Sensor Network Based Parking Management System

Nagarajan Prabakar, Jong-Hoon Kim, Uwe Cerron, and S. Sitharama Iyengar
School of Computing and Information Sciences
Florida International University
Miami, FL 33199, USA

Abstract

Large institutions such as universities, companies, etc. face parking shortage problems due to the increase in number of vehicles and the limited availability of parking spaces. At the peak time of work, invariably all parking spaces will be taken and newly arriving vehicles will be searching for a vacant parking space in the entire parking facility without any clue. The frustration and loss of time for people looking for parking spaces are the major issues. In addition, this wastes lots of fuel and increases the probability for accidents.

The proposed parking information system with distributed sensors will monitor the status of a parking facility and will provide a real-time status summary online. Drivers can access the status summary prior to arriving at the parking lot using smartphones or computers, or through displays at the parking entrance. Further, the frequency and parking duration of each vehicle can be tracked to improve infrastructure security. Other potential applications include effective monitoring and management of air travelers, conference attendees, and visitors in any major facility.

1 Introduction

Increase in number of vehicles in metropolitan areas requires significant amount of man power and resources in monitoring the usage of parking facilities. Automatic optical recognition of car tags for tracking vehicles in a parking zone requires a lot of processing [5]. The accuracy of this approach is not suitable for real world applications.

The emergence of sensor network technology in the last decade facilitated the deployment of sensors in various applications [3]. Particularly, the simplicity and low cost Radio Frequency IDentification (RFID) sensors fostered a vast number of sensor based applications. When a large number of sensors is used in an application, the energy consumption to broadcast the sensor input to a processing node becomes a critical factor. We can minimize the broadcast energy demand with an optimized broadcast protocol [2].

Many applications already exist with RFID sensors. Wisanmongkol, et al. used RFID and photoelectric sensors to identify specific type of vehicles (with fixed length) [6]. Another application monitors the entry/exit time and automates both billing and payment collection [4]. Further, an enhanced application that provides a middleware product lifecycle management and also interface business applications with RFID devices [1]. Although some of these applications use databases to store and process the parking traffic information, there is no support for remote access about the parking status information for end users.

We propose a Parking Management System (PMS) that integrates parking status of several parking facilities in an organization and makes them available online for users through computers or mobile devices. The next section will present the methodology and architecture of our proposed system. Subsequent sections will address the prototype and evaluation of the system and other potential applications.

2 System Architecture

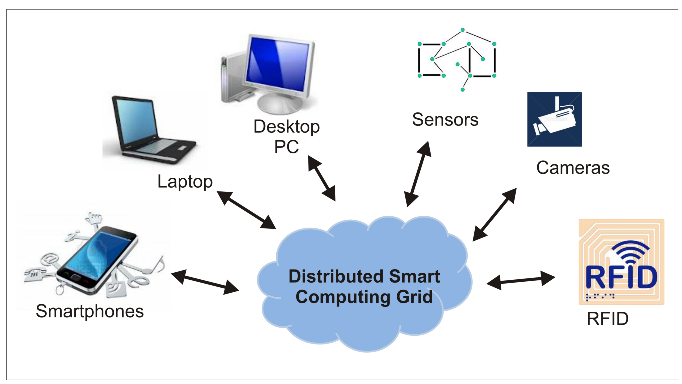

Figure 1: The overview of the system

The core of the system is a set of distributed sensors that are integrated with a smart computing grid (Figure 1). The types of sensors include RFIDs, cameras, and other wireless sensors.

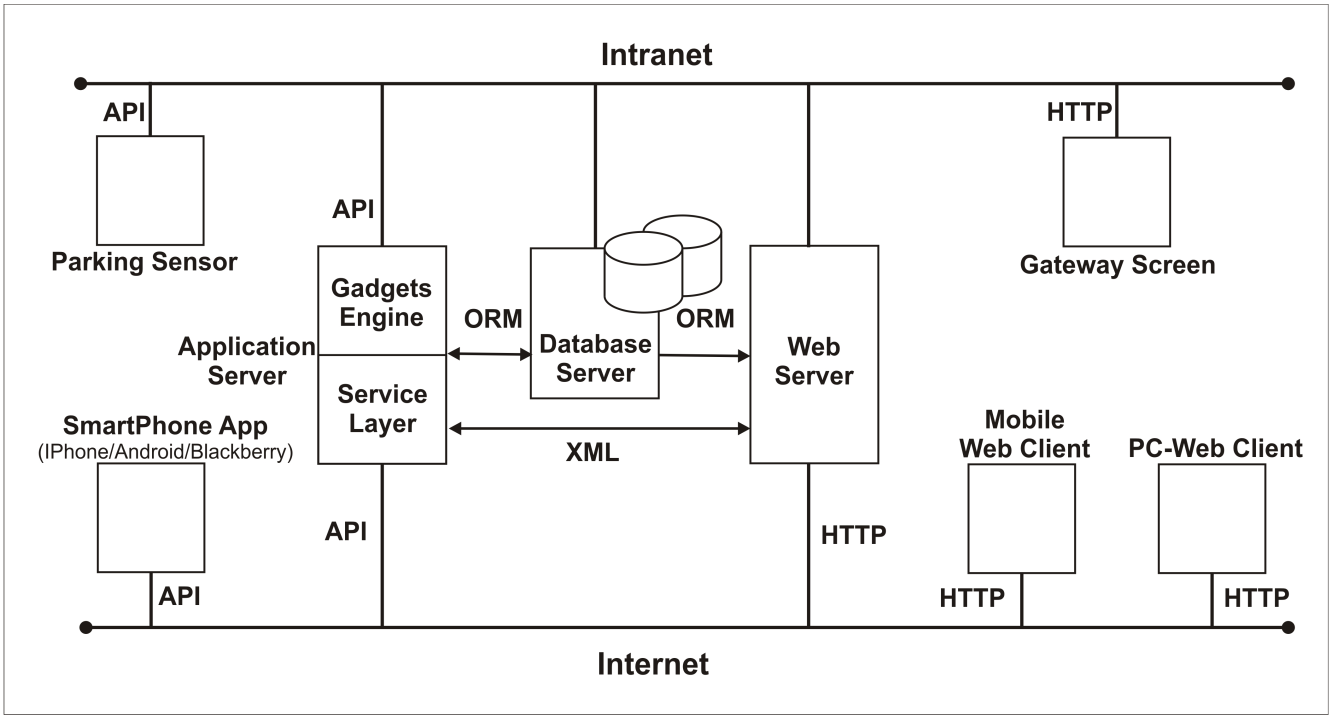

Figure 2: The system architecture

The system architecture (Figure 2) supports both intranet and internet communications along with an application server and a web server. The key feature of the system is a set of services that will be used by both application clients (iPhone/Android/Blackberry) as well as mobile/PC web clients. The service layer provides a modular interface to the database for requests from all clients and allows for an efficient upgrade/maintenance of the system. A direct access to the database for certain web requests that are not part of the existing services is also supported. We use Object Relational Mapping (ORM) to exchange information between software modules and the database through the database server. This architecture offers a seamless integration for storage and retrieval of information from multiple parking facilities.

3 Implementation

The implementation consists of two phases. In phase 1, the system will monitor vehicles at all entry/exit points as shown in Figure 4 and coordinates with the smart grid. In Phase 2, it will identify vacant parking spaces for each type of parking permit and will provide a guided navigation to a vacant space as illustrated in Figure 5.

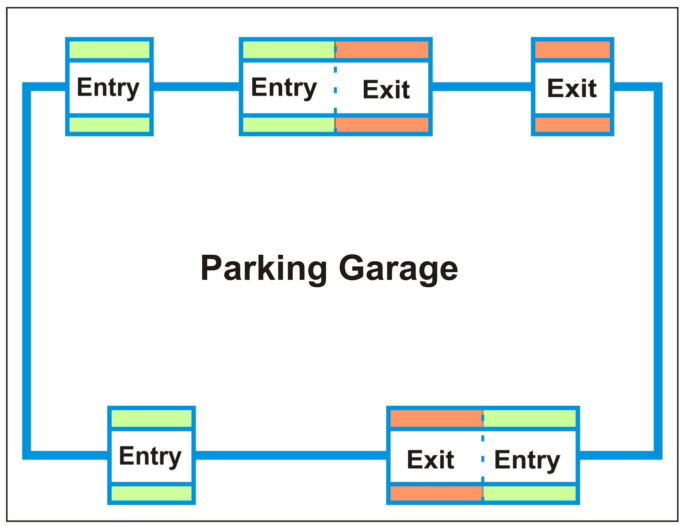

Figure 4: Phase 1 - Monitoring at entry/exit locations

3.1 Vehicle Identification

For electronic communication of the vehicle ID, each vehicle requires an RFID sensor attached to it on the front/rear windshield. At the time of parking decal issue for a vehicle, either an existing RFID such as Mini-SunPass [7] tag or a new RFID tag must be registered with the parking decal of the vehicle along with the vehicle information (make, model, year, color,

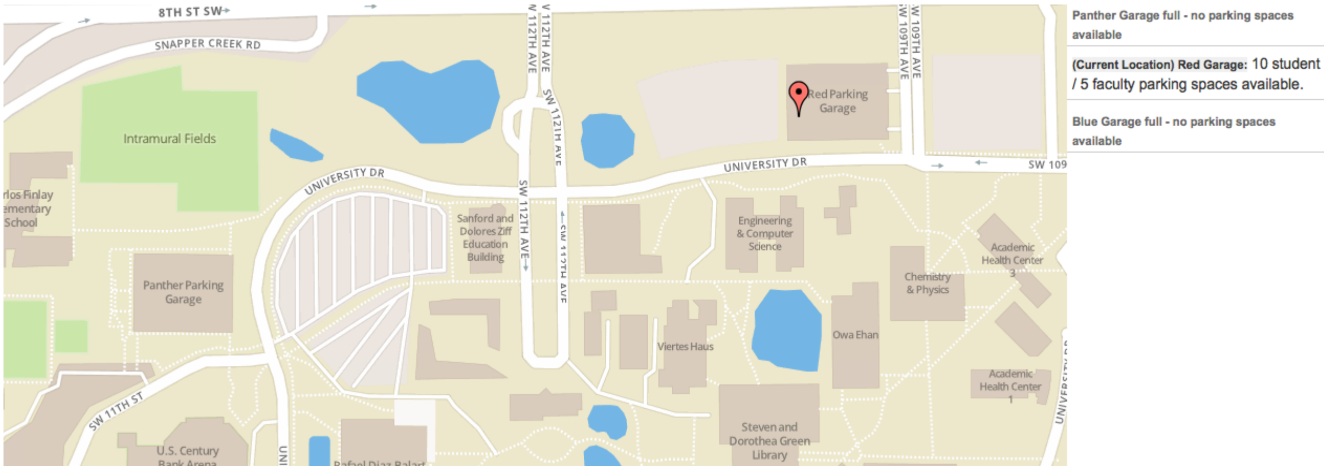

Figure 3: The web access application

state tag, etc.), the duration and the type of the decal. The system will detect vehicles with unregistered RFIDs or without RFIDs using optical/pressure sensors, and will capture digital pictures of them for future investigation and billing.

3.2 Tracking number of vehicles in a facility

The number of vehicles in a facility such as a parking garage in a campus with a few number of fixed entry/exit points can be monitored with sensors. At each entry/exit, RFID readers are placed to identify each vehicle passing through that location and the direction of the movement. Based on the direction, the system determines if the vehicle is entering or leaving the facility. Further, it finds out the type of decal associated with that vehicle and updates the number of available parking spaces for that specific type of decal. The system receives sensor information from all entry/exit locations and keeps track of the number of vehicles present in the facility for each type of decal. Also, the number of available parking spaces for each type of decal is displayed at all entry locations to aid the incoming drivers as well as updated online so that users can access this information through smartphones or computers.

The RFID readers, optical sensors and displays placed at each entry/exit location are connected to a processor within the facility and the processor exchanges information to the distributed computing grid. The cost for deployment of the Phase 1 system with less than ten entry/exit locations in a facility would be about $10,000 to $20,000. The real-time parking status will be tremendously valuable to a large number of people in saving time and will cut down the fuel spent in search of parking spaces.

3.3 Guided parking navigation

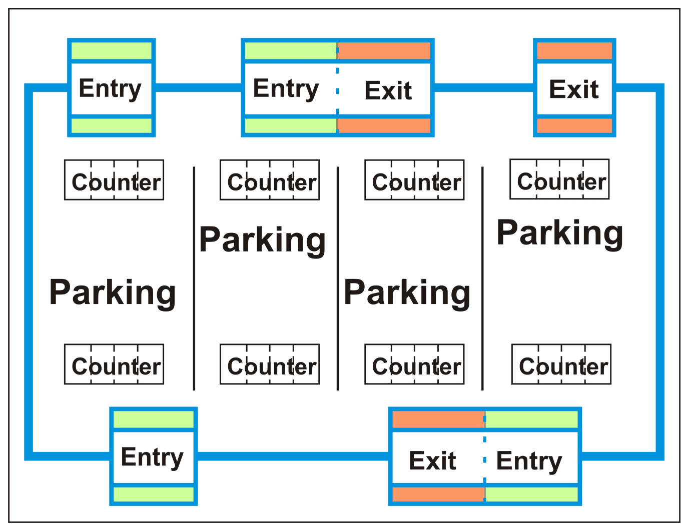

Figure 5: Phase 2 - Guided parking navigation

After a vehicle enters a parking facility, even being aware of vacant parking spaces, searching for the nearest available parking space is not straight forward in a large or multistory garage. To alleviate this problem and to streamline the traffic within the facility, in Phase 2 of the implementation, a guided navigation approach is proposed below. To support this navigation, the location of available parking spaces must be identified. For this purpose, we need one sensor for each parking space to monitor whether the space is occupied or not. A garage of one thousand parking spaces will cost about $40,000 for these sensors, and light indicators at each lane at every floor to display the number of available spaces on that floor for each lane. Accordingly, the light indicators (counters) at each floor will display how many spaces are available in each of the four lanes of the floor. Each lane will have one display counter at each end of the lane. Each counter will show one digit count for each lane on the floor. For instance, a counter in a four lane garage will have four column one digit display and each column represents the number of free spaces in the corresponding lane. If the number of free spaces in a lane is more than nine, the one digit display will be a solid green circle. As the driver enters in a lane, he/she can see at the counters in front on the lane and find out whether a space is available in that floor and in which lane. This will streamline the traffic flow as vehicles will be directed to the nearest floor where parking space is available.

3.4 Front-end applications

(a) Admin view application (b) User view application

Figure 6: Smartphone access application

Two types of people access the system namely admin users (including parking management authorities) and normal users (students/faculty/staff/administrators). We have developed applications for both smartphone clients (Figure 6) and web clients (Figure 3). For users who create online accounts, their sessions will be authenticated and their preferences such as parking facilities of interest will be saved at the server side session cookies.

4 Conclusion

We presented both system architecture and prototype implementation for an integrated real-time parking information system with a service layer for both web clients and smartphone clients. We will collect the performance statistics of the system and measure both accuracy and reliability following a campus wide large scale deployment of this system within a year. This real-time tracking information system can be deployed in several applications. For instance, in air travels, embedding an RFID in each boarding pass, help to track any missing passenger, proper seat occupancy, etc. In a major conference/convention, embedded RFIDs in the name tags of attendees can help to find out how many attendees attend each session and to find out groups of people with a common professional interest. At major security sensitive places, visitors with RFID embedded passes can be tracked for any plausible attempt of security breach and prevent it ahead of time.

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