of sensor deployment.

is a high-accuracy smart parking sensor designed for municipal and private parking management solutions. Due to the reliability of the generated signals regardless of the weather conditions, their low latency, their ubiquitous nature, and long-life battery (10 years), they can ultimately be integrated into robust smart parking solutions in real-time. PlacePod sensors offered by the manufacturer are of two types: ground and surface-level sensors. The sensor's functionality works on a magnetic sensing system for vehicle detection with the combination of a high-performance magnetic sensor and vehicle detection algorithms. The aim is to accurately confirm the presence or absence of a car in the corresponding parking lot. Before installing and mounting the PlacePod sensors, a pre-assessment step is required in order to achieve smooth communication between the sensor and the gateway. The latter consists of the Lora network gateway due to its popularity and consistency with the PlacePod sensor. Besides, following the manufacturer's recommendation, after activating the PlacePod sensors, the received signal strength (RSS) should be kept within range -90dBm as a reference. The senors noise was not considered in the following study to

B. Data Communication

The gateways and data communication represents an essential element of the designed architecture. Gateway acts as a bridge between PlacePod sensor and the cloud message broker. Low-power wide-area networking protocol (Lora-Wan) is designed specifically for battery-operated devices that can be connected to the internet wirelessly on a regional, national, or global scale. The built-in LoRa® radio communication protocol of PlacePod sensor allows us to interact with a gateway straightforwardly. Moreover, they are standardized with the requirement of IoT. The installed 5G network of the University of Oulu is utilized for data transmission. The sensor activation and configuration are performed alongside the gateway for handshaking. This allows the sensor and network to exchange packets and synchronize the emission/reception operation. The android application offered by the manufacturer is employed for this purpose, enabling communication with PNI's PlacePod Vehicle Detection Sensor using Bluetooth Low Energy (BLE). Lastly, utilizing the application features, the sensor is configured with network App EUI and key over the air activation (OTAA) method.

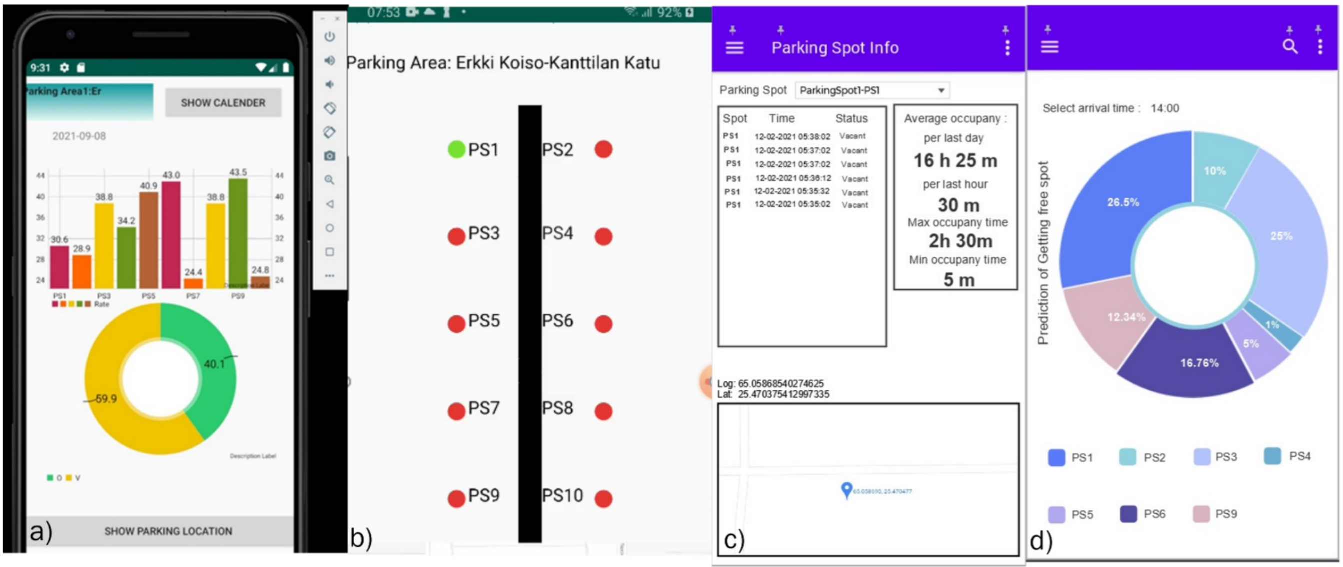

Fig. 3. a) Overall Occupancy of parking area; b)Real time parking status; c)History of parking spot; d)Estimation of parking spot.

C. Cloud Message Broker

Retrieving information associated with the parking spaces from the packets requires further server setup. The latter can be either locally or on the cloud. For scalability, portability, and reliability purposes, using a cloud-based message broker is the best choice. In the proposed system, a cloud platform is employed to manage the communication from the gateway and transmission to the server database using a simple script. The MQTT protocol communicates data between the gateway and the message broker. The essence of the MQTT protocol is similar to the publish-subscribe paradigm, which differs from the client-server model. It distinguishes between the client (publisher) who transmits the message and the client (subscriber) who receives it. The fundamental idea is that all message routing and distribution are handled by an intermediary function known as a broker. In this context, the gateway serves as a publisher, sending data packets to the message broker. We obtained the cloudMqtt online service to function as a message broker and subscribed data packets as messages.

D. Cloud Platform

From a computational and memory standpoint, storing, arranging, and extracting information related to the occupancy state of parking spots is costly. Therefore, the cloud is the best option for these demands, as its storage and computing capabilities provide effective real-time data processing capabilities that meet smart parking demands. In the proposed system, a cloud platform is employed to store and process the information acquired from the parking sensors. Precisely, as stated previously, the cloud platform has been provided with the following modules: i) Scripts that enable data retrieval and *RESTful* server communication and ii) Database for storing and query operations. Since scripts were implemented using python language, we have employed PythonAnywhere cloud services [19] for this purpose. In the data retrieval script, we inherit the MQTT and SQL libraries which are responsible for subscribing the data, and converting them into meaningful form, which is then stored into the database. In particular, the RESTful server-side script represents the functional core of the system. Especially, by employing the flask web framework, the REST request/response paradigm enables us to design a scalable system that could easily integrate into complex smart city architecture. To manage communication between the database and the mobile application, the Rest API was built. REST API web service stands for Representational State Transfer Application Programming Interface. When a RESTful API is used, the server sends a representation of the requested resource's current state to the client system. In our scenario, the mobile application serves as a client, requesting information from the server depending on specific criteria. The server then responds to the client's request with the results of the query. Currently, the server is configured to process responses based on three URL filter requests: (i) Individual sensor [serverip/api/v1/resources/Sensors?id=], which identifies a single parking spot resource, (ii) Datewise [serverip/api/v1/resources/Date?date=], which identifies the information of all parking spot on selected date resource, and (iii) Sensor and datewise [serverip/api/v1/resources/DSensor?deviceid=" date="], which identifies the information of single parking spot and selected date resource. For instance, if a user requests to access the record of only one parking spot, the server will be queried using a request URL that includes the sensor's id (i). Likewise, if the user wishes to see the sensors' data for a specific day, a date-based query will be sent to the server, which will retrieve the corresponding records.

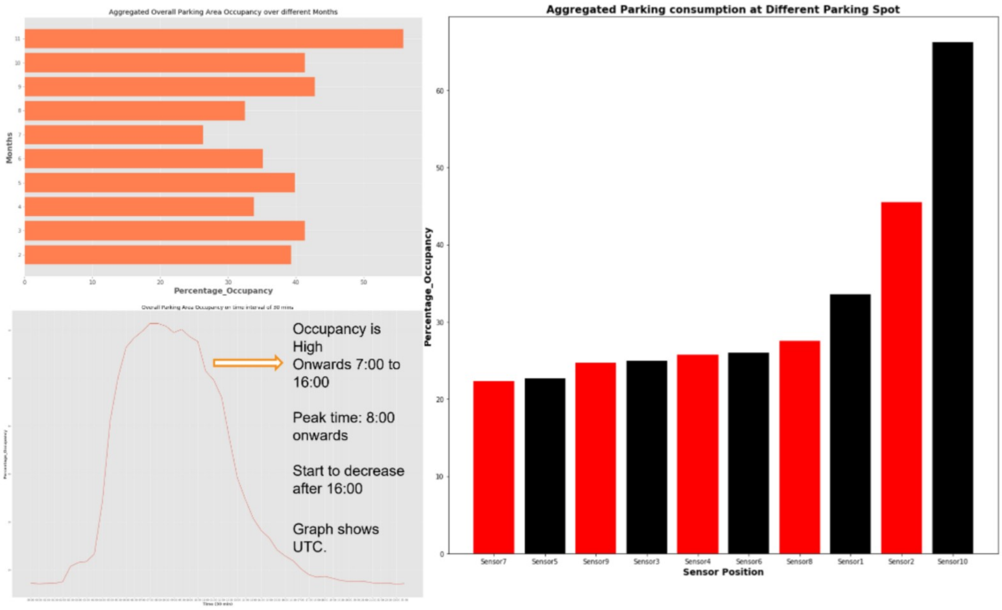

Fig. 4. Aggregated occupancy rate results on day, month and sensor positions.

E. *Mobile application*

The mobile applications facilitate the user interaction with the system via a mobile app. For its popularity, an Android mobile app was used where RESTful services establish the communication with the cloud platform. Overall, the developed Android application offers four basic functionalities to the client depending on the collected information from the deployed sensor.

- Overall occupancy rate of the parking area and individual parking spot: This feature allows the user to visualize the occupancy rate that occurred in each parking spot for the day selected by the user. The second part presents the overall information about the parking area including all parking spots (See Fig 3a).
- Real-time parking spot status: This feature of the application offers the user the possibility to monitor the status of each parking spot and all areas in real-time. As shown in Fig 3, the green dot indicates that the parking space is free and available for use. Similarly, the red mark draws attention to the occupied parking spaces (See Fig 3b).
- History of a parking spot on a day: This interface allows the user to visualize the historical information of each parking spot in view of the parking sensor, (See Fig 3c)
- Predicting the parking spot status in advance: This feature provides the user with the predicting capability about the possibility of getting a vacant parking space, (see Fig 3d). The prediction follows a basic linear regression model that extrapolates from past and current information about each parking spot.

RESTFul API services are employed by the application to communicate with the server. The app requests the server, which then communicates with the database to retrieve records depending on the query demanded by the mobile app functionality.

IV. RESULTS AND ANALYSIS

To demonstrate the technical soundness and feasibility of the developed approach, a pilot study has been conducted. A preliminary exploratory analysis is performed on a dataset gathered between February and November 2021. Three different scenarios have been analyzed based on the occupancy rate (see Fig 4). The first case aims to identify the busiest time in the day for parking? the graph exhibited in Fig 4 shows the aggregated occupancy rate at different hours of the day. The findings revealed that the busiest time for parking occupancy is during business hours. The occupancy rate gradually increases from 7:00 to 16:00 and then begins to drop after 16:00. This indicates the chances of finding a vacant slot are much higher after 4 pm, which is in full agreement with the study and working timetable at the University of Oulu. The second scenario investigates the monthly occupancy rate. The aggregated result of occupancy for every month is illustrated in Fig 4. As shown by the graph, the rate is lowest in the 5th, 6th, and 7th months. This is also widely expected since the following months coincide with the summer period when university staff members and students are most likely on vacation. However, the trends differ as compared to other months, and the 11th month has a higher occupancy rate. Though the natural routine of parking should be observed from August but the higher rate is seen in the month of November due to the implication of Covid-19 restrictions. Finally, the third scenario indicates that the parking lot equipped with Sensor 10 is the most occupied one as compared to other parking spaces. The actual reason for this finding requires further examination. However, the preliminary analysis indicated that this is rather rooted back to the driver's behavior, where users prefer to park their vehicle as close as possible to university premises. This is also in line with other socio-parking studies.

V. Conclusion

In this paper, we have demonstrated an implementation of an IoT-based smart parking system able to gather information on the parking spots and communicate it to the user, which contributes to reducing traffic congestion and improving well-being standards. For this purpose, a set of in-ground PNI PlacePod sensors have been deployed. These sensors enable communication with the LoRa network for the transmission of data packets to some cloud server. On the client-side, an android application has been developed to interface with users and provide several functionalities. Through this application, a user can find out about the availability of the parking lot and real-time parking status, visualize the history of individual parking lot status, and predict the availability of the given parking lot using a simple linear regression-based approach. Moreover, we have conducted a preliminary study investigating the occupancy rate at different time intervals, months, and days. The findings showed and validated that the occupancy rate is at its peak during office hours and low during off-peak hours and holidays. Similarly, the maximum occupancy has been observed in the month of November as compared to other months. This might be because the Covid-19 restrictions imposed during the pandemic period have been lifted. Another interesting finding revealed that some days of months have a high percentage of occupancy than others, which opens up the room to scrutinize further the impact of the individual timetable of some courses or staff activities. The above-stated technical contributions show the significance of a magnetic sensor-based parking system and a smart monitoring and controlling architecture. As a future perspective work, our investigation will explore the impact of season variation on occupancy rate and enhance the predicting model using more elaborated statistical and behavioral clues through some machine learning models.

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