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- Yetunde O. Folajimi
- John B. Oladosu

Developing Smart Car Parking System Using Wireless Sensor Networks

Aliyu Ahmed
Computer Engineering
Federal University of Technology Minna, Nigeria
aliyu.ahmed@futminna.edu.ng

Mikail Olaniyi
Computer Engineering
Federal University of Technology Minna, Nigeria
mikail.olaniyi@futminna.edu.ng

Jonathan Kolo
Computer Engineering
Federal University of Technology Minna, Nigeria
jgkolo@futminna.edu.ng

Stephven Oyetoro
Computer Engineering
Federal University of Technology Minna, Nigeria
oyetorostephven@gmail.com

ABSTRACT
Car parking is a serious problem and one of the major contributors to traffic congestion in urban areas. This challenge is as a result of sharp increase in numbers of automobiles on the roads. This paper presents the development of a smart parking system using wireless sensor networks. The system can monitor the state of every parking lot by deploying a magnetic sensor node on each lot and also identify improper parking using infrared sensor to check if vehicles are properly parked. The system uses Xbee radio for transmitting information to the base station which performs necessary information processing, analysis and interpretation on the data received to usable and meaningful format for the end users. The results obtained after qualitative testing of the developed prototype shows that server concurrency utilization is in the average of 12 users per minute. It was also observed that the system acquire speedup in terms of average response time of 1.414 seconds. This implies that the system is robust to handle large number of users and is also fast enough in terms of response which gives accurate information about the parking lot. With the system in place, traffic related hazards, fuel wastage and other relted hazards could be reduced.

CCS Concepts
• Hardware → Communication hardware, interfaces and storage → Wireless integrated network sensors

Keywords
Car park, Xbee, wireless sensor networks, automobile, traffic, Magnetic sensor

1. INTRODUCTION
Car park are commonly found in cities and suburban areas which have significant effect in reducing the amount of traffic. They are often found in places such as shopping malls, sports stadiums, schools, churches and similar venues. Parking is an act of bringing to a halt and (or) leaving a vehicle unoccupied. A parking lot, also called a car lot or a bay, is a cleared expanse of land - often of extensive or massive size that is meant and designed for parking vehicles. Car parking system is developed with a view to effectively manage parking of vehicle. Smart parking is a scheme which uses numerous technologies to effectively manage a parking space [1, 2]. Traffic congestion in cities and suburban areas have increased due to increase in the number of car users. Recurrent traffic congestion in general is as a result of roadway lacking sufficient capacity for the volume of cars – too many cars or too little roads. The bases of traffic congestion (traffic jam) are complex and composite but they all stems from having too many cars on the same road at the same time. Car drivers searching for parking space contribute to between 8% to 74% of traffic congestion as argued in the research of [3]. A related study conducted by International Parking institute, 2012 appraised that 30% of car steering the city at any instant of time are doing so as car drivers are scanning for parking space [3]. Consequently, traffic congestions lead to frustration on the part of the driver and also waste of time. Economically, it translates to wastage of fuel and carbon emission can lead to environmental pollution and other associated hazard (e.g. Global warming as a result of carbon emission).

A significant way out of these car parking problem is to de- crease the time taken by car drivers to search and find parking spots. This can be achieved by incorporating new technologies to exist- ing systems and this give rise to Wireless Sensor Network (WSN) to be considered as an effective way to improve parking situation [4]. WSN is drawing bigger interest thus, allowing them to speed- ily evolve owing to their massive usage capability across several disciplines [5]. As a result of advancement in technology, WSN stems from wireless networking, which is an interconnection of nodes that do not necessitate any form of cable [6]. This offers mobility and flexibility in transmitting data over a network medium [7]. WSN have found many civil, industrial, military, general engineering, civil engineering, environmental, agriculture and medical application which includes smart office spaces, commercial and residential security, border surveillance, intelligent buildings and bridges, precision agriculture, disaster recovery and so on [2]. With this wide range of application, it is reasonable to consider WSN in car parking system.

In this paper, we present the development of a parking system that will operate by sensing parking spaces if available via sensors, notably a magnetometer. With a parking space in place, combining WSN with the system offers the possibility of developing a smart system for car parking that could be an important factor in solving the problems of parking and none the less offers an easy and cost effective solution which would maximize utilization and minimize

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human interference. The results are communicated wirelessly to car owners when queried, notifying car owners of the condition of the parking space. This system differs from early parking system which utilizes human placed strategically at the parking lots to assist drivers in parking their vehicles. Application of Sensor technology to parking system allows for measurement of conditions of interest such as magnetic (metal) fluctuations and light radiation (radiation or reflection of light from objects).

The rest of the paper is organized as follows. Section 2 presents the related work in this area of study, while section 3 discusses the system design and implementation. The results obtained is presented in section 4 and section 5 concludes the paper.

2. REVIEW OF RELATED WORKS

A number of related works exist in literature. Some of them are presented here. [1] proposed automatic parking indicator utilizing microcontroller whose primary point is to streamline around space accessible for stopping. It enables the stopping of vehicles, floor after floor, also called a multi-level displaying the accessible openings on LCD, subsequently lessening the ground space utilized. The framework permits number of autos to be stopped by prerequisite, making the framework modernized and a space-sparing one. In spite of space saving feature of the system, it does not specify the mechanism used in parking of vehicles on the multi-level system. In addition, it lacks a parking guidance system for guiding drivers to where available parking lot is and it requires much wiring to achieve the system.

Similarly, [8] developed a car parking system based on Field Programmable Grid Array. The parking framework was achieved using Finite State Machine modelling. The framework has two primary modules, the identification module and opening checking module. The Identification module distinguishes the guest and the opening checking module checks the space status. These modules are displayed in HDL and actualized on FPGA. FPGA technology offers flexibility, enhance modification using algorithmic state machine to carry out more task. In this system, the afore knowledge of the status of the parking slot is not known and lacks the guiding system for direction. Furthermore, the IR sensor which is the only car detector sensor used in the system is subjected to environmental conditions such as humidity and light.

Smart parking system with image processing facility (Multi-level car parking system) proposed by [9] obtained information about available parking spaces, process it and then place the car at a certain position. The system is a mechanical framework intended to minimize the territory and/or volume required for parking vehicles. It gives parking to vehicles on different levels stacked vertically to expand the quantity of parking spots while minimizing area use. However, the cost of setting up the system is high and there is a single entry and exit point which can lead to traffic congestion if several cars arrive simultaneously.

In the same vain, [10] carried out an improved work, smart park- ing system architecture using ultrasonic to help drivers in discovering empty parking spots in a brief time frame. The framework utilizes ultrasonic (ultrasound) sensors to identify parking garage inhabitancy or improper parking. Regardless of the minimal effort and simple installation of ultrasonic sensors, the parking system may receive wrong data due to sensor sensitivity to temperature changes and extreme air turbulence. Furthermore, the implementation of improper parking detection using ultrasonic sensor in parking system is not viable.

Smart parking system based on reservation by [11] addressed the difficulty that arises from not knowing where the available spaces may be and reduces traffic congestion which results from many vehicles pursuing limited parking spaces. It determines the parking prices according to their pricing scheme and broadcasts the prices to all users periodically, it also offers a storage system for storing the parking information, QR codes and prices for further analysis; pricing is a centralized decision made in regards decisions to state of parking lots and user demands. The system notwithstanding did not offer parking guidance system and the presence of a reservation authority defeats the aim of smartness of the system.

In [12] Intelligent parking lot application utilizing remote sen- sor systems examined the impact of identifying vehicles by comparing the acoustic, visual light, infrared, temperature, ultrasonic, and magnetic sensors. Their trials checked that ultrasonic and attractive sensors have better precision and unwavering quality in parking spot.

Also, [13] proposed a Smart Parking System utilizing WSN innovation which gives propelled components like remote parking observation, mechanized direction, and parking reservation mechanism. This framework utilizes a dream based location technique (CCTVs) as a detecting nodes to distinguish empty parking spot. The framework is equipped for controlling clients to effectively find empty parking spots in order to stop their vehicles. It shows that the execution of the framework can fulfil the needs and prereq- uisites of existing stopping issues along these lines minimizing the time it takes to discover empty parking garage, constant data ren- dering, and keen reservation components yet no execution metric is utilized as a part of testing the framework.

A car park observing framework utilizing wireless sensor network was presented in [14]. It utilizes different sensor nodes (equipped with a 3-axis AMR sensor) and a sink node, a gateway, and a server to monitor a parking lot. This system shows it reliability in energy usage since radio frequency (RF) transmission only occurs when sensor values show abrupt changes after being com- pared against each other. This reduces the quantity of RF transmis- sion operations and moderate battery power. While [15] proposed a street parking system (SPS) in light of remote sensor systems. The framework can screen the condition of each parking spot by deploying magnetic sensor node (utilizing a HMC5883L magnetic sensor), which recognizes the earth’s magnetic field intermittently along the roadside and every node mounted on the middle floor of a parking spot. Power utilization parity is accomplished by furnish- ing switches with sunlight based board for regular data forwarding. Also, an Intelligent Parking Lot Application Using Wireless Sensor Networks which utilizes both magnetic and ultrasonic sen- sors for precise and solid recognition of vehicles in a parking garage was proposed in [12]. This work depicts an adjusted vari- ant of the minmax calculation for recognition of vehicles utiliz- ing magnetometers, and a calculation for ultrasonic sensors. The work of [16] presents the outline and usage of a model arrange- ment of Smart Parking Services based on Wireless Sensor Net- works (WSN) that permit vehicle drivers to discover free stopping spots. The proposed plan constitutes a remote sensor system, in- stalled web-server, central web-server and an end client application i.e. a mobile phone application that allows vehicle driver to find vacant parking lots.

Furthermore, [7] presented a work on Smart Parking System using Wireless Sensor Networks that describes the implementation of an energy and cost efficient smart parking system for multi-level parking facility using wireless sensor network. The system moni- tors the availability of free parking slots and guides the vehicle to the nearest frees lot. In addition, it monitors other events such as the amount of time the vehicle has been parked for billing purposes along with the status of each mote. By keeping the number of sen- sors low, it minimizes cost. It also keeps the energy consumption of each mote in check by allowing the systems to sleep periodically and also by reducing the communication range of motes.

The system presented here seek to achieve remote parking lot detection, direction guide, correction of improper parking and enhanced performance in terms of system's response time and reliability.

3. SYSTEM DESIGN AND IMPLEMENTATION

The design of the system is presented here

3.1 Overview of System Architecture

The system consists basically of two (2) units: The Transmitting and Detection Unit and the Receiving Unit. These units are further divided into modules. The modules that make up the system are: WSN module, communication module, parking management and guidance module, entrance display module and client module. The block diagram of the system architecture is shown in Figure 1.

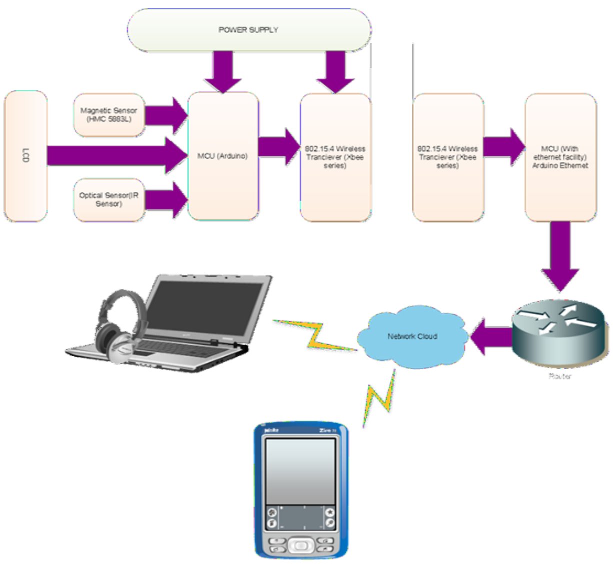

Figure 1. System Block Diagram.

3.2 Transmitting and Detection Unit

The transmitting and detection unit detects the status of the parking lot using sensors and sends the data to the receiving unit using a radio transceiver. The modules here include WSN module and the Communication module.

3.3 Receiving Unit

The receiving unit processes the data received from the transmitting and detection unit. It acts as the sink station and the gateway to the internet. The modules here include the communication module, the parking management, guidance and entrance display module and the client module.

3.3.1 WSN Module

The WSN module consists of a magnetic sensor (to measure physical parameter), an IR sensor (to detect improper parking), RF transceiver, a power source, processor and Arduino Fio. The WSN module is designed to specifically suit the parameters to be measured. The Xbee series 1, which is 802.15.4 enabled is used as the wireless transceiver.

3.3.2 Communication module

The communication module of the receiver unit functions to collect data from the sensor and process them to meaningful information to be forwarded to the entrance display module and client's module. The basic components here are Arduino Uno, which serves as the processor and Xbee radio which receives information from the transmitting unit.

3.3.3 Parking management, Entrance display and Guidance module

The parking management module is the program that is used in managing the parking lot by determining if a parking space is occupied or empty. It forwards its results to the entrance display and guidance module for it to be displayed on the LCD board. This module also contains the web server which hosts the website where information about the parking lot status is displayed on the internet.

3.3.4 Client module

Client module allows car drivers to interact with the system by querying the system for available parking space. This module consists of the parking application called parker and a website, which car drivers use to gain access to required information.

3.4 Hardware Design Considerations

3.4.1 Arduino Fio (Microcontroller)

The Arduino Fio microcontroller board (the heart of the system) is built on ATmega328P and operates on a 3.3V and 8MHz. It consists of 14 digital input/output pins (in which 6 function as PWM outputs), 8 analogue inputs, an on-board resonator. It also has a reset button and outlets used for fitting pin headers. It possesses connections meant for a Lithium Polymer battery and a charge circuit over USB with an XBee socket on the bottom of the board.

3.4.2 HMC5883L Magnetometer

The Honeywell HMC5883L designed for low-field sensing is a surface mount, multi-chip module. It has a digital interface used for applications such as low-cost compassing and magnetometry. HMC5883L has an advantage over other magnetic sensor technologies as it uses Honeywell's Anisotropic Magneto-resistive (AMR) technology. This sensor includes accuracy in-pivot sensitivity and linearity.

3.4.3 IR Sensor

An active IR sensor is engaged to detect improper parking. The sensor employs an infrared light source which projects a beam of light that is detected at a separate detector. IR sensor will be placed at the entrance of the park and detects if cars are parked well or not well parked. It has a range of 0 - 100 meters.

3.4.4 Xbee Radio

Xbee radio is a super-high radio which uses 802.15.4 protocol in creating a radio sensor network. These modules allow a very reliable and simple communication between microcontrollers, computers and systems with a serial port. It also supports point to point and multi-point networks. In this application, the Xbee Radio serve as the transceiver that has the capability to communicate with the Arduino Ethernet shield and the internet via a laptop or an android phone.

3.4.5 *LCD (Hitachi HD44780)*

The LCD unit which is referred to as the liquid crystal display unit is a flat panel display that works by passing a small amount of electricity through liquid crystal i.e. it uses the light modulating properties of liquid crystals to display for visual display. The Hitachi HD44780 is one of the most common LCD controller chips designed for embedded systems and microcontrollers. The chip supports many shapes and sizes of displays using the 16 x 2 display.

3.4.6 Arduino Ethernet Shield

The Arduino Ethernet is a microcontroller board based on the ATmega328. It has a 32kb flash memory of which 0.5kb is used for boot loader. The shield offers the capability for Arduino to communicates with world over Ethernet using common network protocols. For the purpose of this work, the shield serves as a web server listening to client requests and replying appropriately.

3.5 Software Design Consideration

C language was used in programming the Arduino Fio and Arduino Uno using sketches while the HMC5883L uses a kind of rhythmic serial language called I2C. Programs written and used for this work include: Sensing, Detection and Detection Unit code, Improper parking code, Receiving and Display Unit code, and Client Application Code.

3.5.1 Client Application Code Implementation

The client application is coded using Android Studio, an integrated development environment for developing android application. Figure 2 shows the application interface design layout in Android Studio

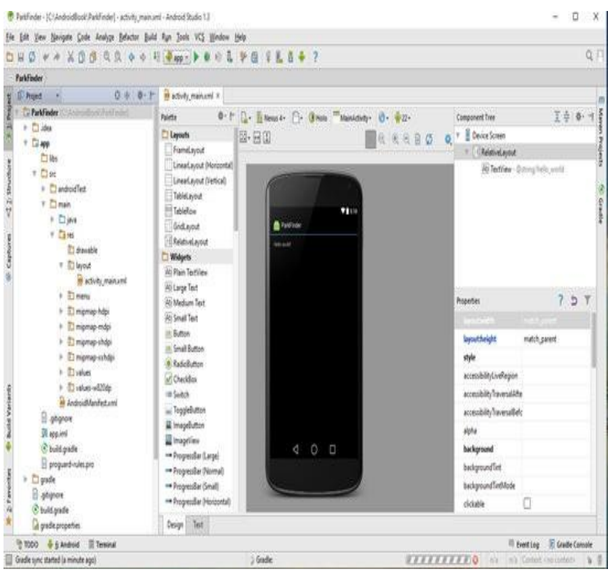

Figure 2. Application interface design layout in Android Studio.

The final Android based client's application is deployed on an Infinix Zero phone as shown in Figure 3.

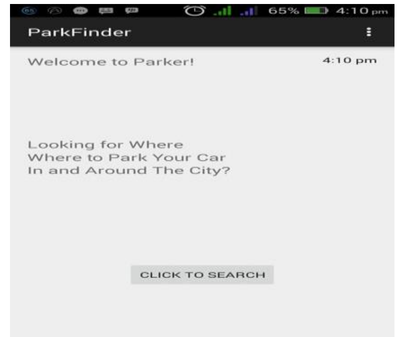

Figure 3. Final Application deployment screenshot taken from an Infinix Zero one phone.

3.6 Network Protocol Configuration

Star Network Topology is employed for this smart parking system. Owing to the fact that a star topology uses a central switch which acts as conduit to transmit messages and provides a common connection points for all nodes, it therefore introduces a single point of collision for all devices connected to it. This reduces the damage caused by failure of devices on the network ensuring that the failure of one device does not affect the entire network. The disadvantage of this system is that the failure of the central node results to failure of entire network. The network has the sensor nodes (source node i.e., the node that generates data) known as the router or end device. This forwards data to a sink which is a collection point where data is processed, stored, or forwarded onward to other networks via longer-range and higher-throughput wireless communications mechanisms. Arduino Ethernet shield serves the purpose of data aggregator, base station or gateway as can be seen in Figure 4.

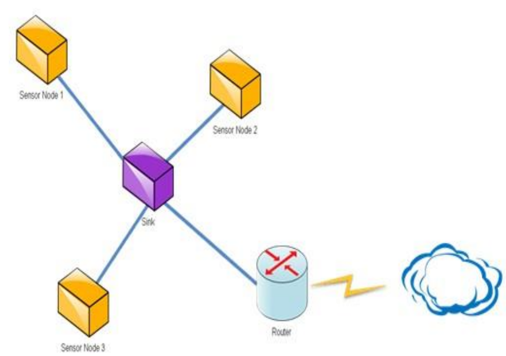

Figure 4. Parking Lot Sensing Network Topology Using Star Topology.

The flowchart of the processes and the operations taken to achieve the overall system implementation is depicted in Figure 5.

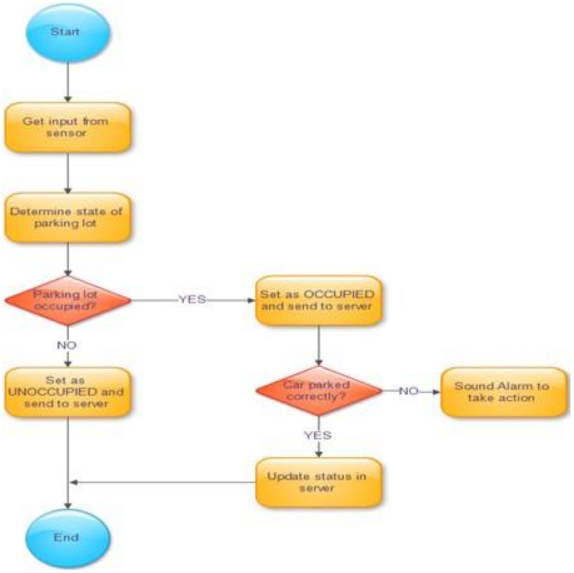

Figure 5. System Flow Chart.

4. PERFORMANCE EVALUATION

1.1 Magnetometer Sensitivity

The sensitivity of the prototype is carried out with respect to different geographical locations. The Magnetometer (HMC5883L) readings for six geographical locations obtained are shown in Table 1.

Table 1. Magnetometer Readings of different locations

Y(cm)	L1	L2	L3	L4	L5	L6
30	-377	-379	-378	-379	-376	-380
20	-381	-382	-383	-380	-381	833
15	-387	-385	-384	-384	-387	-387
10	-392	-390	-394	-393	-394	-393
5	-413	-412	-415	-416	-414	-415
1	-438	-438	-435	-438	-437	-436
0	-918	-916	-916	-917	-919	-917

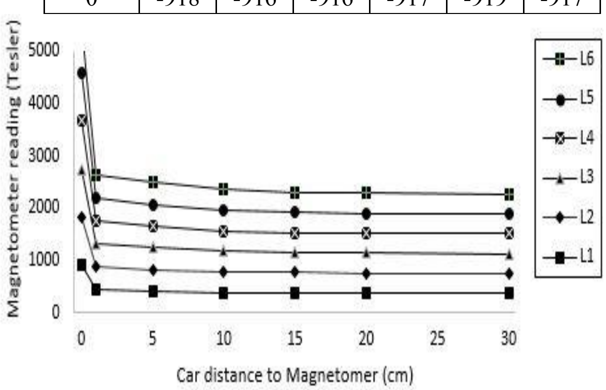

Figure 6. Magnetometer readings against car distance to prototype system.

1.2 Response Time

The response of the system is determined by the threshold set for the system and the corresponding output values using $V_0 = \sqrt{x}$. where V_0 is the output value and x is the distance in centimeters of the car to the prototype system. Thus, Setting the Threshold at 30 i.e. Th = 30, the response of the system is given in Table 2.

Table 2. System Response Interpretation

X (cm)	LCD Response	RGB Response	Interpretation
≥30	Available	Green	parking lot empty
20	Available	Green	parking lot empty
<20 ≥ 1	Available	Green	parking lot empty
< 1 ≥ 0	Occupied	Red	parking lot occupied

Five different trials done with the constant threshold value of 30 is given in Table 3. in each case the corresponding time of the system' response is recorded.

Table 3. System Response Interpretation

Tests	Time to respond (seconds)
1	1.87
2	1.26
3	1.28
4	1.39
5	1.27

Y is the distance of the car to the Magnetometer (our prototype) in centimeters; while, L1, L2, L3, L4, L5 and L6 are X-axis Magnetometer values in Tesler of different geographical locations. The normalized Magnetometer readings (scaled to 5 times the raw values for distinctive view) against the distances of the car to the prototype system is shown in Figure 6.

From Figure 6, it is noted that the magnetometer values vary depending on the type of metal and the magnetic declination of the geographic location. The sensor values equally give information about the status of the lot depending on the value it reads. At a distance of about 2cm to other higher values, it can be seen that lines in the graph maintain a constant slope meaning that,

The average response time of 1.414 seconds is achieved.

1.3 Web server concurrency

Web Server Concurrency is to evaluate the number of concurrent users the web server can serve at the same time. The goal of this evaluation does not concern how fast the website is or how the website scales. For concurrency evaluation, it is evaluated on hourly basis.

the magnetometer values do not change because, no change is detected in the condition of the parking lot. It can also be seen that between 0cm to 1cm, the curves show sharp changes, with highest magnetometer readings which means that a car has been detected in the lot causing fluctuations in its readings. These Magnetometer readings are used to adjust the lighting system of the lot which is interpreted as green for available and red for occupied. Thus, for this work, the Magnetometer readings between 0cm and 1 cm are interpreted as occupied lot and while, the Magnetometer reading between 2cm and 30cm are interpreted as empty lot.

1.3.1 Web server concurrency Analysis

Data collected for three days during the system's deployment are given in table 4. This shows that from the local deployment of the system, three number of users can be served concurrently by the web server. However, this result does not formalize the value of concurrent users for any public deployment of the system as that was not carried out.

Table 4. Web server Concurrency Test Result

Days	Visits/min	Visits/hr	Average Time spent min	Average concurrent user
1	1	12	1.5	0.30
2	3	6	2.5	0.25
3	2	7	2.3	0.26

5. CONCLUSION

The development of a Wireless Sensor Network based smart parking system to efficiently address the issue of car parking has been presented. WSN ensures that data are being forwarded and routed to the base or sink station wirelessly, where the data is further processed. Testing and evaluation of the developed system has shown that server concurrency utilization of averagely three users per minutes and fast response time of about 1.414 seconds guarantees the robustness and efficiency of the system. However, the following future directions are recommended for more effective and efficient system:

- System can be made intelligent to read magnetic reading differ- ence of an area and automatically adjust itself to the reading.
- The system can be integrated with database that stores details of car drivers e.g. face, name, type of car etc. for security purposes.
- Payment solution can be integrated into the system and reserva- tion of parking space.
- A mesh-based WSN topology can be employed in the system to ensure scalability

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