Automated Real-Time Parking Management for Smart Cities

Pampa Sadhukhan and Arijit Talukdar

Abstract The proper management of available parking spaces to enable a driver to locate the parking slot quickly during busiest hours of the day in the urban areas is a major concern to the city authorities. So, a significant amount of research works have been devoted to the development of smart parking systems over the past few years. Most of these have paid attention to the detection of free parking slot within the parking areas along with guiding the driver to reach the parking area. Very few works have paid attention to the real-time management of all parking spaces available within a city. By keeping track of the occupancy status of all the parking spaces available within a city, it is possible to aid not only the driver to locate his/her preferable parking spot quickly but also the city authorities in generating revenues by proper utilization of the parking spaces. Thus, this paper presents an automated real-time parking management system for smart cities to address the above mentioned issues. The proposed parking management system provides online reservation facility for the parking spot in a secured manner via an android application that is to be installed on the driver's phone and also integrate an electronic payment gateway to enable automatic collection of the parking charges by the city authorities. The experimental results and various screenshots of the mobile client application provided in this paper validate the effectiveness of the proposed system.

Keywords Parking · Reservation · Real-time · System

1 Introduction

The proper management of the available parking spaces in the urban areas is a necessity to assist the drivers in locating the parking spot quickly during the busiest hours of the day as well as to enable the city authorities to earn the revenue by

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proper utilization of the parking areas. So, smart parking management is treated as an important aspect of the smart city services [1] in today's world. Thus, the development of smart parking system (SPS) for metropolitan areas to address the abovementioned issues have become an important field of research. Although a lot of research efforts have been contributed in designing various SPSs over the past few years, most of them focus on the detection of free parking slot within a parking area by using some wireless technology like radio frequency identification (RFID), sensor node, sensor network, etc. [2–7]. Very few works concentrate on the automated management of the parking spaces which is a necessity to keep track of available free parking slots within the parking area as well as to enable the driver to reserve some parking spot of his/her choice. Longer the search for a suitable parking slot, more increases not only the fuel consumption, but also the traffic congestion as well as the air pollution.

On the other hand, none of the automated parking management systems proposed in literature untill now has been designed with the aim of managing all parking areas available throughout the city in real-time. Moreover, such systems should ensure the automatic collection of the parking charges based on the duration of parking slot's occupancy by some vehicle. To address the abovementioned issues, the framework of an IoT based E-parking system for smart cities has been proposed in the earlier work [8]. But no experimental results have been provided to validate the proposed work. Thus, this paper not only presents the detailed design of the proposed automated real-time parking management system but also the experimental results to demonstrate the effectiveness of the proposed system. The automated parking management system (APMS) proposed in this paper aids the driver to find out and reserve a parking spot of his/her choice in real-time in a secured way via some control server which is responsible for the management of all parking spaces available throughout the city as well as the city authorities in the automatic collection of the parking charges. Various screenshots depicting the graphical user interface (GUI) of the android based mobile application that enables the authenticated drivers to locate the nearest parking spot and then reserve it have also been provided in this paper. This paper has been structured in the following way. In Sect. 2, a detailed review of existing smart parking management systems has been provided. Section 3 presents the design and implementation details of the proposed automated real-time parking management system. In Sect. 4, some experimental results as well as the prototype of the mobile application used by the drivers to locate and reserve the parking spot are provided in order to validate the proposed system and to demonstrate its effectiveness in managing all parking spaces throughout the city in real-time. Finally, the concluding remarks are given in Sect. 5.

2 Related Work

This section briefly reviews various parking management systems proposed in literature over the past few years. An IoT based smart parking system that also integrates cloud that has been proposed in [9]. The proposed system can monitor the avail-

ability status of each parking space through an IoT module deployed at the parking space and communicate it to the cloud. Moreover, this system provides a mobile application for the end user in order to check the parking space's availability and then reserve a parking slot accordingly. A smart parking system for the commercial stretch in cities abbreviated as SPSCSC has been proposed in [10]. The proposed SPSCSC focuses on reducing the searching time for the suitable parking slots and unnecessary travel for that purpose by deploying sensors and image detectors within each parking area. In [11], the researchers have proposed the design of a parking guidance system that consists of parking slot sensors, sink node, and the parking manager. The parking slot sensors communicate with the sink node via the ZigBee protocol to transmit real-time parking information to the sink node. Upon receiving the status of all parking lots from the sink node, the parking manager will display the information and position of available parking spaces. However, none of the above-mentioned SPSs cannot provide citywide parking management facility as well as an automatic collection of parking charges.

The authors in [12], have presented a Smart Parking System which is based on the integration of Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN) technologies to detect the occupancy state of the parking spaces. The proposed system also employs a customized software application to direct the drivers to the nearest vacant parking spot. Such an application also provides the users the option of paying the parking fees through some near field communication (NFC) based e-wallet. Moreover, it can alert the traffic cops about the improper use of a reserved space or expiration of the purchased time via an Android mobile application. The researchers in [13] have proposed an architecture based on cyber-physical system (CPS) for car parking management. In this system, the server finds out available parking slots based on the current location of the car provided by the driver through some smartphone app and sends this information along with the route directions to the driver. A context-aware parking space locating mechanism which has been implemented using network simulator-3 has been proposed in [14]. This proposed system provides the driver with the shortest route to the nearest parking space by applying a particle swarm optimization algorithm. Moreover, this system also enables the vehicle to gather knowledge from its environment and also to perceive the surroundings via the microsensors and wireless sensors mounted on the vehicle. An automatic car parking and controlling system proposed in [15], has been designed by a small programmable logic controller (PLC). In this system, Infrared sensors (IR) were deployed at the entrance and departure gates to keep track of the availability status of parking lots within the parking space and to ensure proper management of the parking spaces. On the other hand, a vision-based smart parking framework to aid the drivers to locate the free parking slot within a parking space and then reserve it has been proposed in [16]. This system has segmented the parking space into several blocks by applying calibration and then those blocks have been classified to determine how many freely available parking slots are there. The architecture and design of the Arduino based car parking system have been proposed in [17]. This proposed system ensures the security of a vehicle within the parking space by restricting the entry of unauthorized users. This system also helps to park the vehicle in multi-floor

parking spaces. A real-time parking reservation service that employs a mixed-integer programming model in order to allocate the parking slots and then make the schedule of drivers' travel plan accordingly, has been proposed in [18].

3 Proposed Automated Real-Time Parking Management (ARPM) System

This section presents the proposed automated real-time parking management system. The proposed system consists of three modules, which are local parking management system (LPMS), central parking management system (CPMS), and parking reservation module (PRM) as shown in Fig. 1. The detailed design along with the functional specification of each of these modules are provided below.

3.1 Local Parking Management System (LPMS)

This module is deployed onto the local parking management server available within each parking facility area. It is responsible for monitoring the whole parking facility area. For that purpose, it maintains a record for each parking slot to keep track of its status (which can be empty, reserved or occupied) by communicating with the parking meter (PM) deployed at each parking slot. The detailed architecture of PM, its functional specification as well as the architecture of LPMS is already provided in

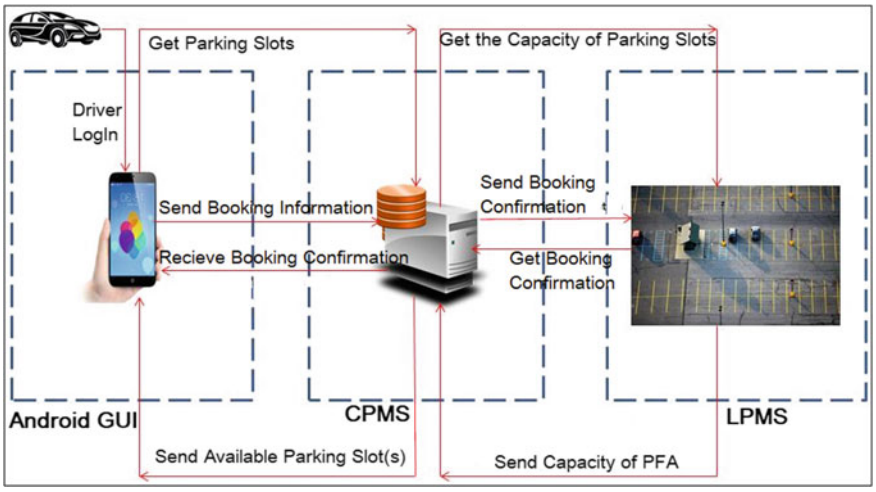

Fig. 1 Architecture of proposed automated real-time parking management system

the earlier work [8]. On the other hand, LPMS has an uninterrupted connection with the CPMS to receive reservation requests for some parking slots as well as to notify CPMS of the number of free parking slots available within the associated parking facility area in a periodic way. This module accomplishes the following tasks.

- It receives the reservation request for some parking slot from CPMS and also notify CPMS of the number of free parking slots available within its associated parking area.
- Upon reserving some parking slot, it sends reservation command to the associated PM.
- Upon receiving the image of a vehicle's license plate from some PM, it attempts to extract the license plate number from it, failing which it immediately sends the signal of improper parking to the corresponding PM.
- If a vehicle's exit is reported by some PM, it can calculate the parking charges and provide this information to CPMS.

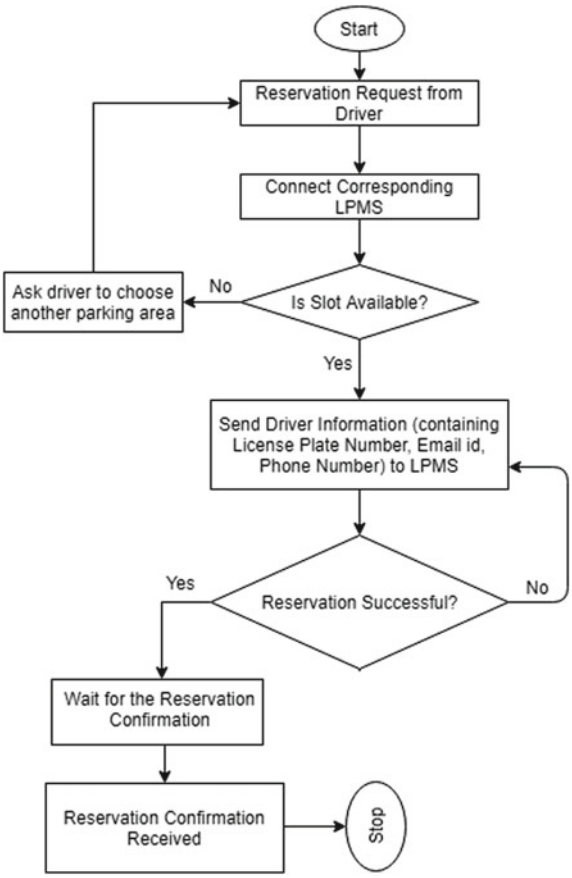

Fig. 2 Work flow diagram of central parking management system

3.2 Central Parking Management System (CPMS)

This module is deployed on the central parking management (CPM) server which is responsible for monitoring all parking facility areas available throughout the city. The CPM server is a high-end server with global IP in order to facilitate the parking reservation module running on the user's handheld device to communicate with it over the Internet. The detailed software specification of this module is already presented in the previous work. Figure 2 shows the workflow diagram of this module.

3.3 Parking Reservation Module (PRM)

This is a GUI based mobile application that would run on the driver's handheld device as mentioned in our previous work [8]. It is developed using android programming. This module enables the driver to reserve as well as locate some parking slot based on his/her choice and also assists the city authorities to receive the online payments from the drivers as already described in our earlier work [8]. Figure 3 depicts the workflow of this proposed client application.

4 Results and Discussion

The performances of the proposed system are evaluated in terms of the response time of the CPMS server upon receiving a reservation request; average booking time of a new user and an already registered user; the waiting time of real-time booking as well as advance booking with respect to the different times of the day. The graphs are plotted based on data provided by the mobile client application deployed and running at various android smartphones at different times of the day.

Figure 4 shows that CPMS takes longer duration to respond during the peak hours and office time as compared to the same in the morning and night, which is a very usual scenario because of higher number of reservation requests received during the peak hours and office time. Figure 5, on the other hand, compares the average waiting time to reserve some parking slot by a new user and an already registered user at different times of the day. The graphical results provided in Fig. 5 depicts that average booking duration of the parking slot is high around 10 a.m. and 6 p.m. due to significantly high reservation requests and it becomes lower in the morning and night. Since the parking management system presented in this paper provides two types of parking slot reservation facilities, i.e., real-time booking as well as advance booking, henceforth Fig. 6 provides the comparison between the waiting time for these two sorts of bookings. Figure 6 shows that the real-time booking that reserves the parking slot at the current time, always take a longer duration than that of advanced booking. This happens because the probability of getting a parking slot

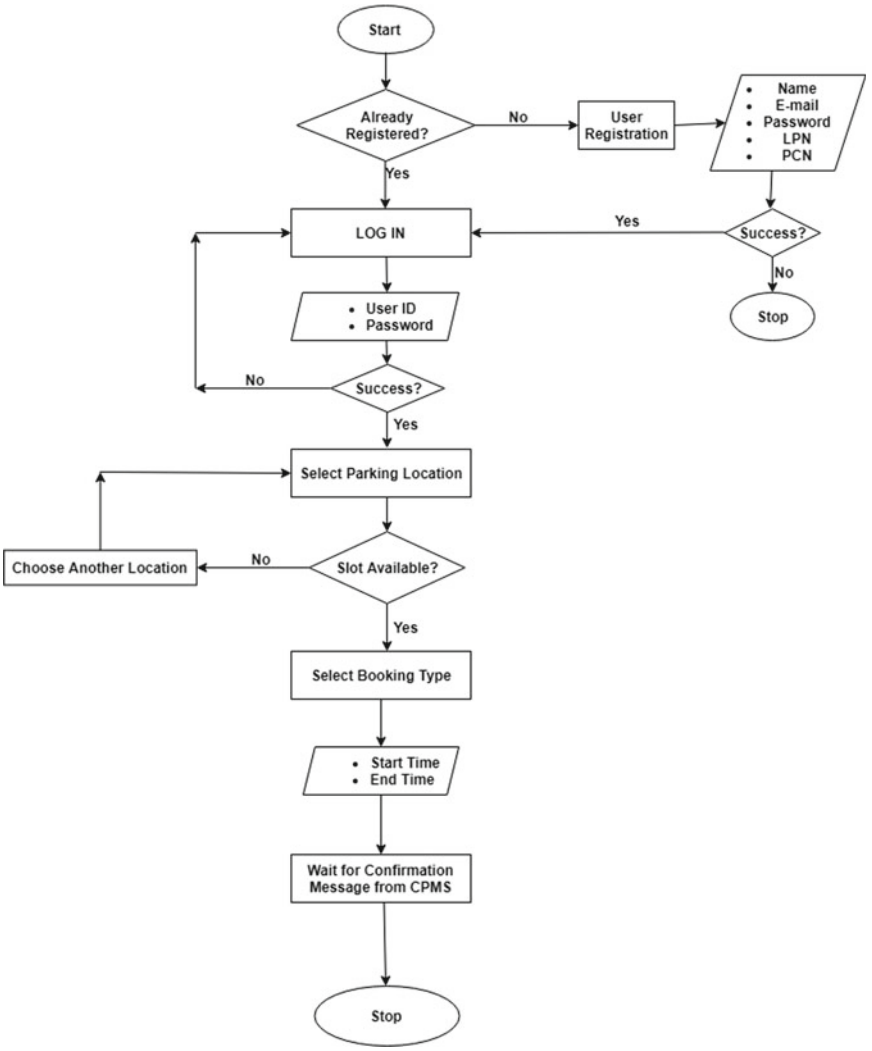

Fig. 3 Work flow diagram of parking reservation module

is more via advance booking compared to real-time booking which make on spot reservation at the current time.

Various screenshots of the parking reservation module, i.e., mobile client application while running on the user's android based smart phone, are displayed by Figs. 7, 8, 9, and 10. Figure 7 shows the GUI of user registration and user login with CPMS before searching for suitable parking spaces. On the other hand, GUI of the android based client application upon locating nearby parking spaces and then trying to reserve some suitable parking slot either via real-time booking or via advance

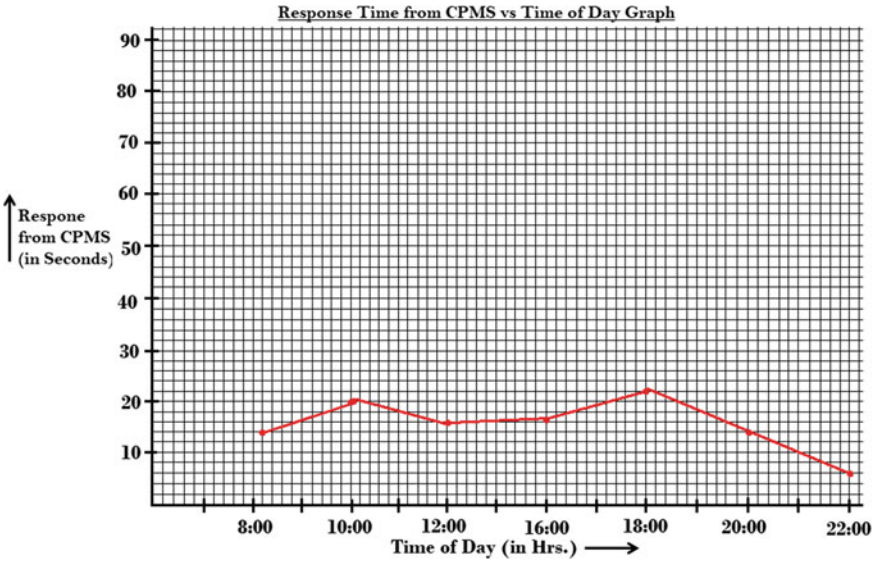

Fig. 4 Response time of central parking management server versus time of day

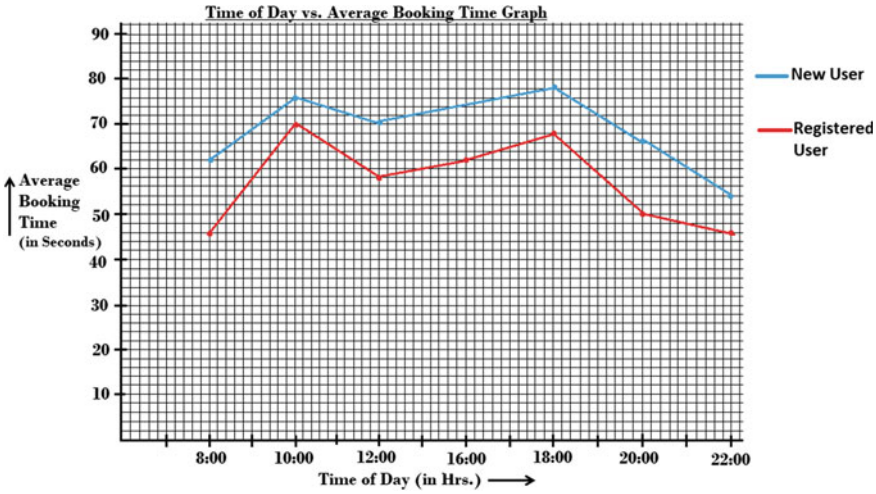

Fig. 5 Average booking time versus time of day

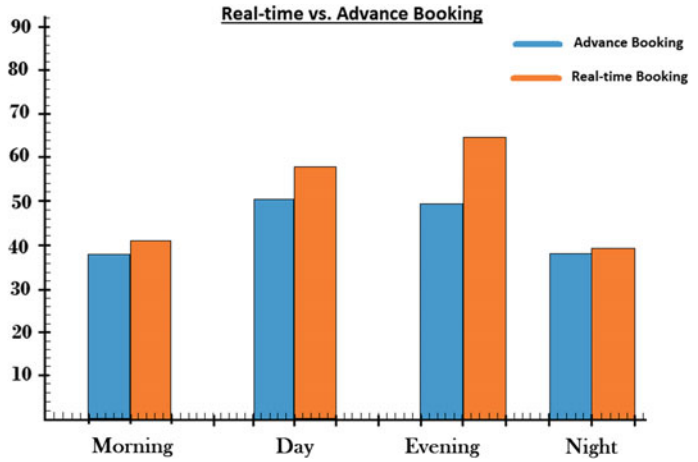

Fig. 6 Comparison of real-time booking and advance booking versus time of day

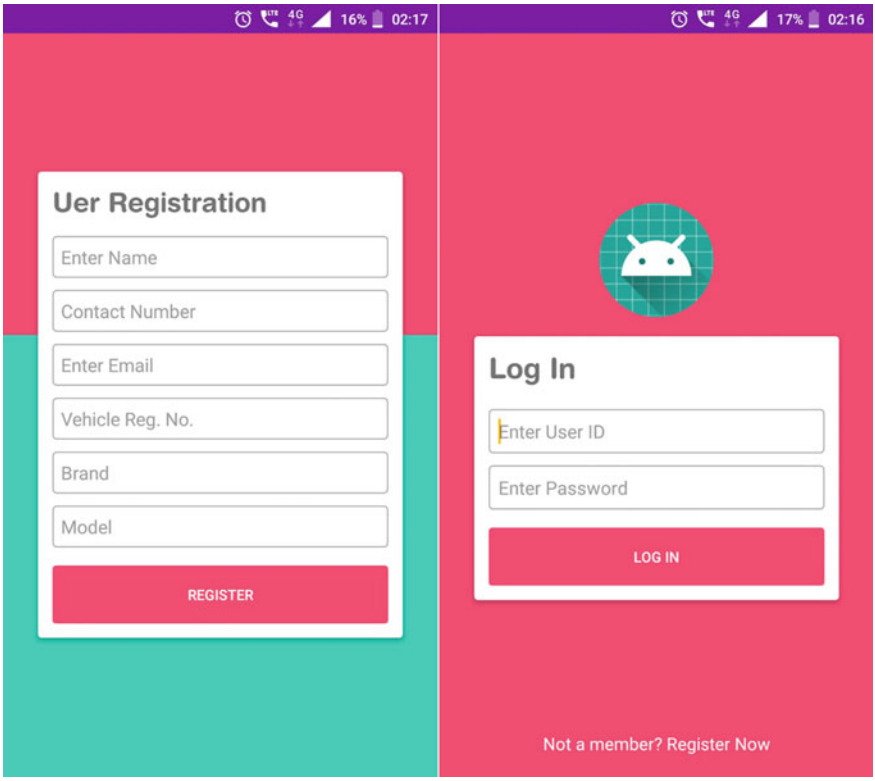

Fig. 7 GUI of user registration and user login

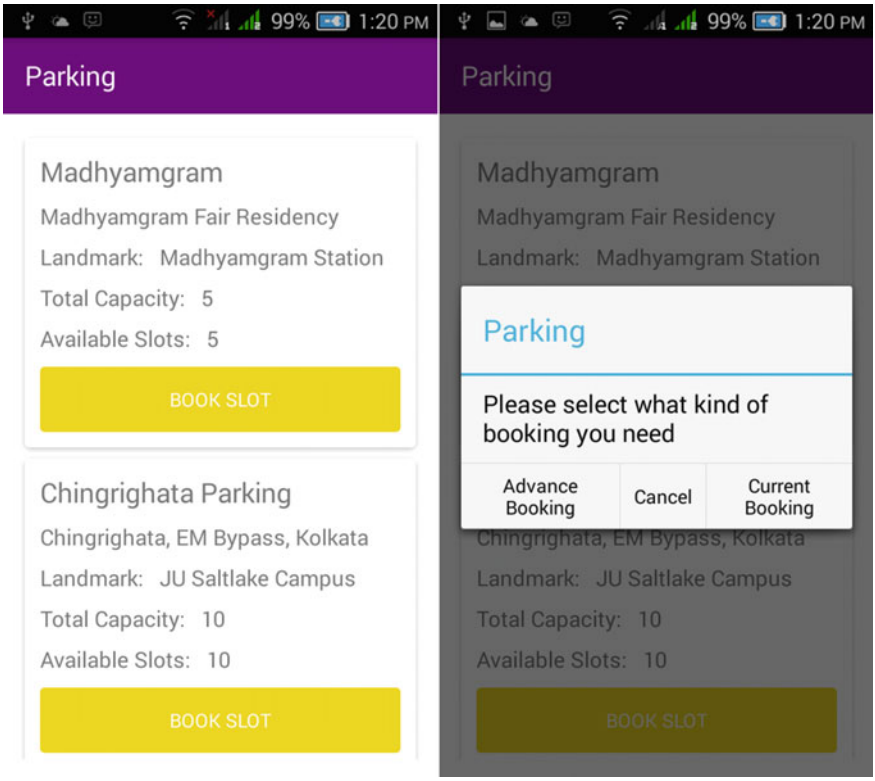

Fig. 8 GUI of the android client upon locating some parking spaces and trying to reserve a parking slot

booking, are depicted in Figs. 8 and 9, respectively. Figure 10 finally shows the GUI of available parking slots within the parking spaces after successful reservation of one parking slot.

5 Concluding Remarks

This paper presents an automatic parking management system that addresses the problem of real-time management of all parking spaces available within a city. The proposed automated real-time parking management system has the following important features.

- It aids the driver to locate his/her preferable parking spot quickly.
- It can detect improper parking of a vehicle at some parking slot.
- It provides an online reservation facility of the parking spot in a secured manner via an android application.

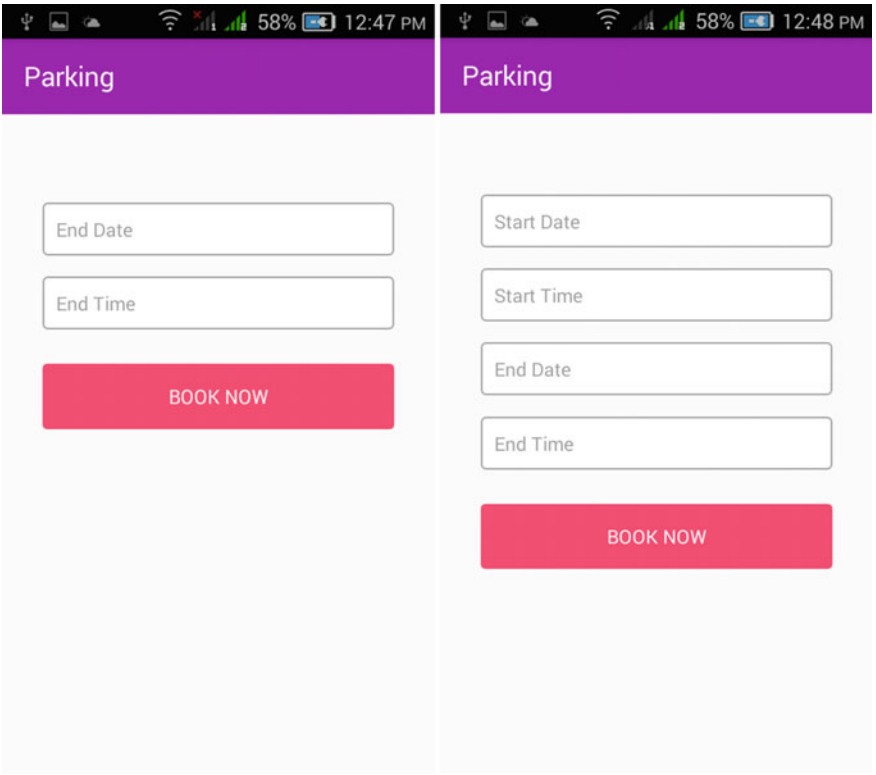

Fig. 9 GUI of real-time booking and advance booking

– It also ensures an automatic collection of the parking charges by the city authorities via an electronic payment gateway.

The experimental results and various screenshots provided in this paper validate the effectiveness of the proposed system. Moreover, the parking reservation module proposed in this paper is much simpler and more cost-effective compared to those that rely on Google Maps and GPS technology.

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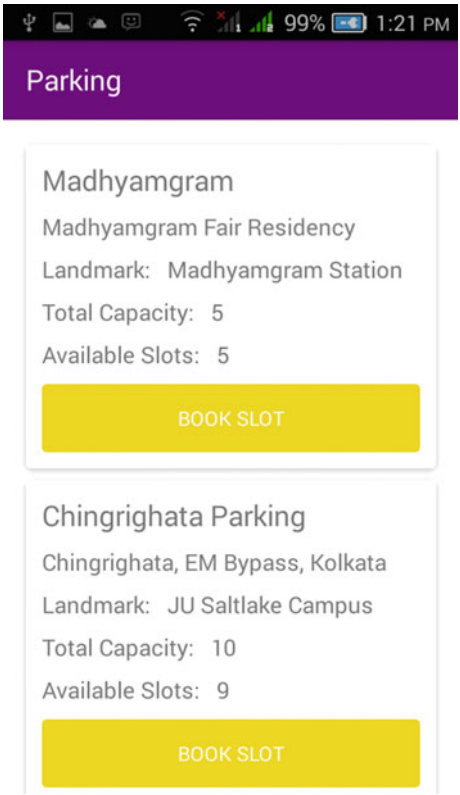

Fig. 10 GUI of an android client after successful reservation of a parking slot

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