A Smart Parking Management System Using IoT Technology

Imed Ben Dhaou*†, Aron Kondoro ‡, Ali Hamad Alsabhawi *, Oumaima Guedhami§ and Hannu Tenhunen‡¶
*College of Engineering, Qassim University, Al Qassim 51452, Saudi Arabia
imed.bendhaou@qec.edu.sa
†University of Monastir, Tunisia
‡Royal Institute of Technology, Sweden
‡Qassim university, Saudi Arabia
¶University of Turku, 20014 Turun yliopisto, Finland
¶Royal Institute of Technology, SE-164 40 Kista, Sweden
hannu@kth.se

Abstract—**Parking management system is vital in modern cities as it reduces traffic-related air pollution, increases the profitability for companies who are managing parking spaces, etc. In this paper, we propose an IoT based parking management solution. The system is composed of a magnetoresistive sensor for car detection and a gateway for delivering the occupancy status of the parking slots to the end-user. A secure prototype system using Arduino and Zigbee module has been built as a proof of concept. The results show that our system is very reliable and can be used to classify car models.**

I. INTRODUCTION

The increasing number of inhabitant in urban areas coupled with the need to improve the living standard for citizen have pushed government agencies, businesses and legislators to adopt the smart-city concept. Although there is no single definition for the smart-city, the EU has proposed a number of indicators to measure the city smartness. This model is depicted in Fig. 1 [1]. The indicators are shown between parentheses.

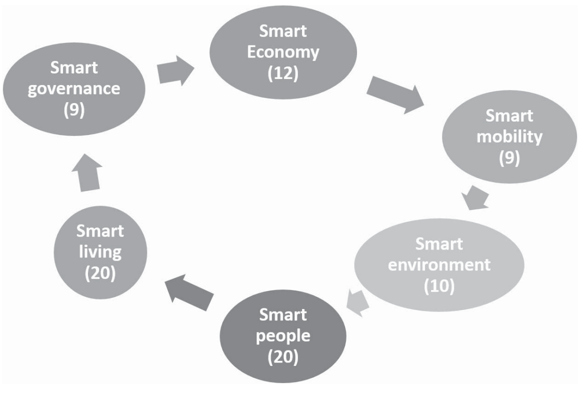

Fig. 1. EU smart city model and indicators

Intelligent transportation system, ITS, is the promising technology to alleviate the problems associated with the transportation (accident, pollution, congestion, etc.) In the EU smart-city model, intelligent transportation system enables the smart mobility. Smart parking management system is considered as a key element for sustainable and eco-friendly transportation system. As pointed out in [2] and [3], parking management in a densely populated cities is a real bottleneck as the motorist can waste his/her time looking for a free parking slot. As report in [4], in Europe that are over 15 million parking spaces. Furthermore, frustrated driver can park in an illegal way which may cause traffic disturbances and potentially block other motorist.

To address the problem associated with parking in densely populated areas, smart parking management system has been proposed. Broadly speaking, the proposed systems can be categorized as invasive or non-invasive. The invasive systems use inductive loops, weigh-in-motion, magnetometers, etc. The non-invasive systems use, among others, cameras, LIDAR, microphone array, pneumatic road tubes, and piezoelectric cables [5].

In this paper, we propose an IoT based smart parking management. The rest of the paper is organized as follows. In Sectionsec:relatedwork, we discuss related work. Section III provides theoretical foundation for the vehicle detection sensor using earth's magnetic field, describes the detection algorithm and describes the proposed architecture. We report the implementation in Section IV. Finally, Section V concludes the paper.

II. RELATED WORK

To reduce the power consumption of the magnetoresistive sensor, in [6], the authors proposed a magnetoresistive sensor triggered by an optical sensor. A prototype system composed of MSP430F2274 microcontroller, an AAH002 analog magnetic sensor, an LDR NORPS-12 optical sensor and a Zigbee transceiver (ETRX2). The proposed solution has reduced the current consumption by over 270%. However, security and reliability issues have not been considered especially if the system is to operate in dark or night time.

The authors of [7] proposed a free space parking management system using IoT technology. The occupancy of the parking is detected using three types of sensors: magnetoresistive, light, temperature. The sensors determine the occupancy of the parking area and transmit the status to a border router using 6lowpan communication protocol. An MQTT server receives the message from the sensors and displays the status of the parking using web interface. While the authors proved experimentally that the system is 98 % efficient at detecting the occupancy of the parking space, security and power consumption have not been considered.

III. Proposed system

A. Magnetic field based sensor

Vehicles are constructed using metals and other materials. The quantity of the metal depends on the vehicle type, year of production and the automaker. Steel, aluminum and magnesium are among widely used metals for the construction of vehicle parts (chassis, engine block, etc.)

In the transportation area, magnetic field has been intensively applied in assorted applications. Two main reasons were behind the deployment of magnetic-field sensor in the regulation of road traffic. The first type of sensor is a magnetometer, such as fluxgate and hall-effect, that measures the magnetic flux produced by a road vehicle [8]. However, this type of sensor is not anymore suitable as most contemporary vehicles have low magnetic signature. The second category is the Anisotropic Magneto-Resistive, AMR, sensor that measures the earth's magnetic field.

AMR sensor is build using Wheatstone bridge that converts the magnetic filed intensity into an electric-voltage of small values. The Earth's magnetic field is a three dimensional vector with the expression given in (1) [9].

$$\vec{B} = -\Delta V(\rho, \theta, \phi, t), \quad (1)$$

where $V(\rho, \theta, \phi, t)$ is the magnetic scalar potential, in spherical coordinate system, which is shown in (2).

$$V(\rho, \theta, \phi, t) = a \sum_{n=1}^{N} \sum_{k=0}^{n} \left(\frac{a}{\rho}\right)^{n+1} \times \left[g_n^k(t)\cos(k\phi) + h_n^k(t)\sin(k\phi) + p_n^k(t)\cos(\theta)\right], \quad (2)$$

where θ is the geocentric co-latitude, ρ is distance from the center of the earth, ϕ is the east longitude, $g_n^k(t)$ and $h_n^k(t)$ are the Gauss coefficient, and $p_n^k(t)\cos(\theta)$ are the Schmidt quasi-normalized associated Legendre functions of degree n and order k.

The Earth magnetic field has usually three components in the (x, y, z) Cartesian coordinate system. The transformation from Spherical coordinate system to the Cartesian system is given below.

$$x = \rho \sin\theta \cos\phi,$$
$$y = \sin\theta \sin\phi,$$
$$z = \rho \cos\theta$$

The intensity of the earth's magnetic field very small(order of few Gauss). The calculation for a the Earth magnetic field needs the following parameters: Latitude, longitude and elevation. Tab. I shows the value of the earth's magnetic field in two Saudi cities: Buraidah and Makkah. The detection of the vehicle using AMR sensor is accomplished by measuring the disturbance of the earth magnetic field. Fig. 2 shows the effect of a vehicle on the earth's magnetic field.

TABLE I. Earth's magnetic field in selected cities

City (Country)	B_x (Gauss)	B_y (Gauss)	B_z (Gauss)	B (Gauss)
Buraidah (KSA)	0.277	-0.07	0.253	0.289
Makkah (KSA)	0.347	0.020	0.208	0.406
Stockholm (Sweden)	0.150	0.015	0.48	0.5

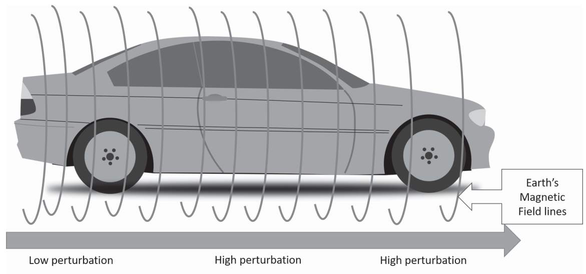

Fig. 2. Impact of the vehicle metal part on the earth's magnetic field

B. System architecture

AMR based mote is the corner stone for the proposed system. The mote is composed of a micro-controller system for processing of AMR data and a transceiver for transmitting short wireless messages. These messages are transmitted to a border gateway that translate and connect the sensors to the Internet Fig. 3 depicts the proposed system. The gateway acts as a bridge between the wireless based protocol used by the mote and the IP based system used by the Internet. On the IP based side, the system uses the MQTT (Message Queuing Telemetry Transport) communication protocol to send data due to its power efficiency and limited bandwidth use. MQTT is a lightweight communication protocol optimized for IoT applications. It follows the publisher-subscriber pattern. As such, compared to other IoT based protocols such as CoAP and XMPP, it offers a dicoupled and more reliable network. In addition, the publisher-subscriber pattern offers a more scalable system that can accomodate lots of nodes. It consists of a component known as a broker that receives messages from publishers and dispatches them to subscribed clients. In our system, motes act as publishers sending information to the broker via the gateway. The broker is implemented in a server that exists in the cloud. It provides an interface through which clients on end user devices can subscribe and receive information. This architecture decouples the publishers of data and clients allowing for greater flexibility and scalability.

On the wireless sensor side, there are plenty of communication protocols that can be used to haul the information from the parking space to the cloud. In IoT, the existing communication protocols are: Zigbee, Z-wave, and 6LoWPAN [10]. Tab. II compares the features of the aforementioned communication

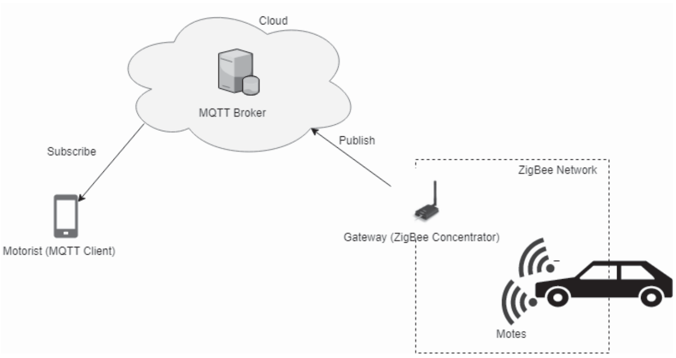

Fig. 3. System architecture

protocols. The common features are the security and RF power. The three protocols support AES and transmit at 20dBm. In our application, Zigbee has been chosen as the

TABLE II. COMPARISON OF KEY IOT COMMUNICATION PROTOCOLS

Protocol	Range	Freq.	Latency	data rate
Zigbee	300 m	2.4 GHz	30ms	250 kbps
Z-Wave	100 m	908.42-868.42 MHz	200ms	40 kbps
6LoWPAN	100 m	2.4GHz	29.35ms	250kbps

wireless communication protocol to connect the sensors to the Internet. To cover a large area, the mesh network configuration has been chosen. The network is composed of end-nodes (motes) that senses the presence of the vehicle, routers and a coordinator as shown in Fig. 4.

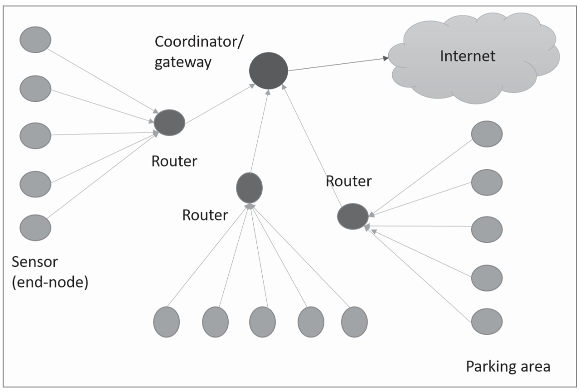

Fig. 4. Zigbee mesh network

In our parking management system, the end-point has been prototyped using using LSM303DLH from ST microelectronics. The LSM3030DLH contains a 3-axis accelerometer and 3-axis magnetometer. Fig. 5 shows the block diagram of the 3-axis magnetometer (LSM303DLH).

The detection algorithm works as follows. The magnetoresistive measures the earth's magnetic field when the parking slot is empty. To minimize the power consumption, the LSM3030DLH measures the magnetic field every 15min. The measuring interval can be adjusted by the user. In case the

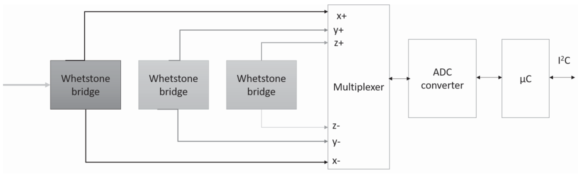

Fig. 5. Block diagram of the magnetoresistive sensor with a microcontroller

measured magnetic field (magnetic field intensity) is larger than a given threshold, then the LSM3030DLH waits for 10 minutes and measures the magnetic field. In case the measured value is higher than the threshold, then the LSM3030DLH informs through Zigbee communication protocol that the slot is occupied. The pseudocode is shown in Alg. 1.

Algorithm 1 Vehicle detection algorithm.

procedure PARKDETECTION(τ, t_{min}, t_{sample})
  wait t_{sample}
  read B_x ,B_y, and B_y;
  $B \leftarrow \sqrt{(}B_x^2 + B_y^2 + B_x^2)$
  if $B > \tau$ **then**
    wait t_{min}
    read B_x ,B_y, and B_y;
    if $B > \tau$ **then**
      Occupied ← true
    elseOccupied ← false
    end if
  elseOccupied ← false
  end if
  return Occupied
end procedure

IV. EXPERIMENTAL RESULTS

The proposed system has been prototyped using two Arduino, two Xbee modules and LSM3030DLH. The detection algorithm was implemented using Arduino IDE and uploaded to the sensor. Fig. 6 shows the sensor node. In case a vehicle is

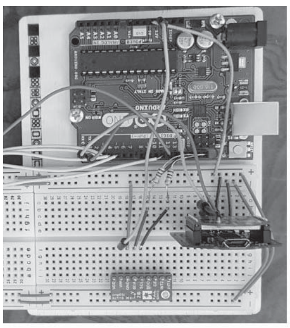

Fig. 6. Prototyped sensor node for vehicle detection

detected, the sensor sends a short message to the MQTT server. The message contains the GPS location of the parking number, its number and the time the vehicle entered the parking.

To correctly determine the threshold level for the earth magnetic field (τ) we conducted intensive experiments using various vehicles.

A. Location of the sensor

As we explained in Fig. 2, the perturbation brought to the earth's magnetic field vary along the vehicle body. To investigate this, we have conducted experiments in which we collected the magnetic field components (x,y, and z) at three positions shown in Fig. 2. The results, reported in Tab. III, emphasis that at the front and in the middle of the vehicle the magnetic field experience strong perturbations.

TABLE III. MAGNETIC FIELD INTENSITY ACROSS THE VEHICLE BODY

Location	Front	Rear	Middle
B (Gauss)	2.64	2.41	2.88

B. Car detection using forward parking

In the first experiment, we placed the sensor under the car engine the x-axis is parallel the frame rails. The results, depicted in Fig. 7 show that the y-component is highly affected compared the x and y components of the magnetic field.

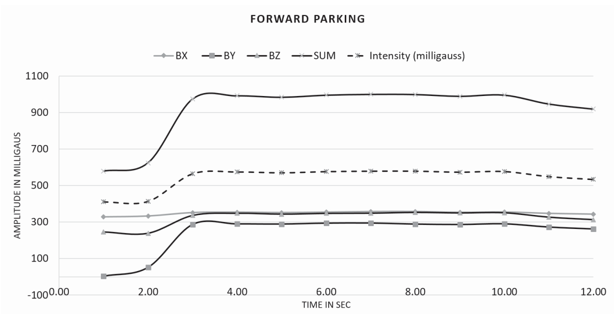

Fig. 7. Detection profile for the parking of a Ford car in forward mode

C. Backward and forward parking

To investigate the behavior of the earth's magnetic field in backward and forward parking, placed the sensor underneath a Prado car. The results for the y-component of the magnetic field are tabulated in Tab.IV. The tables reveals that the driving direction can be determined from the y-axis.

V. CONCLUSION

In this paper, we proposed an IoT based smart parking management system. Magnetoresistive is the cornerstone for the proposed in which the occupancy of the parking lot is determined by measuring the earth's magnetic field. The system is able to detect the parking orientation (backward or forward parking). The occupancy information is hauled to the MQTT server using Zigbee network. The intensive experiment shows that our system is very effective in detecting the presence of the vehicle and can differentiate between backward parking and forward parking.

TABLE IV. BACKWARD AND FORWARD DRIVING

time	Fackward		Backward	
1	B_y	B_x	B_y	B_x
2	1103	2330.9	257	2386.2
3	1107	2327.37	89	2676.7
4	1105	2329.74	104	2671.42
5	1105	2329.74	100	2670.97
6	1100	2323.18	86	2668.22
7	1106	2323.73	90	2683.06
8	1109	2331.69	89	2672
9	1100	2331.6	116	2794.86
10	1100	2331.6	202	2999.31
11	1105	2338.2	346	3076.68
12	1501	2683.7	339	3091.48
13	1598	2780.1	339	3095

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