

Campus Entry and Exit System for Students Using NFC

Hassan Mohamed^{1, b)}, Suresh a/l Thanakodi^{1, a)}, Muhammad Irfan bin Mohd Raffi²,
Sathyaaruban A/L Devaraj², Muhammad Iqbal Daniel bin Arywan¹

¹*Cybersecurity and Digital Industrial Revolution Centre, National Defense University of Malaysia, Sungai Besi, Kuala Lumpur, 57000, Malaysia*

²*Faculty of Defense Science and Technology, National Defense University of Malaysia, Sungai Besi, Kuala Lumpur, 57000, Malaysia*

^{a)} *Corresponding author: suresh@upnm.edu.my*

^{b)} *hassan@upnm.edu.my*

Abstract. The current campus entry and exit system employed at UPNM is deemed inefficient and outdated. Students encounter difficulty in manually inputting information and scanning QR codes merely to record their movements in and out of the campus. This project aims to provide a more efficient and modern approach for recording student entries and exits from the campus using NFC (Near Field Communication) technology. Integrating NFC functionality into the Campus Entry and Exit System can streamline the process for students while offering a more efficient approach. The primary goal of this project is to develop a system for recording student movements on campus using the latest technology, namely NFC. The development of the Student Campus Entry and Exit System in the Android application follows a waterfall model, comprising five phases: planning, analysis, design, implementation, and testing. The results of building the Student Campus Entry and Exit System in the Android application indicate that the system can effectively manage and record student entries and exits from the campus in a more straightforward and systematic manner. Additionally, the information stored in the database is guaranteed to be secured.

Keywords— efficient; near field communication; android application.

I. INTRODUCTION

A good student information system is often associated with efficiency, speed and effectiveness of the system in collecting and processing data that ultimately produces accurate information. This will reflect the level of maturity and ability of an organization in managing and processing the resources it owns. The improvement of the student entry and exit system from the campus to a digital system in the form of an Android-based application using Near Field Communication (NFC) will make it easier for users to access information anywhere more efficiently. NFC technology and its modern uses were examined by [1] computers, smartphones, and tags can wirelessly exchange data over short distances thanks to NFC, a sort of radio-frequency technology.

The existing Campus Access System at UPNM is considered outdated and makes it difficult for students to move in and out of the campus. Apart from slowing down student movement with the need to record using two methods, the current system is also lacking in terms of student movement data security. This project aims to revolutionize the system by introducing the Student Campus Entry and Exit System Using NFC. The aim is to replace the existing system that records the entry and exit of students from the campus with more efficient and systematic data management. Implementation follows the waterfall model, ensuring a systematic and safe development process.

Among the problems found today is the lack of security in student movement data. This is because students must write down their movement data when going in and out of the campus area. This written method has no safety factor and is not supervised by the staff on duty. This will increase the probability of information leakage and indirectly affect student privacy. There are many cases where students' privacy data is stolen and misused. Data thieves can find out the student's identity, their phone number, the time of going in and out of the campus and the purpose of

their outing. This will affect the security of the student's identity. The student entry and exit data collection system from the campus that is currently used is divided into two, which is writing in the entry and exit logbook or by scanning the QR code. The written system takes quite a long time and is less efficient while the digital system used has a significant drawback that if the smartphone used to scan the QR code runs out of battery, students cannot record their movement in and out. If this happens, students will write their movement in and out in the logbook only, causing the movement data to be split into two and inconsistent. There are also a few students who do not write their movement records causing the integrity and consistency of the data to be affected.

The existing system is not easy to manage, and it will consume a lot of resources and time. To record in writing, the security department needs to procure record books, and this can waste money. Coupled with the digital recording system using android, the security center will have difficulty keeping up with two systems. With these two systems, the movement of students going in and out of the campus will be quite difficult to keep up with and will waste precious time.

The main goal of this study is to develop a Student Campus Exit System in Android that uses NFC. This goal can be achieved through three objectives as follows:

- a) Designing a student campus entry and exit system using NFC.
- b) Developing a student campus entry and exit system using android.
- c) Produce a database to record student entry and exit data from campus.

Project scope is the development of a general understanding of what is included or excluded from a study. System development is based on the following scope:

- a) Student identity verification using mobile application.
- b) The method of recording campus entry and exit using NFC.
- c) Student entry and exit management system from campus.

Technically, the development of this system will make student movement more efficient, ensuring the security of student information and in line with the technological advances. This system also makes it easier and more organized for students to come and go from campus. This is because, the use of NFC that allows students to only scan NFC devices to record entry and exit information which improves the existing system which is manual writing towards the computerized system that records data into the database. Thus, can save manpower as well as the use of time in managing the movement of students in and out more effectively.

II. RELATED WORKS

The similar system that uses NFC solution has been used in many applications. An NFC-based system for course verification and attendance has been presented by [2]. When a student's ID card is brought close to an NFC scanner, the system extracts the data from it and sends it to a web application where courses are validated, and attendance is recorded. An NFC-based mobile application has been proposed by [3] to automatically record student attendance in the database, students simply need to tap the lecturers' NFC-enabled smart devices as they enter the lecture hall. The results indicate that the suggested approach shortens the time required for students to complete their attendance forms and lowers their risk of getting infected with the COVID-19 virus. The use of NFC tags as a cutting-edge approach to collecting attendance data has been studied by [4]. This study looks at the creative way that NFC is included into the process of recording attendance, which is connected to a website-based attendance system. A proposed attendance tracking system by [5] makes use of an Android smartphone that has NFC and Global Positioning System (GPS) capabilities. Therefore, by using cellphones to monitor and display their attendance, professors and students may stay in continual communication with one another. RFID and Internet of Things technologies were presented by [6] as a means of tracking attendance. Their approach, which read student IDs from NFC tags and transmitted them via Wi-Fi to a database, correctly documented student attendance. Attendance tracking is made simpler, quicker, and more efficient using this solution.

A smart door that employed biometric NFC Band and OTP-based techniques was the other NFC-enabled system that [7] demonstrated. This idea was developed to reduce the issues with biometric fingerprint sensor authentication times. The low-cost, user-friendly NFC door lock that [8] demonstrated uses Arduino boards as the microprocessor. The devices' ability to function independently provided scalability and ease of installation. In order to provide safe validation access, [9] suggested an intelligent door access system for hotel visitors that uses NFC and smartphone applications that mimic smart keys. Using Host Card Emulation (HCE) technology, this system promotes mobile access systems in the hospitality sector, lowers the requirement for physical keys, and improves security.

Another system that used NFC technology is Campus Security Tracking Technology that uses a MIFARE type NFC smart card as an identity for identification and authentication. [10] has presented a method to improve campus security tracking technology with NFC system. The system's goals were to apply smart cards to smart gates among the academic community as users. The research by [11] focused on the NFC technology-based check-in location system. Using NFC technology, an identification card (IC) served as a smart object (NFC tag), and an NFC detector served as an NFC reader. The data can also be used by authorities to track down people who have tested positive for COVID-19. [12] suggested integrating NFC technology into a local contactless chip card as an electronic wallet. Additionally, the use of mobile phones with active NFC chips to integrate NFC technology in regional passenger transit was suggested. Linking to EMV (Europay/MasterCard/VISA) technology is possible with both approaches. NFC technology, which permits near-proximity wireless communications for uses like ticketing and mobile payments, was covered by [13]. This study examined NFC vulnerabilities and different security assaults, investigating and assessing the cost and practicality of potential solutions.

A medical gadget prototype that measures five health factors was built by [14] using NFC and IoT technology. The study concluded that it would be possible to turn the prototype into a fully functional tool such as to expedite diagnose hence data privacy, device safety, and security procedures for NFC connectivity to protect baby medical records can be focused.

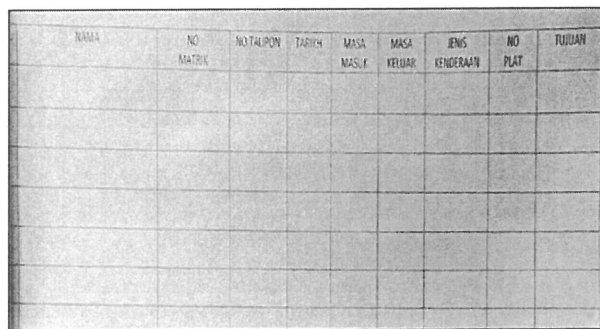
An overview of NFC and a comparison with RFID have been covered by [15]. Scientific procedures to improve the security efficiency of NFC have also been offered, and numerous attack kinds have been studied.



FIGURE 1. Main View of the UPNM Mobile Application

III. MATERIALS AND METHODS

Before developing a system, a study of the current system needs to be done to identify problems or weaknesses in the system being used. UPNM currently uses two methods to record the entry and exit of students from the campus. The first method is to record online using the UPNM Mobile application. Students are asked to scan the QR Code found on the guard booth. The main function of this system is to record student movements online using QR Code technology. Today, QR code technology is widely employed. [16] created and built an e-ticketing system for travelers that combined an Arduino controller and QR codes with Internet of Things technology. [17] demonstrated how consumers can embrace QR code-based mobile applications for interactive e-commerce, such as the "GoShop" app, which allowed for technology demonstrations. Figure 1 shows the main display of the UPNM Mobile student application that is still used until now.



NAMA	NO MATRIK	NOKALPON	TARICAH	MASA MASUK	MASA KELUAR	JENIS KENDERAJAN	NO PLAT	TUJUAN

FIGURE 2. Student Exit and Enter Sheet Form Campus

The second method used to record the movement of students in and out of the campus is physically using the method of filling in student information on the campus entry and exit form. Students who want to leave or enter the campus must fill out a form first at the guard lodge. This is because every movement in and out of students must be recorded for security purposes. Fig. 2 shows the entry and exit sheet form of students from the campus who were placed in the guard lodge before entering UPNM.

The results of the observations and the collection of existing information have unraveled some chronic problems after being studied and refined in depth. Among the weaknesses that can be highlighted in the use of the existing system are:

- A paper-wasting method to record daily movement of students.
- The system is quite outdated and not in line with the latest standards that should be practiced.
- The use of a lot of time in the process of recording student movements.
- Inconsistent collection of student data.
- Lack of security factors can lead to misuse of identity and leakage of personal information.

The study of equivalent systems carried out is to monitor the existing systems. This study is needed to study the functions found in the systems so that the system that will be developed is better and more efficient. This study can help further strengthen the system that will be developed. Here are the equivalent systems that were studied to be used as this equivalent study:

- Graduation Robe Borrowing and Return Monitoring System
- UPNM e-Attendance Portal
- MySejahtera System

A. Graduation Robe Borrowing and Return Monitoring System

The Graduation Robe Borrowing and Return Monitoring System Using QR Codes is developed in parallel with today's rapidly growing technology. This system was built to facilitate the process of borrowing and returning

graduation robes for students at the National Defense University of Malaysia in addition to making it easier for staff to ensure the condition of the borrowed robes. Fig. 3 shows the Graduation Robe Borrowing and Return Monitoring System Front View. The methodology used to make this project a success is the System Development Life Cycle Methodology. The method that has been used is the Waterfall Model. This system is very necessary in the organization because it will change from the old system that still uses manual methods to a more organized, systematic and timesaving. In conclusion, this system can simplify and speed up the process of borrowing and returning graduation robes as well as being able to maintain the condition of the robes. This will also produce a faster and more effective data storage system in addition to being accessible faster.

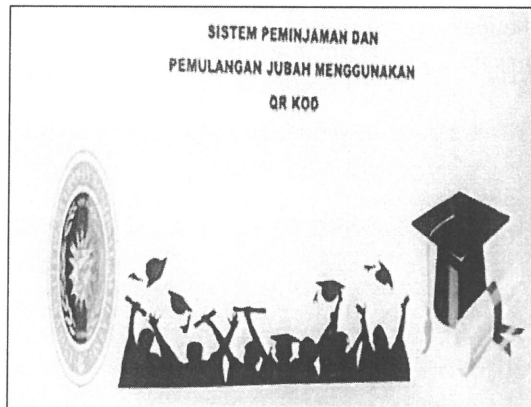


FIGURE 3. Graduation Robe Borrowing and Return Monitoring System Front View



FIGURE 4. UPNM e-Attendance Portal

B. UPNM e-Attendance Portal

The UPNM e-Attendance portal system was developed to record the attendance of UPNM staff. The system is web-based. Staff need to enter their staff ID and password to log in to the system. In this system, attendance records can be easily recorded. System users can record attendance using this system. If the staff is absent, the staff must give a reason for the absence. If it fails, the user record will be red. In addition, this system can generate reports and graphs of UPNM staff attendance records. This system allows users to update personal information. Fig. 4 shows the UPNM e-Attendance Portal.

C. MySejahtera System

The MySejahtera system was developed to record and monitor user movements during the Covid-19 pandemic in a systematic and efficient manner. This system is based on a QR code that needs to be scanned through an application in the user's smartphone. Users need to log in using their phone number and ID card number to log in to the system. In this system, a record of the user's movement is stored in the database when the user scans the unique QR code displayed at any location they wish to enter. Fig. 5 shows the MySejahtera System Home Screen. Users who have completed two doses of vaccination, do not experience symptoms and do not have close contact with Covid-19 patients, the application will display a successful registration message so that the user can enter the location. Fig. 6 shows the Successful Registration Message. If the user does not meet the three specified conditions, the application will display a high-risk message so that the user is not allowed to enter the location. In addition, this system records the history of user movements throughout the Covid-19 pandemic.

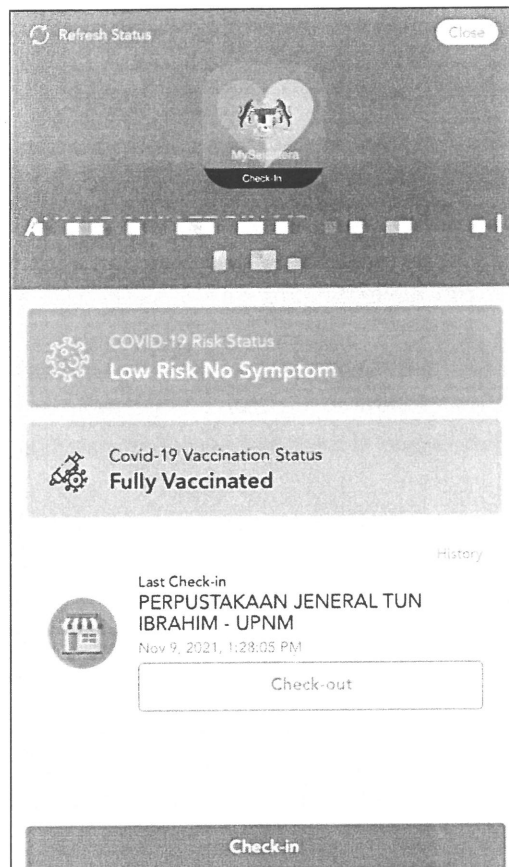


FIGURE 5. UPNM e-Attendance Portal



FIGURE 6. Display Successful Registration Message

The main concept of the Student Campus Entry and Exit System using Android is to record and store the data contained in the NFC chip issued by UPNM. The recorded student information will be stored in the database. Next, this stored information can be viewed through NFC chip scanning. This system was developed using Android Studio programming. Meanwhile, student's information is stored in database using MySQL.

Apart from that, it is well known that the information and technology community often rapidly developed couple with the existence of advanced and modern technology that is already available. For that purpose, the Near-Field Communication (NFC) feature that is applied is the main pillar in producing users who are aware of any changes and improvements to the system over time in an easy and informative manner. In addition, the NFC feature used is very safe because any NFC scanner from a third party cannot directly read the data and information contained in the NFC chip.

The system is developed in several phases. These phases are a cycle known as the System Development Life Cycle (SDLC). SDLC is a general methodology in the system development cycle. The Waterfall model was chosen to be used in developing this system. There are five main phases in the Waterfall Model, namely the planning phase, the system analysis phase, the system design phase, the system implementation phase and the system testing phase. Fig. 7 shows the Waterfall Model. [18] used waterfall model in developing Log Monitoring System Using Quick Response (QR) Code. This system monitors the logs of the faculty, students, admin employee, and visitors who enter the campus for tracing the possible COVID –19 suspect. [19] created an automatic attendance system with

NFC and the Software Development Life Cycle (SDLC) development method, which can process data automatically, for the purpose of physical contactless during the COVID-19 pandemic.

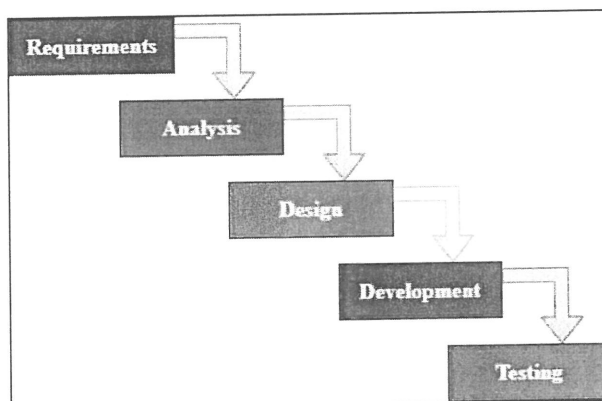


FIGURE 7. Waterfall Model

The Waterfall model was chosen because this model has its own specifications, so a system can be developed according to what is desired. This methodology was also chosen because the activities carried out to develop this project are sequential. The selection of this model is done because the phases are sequential where the output of the first phase flows to the second phase and so on linearly. Not only that, the progress of this waterfall model is also easy to monitor.

A. Requirements Phase

This phase is the main method in carrying out research and planning related to a project that wants to be developed. This phase describes the studies that have been carried out on the current system of databases, network systems and data security in the process of developing this system. In addition, the process of identifying all the main related components such as construction objectives, project scope, and the problems encountered can be planned as well as possible before the project begins to be developed.

Among the preliminary plans that have been identified in this phase in relation to the project title that has been approved are:

- a) Analyze and understand the objectives, management methods and benefits of the old campus access system so that it can be upgraded to the use of an Android-based system that uses NFC.
- b) Identify some of the constraints and problems faced and how to solve them against the current system. As well as a preliminary study of the objectives for the system to be developed.
- c) Analyze and determine the objectives and scope of the project to be implemented. The study covers all aspects including the boundaries of the system to be built.

B. Analysis Phase

The system analysis phase is the second phase after the system planning phase. The analysis phase is very important to know the weaknesses faced by the current system. The existing campus entry and exit system that has been studied will be used as a reference to facilitate the analysis of the information collected. The purpose of studying this system is to develop a system that can meet the needs and wants of users. In this phase, the identification of the content and scope is also implemented.

Research and problem analysis has also been carried out on the college residential organization to identify work rules and data flows related to the system to be developed and to identify existing problems in the current system. The analysis of this problem is done to ensure that the Student Campus Exit System android application that will be developed can solve the problems encountered in the current system.

C. Design Phase

The system design phase is a phase that involves system modeling. This phase is a process of converting ideas into reality. This design phase will identify how the system will produce database design, user interface design and input and output specifications for the system to be developed. System development designs accurate data entry procedures so that the data used in the system is correct. This design phase is the main pillar for moving the Student Campus Exit System in the developed android application. Diagrams such as data flow diagrams, system flowcharts and interface designs are produced and used to explain the logical design of this system.

D. Development Phase

This development phase involves the development of the actual system where the development of system programs will be implemented using appropriate software. This phase will translate the design to programming code. This is usually done by the programmer. This phase is the easiest phase if the analysis and design phases are done correctly and completely.

E. Testing Phase

After completing the development phase, the system will be tested to see if it can work as designed. This phase will ensure the development of the developed system works well. The testing process is also made so that errors and weaknesses in the system can be identified so that the system can be improved. It is a way of measuring the quality of the developed system. A good test is one that detects at least one error in the system.

IV. RESULTS AND DISCUSSION

During the system development process, there are several algorithms that have been implemented. Among them is the algorithm for user login.

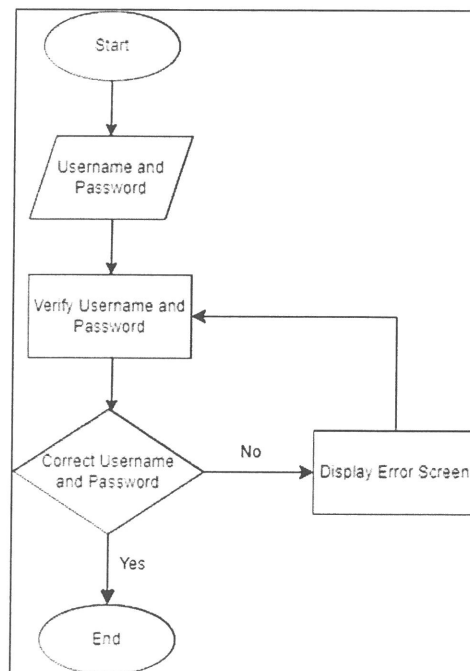


FIGURE 8. User Login Algorithm Process

Fig. 8 shows one of the algorithms used in the system's login system. When a user enters an incorrect username and password, an error will occur. Therefore, the user needs to repeat the login process by entering the correct

username and password. The testing phase is carried out with the aim of ensuring that the developed system operates as planned and meets the needs of the users. The test session must first be carried out by the developer himself to test the effectiveness of the system. Then, this testing process is focused on the operational effectiveness of the modules and functions found in the system.

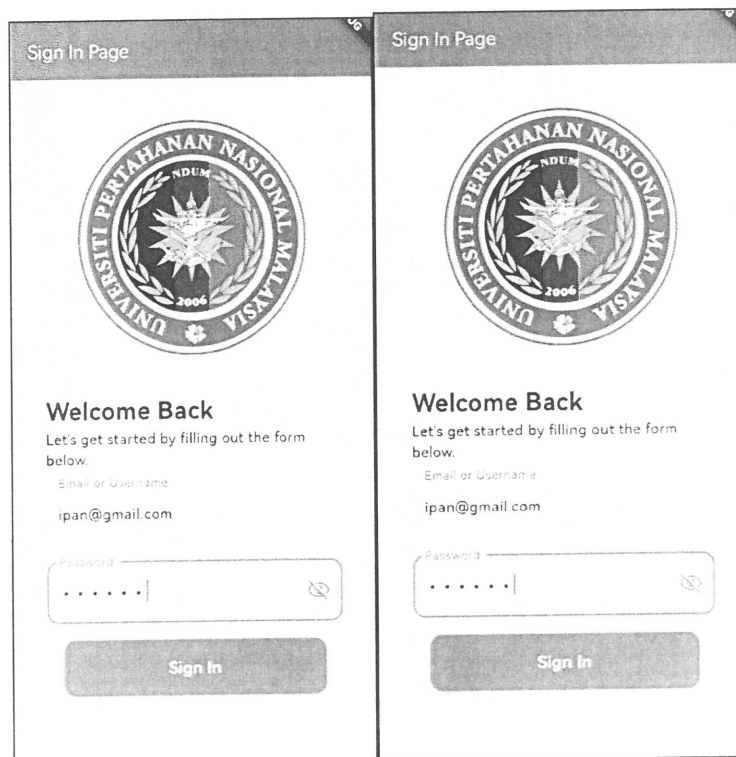


FIGURE 9. Error Display During System Login Process

Users who use this system need to enter a username and password to log in to the next page. An error will occur when the user enters the wrong username and password or does not enter any information. The display "Invalid email or password" will be displayed and the user will need to enter a username and password again. Fig. 9 shows the error display during system login process.

V. FUTURE WORKS

The system that we develop is at the early stage where the security issues are still lacking. There are many types of threat that related to NFC that can affect integrity, availability and confidentiality of an NFC. Any organization using NFC applications and technology may be impacted by these attacks, which result in the disclosure of sensitive user data. [20] has elaborated NFC vulnerability that causing both security and privacy attacks such as DOS and data corruptions. Additionally, using the Analytical Hierarchy Process (AHP) approach, the existing risk assessment models have been reviewed [20]. As a result, the optimal attack mitigation technique was given. Therefore, the best practice in mitigating attacks was presented. A lightweight security middleware that might be utilized in apps has been presented by [21]. In addition, security measures were put in place to cope with harmful tag content in NFC applications.

To increase the protocol's performance and security, [22] employ technologies such as hash functions, timestamps, asymmetric encryption algorithms, and survival periods. In addition, to lower the number of messages transmitted during the authentication process and increase the security of NFC device authentication, the enhanced NFC device authentication protocol successfully withstands brute force, man-in-the-middle, and replay attacks.

To improve our system security, we will adopt the [20], [21] and [22]. This will ensure that all exchanged data and information is safe from any kind of assault, we would like to increase NFC's security. The best method for safeguarding our data is to create a secure channel in the NFC.

CONCLUSION

Overall, it can be concluded that this study successfully achieves the goals, objectives and fulfills the scope. Without an organized work plan, this system will not be able to be produced successfully. In relation to that, this system should be implemented in the campus entry and exit record system that is currently in use because this system is able to help the administration to record and keep records of student movements more easily and systematically.

ACKNOWLEDGMENTS

The authors thank National Defense University of Malaysia for helping with the publication. We are also grateful for the comments from individuals who were involved in this paper publication.

REFERENCES

1. N. K. Singh, Near-field Communication (NFC): An Alternative to RFID in Libraries. in *Information Technology and Libraries*, 39(2) (2020). <https://doi.org/10.6017/ital.v39i2.11811>
2. A. R. Ajayi, E. T. Olawole, M. O. Ajayi, and H. Mahmud, Development of A Near Field Communication-Based Attendance and Course Verification System. in *Lautech Journal Of Computing And Informatics*, 4(1), 34-43 (2024). Retrieved from <http://laujci.lautech.edu.ng/index.php/laujci/article/view/94>
3. A. T. Islam Mazumdar, S. Islam, C. L. Thong, and K. H. Keoy, "NFC-based Mobile Application for Student Attendance in Institution of Higher Learning," in *International Conference on AI in Cybersecurity (ICAIC)*, Victoria, TX, USA, 2022, pp. 1-5, doi: 10.1109/ICAIC53980.2022.9896975.
4. G. A. Hutagalung, Y. A. Dalimunte, I. Khairina, M. Z. Lubis, D. Firmansyah, D. N. Sinaga, I. S. Simanjuntak, and Z. Indandi, Attendance Data Collection Using NFC Tags. in *International Journal of Research in Vocational Studies (IJRVOCAS)*, 3(4), 67–72 (2024). <https://doi.org/10.53893/ijrvocas.v3i4.28>
5. T. W. Chiang, C. Y. Yang, G. J. Chiou, F. Y. S. Lin, Y. N. Lin, V. R. L. Shen, ... C. Y. Lin, Development and Evaluation of an Attendance Tracking System Using Smartphones with GPS and NFC. in *Applied Artificial Intelligence*, 36(1) (2022). <https://doi.org/10.1080/08839514.2022.2083796>
6. J. Dixon and A.-s. Abuzneid, "An NFC Based Student Attendance Tracking/Monitoring System Using an IoT Approach," in *International Conference on Computational Science and Computational Intelligence (CSCI)*, Las Vegas, NV, USA, 2020, pp. 1082-1086, doi: 10.1109/CSCI51800.2020.00201.
7. V. J. Govindraj, P. V. Yashwanth, S. V. Bhat, and T. K. Ramesh, "Smart Door Using Biometric NFC Band and OTP Based Methods," in *International Conference for Emerging Technology (INCET)*, Belgaum, India, 2020, pp. 1-4, doi: 10.1109/INCET49848.2020.9153970.
8. J. Pacheco and K. Miranda, "Design of a low-cost NFC Door Lock for a Smart Home System," in *IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS)*, Vancouver, BC, Canada, 2020, pp. 1-5, doi: 10.1109/IEMTRONICS51293.2020.9216409.
9. Joseph Ng P. S., Brandon Chan P. S., and Phan K. Y., Implementation of Smart NFC Door Access System for Hotel Room. in *System Innovation*, 6(4):67 (2023). <https://doi.org/10.3390/asi6040067>
10. A. Maulana, A. S. P. Tarigan, and Hamdani, Improved Campus Security Tracking Technology with NFC System in *International Journal of Economic, Technology and Social Sciences (Injects)*, 3(2), 213–218 (2022). <https://doi.org/10.53695/injects.v3i2.769>
11. O. N. Chze, M. A. Markom, O. X. Hui, W. T. Chin, K. Y. Vern, E. S. M. M. Tan, and N. Nordin, Check-In Location System Using NFC Technology in *Journal of Physics: Conference Series*, 2107 (2021) 012020. IOP Publishing. doi:10.1088/1742-6596/2107/1/012020
12. E. Brumerickova and B. Bukova, Proposals for Using the NFC Technology in Regional Passenger Transport in the Slovak Republic. *Open Engineering*, 10(1), 238-244 (2020). <https://doi.org/10.1515/eng-2020-0005>
13. A. Alrawais, (2020), Security issues in near field communications (NFC) in *International Journal of Advanced Computer Science and Applications (IJACSA)*, 11(11). <http://dx.doi.org/10.14569/IJACSA.2020.0111176>

14. E. Sutjiredjeki, N. C. Basjaruddin, D. N. Fajrin, and F. Noor, Development of NFC and IoT-enabled measurement devices for improving health care delivery of Indonesian children in *Journal of Physics: Conference Series*, 1450 (2020) 012072. IOP Publishing. doi:10.1088/1742-6596/1450/1/012072
15. A. Albattah, Y. Alghofaili, and S. ElKhediri, "NFC Technology: Assessment Effective of Security towards Protecting NFC Devices & Services," in *International Conference on Computing and Information Technology (ICCIT-1441)*, Tabuk, Saudi Arabia, 2020, pp. 1-5, doi: 10.1109/ICCIT-144147971.2020.9213758.
16. Y. L. Ong and N. Abdullah, Design and Development of Ferry E-Ticketing System with QR Code based on IoT Technology in *Information Technology and Computer Science*, 4(1), 308-326 (2023). <https://publisher.uthm.edu.my/periodicals/index.php/aitcs/article/view/7671>
17. Y. Yusof, L. C. Hooi, and A. Abas, User Acceptance of QR Code based Mobile Application in Interactive E-Commerce in *Annals of Emerging Technologies in Computing*, 5, 102-107 (2021). doi: 10.33166/AETiC.2021.05.012
18. A. M. C. Paculaba, Log Monitoring System using Quick Response (QR) Code: A State University's COVID-19 Contact Tracing System in *International Journal of Informatics, Information System and Computer Engineering (INJIISCOM)*, 3 (2022). doi: 10.34010/injiiscom.v3i2.9037
19. D. Hadiatullah, EMPLOYEE PRESENCE DESIGN BASED ON NEAR FIELD COMMUNICATION (NFC) in *jicon*, 11(1), 7-13 (2023).
20. M. K. M. Singh, K. A. A. Ku Adzman, and R. Hassan, Near Field Communication (NFC) Technology Security Vulnerabilities and Countermeasures in *International Journal of Engineering & Technology*, 7(4.31), 298-305 (2018).
21. S. Hameed, B. Hameed, S. A. Hussain, and W. Khalid, Lightweight Security Middleware to Detect Malicious Content in NFC Tags or Smart Posters in *IEEE 13th International Conference on Trust, Security and Privacy in Computing and Communications* (pp. 900-905), Beijing, China (2014). DOI: 10.1109/TrustCom.2014.118
22. H.-J. Lu and D. Liu, An improved NFC device authentication protocol in *PLoS ONE*, 16(8): e0256367 (2021). <https://doi.org/10.1371/journal.pone.0256367>