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An App-based Smart Interconnected Parking System

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Abstract - These days, people spend hours trying to find a parking spot especially during the rush hours. The main challenge is not knowing where the free or available spaces are located, even if known many vehicles simultaneously pursue the free spot which leads to traffic congestion. In this paper we are presenting the architecture and design of proposed reservation-based interconnected parking system. The system implements reservation facility to reduce the problems related parking management. By reading the info sent by our sensors deployed in the parking spots periodically, we can update the status of the spot. The Drivers can access this interconnected system through an app on their smartphone.

Keywords **- Smart Parking, App, IOT.**

1. Introduction

Searching for a vacant parking space in a metropolitan area is the daily concern for most drivers, and it is time-comsuming. It commonly results more traffic congestion and air pollution by constantly cruising in certain area only for an available parking space. For instance, a recent survey [1] shows that during rush hours in most big cities, the traffic generated by cars searching for parking spaces takes up to 40% of the total traffic. To alleviate such traffic congestion and improve the convenience for drivers, many smart parking systems aiming to satisfy the involved parties (e.g., parking service providers and drivers) have been deployed. The current smart parking or parking guidance systems only obtain the availability in-formation of parking spaces from deployed sensor networks, and simply publish the parking information to direct drivers. However, since these systems cannot guide the drivers to their desired parking destinations, even sometimes make the situation worse, they are not "smart" enough. For instance, when the number of vacant spaces in an area is limited, more drivers, who obtain the parking information, are heading for these spaces. It will cause severer congestion. It is, therefore, strongly desired to provide an effective strategy to address these concerns. In this paper, we design and implement the prototype of an app based Smart interconnected Parking System(ABSPS) not only to broadcast real-time parking information to the drivers as part of a communal application, but also to provide reservation service as part of user-targeted service. Built on advanced sensing and mobile communication techniques, ABSPS processes streams of timestamped sensing data from sensor network in parking lot and published parking availability information. The drivers can retrieve parking information and reserve their desired vacant spaces via Wi-Fi or Internet.

The rest of this paper is organized as follows. In Section II, we set the background of the proposed research by introducing several existing approaches and challenges for smart parking systems. In Section III, we present the detailed architecture of proposed reservation-based smart parking system. In Section IV, we summarize the future scope. Finally, we conclude this paper in Section V.

2. Background

In this paper, we mainly focus on designing a new smart parking system that assists drivers to find parking spaces in a specific parking district. In addition, an important goal of the system is to reduce the traffic searching for parking, hence reduce energy consumption and air pollution.

2.1. State-of-the-Art Parking Management

Many parking guidance systems have been developed over the past decade [3][4]. In this subsection, we study several existing parking guidance approaches and explain their limitations.

- **Blind Search:** Blind searching is the simple strategy applied by users when there is no parking information. In this case, the drivers keep cruising for parking spaces within a certain distance to their destination. The drivers will stop searching until finding any available space. Otherwise, the drivers will extend the searching area and

continuously look for vacant spaces in the neighboring parking lots.

- **Parking Information Sharing (PIS):** This mechanism is commonly adopted by the current state of the smart parking system design [7]. After the smart parking sys-tem publishes the parking availability information to the drivers in certain area, the driver will decide their desired parking destination where the parking lot has available spaces, according to the obtained parking availability information. However, if the number of vacant spaces in a parking lot is very limited in busy hours, it is likely that the number of drivers in demand for these parking spaces would increase, which is based on parking information. This phenomenon is called "multiple-car-chasing-single-space", which may cause severe congestion.

- **Buffered PIS (BPIS)** To address the problematic "multiple-car-chase-single-slot" phenomenon, some de-signers of smart parking systems modify the PIS mechanism. They intentionally reduce the number of vacant spaces, when publishing the live availability information, to keep a buffer. Therefore, though there may be more drivers pursuing the limited available spaces, the system has some extra spaces to avoid the conflict. But it is difficult to determine the number of the buffer spaces. If the buffer is too small, the problem of "multiple-car-chase-single-space" will not be eliminated. If it is too large, the utilization of parking spaces will be low.

As indicated above, the blind search system is an open loop system, where users make decision without looking at the state of the system. The PIS and BPIS strategies allow drivers to make decisions based on the system state (e.g., parking avail-ability information). However, the phenomena of multiple-car-chase-single-space cannot be fully eliminated. To reduce the traffic searching for parking, we suggest a reservation-based system, where drivers make reservations through the parking management system.

If a driver makes the reservation successfully, it guarantees an available parking space for him, and the driver can park at the reserved space without searching. The reservation-based system allows drivers to select the most convenient parking space under their budget constraints.

2.2. Performance Metrics

In order to evaluate the performance of the strategies imple-mented in smart parking systems, we introduce the following metrics, which reflect the willingness of drivers, and our concerns on traffic congestion and environmental protection.

- **Walking Distance:** Walking distance is defined as the distance from a driver's selected parking space to the destination. This important factor reflects the willingness of drivers when selecting parking spaces. The driver commonly wants to choose the most convenient parking space where it is closest to his destination. In the proposed model of ABSPS, the drivers select the parking spaces depending on this factor, which indicates their satisfaction.

- **Traffic Volume:** In our proposed model, traffic volume is specifically defined as the amount of traffic generated by parking searching. This factor is not negligible and associated with the traffic congestion and air pollution. The proposed reservation-based smart parking system is design to reduce the traffic volume caused by parking searching, as well as satisfy the need of drivers.

We investigate performance of the proposed smart parking system using these performance metrics.

2.3. Challenges

Given the design objectives of smart parking systems that requires the coordination among multiple parties, we summa-rize the main design considerations as follows:

2.3.1. Reservation Performance

The ABSPS utilizes both the Internet and Wi-Fi, whereby drivers can check the real-time parking information and complete their reservation. However, there is a bottleneck to the system when many drivers are simultaneously making reservation. In this case, the system has to synchronize the parking information and handle each reservation request, which significantly reduce the system performance, and even cause some conflicts. In order to address this challenge, we design a distributed reservation strategy implemented in the proposed smart parking system. When a drivers selects desired parking lot, the system will reconnect the driver to the subsystem in related parking lot, the driver can complete the reservation without communicating with the central system. Therefore, the central system no longer needs to maintain the reservation service.

2.3.2. Data Collection and Local Presentation

The system collects and stores the data about the performance metrics, including the status of parking space, reservation time, parking location, driver's identity. All data stored by the system is at least stamped with time metadata. Further-more, the system allows the driver to check the parking information, including the location of parking spaces, the vacancy time of parking spaces and reservation information. In order to protect the security of the system, we separately design a repository of sensing data and a mirror database of reservation. The repository is the sink of the sensing data, and the mirror database is synchronized with the repository and stores the reservation information. In this way, the drivers are only able to check and update the information in the mirror database. Drivers' Identity Verification Once the reserved space is detected to be occupied by a vehicle, the system should verify the driver's identity. If he/she did not reserve the space, the system will alarm the driver this space is reserved. In our proposed system, the drivers can visit the website and verify their identity via Internet.

3. System Architecture and Design

In this section, we present the architecture and design of proposed reservation-based smart parking system, which implements a reservation service to reduce the traffic volume caused parking cruise.

3.1. Overview

Fig. 1 shows three components in the smart parking model, including parking lots, users and the smart parking system.

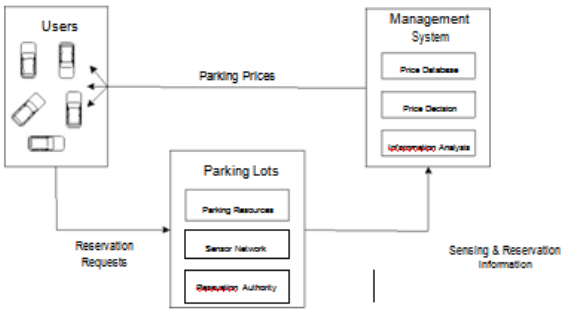

Fig. 1. System architecture

The management system determines the parking prices, and broadcast live parking availability information to users (also drivers). Upon receiving parking information, the user selects a desired parking lot and reserves a space in the parking lot. As a result, the state of parking resources is changed by users' parking decisions.

The parking lot consists of a group of parking spaces. The on-street parking can also be considered as a virtual parking lot. The state of a parking lot is the number of occupied spaces versus total spaces. Every parking lot has access to the Internet to communicate with the management system and users, and share parking information with other parking lots. In each parking lot, the reservation authority is deployed for authenticating the individual user's identity and reservation request. In this case, the reservation authority in the parking lot communicates with the specific user individually. Once the reservation order is confirmed, the reservation authority updates reservation information to hold the related space for the user. The sensor system deployed in parking lot is responsible for monitoring the real-time condition of parking lots and delivers the live aggregated sensing information (the number of available spaces or occupancy rate) to the smart parking system. The sensing information is updated on demand. Upon retrieving the parking information, the system updates the state of the parking lot. Based on the state of parking lots, the system (1) analyzes their occupancy status and congestion level, (2) determines the parking prices according to their pricing scheme, (3) broadcasts the prices to all users periodically, and (4) stores the parking information and prices for further analysis. The system serves as the centralized decision-making body in a planned economy. It makes all pricing decisions regarding the state of parking lots and user demands [18]. This system is a closed-loop system to dynamically adjust parking price, balance the benefits between users, and service providers and reduce traffic searching for parking.

Also, since each parking lot manages its own reservation information, it makes the reservation requests from users easily to be synchronized, comparing with reservation synchronization in the system.

3.2. Hardware

The system hardware is organized into three main components, the sensor network, the central server and the mobile device, as shown in Fig 2. In the following, we discuss the detailed design and implementation of each component, along with the specification of communication between them.

In our project, we developed a number of functions on proximity sensors that provide a continuous measure of parking status for each space. Each sensor is integrated with the raspberry pi 2.

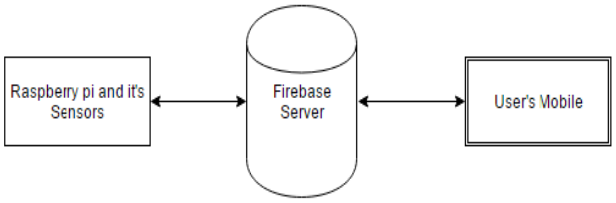

Fig. 2. System hardware components

The Raspberry pi platform is used to collect the sensor data and also update the central server (Firebase) about the availability of the parking spots. The sensors we are using are VCNL 4010 proximity sensor by adafruit. We are using VCNL sensors instead of the conventional infrared sensors as they have I2C capability which lets us connect multiple sensors to a single board. As a result, a large array of sensors can be used in a single board.

The mobile phone is used to assess Internet, over Wi-Fi or a GSM cellular network, to obtain the information of parking availability and make parking reservation from the Internet server.

There is a central server (Firebase) deployed with storage and computational power. These servers provide hardware support for the software services, which are described in section III.C. In particular, it is for system users to request the services of parking information and parking reservation. Once user's reservation is authorized, the server will update the state of related parking sensor.

3.3. Software

The system software mainly involves the firebase server, program on the raspberry pi and the end user android application. The firebase server provides us a secure and convenient way of managing our data. It also helps us authorize and manage our end users.

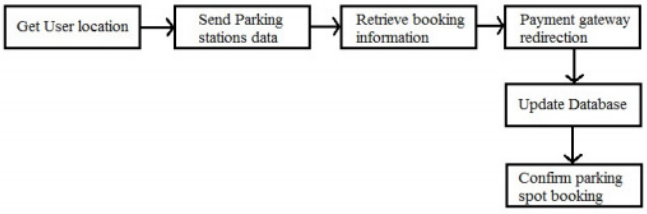

Fig. 3. System software flow diagram

ABSPS has a subsystem of sensor network in the parking lots. The sensor networks provide the real-time parking information to the upper layer. Here we categorize sensor nodes to detecting nodes and collecting nodes. Specifically, the detecting nodes take the responsibility to monitor the status of parking space.. Moreover, the collecting nodes advertise itself as the root node and are responsible to collect and deliver the detected event and data from detecting nodes. In our case our raspberry pi is a collector node and runs a script to constantly check the status of the sensor network and update the same in the Firebase database using RESTful API's.

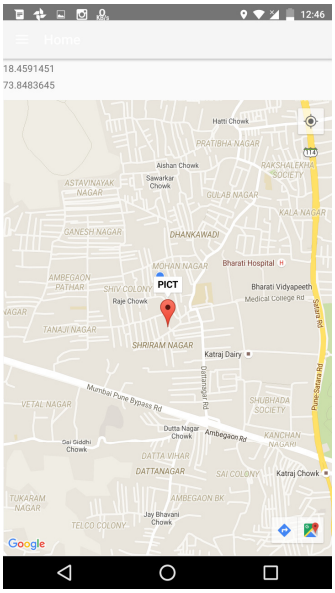

Fig. 4. Smartphone app

Finally we have our android application, it provides the end user a convenient way to see what spots are available and also book the same. We have also added a payment gateway through which the customer can make secure payments. The application is swift and uses firebase API's to communicate with our central database.

4. Future Scope

Currently, most research work on smart parking is from the perspective of system design, which focus on implementing a larger sensor network (city wide) to detect parking information and provide real-time parking service. In addition, we introduce the pricing-related topics in networks, which provide us a powerful tool to manage parking lots. We also want to add a way to identify the vehicle either by using Bluetooth beacons or through image processing.

5. Conclusions

In this paper, we have developed a new prototype of App-based Smart Parking System (ABSPS) to optimize parking

management. In this system, we implement parking reservation policy to balance the benefit of service providers and requirements from the users. Moreover, we have presented the detailed design, implementation of the prototype. We conclude that the proposed App-based smart parking system can alleviate traffic congestion caused parking searching and reduce the amount of traffic volume searching for parking.

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