

An Intelligent System Based on the Internet of Things for Real-time Parking Monitoring and Automatic Billing

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Abstract—This paper describes an internet of things (IoT)-based parking sensing system that deploys a robust outdoor vehicle localization and recognition methodologies. Although, parking occupancy monitoring systems have made a considerable progress, smart parking payment is rarely studied in smart parking research. This paper proposes a new low-cost sensor system allowing real-time parking occupancy monitoring along with parking payment without requiring any user/driver interaction. The proposed on-board vehicle transceiver device (VTD) sensor, will be deployed without having to install new components on each parking lot. It has benefits in terms of detection and payment reliability, and reduced expense by reducing the system complexity, infrastructure investment, and battery replacement expense. A robust vehicle recognition and parking occupancy monitoring is achieved using two-fold sensing approach. It is a sequence of motion detector and global navigation satellite system (GNSS) sensing techniques. The sensor is triggered when the vehicle is within a parking area thanks to a proposed radio frequency (RF) wake-up technique. As consequence, the energy consumption is optimized and the VTD has a power saving scheme with a power consumption as low as 20 μ W at 3 V supply. The VTD can be seamlessly integrated into the intelligent vehicular ad-hoc networks (inVANETs).

Keywords— parking sensor, low-power sensor, Internet of Things (IoT), RF wake-up sensor, smart parking, smart billing, inVANETs

I. INTRODUCTION

Today, the parking industry is being transformed by new technologies that are allowing cities to reduce rates of congestion significantly. Sensor networks that sense vehicle occupancy are providing the basic intelligence behind smart parking systems. Thanks to the Smart Parking technology, it is now possible to know in real-time the location of free parking spaces and to help drivers to get to their ultimate destination.

A variety type of vehicle detectors has been used in parking information acquisition. These vehicle detectors mainly include the inductive loop [1], acoustic sensor [2], infrared sensor [3], or ultrasonic sensor [4]. System using video camera sensor technologies have been proposed to collect the information in vehicle parking field [5], [6]. However, a video camera sensor is vulnerable to bad weather and nighttime operation. Furthermore, it is expensive, and can generate a large amount of data that can be difficult to transmit in a wireless network.

The magneto-resistive based detection systems combined with a wireless area network are the most popular technique [7]-[9] due to their high accuracy. Yet, this type of sensor is facing different issues, i.e. it can be bedeviled by electromagnetic interference, which affects the accuracy [10],

the reading from sensor needs to be collected constantly which will result in wearing out the battery [11]. To extend the battery lifetime and increase the vehicle detection accuracy, a parking sensor system has been proposed [12]. While power management technique has been implemented to optimize energy consumption, high occupancy monitoring accuracy is achieved using two-fold sensing approach. It is a sequence of darkness and Signal Strength Indicator (RSSI) measurement-based techniques.

The wireless sensors are still intrusive, they are embedded in the pavement, or taped to the surface of each individual parking lot. Existing sensors, such as groundbased parking sensors costs up to \$200 per parking lot [13]. As consequence, smart-parking technology using wireless sensors for outdoor parking is costly due to the large number of sensors units required to cover the entire parking lot [13].

Although, parking occupancy monitoring systems have made a significant progress, smart parking payment is rarely studied in smart parking research [14]. Yet, there are companies working on the patents of parking systems for payments.

A first approach consists in using a camera or an RFID transceiver for vehicle detection and identification [15]. A limitation of this solution lies in that the system is complex and its implementation is expensive when a detection device is installed on each parking lot. Furthermore, when only RFID transceiver is used for vehicle detection and identification, the system can be bedeviled by electromagnetic interference, which affects the accuracy. Moreover, this system is designed to detect a vehicle when entering a parking and seek payment, whereas information on vacant parking lots is not provided.

A technique for monitoring vehicle parking using one camera to record the entrance of a vehicle and a second camera to record the vehicle leaving the parking has been proposed [16].

Moreover, in [17] a system and method for obtaining and displaying information on vacant parking space is described. When a user occupies a parking space designated with an individual ID, he enters this ID into a parking meter or via a smart phone mobile app., and pays the parking fees. The database processes the received data and changes the status of the parking space with its ID from unpaid to paid. These data are used as information on the occupation of a parking space.

In this paper, we propose a smart sensor system allowing outdoor parking monitoring and payment without requiring any user/driver interaction. It will be deployed without having to install new components on each parking lot. The proposed sensor has benefits in terms of detection and payment reliability, and reduced expense by reducing the system

complexity and installation, and extending batteries lifetime through the reduction of the system power consumption.

The paper is organized as follows. In Section II the principal of the proposed sensor system is described. Section III presents the sensing methodology. The experimental results are presented and discussed in Section IV followed by the conclusion in Section V.

II. PROPOSED PARKING SENSOR SYSTEM ARCHITECTURE

A. Actual Parking meter

At present, most outdoor parking lots are paid in the following way: the driver inserts coins, a personal card at the parking meter, or a mobile phone is used for payment. (Fig. 1). The ticket machine prints a ticket that the driver displays in the vehicle. When the time is about to expire, the driver can extend his stay by inserting coins or a personal card at the parking meter. In addition, pay-by-mobile phone and real-time parking reservation systems and smart phone applications are used for parking lot reservation and payment (Fig. 1). Therefore, paying a parking space requires user/driver interaction that can be problematic when the user has no coins or mobile phone. Moreover, the traditional parking payment is not counting only the minutes of parking actually consumed. In many cases, the users pay for extra minutes, because a slot of one hour is used for payment.

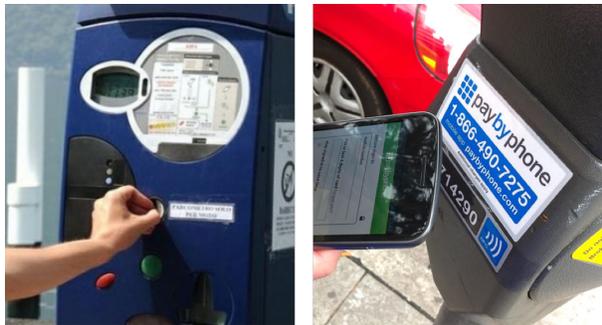


Fig. 1. Actual parking meters.

B. Proposed Sensing System overview

Figure 2 shows the overall proposed sensor system architecture for parking lot monitoring and payment. The system employs three integrated techniques; i.e. 1) the radio frequency (RF) wake-up sensor, 2) motion detector wake-up sensor, and 3) positioning sensing technique. The vehicle transceiver device (VTD) consists of processor, a power management unit, a radio transceiver, an RF wake-up sensor, and global navigation satellite system (GNSS). Once the vehicle enters a strong RF field transmitted by the parking enable device (PED), which defines the parking entrance/exit, the VTD wakes up and triggers the accelerometer. Once the vehicle is stopped on a parking lot, the radio transceiver module is powered up and forwards the vehicle ID and position to the cloud-based server. The parking occupancy in then updated and start time is recorded.

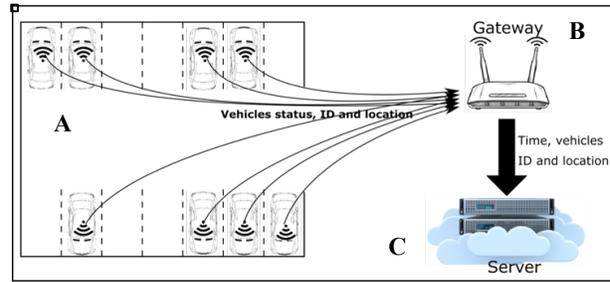


Fig. 2. Proposed system architecture; (A) wireless occupancy sensor; (B) wireless gateway; (C) data storage and processing unit.

III. PARKING SENSING METHODOLOGY

A. Vehicle entering a parking area

When a vehicle approaches a parking area, the VTD is activated by the PED acting as a wake-up signal (Fig. 3). The PED sends a wake-up signal to the VTD by transmitting a short RF wake-up code. Thus, the VTD will be then activated when only entering a parking equipped with a PED.

Compared to the prior art, the PED is not used to identify a vehicle. Therefore, the system is not subject to the accuracy problem as no data is exchanged between the PED and VTD devices. Furthermore, the PED will have a simpler implementation and lower cost, as it not used to identify and transmit the identification information of the vehicle.

When enabled, the VTD wakes up, and transmits the vehicle unique identification code (ID) to a wireless gateway. After transmitting the ID, the VTD goes back to deep sleep mode for power saving. This technique allows extremely low power consumption and prolongs the battery lifetime of the VTD.

Once the vehicle occupies a free parking lot, the accelerometer triggers the VTD, which transmits this time the ID and position while the vehicle is idle in a parking lot. After transmitting the ID and position, it goes back to deep sleep mode.

Once receiving the vehicle ID and position, the processing unit updates the information on the parking occupancy and records a start time.

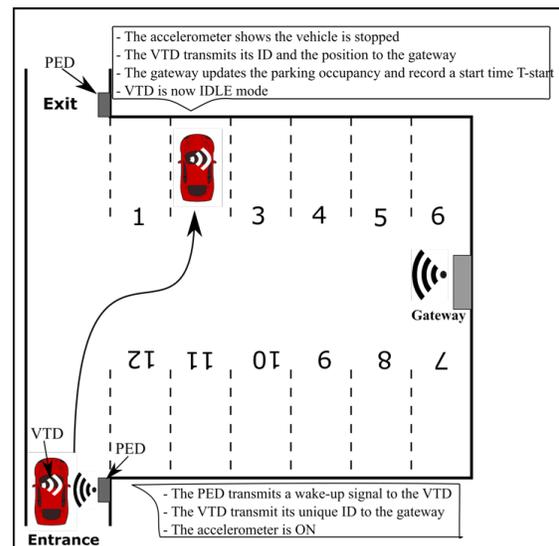


Fig. 3. Vehicle entering a parking area.

Table I elaborates an algorithm of the parking lot occupancy monitoring and start time recording. Figure 4 illustrates the methodology.

TABLE I. ALGORITHM FOR PARKING LOT OCCUPANCY MONITORING AND START TIME RECORDING

<p>Algorithm Parking lot occupancy monitoring and start time recording</p> <p>VTD Sensor sleep mode</p> <p>if vehicle inside RF field then</p> <p>Via proximity, RF wake-up sensor powers up the VTD's accelerometer and radio module.</p> <p>VTD transmits a wireless telegram which includes 32-bit unique ID.</p> <p>Keep the accelerometer ON and enter sleep mode.</p> <p>if vehicle is stopped then</p> <p>the accelerometer enables the VTD</p> <p>VTD transmits a wireless telegram which includes 32-bit unique ID and position.</p> <p>Wireless gateway receives the telegram.</p> <p>The processing unit records (ID, Start time).</p> <p>Update parking lot map.</p>

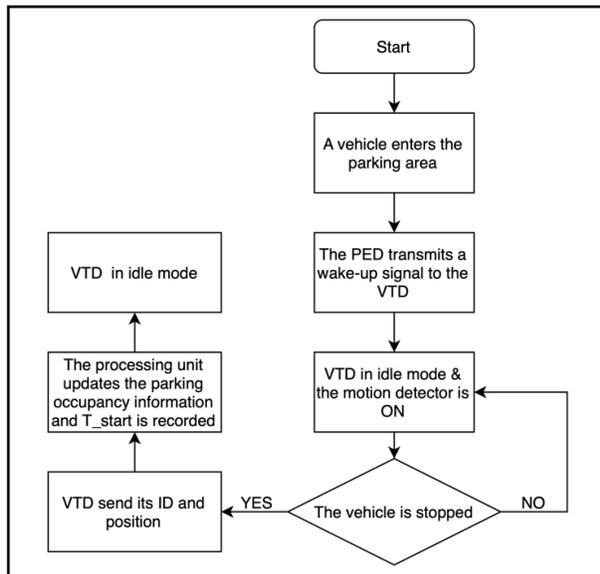


Fig. 4. Vehicle entering a parking area methodology

B. Vehicle leaving a parking area

When the vehicle is leaving a parking (Fig. 5), the accelerometer enables the VTD, which transmits the ID to a wireless gateway. Once the vehicle goes through the parking exit, the PED transmits an RF wake-up signal to the VTD. The VTD transmits a second time the ID without transmitting its position information because the motion detector is ON. Sending the ID twice is a confirmation that the vehicle left a parking area. Once receiving the vehicle ID, the processing unit updates the information on the parking occupancy, records the stop time, and computes the charge based on the difference between the entry time and the exit time.

After the second transmission of the ID, the VTD enters to a deep sleep mode.

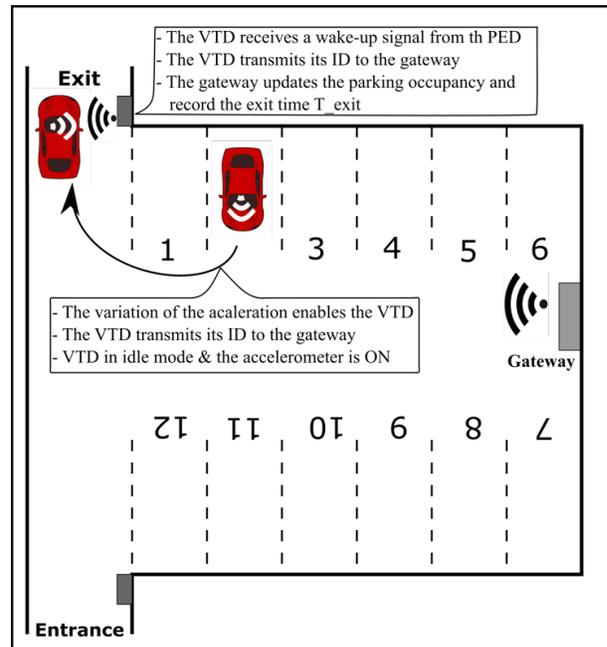


Fig. 5. Vehicle leaving a parking lot

Table II elaborates an algorithm of the parking lot occupancy monitoring and stop time recording. Figure 6 illustrates the methodology.

TABLE II. ALGORITHM FOR PARKING LOT OCCUPANCY MONITORING AND STOP TIME RECORDING

<p>Algorithm Parking lot occupancy monitoring and stop time recording</p> <p>VTD Sensor sleep mode</p> <p>if vehicle moves then</p> <p>The accelerometer is ON</p> <p>The accelerometer enables the VTD.</p> <p>VTD transmits a wireless telegram which includes 32-bit unique ID.</p> <p>Keep the accelerometer ON and enter sleep mode.</p> <p>if vehicle inside RF field then</p> <p>Via proximity, RF wake-up sensor powers up the VTD</p> <p>VTD transmits a wireless telegram which includes 32-bit unique ID.</p> <p>Wireless gateway receives the telegram.</p> <p>The processing unit records (ID, Stop time).</p> <p>Computes the difference between the start and stop time.</p> <p>Computes the charge.</p> <p>Update parking lot map.</p>

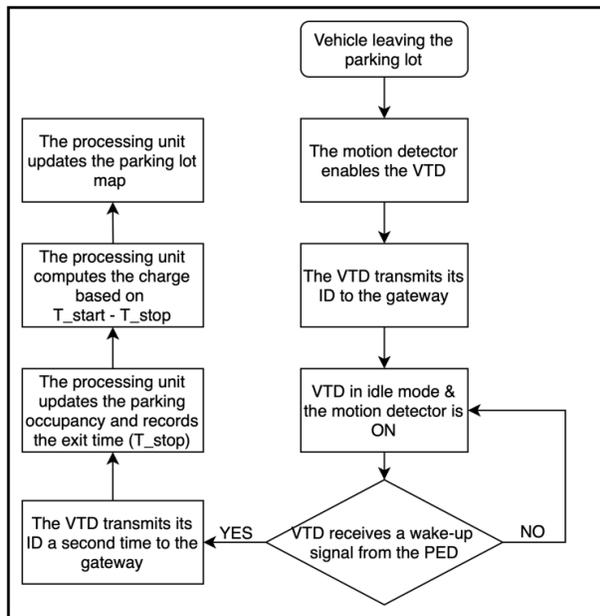


Fig. 5. Vehicle exiting a parking area methodology

IV. RESULTS AND DISCUSSION

Fig. 6 represents the on-board sensor VTD. It is composed of our proposed application-specific integrated circuit (ASIC) wake-up and a power management module, a microcontroller, a low-power radio module, a motion detector, and a localization system.

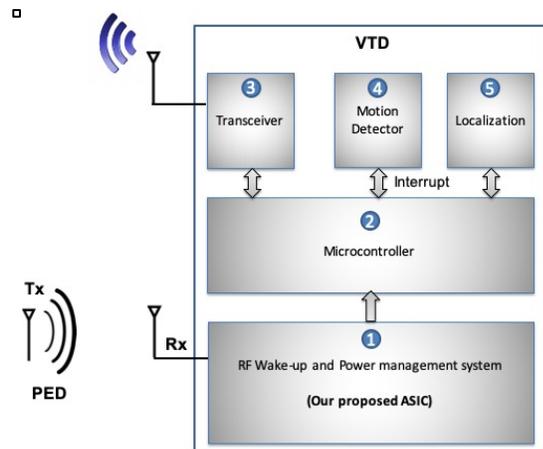


Fig. 6. VTD block diagram

The proposed passive RF wake-up integrated circuit (IC) relies on the transmitted PED's RF wave as the sole power source (Fig. 7). A storage capacitor of 100 pF is implemented on chip that acts as a buffer during the loss of energy when the wake-up code is transmitted.

The RF wake-up sensor enable signal (Fig. 6, Fig. 7) triggers the microcontroller to wake up when a threshold voltage has been exceeded within the RF field close to the PED, implemented at the parking entrance/exit. In addition, the received code ratifies the wake-up action once it matches a predefined wake-up code.

For the protection of the user privacy, the sensor only broadcasts the vehicle information and position once the VTD is triggered within a parking area. Therefore, The VTD is only activated when a vehicle approaches a parking entrance/exit thanks to the proposed RF wake-up sensor. Elsewhere, the VTD is in idle mode. Consequently, the RF wake-up sensor allows energy saving mode with a total power consumption of 20 μ W.

Fig. 8 is showing the measured accelerometer signals. The implemented interrupt signal warns when the vehicle is idle on a parking lot and when the driver vacates the place (Table I and II). Accordingly, the accelerometer interrupt allows the VTD to broadcast the vehicle ID and position after occupying a parking lot or leaving it allowing the processing unit to compute the start time and the stop time as shown in Fig. 5.

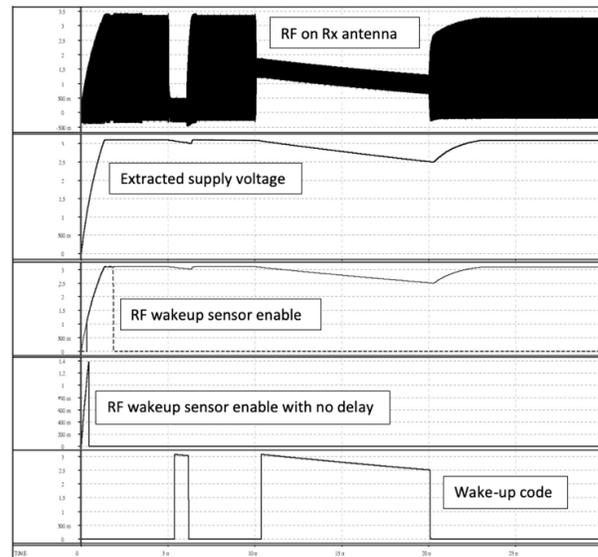


Fig. 7. RF wake-up sensor signals

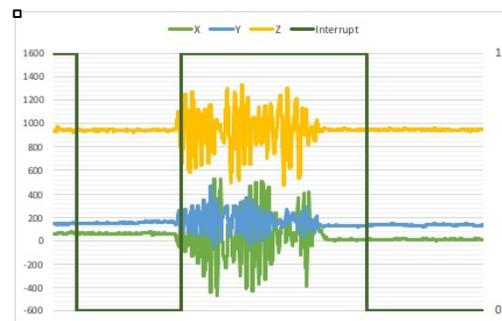


Fig. 8. Measured accelerometer signals

V. CONCLUSION

A novel intelligent parking sensor system was presented. It allows real time parking monitoring along with parking payment without requiring any user/driver interaction. Thanks to the proposed innovative approach, the sensor system has advantages in terms of detection and payment reliability and reduces costs by reducing system complexity, investing in infrastructure and replacing batteries.

Additional validation tests are being carried out to further optimize the system.

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