An IoT-based E-Parking System for Smart Cities

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***Abstract*—The increasing number of vehicles on the road along with the mismanagement of available parking space leads to the parking related problems as well as increased traffic congestion in urban areas. Thus it is highly required to develop an automated smart parking management system that would help the driver to find out some suitable parking space for his/her vehicle very quickly. Although ample amount of research works on the development of smart parking system exist in literature, but most of them have not addressed the problem of real-time detection of improper parking and automatic collection of parking charges. In this paper, a prototype of internet-of-thing based E-parking system is proposed. The proposed E-parking system uses an integrated component called parking meter to address the above-mentioned issues as well as to provide smart parking management throughout the city.**

***Index Terms*—smart parking system (SPS), parking lot, parking meter (PM), internet-of-thing (IoT), E-parking.**

I. Introduction

The huge proliferation in the number of vehicles on the road along with mismanagement of the available parking space has created parking related problems [1] as well as increased the traffic congestion in urban areas. Thus, it is required to develop an automated smart parking management system [2] that would not only help a driver to locate a suitable parking space for his/her vehicle, but also it would reduce fuel consumption as well as air pollution. It has been found that a driver′s search for a suitable parking facility takes almost 15 minutes which increases the fuel consumption by the vehicle, traffic congestion and air pollution.

A significant amount of research works exist in the area of design and development of smart parking system. Various features of smart parking system are listed below.

- Inquiry on availability of parking space and reservation of parking lot
- Real-time parking navigation and route guidance
- Vehicle occupancy detection and management of parking lots

Most of the smart parking systems (SPS) proposed in literature over the past few years provides solution to the design of parking availability information system, parking reservation system, occupancy detection and management of parking lot, real-time navigation within the parking facility etc. However, very few works have paid attention to the real-time detection of improper parking and automatic collection of parking charges. Thus, this paper presents an internet-of-thing (IoT) based E-parking system that employs an integrated component called parking meter (PM) to address the following issues.

- Real-time detection of improper parking
- Estimation of each vehicle′s duration of parking lot usage
- Automatic collection of parking charges

The E-parking system proposed in this paper also provides city-wide smart parking management solution via providing parking facility availability information and parking lot reservation system and it is named as parking meter (PM) based E-parking (PM-EP).

II. Related Work

Significant number of smart parking systems based on various technologies like radio frequency identification (RFID), wireless sensor network (WSN), Bluetooth, Wi-Fi, ZigBee etc. as well as agent based technologies and image processing techniques have been proposed in the literature over the past few years. Among these, a prototype of RFID-based smart sparking application that implements automated check-in and check-out process of the vehicle from parking lot area by using RFID reader is presented in [3].

On the other hand, either the sensor node or WSNs have been utilized to design several SPSs [4, 5, 6, 7, 8]. Among these, a prototype of wireless sensor network based intelligent car parking system is presented in [4]. The proposed system deploys low-cost sensor node at each parking lot within some parking field to detect and monitor the status of each parking lot. The detected status of various parking lots is periodically reported to a database via WSN gateway deployed at the parking field. Apart from monitoring the parking field, the system proposed in [4] also provides other services like auto-toll, security management etc. Smart parking (SPARK) management system proposed in [6] also uses wireless sensor networks to perform various functionalities such as remote monitoring of parking area, reservation of parking lot, automated guidance to the parking space etc. The ultrasonic sensor node based SPS presented in [6] provides various functionality that include vacant sparking space detection, detection of improper parking, display of available parking spaces, payment facilities etc. The SPS and car parking management system proposed in [7, 8] integrate WSNs and RFID technology.

A vehicular ad hoc network (VANET) based smart parking system for large parking area is proposed in [9] and this proposed parking scheme provides the drivers three important services which are real-time parking navigation, intelligent

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anti-theft protection and dissemination of friendly parking information. A reservation-based based SPS proposed in [10] uses 802.15.4 low power wireless technology, Bluetooth and Wi-Fi to enable the driver to find and reserve the vacant parking spaces. An intelligent parking guidance and information system that uses webcam to detect free parking slot and provides SMS based reservation service to the driver is proposed in [11]. Image processing technique is applied to design some intelligent parking guidance system [12].

A smart and secure parking reservation system based on GSM technology is proposed in [13]. An automated parking system that uses Bluetooth technology as a means of communication is proposed in [14]. The researchers in [15] have presented an intelligent parking negotiation and guidance system that uses mobile agents to make quick negotiation between the vehicle and parking facilities and also to reduce the amount of data to be transmitted over wireless networks. The cloud-based platform has been used as a service to design the SPS by the researchers in [16].

On the other hand, IoT based car parking management system have been proposed [17, 18]. A location-centric IoT-cloud based on-street car parking violation management system has been proposed in [19]. The proposed parking violation management system assists the authoritative officers to locate the vehicles improperly parked on street and also recommends the officers some minimum cost route to reach those vehicles in order to reduce travel cost as well as average period of parking violation detection.

An energy efficient automated car parking system that allocates some free parking slot nearest to entrance of the parking area in order to save parking time as well as to utilize parking space efficiently, has been proposed in [20]. The proposed system [20] saves energy by switching the lights on only when some car is in motion within the parking area. A smart car parking system based on efficient resource allocation, reservation and pricing is proposed in [21]. The researchers in [21] have attempted to provide guaranteed parking reservations with lower cost and smaller searching time for the drivers whereas higher revenues and resource utilization for the managers of the parking area. The proposed system utilizes mixed-integer linear programming to meet its objective.

III. Proposed Parking Meter (PM) based E-Parking (PM-EP)

The E-parking system proposed in this paper consists of the following components. These are parking meter, a WLAN or Wi-Fi integrated laptop/workstation called local parking management server along with some Wi-Fi access points (APs) deployed within each parking facility and a central server for providing parking availability information throughout the city and receiving parking lot reservation request from the driver of a vehicle. The network architecture of the proposed e-parking system is shown in fig. 1.

According to the proposed PM-EP system, each parking lot is equipped with a PM which is positioned at the middle

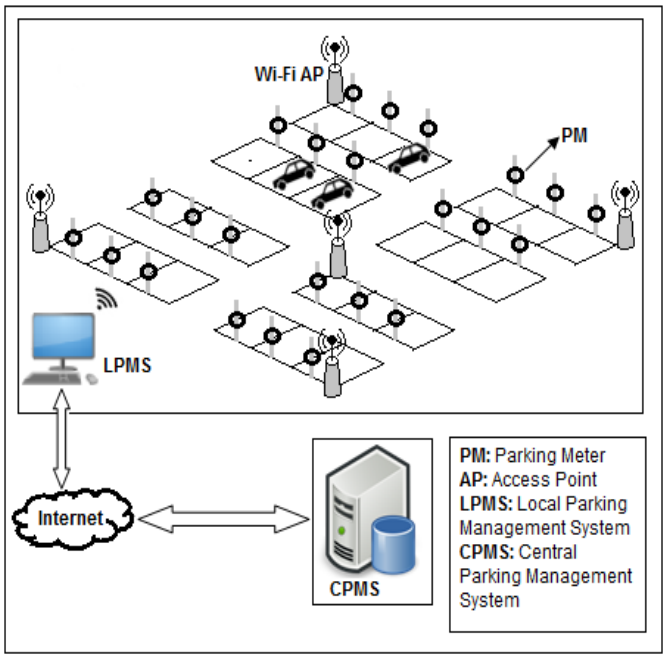

Fig. 1. Network architecture of proposed E-parking system

of the back end of the parking lot as shown in fig. 1. The hardware configuration of the parking meter is shown in fig. 2. The PM consists of an ultrasonic sensor node used for detecting presence of vehicle within the parking lot, a led for indicating the status of parking lot (reserved or not reserved), microcontroller arduino MEGA 2560, an alarm IC module to create warning sound in case of improper parking, a camera module for taking snapshot of the vehicle′s license plate and IEEE 802.11 b/g/n compatible wireless module for communicating with the local parking management server. The PM also includes two smaller solar cells to recharge the batteries as shown in fig. 2. A GSM module [22] is attached with the local parking management server via some serial port for sending SMSs to the site officer as well as the vehicle′s driver. The software architecture and functional specification of proposed e-parking system is presented below.

A. Software Architecture of Proposed PM-EP System

The proposed PM-EP presented in this paper consists of four different modules. These are parking lot monitoring system (PLMS), local parking management system (LPMS), central parking management system (CPMS) and lastly parking availability information and reservation GUI. The functional specification of each of these modules along with work flow diagram on parking management done by this proposed system is presented in this section.

1) Parking Lot Monitoring System (PLMS): This software module is deployed on microcontroller arduino MEGA 2560. It can detect the presence or absence of a vehicle within the parking lot based on time differences between the transmitted and received signal by the ultrasonic sensor node which emits

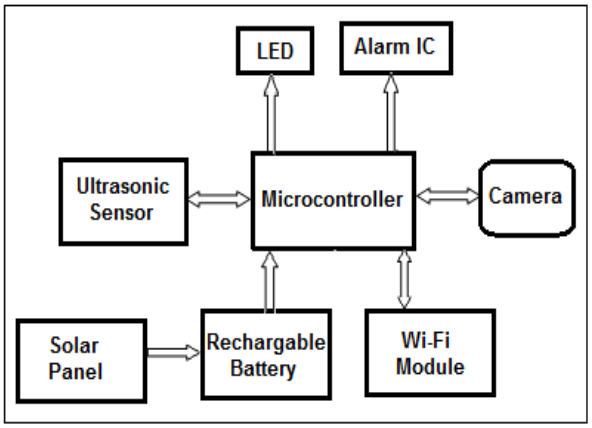

Fig. 2. Block diagram of Parking Meter (PM)

sound wave every 60 milliseconds [6]. Upon detecting some vehicle′s presence within the parking lot consecutively three times, the occupancy of that parking lot by some vehicle is confirmed. Then it takes a snapshot and sends the image to the LPMS for further processing over the Wi-Fi connection as depicted by the work flow diagram in fig. 3. If the vehicle is improperly parked in which case LPMS fails to extract license plate number from the image and then provides PLMS a command to create warning sound through alarm IC for improper parking of vehicle. When it detects the vehicle′s exit from the parking lot, it can calculate duration of parking lot′s occupancy by the vehicle and report it to LPMS as shown by work flow diagram in fig. 3. Fig 3 also shows that LED is turned on if PLMS receives reservation command for the associated parking lot from LPMS.

2) Local Parking Management System (LPMS): This module deployed onto the local parking management server available within each parking facility area. It is responsible for monitoring the whole parking facility area. It maintains a record for each parking lot to keep track of its status which can be empty, reserved or occupied. The work flow diagram of LPMS is depicted in fig. 4. The various tasks accomplished by this system is listed below.

- It attempts to determine the license plate number of the parked vehicle by applying automatic license plate recognition (ALPR) algorithm [23] to process the image received from PLMS. If ALPR fails to extract the license plate number, it sends some SMS to the site officer via the GSM module attached to the LPMS for manual entry of license plate number (LPN) into the system. ALPR fails if the vehicle is incorrectly positioned or improperly parked in which case site officer receives SMS for manual entry of LPN. Improper parking of the vehicle can be easily detected if license plate is not visible within the image in which case manual entry of LPN fails and then LPMS sends improper parking signals to the PLMS for making warning sound of improper parking as depicted by the work flow diagram in fig. 3 and fig. 4.

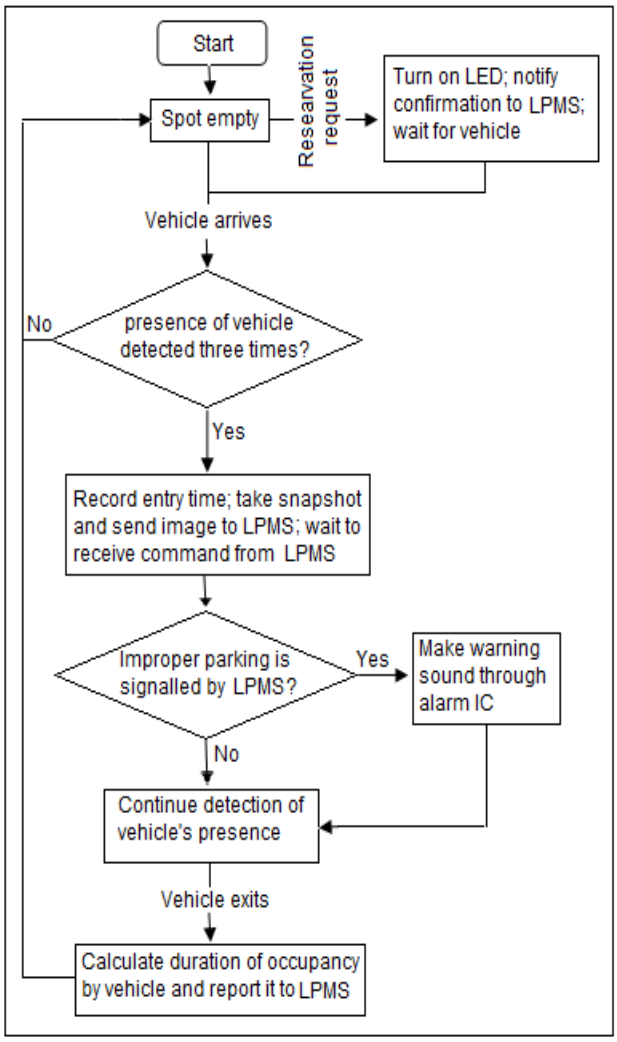

Fig. 3. Work flow diagram for Parking Lot Monitoring System

- On the other hand, if license plate number of some parked vehicle is obtained successfully the associated parking lot′s record is modified to change its state from ′empty′ to ′occupied′ and also to include vehicle′s information. When some vehicle exits from the parking lot, it receives duration of occupancy of the parking lot by that vehicle from PLMS. Then LPMS calculates the parking charges for that vehicle and sends SMS containing payment option to the driver if payment is due.
- Whenever it receives reservation request for a parking lot from central parking management server (CPMS), at first it selects an empty parking lot if the parking area is not full and then sends reservation command to the corresponding PLMS. If reservation is confirmed by the PLMS, the record of corresponding parking lot is modified to make its status reserved and also include information of reserving vehicle. After that LPMS sends reservation confirmation message along with number of empty parking lots to the CPMS as depicted by the work

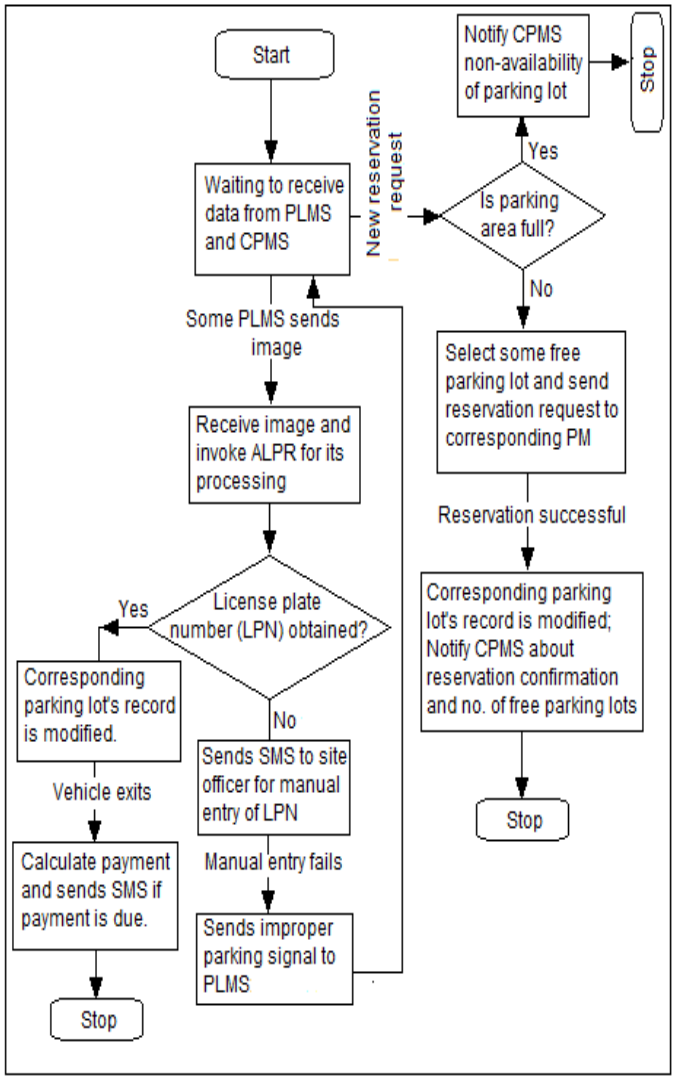

Fig. 4. Work flow diagram for Local Parking Management System

flow diagram in fig. 4. In case parking lot area is full, LPMS notifies CPMS about the non-availability of free parking slot in that parking facility area.

3) Central Parking Management System (CPMS): CPMS is deployed on central parking management server which is a high-end server with a global IP [24] to make CPMS available on Internet. Thus it can be communicated over the Internet. It maintains a record for each parking facility to keep track of free parking lots within that parking facility. Therefore, it can provide information on available parking facilities throughout the city along with number of free parking lots through the parking availability information GUI running at the driver′s handheld device. When it receives reservation request for a parking lot within some particular facility area from some vehicle′s driver it forwards the request to the corresponding LPMS associated with that parking facility area. Once LPMS has reserved a parking lot and sends the reservation confirmation, CPMS can deliver it to the client application along with payment options.

4) Parking Availability Information and Reservation GUI: This is the client application deployed onto the driver′s hand held device. This client GUI enables the driver to obtain information on availability of various parking facilities throughout the city as well as to reserve a parking lot within the suitable parking facility area over the Internet. If reservation is successful, driver is asked for making payment based on duration of reservation. After the payment has been made, the image of the parking facility area displaying reserved parking slot is delivered to the client application.

IV. Concluding Remarks

This paper presents the prototype of an E-parking system that provides novel parking management solution for various parking facility areas throughout the city. The proposed E-parking system enables the drivers to obtain information on availability of parking space and to reserve some parking lot via a suitable GUI that means reservation based parking management facility. This proposed system can easily detect vehicle′s improper parking within the parking lot and estimate the duration of the parking lot′s occupancy by some vehicle by using an integrated component called parking meter that is deployed at each parking lot. The proposed system also enables the automatic collection of parking charges by providing smart payment options to the driver.

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