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MAC ADDRESS BASED SMART PARKING PROTOTYPE USING SOLAR CELL

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ABSTRACT

When entering a parking building, parking management cannot guarantee a parking space to a driver. Many times a driver wastes his time to find one free space. This leads to waste of fuel, congestion, and frustration for the driver. This paper presents a prototype of a parking system that enables a driver to reserve a parking space using an application. MAC Address from driver's device used as an identifier and extracted using Airodump-ng. Parallax PING sensor is used at the parking space to detect the presence of a car. An Arduino is used as a microcontroller to control the system. Solar panels are used to provide power for the system. This system helps a driver to reserve a parking space before he enters the building, provide certainty to the driver and eliminating the time needed to find a space.

Keywords: parking, reservation, MAC address, parallax PING, solar panel.

INTRODUCTION

In this day when public transport cannot offer safe and comfort service, personal transport became more than the alternative. When the price of cars and motorcycles turn to the more affordable point, it raises problems. One problem is the limitation of parking space. In a big city on rush hour, finding a parking spot becomes more and more difficult. Due to the rapid increase of vehicle, parking on the road side is not permitted anymore. When entering a parking building or parking area, a driver actually does not know whether he could get a spot or not. He must find the empty space to park. Sometimes a driver must search one free spot for a long time. Many times they face disappointment because the parking is full. Many complaints filed by drivers damaging reputation of the parking management. Fuel was wasted, and for the driver, this causes frustration. In this paper, we present a parking system so a driver can spot an empty space and make are servation before he enters the parking building or parking area. In brief summary, sensor scans parking space for physical changes and detects if space is free or occupied. The map of parking area then updated. Two options are available. For a registered driver, he can choose where he wants to park and makes are servation using his wireless device. Verification for the registered driver is done by comparing MAC address from driver's device with a database. For the non-registered user, he can make are servation for space when he arrives at the parking gate, using a terminal. When a driver makes areservation, the system updates the status of the space. When the car arrives at reserved space, the sensor will verify the status. When a vehicle leaves, sensor then updates the status of the space to free, so it can be used for another driver. This system uses solar panels for the power source, so it can operate independently.

Previously, we compare sensors performance at different placement to detect a car in parking space (Mutiara, Agung, & Handayani, 2015). Tang proposed wireless sensors to monitor parking space (Tang, Zheng, & Cao, 2006). Noor Hazrin proposed a smart parking system using SMS and micro Remote Terminal Unit (Hanif, 2010). Wang proposed parking system that enables thedriver to reserve an empty space. The sensor was used to periodically scan changes of the physical parking status to determine empty spaces (Wang & He, 2011). Piotr and Jaroslaw proposed parking reservation system using Unstructured Supplementary Service Data (USSD) (Trusiewicz & Legierski, 2013). Rahayu proposed parking reservation system for GSM users using SMS, along with the password to enter and exit the parking lot (Rahayu & N. Mustapa, July 2013). K. Sushma *et al.* proposed parking reservation using Short Message service (SMS) and RFID (Sushma, Babu, & Reddy, Sep-Oct 2013). V. Venkateswaran proposes a parking reservation system along with barrier gate control security system through the internet in an urban environment (Venkateswaran & Prakash, Feb. 2014). Karbab proposed car park management system using networked wireless sensors and RFID as an identifier(Singh, Anand, Kumar, & Sharma, May 2014). Patil proposed parking reservation using QR Code to simplify parking operation and to minimize traffic caused by parking searching (Patil &Sakore, Smart Parking System Based on Reservation, June 2014). Annosha proposed a car parking system using shared memory concept (Annosha S, S., Sivambiga, & Soundarya, 2015). Singh used driver's Bluetooth device to identify vehicle and register parking (Karbab, Djenouri, Boulkaboul, & Bagula, 2015). Shaikh compared the performance of various parking reservation technique (Shaikh, B.S., Kulkarni, Jadhav, & Saideep, October 2015). Ramya uses sensors to find available parking space as parking solution (Ramya & Ravi, April 2016). Baratamproposed an IOT-based car parking management prototype using RFID, IR sensor (Baratam & Rao, May 2016).

PROPOSED SYSTEM OVERVIEW

For every spot available, a Parallax PING (PING) sensor is used to periodically detect a physical change in the parking space. These sensors located on the ground (below the car) and connected to Arduino, which is used as a microcontroller to process the signal.

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The system architecture can be seen in Figure-1, while diagram of the proposed system is described in Figure-2.

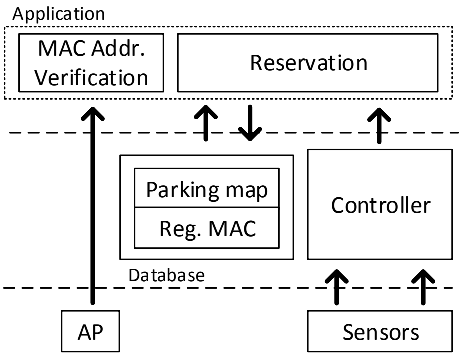

Figure-1. System software architecture.

The position of the sensor can be seen in Figure-3. Arduino then connected to a server, which acts as a server for the database and hosting the parking application.

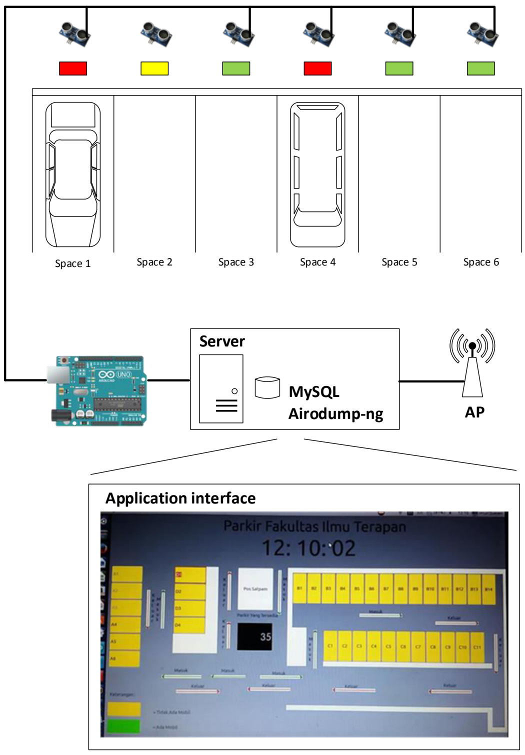

Figure-2. Schematic diagram.

The application is built as an interface to show the map of the parking area, also as an interface for the unregistered driver to make a reservation. This application is built using Gambas, an object-oriented language for BASIC programming language. For the database, we use MySQL.

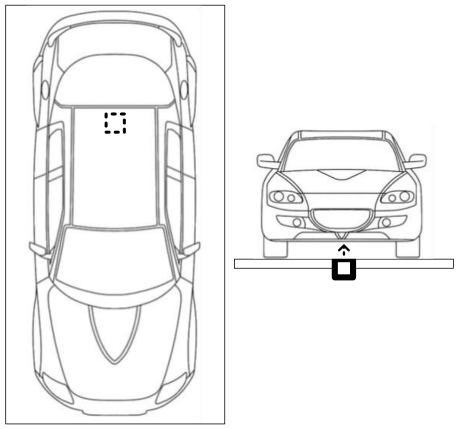

Figure-3. Sensor placement.

The server is connected to an Access Point, which is used by the driver to connect his mobile device. To obtain the device's MAC Address, we use Airodump-ng tool. This tool scans connected clients at the specific access point and extracts their MAC Address.

Entrance scenario

When a registered device connected to building access point, a driver opens the parking application, finds an empty space and makes a reservation. For unregistered users such as guest, the driver can use a terminal at the parking gate, to find an empty space and make a reservation.

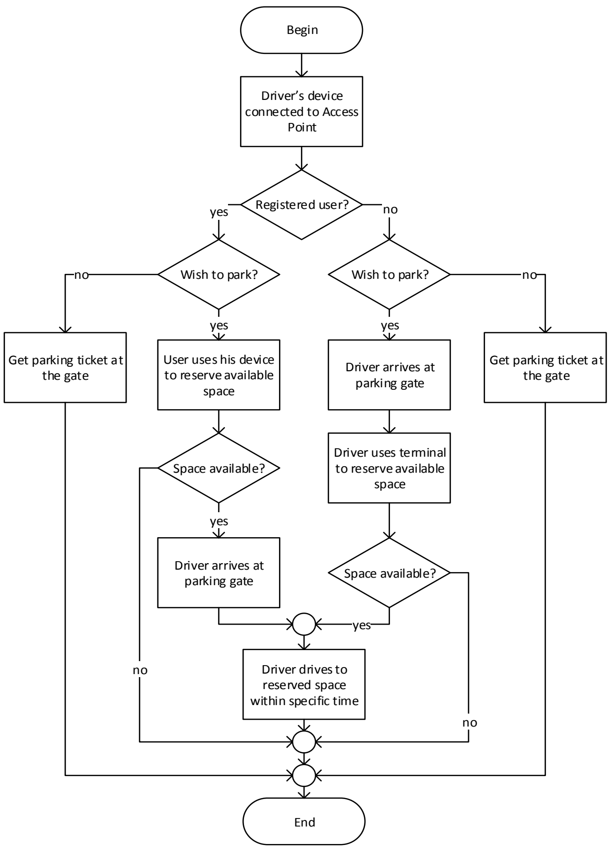

Figure-4. Parking entrance.

After the driver makes a reservation to specific space, he must arrive at a specific time, to avoid expiration on the reservation. This time can be adjusted according to traffic situation inside the parking building. If the driver failed to arrive in specific time, he must exit and repeat the process. Reservation will be dropped and space can be reserved by another driver. If the driver manages to arrive in time, he can occupy the space.

Many parking building or area is integrated with business or residential area, not dedicated only for parking. If a driver enters the parking space but does not want to park (for example to pick up or drop off), he can bypass reservation scheme but still, the driver needs to get a parking ticket at the entrance gate. Figure-4 shows flowchart for parking entrance scenario.

Exit scenario

When a car exits the occupied space, the sensor will detect the changes. To avoid reserved space accidentally released, a timer can be used. If the car enters the space again before the timer expires, space status will not be changed. This scenario accommodates a driver who needs to get out of the space because he wants to correct his parking, for example.

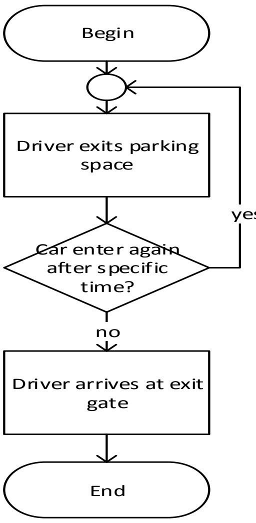

Figure-5. Exit flowchart.

When a car does not re-enter the space after a specific period of time, the system will assume that the driver exits the space permanently, and the system will release the reserved space. Figure-5 shows exit flowchart for the driver.

Parking status sequence

There are four statuses for one parking space, three normal statuses, and one ERR status. At first, all spaces are set to 'free' (green). When a driver reserved a space, the system will change the status to 'reserved' (yellow). Counter then started. If the driver arrives at the reserved space before the timer runs out, status for that space is set to 'occupied' (red). If the does not, the system will drop the reservation and the status will be set to 'free'. Sensor periodically scans for changes at the parking spaces. If the sensor detects car's absence for a period of time, the system will assume the car exits the space, and status for that space will be set to 'free'. However, if space is not reserved and the sensor detects a vehicle, an 'ERR' status will be set to identify wrong parking. Parking status flowchart can be seen at Figure-6.

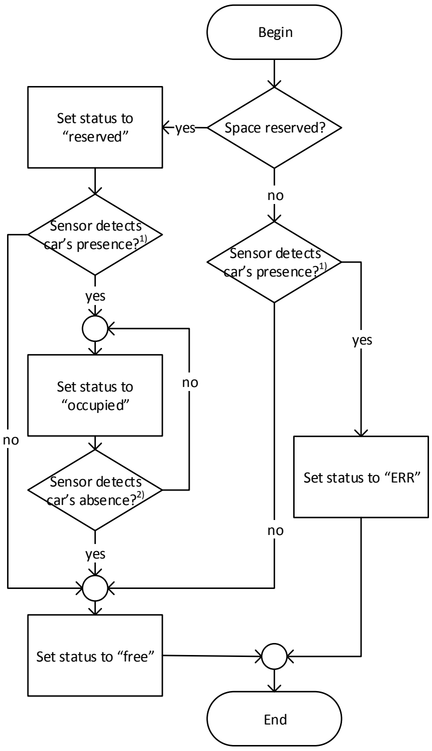

Figure-6. Parking status flowchart.

Parallax PING sensor

Parallax PING is an ultrasonic sensor that operates at 40 kHz. This sensor operates at 5 volts DC using 30-35 mA current.

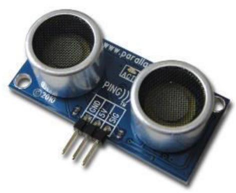

Figure-7. Parallax PING sensor.

At relatively small in size, this sensor can be easily concealed (Parallax, Inc., n.d.). When located this at the bottom of a car or above a car, the sensor can detect a car from 10 to 150 cm (Mutiara, Agung, & Handayani, 2015). This sensor can be seen at Figure-7.

Wireless LAN

Wireless LAN standard approved by IEEE in 1997 and known as 802.11. This standard consists of a set of media access control (MAC) and physical layer (PHY)

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needed to implement a wireless access network. Since 1997, there are various version of this standard, 802.11a, 802.11b (both released in 1999), 802.11g (released in 2003), 802.11n (released in 2009), 802.11ad (released in 2012) and 802.11ac (released in 2013) (IEEE). These versions have different characteristics, such as in frequency used and bandwidth, thus affect the data rate and range for each standard (IEEE Computer Society, 29 March 2012).

When a source sends data to a destination, it is sent in packets. Figure-8 shows packet structure used in 802.11 standards.

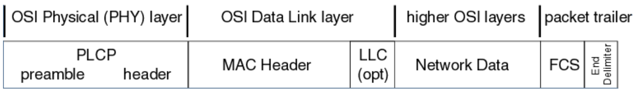

Figure-8. 802.11 Packet structure(Savvius Inc.)

Every packet contains its source and destination address. These addresses located at the MAC Header inside a packet. Figure-9 shows the structure of a MAC Header inside a packet.

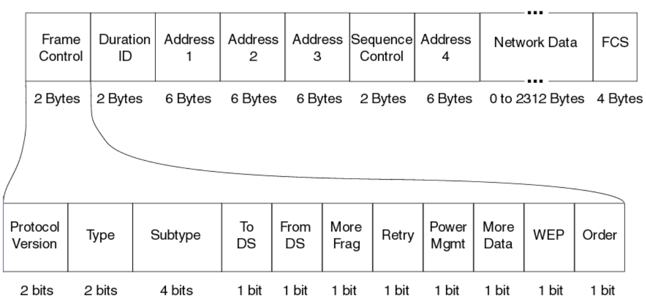

Figure-9. 802.11 MAC header(Savvius Inc.)

There are four address fields inside a MAC Header. Each address field contains a 48-bit address. Some packet may not contain all these four addresses. Those addresses may contain the basic service set identifier (BSSID), source address, destination address, transmitting station (STA) address, and receiving STA address.

- The value of BSSID field is the MAC address currently in use by the STA in the access point of the BSS.
- The Source Address field contains MAC address of an individual where thepacket is originated.
- The Destination Address field contains MAC address of individual or group of the packet's final recipient(s).
- The Transmitting Station Address field contains a MAC of an individual address that identifies the STA that has transmitted.
- The Receiving Station Address field contains a MAC address of an individual or group that identifies the intended immediate recipient STA(s), for the information contained in the frame body field.

Airodump-ng

Airodump-ng is an application that is used to capture raw wireless LAN (802.11) frame packet. Airodump-ng scans devices connected to a specific access point and extracts their MAC Address. Before using the application, the airmon-ng script should be running to enable monitoring on wireless interface (Aircrack-ng, n.d.).

~# airmon-ng start wlan0

After monitoring is started, alist of devices' MAC Address that is connected is extracted and saved to a file.

~# airmon-ng start wlan0
~# airodump-ng -w macaddrfile --bssid C0:C2:A0:E2:7D:A0 wlan0mon

Sample result for the command above will be as follow.

CH 3][Elapsed: 15 s][2016-06-06 09:22
BSSID PWR Beacons #Data, #/s CH MB ENC CIPHER AUTH ESSID
C0:C2:A0:E2:7D:A0 -27 12 0 0 6 54e WPA TKIP PSK Smart
BSSID STATION PWR Rate LostFrames Probe
C0:C2:A0:E2:7D:A0 D8:7F:2A:22:AB:32 -44 0 -54 09

Solar cell

To power the system, we use solar cell. For the setting, we use three 100w solar panels, arranged and faced to north direction with 5°-10° inclination

Figure-10. Solar panel arrangement.

This arrangement ensures that the panels, as shown in Figure-10, receive sunlight throughout the day. Two 100Ah batteries used to store the electricity also served as a backup. This ensures the system can operate 24 hours a day, in various weather conditions.

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Table-1. Solar panel specification.

Characteristic	Value
Maximum Power at ST (P_{max})	100Wp
Maximum Power Voltage (V_{mp})	18V
Maximum Power Current(I_{mp})	5.73A
Open Circuit Voltage (V_{oc})	19.05V
Short Circuit Current (I_{sc})	6.09A
Cell Efficiency	17.90%
Module Efficiency	15.04%
Size of Module (mm)	1000*665*30
Solar Cell	156*104
Number of Cell	36 pcs
Weight	7.13 kg
Power Tolerance	0~+3%

Power from the panels then inverted to 220 VAC by an inverter to power the server, Arduino and an access point. Table-1 shows specification of the solar panels used in this work and Table-2 shows specification for the battery.

The power scheme was tested in various conditions, sunny day, overcast and heavy rain. This arrangement can provide power for the system, and have enough reserved power from the battery.

Table-2. Battery specification.

Characteristic	Value
Nominal Voltage (V)	12
Capacity (Ah)	100
Internal Resistance (M)	5
Dimension	330*171*220
Terminal Type	T9
Terminal Position	C
Weight (kg)	32

Server

For the server, we use Intel® NUC5CPYH mini PC. This model was chosen because it has a compact size, affordable yet can deliver enough processing power to the system's server. More specification about this PC can be seen in Table-3.

Table-3. Server specification.

Component	Specification
Processor	Celeron N3050 1.6 GHz
Memory	2 GB DDR3L
Network Connectivity	Wired: 10/100/1000 Mbps Wireless: IEEE 802.11abgn, 802.11ac, 802.11d, 802.11e, 802.11i, 802.11h, 802.11w compatible

TESTING AND RESULT

The prototype was tested at School of Applied Science (Fakultas Ilmu Terapan, Universitas Telkom) parking area. Figure-11 shows the testing area. Green bars represent parking space available, while Purple Square represents the location of the microcontroller and the server. The system was tested using a one-entry, one-exit scenario. Parking gate is located at the main entrance of the complex. An access point located near main parking gate.

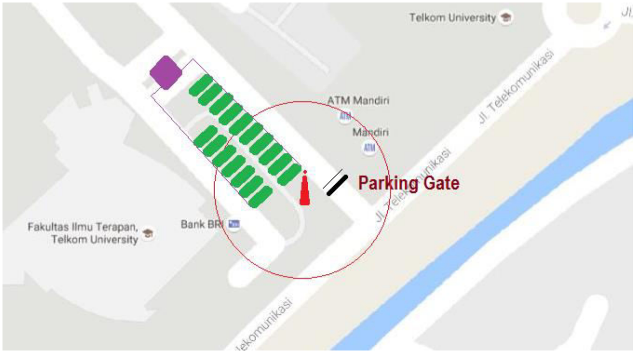

Figure-11. Testing location (Google Maps).

In the testing scenario, the distance between parking gate and parking spaces varies from about 100 to 150 meters (328 to 492 ft.). Time needed to drive is about 2 to 5 minutes, at normal speed. We set expiration time between reservation and arrive at reserved space to 5 minutes, and expiration time for exiting the space to 30 seconds.

Table-4. Connection testing result.

Scenario	System response
Device with unregistered MAC Address reserves a space	Request denied
Device with registered MAC Address reserves a space	Request granted

Table-4 shows testing result for requests made from the driver. Table-5 shows testing result for various parking scenario.

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Table-5. Reservation testing result.

Scenario	Parking space state
Driver reserves a space, enters before timer expires	reserved → occupied
Driver reserves a space, enters after timer expires	reserved → free
Driver exit his space, re-enter before timer expires	occupied → occupied
Driver exit his space, re-enter after timer expires	occupied → free
Driver does not make reservation, enters a space	free → ERR
Driver exit his space, another car enter before timer expires	occupied → occupied

CONCLUSIONS

From the testing result, a driver with the registered device can spot a free space and make a reservation before he enters a parking area. Guests, along with other drivers with theunregistered device also can spot a free space and make a reservation using a terminal at the parking gate, before he enters the parking area. This system saves the time needed to find a free space and ensure the availability of a parking space before entering the area. Since the verification based on registered MAC address, a driver can make a reservation with a different car every time he enters the parking area, as long he brings the registered device. The system can also record drivers' parking history that can be used for security or other purposes. For the parking management, this can reduce complaints. When necessary, parking management can also set the billing scenario. Billing can be set to start when the driver made a reservation, or when the car arrives at the parking space. Billing can also be set to end after car leaves the space, or when it arrives at the exit gate. Much further, management can put different price for different space, based on driver's preference history. Automatic electronic billing can also be implemented to avoid queue at the exit gate. Reservation via the internet can also be implemented for better flexibility. For large parking area, guidance from the entrance gate to reserved parking space, as well from the parking space to exit gate can be added to provide convenience for the driver. This can use GPS or mobile signal. This system can be used for multiple-entry, multiple-exit parking, as well with multiple story building.

This system, however,has several limitations. A verification scheme is needed to ensure the right car occupy the reserved space. This can be achieved by sending the identifier to registered driver's mobile device, such as a password or QR Code. Combined with security gate, this code can also be used as a security code, later to be used by the driver to enter and exits the reserved space. Drivers with unregistered device or guests can have this code printed after he makes areservation at the parking gate, or sent to his device using SMS. The current system accommodates when the driver enters a parking area and he does not want to park (for example to pick up or drop off). But when he changes his mind after he enters the gate, a scheme must be added to accommodate this change. For a registered driver, he can use his device to make further registration, but for the unregistered driver, we suggest to install a terminal inside the parking area so he can make a reservation there.

The implication of this research is, smart parking system will change the way park. This includes how we make reservation, security system at the parking space (and the parking building) and also payment method. With smart parking system, fairness for both the management and the drivers can be achieved, and more environmentally friendly.

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