Developing parking queue monitoring system using Wireless Sensor Network and RFID technology

Banu Santoso¹ and Marti Widya Sari²*

¹Department of Computer Engineering, Faculty of Computer Science, Universitas Amikom Yogyakarta, Yogyakarta, Indonesia
²Department of Informatics, Faculty of Science and Technology, Universitas PGRI Yogyakarta, Yogyakarta, Indonesia

Corresponding Author: *widya@upy.ac.id

Abstract. Parking areas in urban centers are increasingly limited, but not in line with technological developments in addressing the problem of parking service needs in the urban public service center by implementing smart city technology. Many times the parking service waiting time is too long, due to a complicated procedure. Waiting time for services that are too long makes the parking queue increase in length, especially when registering for the end of a new parking lot. Besides, the storage of visitors’ parking slip accumulation is still manual and not paperless. Therefore, in this study, a solution was proposed in the form of a system to accelerate administrative services for parking visitors by integrating Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN) technologies. This system utilizes the database so that the results of data processing can be used by management to obtain visitor data information on parking online and quickly. The results obtained from this study are a prototype of a parking visitor monitoring system using WSN technology based on Zigbee and RFID protocols. Meanwhile, the results of visitor parking information presented in data processing can be used by management to find out statistical data relating to parking services.

1. Introduction

Parking areas in urban centers are increasingly limited in each building, but not in line with technological developments in addressing the problem of parking service needs in shopping centers or improving the service of city residents for parking needs that apply smart city technology and are still manual [1][2]. The development of parking services has not been in line with the growth of the speed of service for parking visitors, this is due to the length of administration such as the parking registration process, and the determination of available parking lots, especially if visitor registration is still manually parking, will further slowdown the parking handling process. Every visitor to the parking lot must immediately get treatment without having to wait in line.

Wireless technology that is growing varies, and its use is extensive in almost all fields, can be used for this control. For example, Bluetooth technology [3] (IEEE 802.15.1), ZigBee [4] (IEEE 802.15.4) and WiFi [5] (IEEE 802.11b). All have different user segmentation and have advantages and disadvantages in their use[6][7]. ZigBee-based Wireless Sensor Network (WSN) is one of the right ways to be applied in a parking lot to speed up parking services for visitors. ZigBee is IEEE 802.15.4 modified by ZigBee Alliance to transmit data packets that work in low bit rates, are coordinated, capable of forming mesh networks, inexpensive infrastructure and are very energy efficient in...
operation when compared to Bluetooth designed for communication of equipment with PC (Personal Computer) and have limited network members. IEEE 802.11 works at a high bit rate and requires expensive infrastructure and allows network members to fight for available resources so that data security can be disrupted. Based on these comparisons, ZigBee is more likely to be applied in the system to be created. Another wireless technology is RFID (Radio Frequency Identification). RFID [8] is an identification technology that utilizes radio waves as a transmission medium consisting of RFID-tags and RFID-readers. Each RFID-tag has a unique code [9] as an identity that can be read by an RFID-reader by sending a request. RFID works at various wavelengths with an area of up to 30 m [10].

This research took place in the parking lot of the Private University in Yogyakarta. The length of waiting time for parking services on campus includes the appointment of vehicle registration vehicles to officers or handwriting if they do not bring their vehicle ID to the officer. Based on this, a system is needed to accelerate administrative services for parking visitors on campus by integrating RFID and WSN technology and using the database so that it will produce a parking application monitoring system that can be used by campus management. Through this technology allows the parking administration officer to know the visitor's parking data entirely without having to search for data manually.

1.1 The authenticity of Research

Some summaries of research results related to reducing queues in public services, such as hospitals, banks, train stations, movie ticket sales and services in supermarkets that have been carried out by several previous researchers, can be seen in Table 1. In the table explained about previous studies concerning researchers, location, research contributions, and methods.

| Researcher / Year | Location | Research Contributions | Method |
|------------------|----------|------------------------|--------|
| Muthu Kumar, et al / 2012 [11] | Bank ATM | Reduce the time to queue for cash withdrawals through ATMs for bank customers. | Virtual Pre-Transaction (VPT) uses mobile banking to withdraw money through ATMs |
| Abdul Hamid, et al / 2012 [12] | Football stadium | Reduce the time to queue for ticket purchases for soccer fans and save on ticket printing costs. | e-Ticketing |
| Kishore Kumar, et al / 2013 [13] | Railway station | Reduce the queue time for purchasing train travel tickets | Smartphone and WiFi |
| Idris Gautama, et al / 2014 [14] | Cinema Building | Reduce the time to queue for purchasing movie tickets with mobile ticket sales. | Smartphone |
| Andy Maulana Hidayat, et al / 2014 [15] | Supermarket | Reduce queue times and identify items at the checkout. | Zigbee (WSN), Barcode and Load Sensor |
| Prashant Patil, et al / 2019 [16] | Hospital | Patient waiting time prediction in hospital queueing system | Random Forest Algorithm in Big Data |
| This research | Parking of Motor Vehicles | Improve parking service waiting time when registering and monitoring parking visitors and analyzing parking visits data online and fast. | HF Radio Frequency (RFID) and Zigbee (WSN) |
Based on the literature study there are differences that are proposed as positive contributions in this study, namely in the form of designing and making prototypes by integrating the use of Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN) technologies in improving parking service waiting times during the registration process and facilitating processing online and fast parking statistics.

1.2. Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is a technology of capturing data automatically that identifies electronic devices, tracks, and stores various information on a product in groups or separately [17]. RFID [18] is one part of Auto-ID Technology (Automatic Identification). Besides, there are also Barcode systems, Optical Character Recognition (OCR), Smart Cards, and Biometric.

In this study, it was chosen to use RFID based on the ease of reading tags through the RFID Line of Sight Reader / Writer module. The process of learning the tagged data is faster, besides that the RFID card tag functions as a visitor's parking card that is not easily damaged and can be used to store the visitor's parking data identity, thus speeding up visitors' parking services in the parking lot. Table 2 shows a comparison of RFID, barcode and Smart Card.

### Table 2. Comparison of RFID, Barcodes and Smart Cards [19]

| Classification          | RFID                          | Barcode                  | Smart Card         |
|-------------------------|-------------------------------|--------------------------|-------------------|
| Data Size (bytes)       | 16-64 k                       | 1-100                    | 16-64 k           |
| Distance (maximum)      | 0-5 meters, Microwave, without direct contact or Line of Sight | 0-50 cm / LoS (Line of Sight) | Direct contact / short distance |
| Reading speed           | Speedy ~ 0.5 seconds          | Slow ~ 4 seconds         | Slow ~ 4 seconds  |
| Data Density            | Very high / data can be updated. | Little / static data     | Very high / data can be updated. |
| Machine readability     | Good / Able to read multiple tags simultaneously | Good / Reading 1 tag per time | Good / Reading 1 tag per time |
| Human readability       | Impossible                    | Limited                  | Impossible        |
| Cost                    | Cheap                         | Cheap                    | Expensive         |

1.3. Wireless Sensor Network

Wireless Sensor Network (WSN) [20] [21] is a set of independently distributed devices (nodes) that are interconnected wirelessly and cooperatively using sensors [22][23] to monitor physical or environmental conditions such as temperature, sound, vibration, pressure, and movement or contaminants in control parameters specific. The ZigBee protocol (IEEE 802.15.4) [24] is part of the wireless sensor network technology. Zigbee, Bluetooth, and WiMedia are in the PAN (Personal Area Network) group.

Zigbee is in a short range and has a low data rate, Bluetooth (IEEE 802.15.1) is between Zigbee and WiMedia (IEEE 802.15.3), then WiMedia has a high data rate. ZigBee works [25] on the 2.4 GHz frequency with data transfer speeds of only 250 Kbps. This speed difference is very striking when compared to Bluetooth technology which can reach 3 Mbps, but concerning distance ZigBee's communication range is superior because it can reach 1.5 Km if connected to many nodes. Table 3 is a comparison between wireless technologies including ZigBee, Bluetooth, WiMedia, and WiFi.
Table 3. Comparison of Zigbee, Bluetooth, WiMedia, and Wi-Fi [19][26]

| Classification      | Zigbee | Bluetooth | WiMedia (UWB) | Wi-Fi |
|---------------------|--------|-----------|---------------|-------|
| Standard / Reference| IEEE 802.15.4 | IEEE 802.15.1 | IEEE 802.15.3 | IEEE 802.11 a/b/g |
| Distance (maximum)   | 100 meters | 100 meters | 10 meters | 100 meters |
| Data transfer (maximum) | 0.25 Mbps | 3 Mbps | 600 Mbps | 54 Mbps |
| Connection           | Ad hoc, peer to peer, star, or mesh | Ad hoc, scope network is very small | Point to point | Point-to-hub |
| Power consumption    | Very small | moderate | High | High |
| Application Focus    | Sensing, Control and Monitoring | Voice and Data applications for personal computing devices | Short range radar system, military application for short distances | Web, Email, Video |
| Security             | 128 bit AES Encryption | Authentication and Encryption | 128 bit AES Encryption | Authentication and Encryption (WEP) |
| Cost                 | Cheap | moderate | Expensive | Expensive |

In this study, I prefer to use Zigbee because Zigbee accommodates a large number of nodes with connections that can be Ad hoc, peer to peer, star or mesh. Zigbee is very suitable for use in this study, because of the many portals used in the parking area so that it requires a lot of sensor nodes. The number of sensor nodes scattered on the entrance is connected directly to the coordinator node through Zigbee communication. Zigbee has very little power consumption compared to Bluetooth, WiMedia, and WiFi so that users can last longer. Besides, infrastructure costs for implementing Zigbee technology are cheaper than using Bluetooth, WiMedia and Wi-Fi technology.

2. Method

2.1. Research Materials

The material used in this study is the test results data directly with the authorities and related to the issues examined in this case are from the side of the campus of Private University in Yogyakarta. Research location at the Private University in Yogyakarta Campus. The material of this study also uses data obtained through literature studies on the development of information systems and knowledge about Radio Frequency Identification (RFID) and Wireless Sensor Network (WSN) technologies.

2.2. Research Tools

2.2.1. Hardware

The hardware used in this study is as follows.

a) Xbee Pro RPSMA Series 2B Module, duck antenna, and Shield are three units, connecting between sensor nodes to the coordinator node wirelessly.

b) Arduino Uno R3 consists of four groups, functioning as a microcontroller or processor placed at each parking node, register node, and coordinator.
c) The number of RFID Reader / Writer is three units, functions as a module of readers and writers of RFID tags placed in the two parking nodes and one register node.

d) Some five RFID cards, functioning parking visitor ID cards.

e) The I2C LCD backpack module serves the Display Module by displaying the UID of the visitor's parking name.

f) 9 volt 1 Ampere power supply adapter or 2 cell 7.4-volt Li-Po battery 1000 mAh, functions as a power supply for the two parking nodes and one register node.

g) The ASUS X200CA laptop has one unit, which functions to place the WSN application installation along with the database.

2.2.2. Software
The software used in this study are as follows:

a) Windows 8.1 Pro-64 bit Operating System.

b) Arduino IDE 1.6.0 software, functions to facilitate programming control on Arduino, Shield for Arduino and several modules.

c) X-CTU software version 5.2.8.6, functions to configure the Xbee module as a Coordinator, Router or End device.

d) Sublime Text or Notepad ++ functions as the NodeJS program editor.

e) NodeJS functions as a web-based JavaScript server application.

f) MySQL functions as a database server.

2.2.3. Research Path
The path of research carried out is presented in Figure 1 about the research flow diagram, which includes:

a) Conduct literature studies by studying several journals and papers relating to the research theme, namely about monitoring parking visitors using Arduino and XBee.

b) Identify needs in system development. The requirements of the system built include hardware, such as Arduino, XBee modules, and RFID writer/reader modules, while software needs, such as Arduino IDE 1.6.0, Node JS and MySQL Server software.

c) Build a system design that provides an overview of how the system works. Model making system design for monitoring and sending data from reading RFID tags.

d) Test the functionality of the application system and then conduct trials to write and read RFID tags by sending data to the server and analyzing the quality of the results of data transmission.

![Research Flow Chart](image)

**Figure 1.** Research Flow Chart
3. System Design
The WSN system design uses a star topology, considering that the parking area is generally accessible by the Xbee transceiver module to the server room. The RFID Reader / Writer module is placed in the registration room (Campus Security Room) to write the UID in the form of the identity of the visitor’s name parked on the RFID card tag while in the first parking gate until then for the UID reading of the visitor's parking name. Figure 2 shows the system architecture that explains the flow of the system starting from number 1 to number 9.

The explanation of the system architecture is as follows.

a) Number 1, parking visitors register in the registration room (security room) by filling in the registration form and providing an identity card.

b) Number 2, operators input new parking visitor data whose data will be stored in the database through cable communication media and UID in the form of parking visitor name identity stored in RFID card tags through RFID Reader / Writer module.

c) Number 3, parking visitor data will be grouped and stored according to the tables provided in the database.

d) Number 4, visitors to parking after registering when exiting the campus environment will enter the parking gate to be validated by the parking attendant who will begin sending to the server.

e) Number 5, parking visitor data is transmitted to the coordinator node in the server room through Zigbee communication media.

f) Number 6, from the coordinator node, the average value of the data is sent to the server via serial port communication media for processing the data and stored in the database.

g) Number 7, as well as visitors to parking at other parking gates, parking nodes will be placed by parking attendants then parking attendant validation and visitor parking data will begin to be sent to the server.

h) Number 8, the measurement results will be sent to the coordinator node in the server room through Zigbee communication.

i) Number 9, carry the value of the data to the server for processing the data and store it in the database.

Figure 2. System architecture in research
Figure 3. The registration process for parking visitors at the university

Figure 3 shows that the system prototype is from the input, process, and output for parking visitors. In the process of registering parking visitors through a system using applications with integration between RFID and WSN, besides that, the output produced is stored directly into the database and in the form of an RFID Card Tag.

4. Results and Discussion

The vehicle queue monitoring system using a single channel single phase model, which can be seen in Figure 4. Single channel is a line that has a service system, while single phase is a service facility. Vehicles will enter the parking lot through the entrance, then will queue up a waiting line.

Figure 4. Single Channel Single Phase

Testing of the queue of vehicles when exiting the University Parking Building was carried out on 30 vehicles, and the results are shown in Figure 5 and Figure 6. Testing of vehicle queues using the traditional system compared to the prototype system, which was carried out in 2 different parking buildings, namely Parking Lot 1 and Parking Lot 2. Results in Parking Lot 1 (Figure 5), the average time difference between the traditional system and the prototype system is 2 minutes 27 seconds. Results in Parking Lot 2 (Figure 6), the average time difference between the traditional system and the prototype system is 2 minutes 14 seconds.
From the graph above, it can be seen that testing the queue of vehicles using the traditional system has a longer time than testing the prototype system. In Parking Lot 1 (Figure 5), the maximum time difference between the traditional system and the prototype system is 2 minutes 50 seconds, while the minimum time difference is 1 minute 41 seconds. In Parking Lot 2 (Figure 6), the maximum time difference between the traditional system and the prototype system is 2 minutes 51 seconds, while the minimum time difference is 1 minute 39 seconds.

Figure 5. Results in Parking Lot 1

Figure 6. Results in Parking Lot 2
5. Conclusion
The prototype service for queuing vehicles using wireless sensor network technology and RFID has been tested at 2 locations, namely Parking Lot 1 and Parking Lot 2. Testing of vehicle queues using the traditional system compared to the prototype system. The average time difference between the traditional system and the prototype system in Parking Lot 1 is 2 minutes 27 seconds. Results in Parking Lot 2, the average time difference between the traditional system and the prototype system is 2 minutes 14 seconds. For further research, prototype systems can be made with different sensors, so that vehicle queues can be detected more quickly.

6. References
[1] F. Kirschner and M. Lanzendorf, “Support for innovative on-street parking policies: empirical evidence from an urban neighborhood,” *J. Transp. Geogr.*, vol. 85, no. March, p. 102726, 2020.
[2] M. Margreiter, F. Orfanou, and P. Mayer, “Determination of the parking place availability using manual data collection enriched by crowdsourced in-vehicle data,” *Transp. Res. Procedia*, vol. 25, pp. 497–510, 2017.
[3] P. Seymer, D. Wijesekera, and C. D. Kan, “Secure outdoor smart parking using dual mode bluetooth mesh networks,” *IEEE Veh. Technol. Conf.*, vol. 2019-April, 2019.
[4] I. Kuzminyk, A. Snihurov, and A. Carlsson, “Testing of communication range in ZigBee technology,” *2017 14th Int. Conf. Exp. Des. Appl. CAD Syst. Microelectron. CADSM 2017 - Proc.*, pp. 133–136, 2017.
[5] C. Yuan, L. Fei, C. Jianxin, and J. Wei, “A smart parking system using WiFi and wireless sensor network,” *2016 IEEE Int. Conf. Consum. Electron. ICCE-TW 2016*, pp. 16–17, 2016.
[6] S. Sadowski and P. Spachos, “Comparison of RSSI-Based Indoor Localization for Smart Buildings with Internet of Things,” *2018 IEEE 9th Annu. Inf. Technol. Electron. Mob. Commun. Conf. IEMCON 2018*, pp. 24–29, 2019.
[7] Q. Jun, H. Chao, Y. Yunhan, and Q. Jizui, “Application of modern communication technology in smart home system,” *2018 IEEE Int. Conf. Inf. Autom. ICIA 2018*, no. August, pp. 1577–1581, 2018.
[8] Y. C. Wang and S. J. Liu, “Minimum-cost deployment of adjustable readers to provide complete coverage of tags in RFID systems,” *J. Syst. Šofiw.*, vol. 134, pp. 228–241, 2017.
[9] M. Mumtaz, S. F. Amber, A. Ejaz, A. Habib, S. I. Jafri, and Y. Amin, “Design and analysis of C shaped chipless RFID tag,” *2017 Int. Symp. Wirel. Syst. Networks, ISWSN 2017*, vol. 2018-Janua, no. c, pp. 1–5, 2017.
[10] F. Bibi, C. Guillaume, N. Gontard, and B. Sorli, “A review: RFID technology having sensing aptitudes for food industry and their contribution to tracking and monitoring of food products,” *Trends Food Sci. Technol.*, vol. 62, pp. 91–103, 2017.
[11] R. M. Kumar, G. Varaprasad, and R. Sridharan, “An innovative proposal to increase the efficacy of the Automated Teller Machine using mobile banking,” *4th Int. Conf. Intell. Hum. Comput. Interact. Adv. Technol. Humanit. IHCI 2012*, 2012.
[12] A. Hamid, a M. F. Ai, and M. L. Yap, “e-Ticketing system for football events in Malaysia,” *2012 Int. Conf. Internet Technol. Secur. Trans.*, pp. 556–561, 2012.
[13] K. K. S. P, R. Kishore, M. Deepak, M. Somasundram, and S. P. Karthikeyan, “Instant payment for services through mobile devices,” in *2013 International Conference on Green Computing, Communication and Conservation of Energy (ICGGCE)*, 2013, pp. 928–933.
[14] I. Gautama, H. Ongowarsito, R. Aryanto, and E. Andrew, “Optimizing sales using mobile sales ticketing application,” *ISTMET 2014 - 1st Int. Symp. Technol. Manag. Emerg. Technol. Proc.*, no. Istmet 2014, pp. 6–13, 2014.
[15] A. M. Hidayat, I. W. Mustika, and S. Sulistyo, “Implementation of wireless sensor network to reduce cashier queue,” *Proceeding - 2014 Makassar Int. Conf. Electr. Eng. Informatics,*
[16] P. Patil and S. Thakur, “Patient waiting time prediction in hospital queuing system using improved random forest in big data,” *IEEE Int. Conf. Issues Challenges Intell. Comput. Tech. ICICT 2019*, 2019.

[17] M. Vagaš, A. Galajdová, D. Šimšík, and D. Onofrejová, “Wireless data acquisition from automated workplaces based on RFID technology,” *IFAC-PapersOnLine*, vol. 52, no. 27, pp. 299–304, 2019.

[18] F. Chetouane, “An overview on RFID technology instruction and application,” *IFAC-PapersOnLine*, vol. 28, no. 3, pp. 382–387, 2015.

[19] A. Baviskar, J. Baviskar, S. Wagh, A. Mulla, and P. Dave, “Comparative Study of Communication Technologies for Power Optimized Automation Systems: A Review and Implementation,” in *2015 Fifth International Conference on Communication Systems and Network Technologies (CSNT)*, 2015, pp. 375–380.

[20] R. P. Kristianto, B. Santoso, and M. W. Sari, “Integration of K-means clustering and naïve bayes classification algorithms for smart ac monitoring and control in WSAN,” *2019 4th Int. Conf. Inf. Technol. Inf. Syst. Electr. Eng. ICITISEE 2019*, pp. 495–500, 2019.

[21] B. Santoso, A. E. Permanasari, and A. Bejo, “Perbaikan Waktu Tunggu Pelayanan Pasien Rumah Sakit Menggunakan Teknologi RFID dan WSN,” *Semin. Nas. Teknol. Inf. dan Komun. 2016 (SENTEKA 2016) Yogyakarta, 18-19 Maret 2016*, no. Sentika, pp. 658–665, 2016.

[22] B. Santoso and M. W. Sari, “Design of Student Attendance System Using Internet of Things (IoT) Technology,” *J. Phys. Conf. Ser.*, vol. 1254, no. 1, 2019.

[23] R. Hafid Hardyanto and P. W. Ciptadi, “Smart Aquaponics Design Using Internet of Things Technology,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 835, no. 1, 2020.

[24] H. Fitriawan, M. Susanto, A. S. Arifin, D. Mausa, and A. Trisanto, “ZigBee based wireless sensor networks and performance analysis in various environments,” *QiR 2017 - 2017 15th Int. Conf. Qual. Res. Int. Symp. Electr. Comput. Eng.*, vol. 2017-December, no. 1, pp. 272–275, 2017.

[25] D. Mankar and B. S. Chaudhari, “Dynamic performance analysis of IEEE 802.15.4 devices under various RF interferences,” *Proc. Int. Conf. Inven. Comput. Technol. ICICT 2016*, vol. 1, pp. 15–18, 2016.

[26] S. P. Lim and G. H. Yeap, “Centralised Smart Home Control System via XBee transceivers,” in *2011 IEEE Colloquium on Humanities, Science and Engineering (CHUSER)*, 2011, pp. 327–330.