# Implementation of Low Resource Parking Information System Prototype Based on Wireless Sensor Network

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***Abstract***—In everyday life, humans need vehicles to support various activities. One thing that must be considered is the issue of parking availability in public places such as office buildings, campuses, shopping centers. In the previous technology, a parking system using automatic hydraulics was made. However, it requires a complex construction. In this study, a wireless parking availability information system was developed. This system is built using a ZigBee communication network. The installed low-cost light sensor will detect the presence or absence of a car occupying a parking slot. Then every driver who enters the parking area can find out information on parking availability. Based on the test results, the system can automatically provide information related to the status of the parking lot (filled or empty) with a sensor threshold (light intensity) of 153 cd. The maximum delay generated by the system during testing is 2.518462ms. The optimal data transmission distance is 40 meters.

***Index Terms***—Parking system, wireless, ZigBee, information

## I. Introduction

The development of parking equipment technology began in the early 20th century. The rapid growth in the number of vehicles in densely populated areas makes it difficult to find parking spaces in public areas. According to [1], citizens looking for a parking space by walking around the parking area to find a space takes an average of 7.8 minutes. The vision-based monitoring system calculates the number of available empty parking slots based on the number of vehicles entering and leaving [2]. This results in wasted time, increased fuel requirements, air pollution, and even stress on the driver. This problem encourages researchers to develop parking technology to improve their services. On the other side, the rapid advancement of information and communication technology allows the application of smart cities to provide convenience to residents [3]. One of the technologies that can be developed in smart parking system applications is wireless sensor network (WSN). This technology may consist of a number of sensor nodes [4], with the function of supervising [5].

Several studies use sensors to develop a parking monitoring system [6]-[13]. The reason is the low cost of implementation and maintenance. Sensors can detect the presence of an object. In the parking system, problems are often encountered, especially the availability of parking spaces. Rahman Atiqur implemented an ultrasonic sensor, raspberry pi 4, a WiFi module, and a led to getting an empty parking spot. This intelligent parking system provides faster search times and shorter distances than existing parking systems [9]. In [10], parking system was built to provide information on the availability of parking spaces in real-time so that customers can book slots through a mobile application. This system is integrated between ultrasonic sensors that function to detect the presence of cars with IoT. Another study [11] incorporates GSM module, RFID card, IR sensors to reduce parking time searching. The customer must have an RFID card containing customer data. When the customer scans the RFID, the available parking space information will be sent via the GSM module. Information is obtained from IR sensors placed in the parking lot. In research [12], low-cost parking based on IoT modules was implemented on-site to manage available parking slots, and a platform for booking parking spaces was also created. This system consists of IR sensors, ultrasonics, and Raspberry Pi 3. Akash Gupta et al. presented a smart parking feature to get free parking locations in the city. This system is built with ultrasonic, RFID, and Rasberry Pi B+ sensors that can find the nearest parking space based on the occupied parking slots [13].

Several researchers designed a smart parking system using technology based on a WSN [14]-[18]. In [14], the authors built a new architecture of smart parking systems based on different technologies, such as WSN, IoT, RFID for outdoor city parking areas. Research [15] adds Ad hoc technology and security features to its smart parking system. The smart parking system uses wireless sensors connected via WiFi and Low Power RF transceivers. In addition to finding the location of empty parking spaces, this system also provides RFID-based payments [16]. Research [17] implemented a low-cost parking space monitoring system using a wireless sensor network based on IPv6, using the 6LoWPAN protocol, a cloud-based management system, and photoelectric sensors. Sensors are placed at the entrance or exit of the parking lot to detect the entry and exit of vehicles. The detection results are sent to nodes that will communicate wirelessly to a central management server for processing or distribution over the Internet. Antoine Bagula et al. developed a smart parking infrastructure by placing sensors to detect the

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presence of cars in the parking area and RFID readers embedded in parking gates to identify cars and calculate bills [6].

In areas with limited parking areas, a hydraulic automatic parking system has been developed. However, the parking system still has weaknesses, including complicated installation and high costs [18], [19].

Therefore, this study developed a detection and monitoring system for parking space availability based on a wireless sensor network using a mesh topology. The node detector in the form of a low-cost sensor will detect the presence of a vehicle which will then automatically send it to the database. This sensor connects nodes with one another that is installed in each row of a predetermined parking location. The sensor data is then sent to a PC as a server for further display at the parking area gate.

## II. Model Implementation

### A. System Design

In this study, the developed parking monitoring system consists of main components, including sensor nodes, transmission, and control unit. The sensor node is in the form of a Light Dependent Resistor (LDR), which reads the intensity of light in detecting the presence of a car. Data transmission between sensor nodes and central coordinator using ZigBee. Fig. 1 shows in detail the proposed system. The transmission medium in this system uses a 2mW XBee as a transceiver. The selection of the ZigBee module is considered appropriate because data is sent by the sensor node to the server only if the area is filled with vehicles. Power efficiency is also a consideration because the ZigBee module allows for a sleep mode when it is not active in sending and receiving data packets.

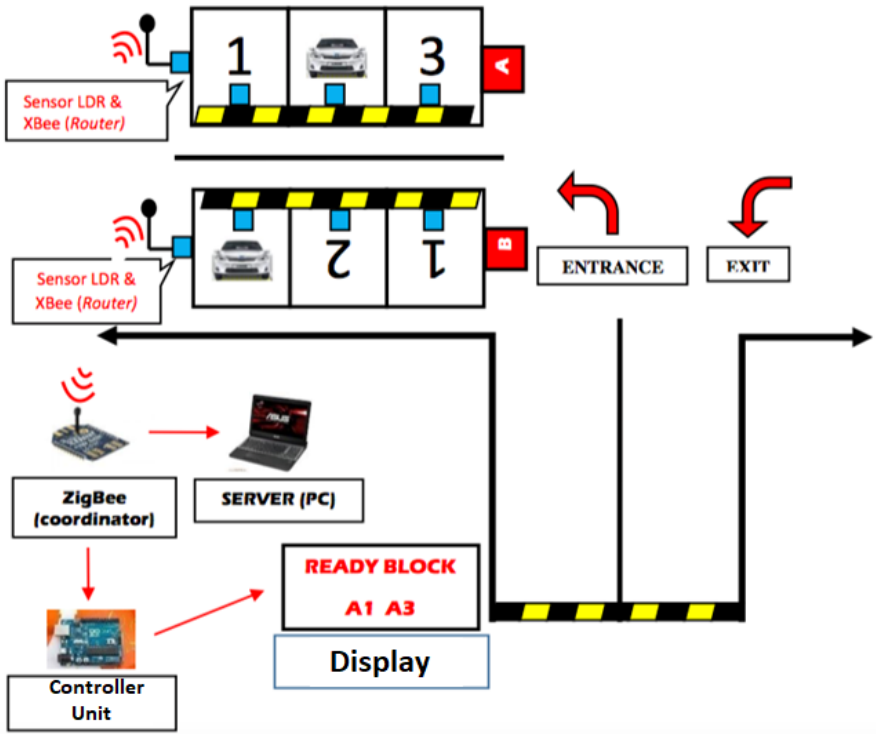


Fig. 1. Design of the proposed system

This system provides information to make it easier for car drivers to find parking spots. The LDR sensor is installed in each car park row slot. As shown in Fig. 2, the sensor's placement is proper in the middle of the parking lot. Moreover, the light in the parking area is right above the sensor. If there is a car parked in a spot, the sensor reads if there is a change in light intensity. This is a signal that is sent to the main control for calculation and then displayed on a 32x16 dot matrix display. Every car driver who enters the car park area will be given information on the parking slots that are still available. The resulting display on display is in the form of running text that provides information on where car drivers can park their vehicles. Sensor nodes installed in each row of parking locations are interconnected with each other to form a network with a mesh topology.

### B. System Architecture

Fig. 2 illustrates the proposed system consisting of sensor nodes to detect cars parked in blocks A1 and A2. There is also a microcontroller at the sensor node to process data and send information to the coordinator node.

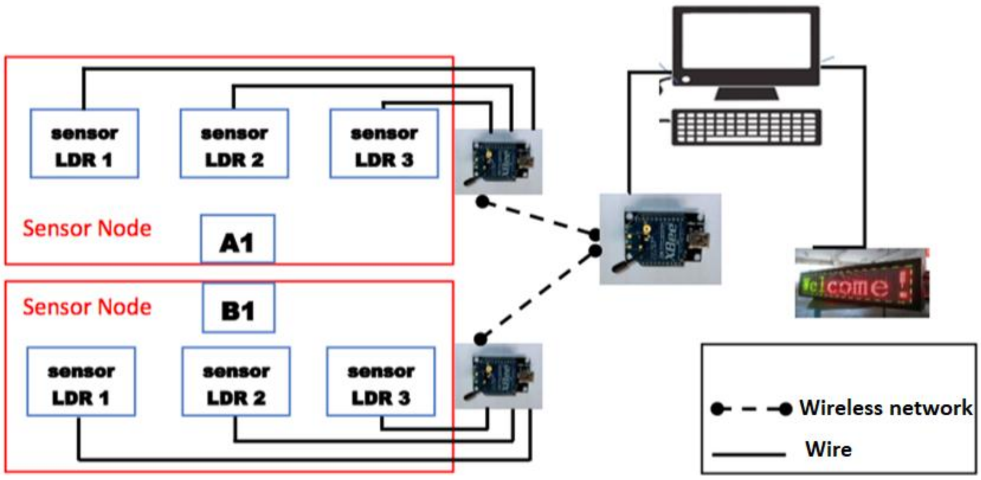


Fig. 2. System architecture

Fig. 3 shows how the system works. The data received by the XBee coordinator is processed in the main control unit to display the available parking areas. The sensor side consists of 3 LDRs installed in parallel and then connected to one XBee that acts as a router. The LDR sensor will detect the presence of a car; that is, if the A1 parking block is occupied by the first car in row 1 and covers the LDR 1 sensor, the dot matrix display will show parking availability information with the status of two empty parking rows available. If the second car enters and occupies row 2 and covers the LDR 2 sensor, then the dot matrix display will show parking availability information with the status of the available one line that is still empty. The last condition is if the third car enters and occupies row 3 and covers the LDR 3 sensor, then the dot matrix display will show parking availability information with full parking status. After that, it shows the availability of the following parking block, namely block B, C, D, and E.

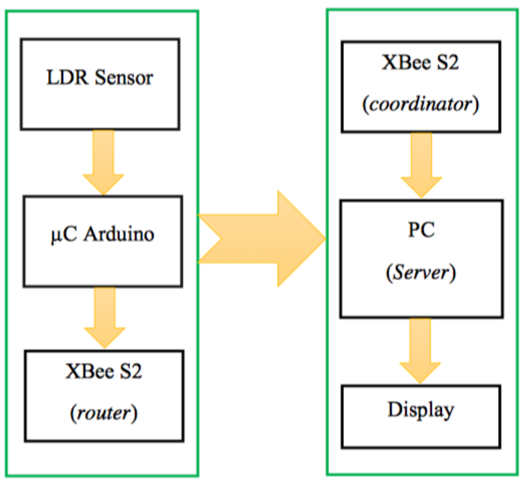


Fig. 3. System workflow

## C. *Performance Test Scenario of the Proposed System*

Tests are carried out on the system, both for each module and the whole system. This is intended to test the accuracy of the system's data and test the performance of the wireless sensor network used in this system. The test includes the sensor threshold test, RSSI level test, and transmission delay.

Threshold sensor testing aims to test and analyze the accuracy of the sensor by determining the limit value read by the sensor so that data can be sent to the router. This experiment tested and set the threshold (minimum limit) of sensor data that is read to ensure accurate reading of car objects. This is because the LDR sensor has a resistance value depending on the intensity of the light it receives. The LDR resistance value will decrease when the light is bright, and the resistance value will be high when it is dark. So, we need a threshold to limit the lower limit of the black level of light intensity that the sensor reads. The design of this system test serves to ensure that there is no error in the data read by the sensor, causing incorrect information obtained by parking users. The last stage is to determine the threshold as a comparison to the data read by the sensor so that the system can produce accurate information. The illustration of this test is shown in Fig. 4.

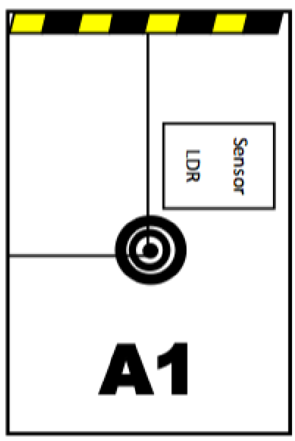


Fig. 4. Sensor placement

The RSSI (signal strength) level test aims to analyze the RSSI generated by the system network in order to determine the optimal distance between the sensor node and the data receiving computer. For testing purposes, the parking plan, which is divided into three distances, is tested, including 10 meters, 20 meters, and 30 meters. Meanwhile, the delay test aims to test the delay generated by the network during the data transmission process. The data is sent 15 times as a reference, and the distance between nodes is 10 meters, 20 meters, 30 meters, 40 meters, 50 meters, and 60 meters.

## III. Results and Discussion

The prototype was implemented and tested in the basement parking area of an electronics center building in Bandung, Indonesia, as shown in Fig. 5 and Fig. 6. It is hoped that this implementation will get actual field conditions. Tests of data transmission for transceivers with different floor conditions were also carried out. Details of the test results and analysis of each scenario are discussed in the following subsection.

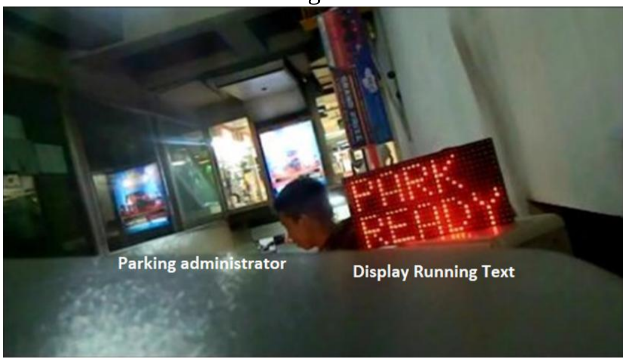


Fig. 5. Parking space status


Fig. 6. LDR sensor placement

### *A. Threshold Sensor Test Results*

The test was carried out with actual conditions in the basement parking area. Sensor data is taken when the parking lot is filled and the parking lot is empty. The goal is to determine the threshold of the range of conditions so that the sensor can be used to detect cars. The value of light intensity in Candela (cd) units is then compared with the value of digital AD conversion (ADC) with a resolution of 10 Bit (0-1023). A higher ADC value represents low light intensity. The test results are presented in Table I.

TABLE I: COMPARISON OF LIGHT INTENSITY TO ADC VALUE

| Test | Light Intensity (cd) | | ADC value | |
|---|---|---|---|---|
| No. | Empty | Filled | Empty | Filled |
| 1 | 155 | 78 | 405 | 704 |
| 2 | 155 | 80 | 405 | 700 |
| 3 | 155 | 79 | 405 | 704 |
| 4 | 154 | 79 | 400 | 704 |
| 5 | 154 | 79 | 400 | 704 |
| 6 | 153 | 88 | 400 | 696 |
| 7 | 153 | 77 | 397 | 708 |
| 8 | 153 | 51 | 397 | 750 |
| 9 | 154 | 51 | 400 | 750 |
| 10 | 154 | 51 | 400 | 750 |
| 11 | 152 | 50 | 395 | 750 |
| 12 | 151 | 53 | 390 | 740 |
| 13 | 151 | 61 | 390 | 745 |
| 14 | 152 | 63 | 395 | 745 |
| 15 | 152 | 63 | 395 | 745 |
| **Ave.** | **153.2** | **66.87** | **398.27** | **726.33** |

From this test, it is known that the average value of light intensity when the parking spot is filled is 66.87 cd with an average ADC value of 726.33. Meanwhile, in the empty condition, it is known that the average value of light intensity is 153.2, with an average ADC of 398.27. These results indicate a significant difference in ADC values between the conditions of the filled parking spots and the empty parking spots. Then these results become the basis for setting a threshold in detecting cars. In this system, if the ADC value > 600 indicates a parked car. In addition, it means that there are no parked cars. Then an objective test is carried out where the system generates 100% accuracy in detecting cars that are parked or leaving the parking lot.

### *B. Delay Test Result*

This test is conducted to measure the delay of the system network. This test is to observe the effect of distance on transmission time. The scenario for placing the sensor nodes and the main control system is in accordance with the parking plan in Fig. 2. Each distance scenario is sent 15 data with the router and coordinator distances being 10, 20, 30, 40, 50, and 60 meters. The test results are presented in Table II.

TABLE II: DELAY TEST RESULTS

| Dist. (m) | Average Delay (ms) |
|---|---|
| 10 | 1,061,538 |
| 20 | 1,596,923 |
| 30 | 2,062,963 |
| 40 | 2,518,462 |
| 50 | RTO |
| 60 | RTO |

*RTO: request time out

From the test results, as shown in Table II, the maximum system delay is 2.518462 ms at a distance of 40 meters. The maximum transmission distance (indoor range) achieved is similar to the actual study reported in [20] and the technical specifications of the XBee datasheet [21]. Based on the delay, the network quality is suitable for real-time system requirements refers to ITU-T standard [22]. Meanwhile, for distances greater than 40, the coordinator node does not receive data. So that, if the system desired to send data with a distance of more than 40 meters, a router node is needed to relay the transmitted data.

### C. RSSI Level Test Result

The RSSI test of the transceiver system according to the parking design as shown in Fig. 2. According to the scenario, each distance between the transceivers and the test is carried out by sending 15 data at parking distances of 10, 20, 30, 40, 50, and 60 meters. RSSI level testing is carried out using the "XCTU" application. The test results are presented in Table III.

TABLE III: EFFECT OF DISTANCE ON RECEIVE LEVEL AND SUCCESS TRANSMISSION RATE

| Dist. (m) | RSSI (dBm) | Success Rate |
|---|---|---|
| 10 | -42 | 100% |
| 20 | -64 | 100% |
| 30 | -72 | 85% |
| 40 | -88 | 80% |
| 50 | -100 | 0% |
| 60 | -105 | 0% |

From the results of testing the effect of distance on RSSI as shown in Table III, it is known that the maximum distance at which data can still be received is 40 meters with an RSSI level of -88 dBm. This is like the results of the delay test. At a distance greater than 40 meters, the transceiver can still communicate, but the error generated is so large that the information is corrupted. For the floor, difference measurements are also carried out in this test. The transceiver module is entirely unable to receive data in this condition. So, if this system is desired to communicate between floors, a relay node is needed to continue data transmission.

## IV. CONCLUSION

We have successfully implemented a simple and low-cost parking system to manage indoor parking at a mall in Bandung, Indonesia. This system satisfies customers by knowing the available parking space when the vehicle enters the parking lot. The parking space monitoring system uses Zigbee wireless sensor network, LDR sensors installed in each parking slot, and Arduino Uno. The LDR sensor is connected to a node capable of processing the signal, which is then sent to the Zigbee coordinator to detect the presence or absence of a vehicle. The resulting is presented on the dot matrix display at the entrance. The test results show that the system can detect vehicles parked or leaving the parking lot with an accuracy rate of 100%. The maximum system delay is 2.518462 ms at 40 meters, better than conventional parking systems.

For future research, we propose implementing the system in outdoor areas and adding integrated features such as billing and online parking reservations. Utilization of parking technology according to needs feels more efficient in financing and effective in utilization.

## CONFLICT OF INTEREST

The authors declare no conflict of interest.

## AUTHOR CONTRIBUTIONS

All authors contributed to the findings of this work. The first author implemented hardware and computer programming. The system design and simulation design were carried out by the second author. The third author provides the basic concepts of a digital parking information system and conducts surveillance. The preparation, revision, and finalization of the manuscript were carried out by all authors

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