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COMPARISON PERFORMANCE ANALYSIS OF ATTENDANCE SYSTEM IN LOS AND NLOS CONDITIONS USING LORA, FSK, AND OOK MODULATION

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Abstract

The traditional attendance mechanism of a sheet of paper is still widely utilized. However, using the live scanner approach is the most recent breakthrough. Fingerprints are the most often used live scanning method. However, fingerprint devices still have flaws, such as the inability of the device to transfer attendance data to a computer; therefore, the data is only saved in the device. Since 2013, low power wide area network (LPWAN) technology has been developed to address this issue. At the moment, three LPWAN technologies are quickly evolving: SigFox, Low Range-wide Area Network (LoRaWAN), and narrowband (NB) Internet of Things (IoT). LoRa offers various advantages in its application, including geolocation, low power consumption, the ability to send a signal up to a maximum distance of 100 kilometres, and the safety of use due to end-to-end AES128 encryption. In this paper, the LoRa performance analysis compares three different modulations, namely LoRa, FSK, and OOK modulations in Line of sight (LOS) and Non-Line of Sight (NLOS) conditions. The test areas are chosen at Universitas Riau. The equipment used in the design of the attendance system is the FPM10A sensor as a fingerprint sensor. This sensor is operated using an Arduino Uno microcontroller. The transceiver module used in this design is LoRa RFM96. The analysis shows that LoRa modulation can send the data up to 250 m, and the best RSSI value is -73.4 dBm in LOS conditions and -87.9 dBm in NLOS conditions. Furthermore, the best packet loss in NLOS conditions is 0% at a distance of 100 m using LoRa modulation, while in LOS conditions, the best packet loss is 0% at a distance of 50 m and 100 m using LoRa modulation.

Keywords: FSK, IoT, LoRa, LOS, LPWAN, OOK, NLOS.

1. Introduction

Attendance is a highly significant aspect in many institutions and organizations for various reasons, and it is one of the essential requirements that students and organization personnel must follow [1]. The attendance system has been known since ancient times. At first, the attendance system only used paper and was done manually by calling the names listed and marked or absent [2]. The conventional attendance system where the teacher calls each student's name is just a waste of time. This is exacerbated because the number of students in one class is very large [3].

Taking students' attendance throughout each session by university instructors is time-consuming, especially when courses are large. Some faculty policies require the instructor to undertake this task throughout each lecture. In other words, out of the total hours assigned to a given course, which is normally forty-five hours every semester, up to eight hours may be lost to execute this process, which typically takes roughly 10 minutes per lecture [4].

Furthermore, due to employers' concerns about employee absenteeism and difficulty in monitoring student attendance throughout the study time, the numerous levels of impersonation observed every day in both the commercial and public sectors pose a threat at all levels of government [5].

Attendance is crucial to a student's ability to succeed in a class. Therefore, student attendance in a course is utilized as one of the conditions for students to take the exam at a particular university [6]. In addition, the existing attendance data is utilized as a reference to demonstrate each student's reliability and used by lecturers as data for student grades and evaluation [7].

In general, there are three (3) applications of the presence system currently in use: the conventional system, the system using an identity card, and the system using a live scanner. The conventional system is the weakest because it is very vulnerable to manipulation. The system of using an identity card has the advantage of being low-cost. However, this system still has weaknesses, namely that it is still possible for fraud to occur during attendance. Finally, the live scanning system is an innovation from the existing system. This system identifies a person based on physical characteristics. Various regular biometric techniques are used for objective identification and verification, such as iris recognition, voice recognition, facial recognition, fingerprint recognition, DNA recognition, hand geometry recognition, signature recognition, and gait recognition [4].

LoRa is a spread spectrum modulation system derived from Chirp Spread Spectrum (CSS) technology. It is a long-range, low-power wireless platform that can establish Internet of Things (IoT) networks worldwide. LoRa Technology allows smart IoT applications that address some of our planet's most pressing issues, including energy management, natural resource reduction, pollution control, infrastructure efficiency, disaster prevention, and more. LoRa Technology has over 600 identified application cases for smart cities, smart homes and buildings, smart agriculture, smart metering, smart supply chain and logistics, and more.

LoRa is used as new technology to boost communication between computer systems, other areas of education, and devices in the classroom. It enhances the school system by adding significant value to the physical classroom environment and organized learning. Smart educational institutes feature well-functioning facilities and highly tailored learning approaches. Therefore, it is one of the most promising LPWANs technologies. It also transmits in unlicensed sub-gigahertz frequency bands, which is critical since an Educational Institute can operate its own LoRa infrastructure rather than a cellular provider's infrastructure. Furthermore, it provides a long range of up to 30 miles, which may cover even the largest campus (or connect spread campuses in a metropolitan region), as well as low energy, with a battery life of up to 10 years, which reduces maintenance and battery replacement expenses [8].

Frequency Shift Keying (FSK) is the usual modulation scheme to transmit digital information between digital devices. Data is transmitted by shifting the carrier frequency in a binary way to one or the other of the two discrete frequencies. Amplitude Shift Keying (ASK) modulation uses the (on) condition and (off) conditions to state bits 1 and 0 or can be called modulation On-Off Keying (OOK). The carrier amplitude is switched On and Off in this modulation according to modulating signal speed. Signals can be represented in two conditions change in carrier wave amplitude in logic 1 and 0. Logic 1 is represented by the On state, i.e., there is a carrier wave. Whereas logic 0 is represented by the Off state, i.e., there is no wave carrier [9].

Based on Table 1, LoRa was chosen as the medium for transmission in this study. This is because the transmission process requires a long range. Zigbee has a maximum range of 100 m, LoRa of 15 km, and Wi-fi of 100 m. LoRa has the farthest range among these three technologies, so LoRa fulfils this research's need.

Table 1. Comparison of wireless technology [10].

	Zigbee	**LoRa**	**Wi-Fi**
Frequency	2.4 GHz, 868 MHz, 915 MHz	433, 868, 915 MHz	2.4 GHz and 5 GHz
Range	10 - 100 m	2-15 km	50-100 m
Power	-25 dBm - 0 dBm	*Maximum* 20 dBm	15 - 20 dBm
Data Rate	25-250 kbps	0.3 - 50 kbps	54Mbps
Receiver Sensitivity	-85dBm	-148dBm	-94 dBm

As far as the author's knowledge, no literature has discussed the LoRa performance for an attendance system from the perspective of throughput, transfer rate, delay, Received Signal Strength Indication (RSSI), and packet loss with three types of modulation, as we have been proposing. This paper comprehensively discusses the LoRa performance in three types of modulations for an attendance system performed at Universitas Riau, Indonesia. The LOS and NLOS areas are chosen as the Faculty of Engineering and open public areas. The LoRa transceiver devices have the advantage of being able to transmit data over long distances at low power. This paper uses the FPM10A fingerprint sensor. The attendance results will be sent to the LoRa receiving device in real-time as backup data and stored on the SD card.

2.Literature Review

The first journal, entitled *Wireless Fingerprint Based College Attendance System Using Zigbee* Technology [11], proposed a system that automatically checks student attendance and keeps track of their records in an academic institute. This system uses a fingerprint sensor module to register attendance, and all records are saved on a computer. The fingerprint sensor module and LCD panel are both mobile and can be moved around the room. Students must place their fingers on the fingerprint sensor module to mark attendance. When a specific student is identified, his attendance record in the database is updated, and they are notified via the LCD panel. In this system, a Microsoft Excel attendance report on the computer is generated automatically after 15 days. This report will be emailed to the respected Head of Department (HOD), instructor, and student's parent's email ID.

The second journal, entitled *Face Recognition Attendance System Based on Real-Time Video Processing* [12], described the design of a real-time video processing-based face recognition attendance system. This article focuses on four issues: the accuracy rate of the face recognition system during actual check-in, the stability of the face recognition attendance system with real-time video processing, the truancy rate of the face recognition attendance system with real-time video processing, and the interface settings of the face recognition attendance system with real-time video processing. As a result, it significantly improves class efficiency and is critical in guiding the development of the time and attendance system.

The design and implementation of a voice biometric-based attendance system was demonstrated in the third journal, Speech Biometric-Based Attendance System [13]. The system is accessed by dialling a specific number of cell phones. An IVR system guides a new user through the enrolment process and a logged-in user through the verification procedure. The system uses text-independent speaker verification and i-vector-based speech modeling to authenticate the user. In order to normalize the effects of session/environment fluctuations, linear discriminant analysis and within-class covariance normalization are applied. The classifier is a simple cosine distance scoring with score normalization, and the decision is made using a predefined threshold. A group of 110 students has been using the designed system regularly for roughly two months. The system performance in recognition rate is 94.2 percent, while the system's average response time for test data duration of 50 seconds is 26 seconds.

The fourth journal, entitled *An Efficient Automatic Attendance System Using Fingerprint Reconstruction Technique* [1], constructed a precise, fast, and highly efficient automatic attendance system based on fingerprint verification. The authors presented a system for fingerprint verification using the extraction of minutiae technique, as well as a system for automating the entire process of taking attendance. The experimental results reveal that the suggested approach is quite effective at verifying user fingerprints.

The fifth journal, entitled *Antecedents, Presents State and Perspective of the Conduction of Clinical Tests in Ciego de Avila Province* [4], proposed a method based on a QR code displayed to students during or at the start of each lecture. To validate their attendance, the students must scan the code. The paper went over the high-level implementation details of the proposed system. It also demonstrates how the system validates student identities in order to prevent fake registrations.

The sixth journal, entitled *Smart Attendance Management System* [14], proposed a method based on a fingerprint device in a modified enterprise environment ported to an academic environment. The device used in this paper is a computer to store and verify fingerprints.

The seventh journal, entitled *Fingerprint-Based-Attendance-Management-System* [15], presented a fingerprint attendance system designed to operate as a standalone and handheld system without using a computer, unlike other fingerprint attendance systems.

The latest journal, *Random Interval Attendance Management System (RIAMS): A Novel Multimodal Approach for Post-COVID Virtual Learning* [16], presented an innovative solution to problems with attendance monitoring, student disengagement, and attendance faking during virtual learning. The authors used a face recognition module created with the open-source software library Dlib, as well as two auxiliary modalities: CAPTCHA verification and UIN (Unique Identification Number) queries. Face recognition and ancillary modalities both function at random.

3.Materials and Methods

The equipment used in the design of the attendance system is the FPM10A sensor as a fingerprint sensor. This sensor is operated using an Arduino Uno microcontroller. The transceiver module used in this design is LoRa RFM96. This LoRa module can function as a sender and receiver. The analysis carried out in this study is the performance of LoRa in sending and receiving signals. Performance analysis is carried out based on the parameters used. The parameters that determine the quality of LoRa performance are the Spreading Factor (SF), bandwidth, coding rate, bit rate, RSSI, transfer speed delay, throughput, and packet loss.

The SF is the ratio between the symbol rate and the chip rate. A higher spread factor can increase the signal noise to the ratio (SNR) value, sensitivity, and range. But it can also increase packet airtime [17]. For example, LoRa has a spreading factor value in SF7 to SF12.

Bandwidth is a very important parameter in determining the chip rate. A higher bandwidth value will provide a higher data rate. This is due to the shorter time in the transmission process but the low sensitivity value due to the integration of additional noise. Meanwhile, a lower bandwidth value has high sensitivity but low speed. The bandwidth values range from 7.8 kHz to 500 kHz, but what can be used on LoRa is 125 kHz, 250 kHz, and 500 kHz [18].

The coding rate can be the number of bits containing data or information transmitted. Therefore, the coding rate can be formulated as follows.

$$CR = \frac{4}{(4+n)} \tag{1}$$

Where n represents {1,2,3,4}. The coding rate is formulated to handle Packet Error Rate (PER) due to interference. A larger coding rate increases the resistance to interference and decoding errors [18].

Bitrate (Rb) is the basic unit of digital information and has binary properties, namely 0 or 1, high or low. Bit rate is the rate of change of bits per unit of time. Bit rate values are expressed in bps. The following is a formula that shows the relationship between the spreading factor (SF), coding rate (CR), and bandwidth (BW) in determining the bit rate [19].

$$R_b = SF \times \frac{[CR]}{\left[\frac{2^{SF}}{BW}\right]} \tag{2}$$

Transfer speed is the ability to send data in units of time. The following is the formula for calculating the transfer speed [20].

$$Transfer\ speed = \frac{Amount\ of\ data}{Time} \tag{3}$$

Throughput is the actual bandwidth measured at a given time. Throughput describes the actual bandwidth usage under certain time conditions. Then the formula for calculating throughput can be written as: [21]

$$Throughput = \frac{Transfer\ speed}{bandwidth} x100\% \tag{4}$$

Delay is the amount of time it takes for a packet to be delivered from sender to receiver. The following is the formula for calculating the delay [20].

$$Delay = \frac{Time\ the\ package\ was\ received}{Time\ the\ package\ was\ sent} \tag{5}$$

RSSI is the received signal power in milliwatts and is measured in dBm. This RSSI value can be used as a benchmark for how well the receiver can receive signals from the signal's sender. The RSSI value gets closer to 0, the better the value will be. In general, the RSSI values for LoRa are :[22]

- RSSI minimum = -120 dBm
- If RSSI = -30 dBm, then the signal is strong
- If RSSI = -120 dBm, then the signal is weak

Packet loss is the number of packets that fail to reach the recipient when sent, and the packet is lost. The following is the formula for calculating Packet loss [20].

$$Packet\ Loss = \frac{Packet\ sent - Packet\ Received}{Packet\ sent}\ x\ 100\% \tag{6}$$

The presented system block diagram in this design can be seen in Fig. 1. The figure shows a block diagram of the system using LoRa-based fingerprints.

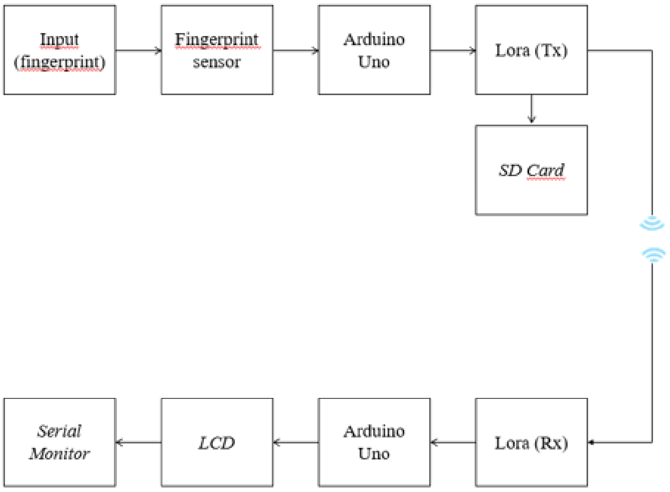

Fig. 1. Block diagram of the attendance system.

The presence device that is part of the sender and receiver device used in this test is shown in Figs. 2 and 3, respectively.

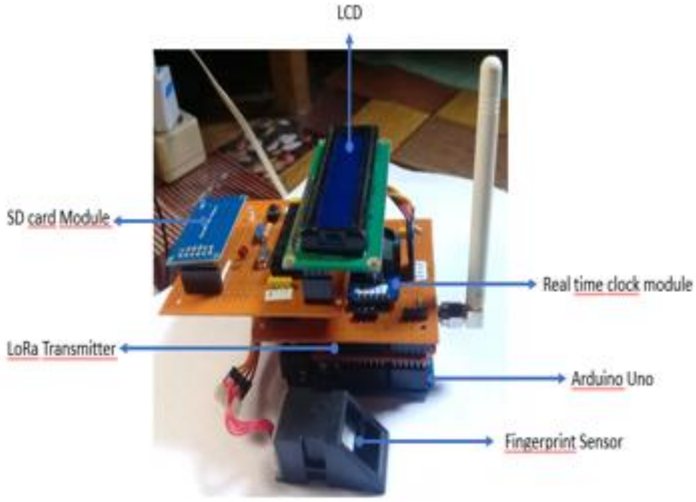

Fig. 2. Fingerprint sensor.

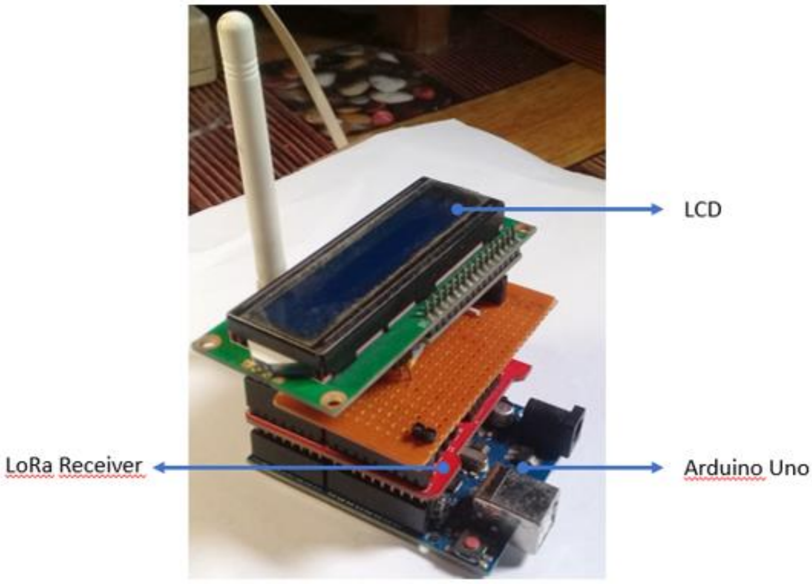

Fig. 3. Receiver device.

The input section is a fingerprint sensor and LoRa sender, as presented in Fig. 2. The fingerprint sensor will scan and change the fingerprint pattern to digital. Arduino Uno, a microcontroller, will process the fingerprint data. After the data is processed, the data will be sent by the LoRa sender. The modulations used are LoRa modulation, FSK modulation, and OOK modulation. The LoRa recipient will receive the data that has been successfully sent. The data will be reprocessed using the Arduino Uno microcontroller, as shown in Fig. 3. Liquid Crystal Display (LCD) and serial monitor function as output to display the data that has been received.

The test scenario in this study was carried out under two conditions, namely the Line of Sight (LOS) and Non-line of Sight (NLOS) conditions. The test is carried out at 5 points in each condition. The test points are located inside the University of Riau, Indonesia, with a distance of 50 m, 100 m, 150 m, 200 m, and 250 m. Presence system performance testing uses LoRa Modulation, FSK, and OOK. Figures 4 and 5 show the test points, respectively.

Fig. 4. NLOS test points at Faculty of Engineering, Universitas Riau, Indonesia.

Fig. 5. LOS test points.

The NLOS condition is the condition of the sender and receiver getting obstructed by buildings, trees, and other objects. This test point is located at the Faculty of Engineering, Universitas Riau. Some laboratory buildings and big trees are around the test area. The LOS condition is that the sender and receiver do not have a barrier. For this test, we choose the open public area nearby the football field area at Universitas Riau. We perform the test along the road, whereas this area is free of obstructions like buildings. The parameters used in this study refer to Table 2, using the SF7. The choice of SF7 is due to the farthest distance to be tested in this study being 265 meters. Therefore, the SF7 can operate up to 2 KM. The bandwidth used is 125 kHz with a coding rate of 4/5. The bitrate value of 5469 bits/sec is calculated using the bitrate formula.

4. Results and Discussion

4.1. Results of attendance based on distance

The first testing based on distance is carried out at five test points. The test points are 50 m, 100 m, 150 m, 200 m, and 250 m. At each test point, three different modulations were tested: LoRa modulation, FSK modulation, and OOK modulation. Determination of the distance based on the farthest distance between Building C, Faculty of Engineering, University of Riau, and the Laboratory of Electrical Engineering, University of Riau. Based on the results of measurements using the Google Earth application, the distance between Building C, Faculty of Engineering, Universitas Riau, and the Electrical Engineering Laboratory of Universitas Riau is 265m away. The distance is divided into five test points spanning 50 m. The determination of test points is done using the Google Earth application. Table 2 shows the results of the presence test based on distance.

Table 2. Comparison of wireless technology [9].

Distance (m)	Modulations	Condition	
		LOS	NLOS
50	LoRa	Successful	Successful
	FSK	Successful	Successful
	OOK	Successful	Successful
100	LoRa	Successful	Successful
	FSK	Successful	Successful
	OOK	Successful	Successful
150	LoRa	Successful	Successful
	FSK	Successful	Fail

Table 3 shows the first test results based on various distances. Based on the test results in LOS conditions, LoRa modulation is able to send data up to the farthest distance of 250 m. Then the FSK modulation is capable of sending data up to a distance of 150 m, while the OOK modulation can receive up to a distance of 100 m. Based on the test results in NLOS conditions, LoRa modulation is able to transmit data up to the farthest distance of 250 m. On the other hand, FSK and OOK modulation can only send data up to a distance of 100 m.

LoRa modulation divides data before sending data so that the data sent can reach long distances. This method is stronger against noise and interference. OOK modulation cannot transmit data over long distances because this method is straightforward to get interference. Therefore, this method is recommended for use at close range.

4.2. RSSI performance analysis

Before performing a performance analysis, first, determine the test parameter values. Then, referring to the parameters described in the method section, Performance analysis is performed to obtain the RSSI value, delay value, transfer speed value, and throughput value. Based on the test results, the RSSI value is obtained. Table 3 is the RSSI value based on LOS and NLOS conditions.

Table 3. RSSI value based on LOS and NLOS.

Distance (m)	Modulations	RSSI (dBm)	
		LOS	NLOS
50	LoRa	-73.40	-87.90
	FSK	-86.09	-91.05
	OOK	-86.80	-90.45
100	LoRa	-91.50	-102
	FSK	-92.80	-91.20
	OOK	-93.05	-90.60
150	LoRa	-100.7	-108.6
	FSK	-91.70	0
	OOK	0	0
200	LoRa	-112.8	-114.2
	FSK	0	0
	OOK	0	0
250	LoRa	-115.5	-114.4
	FSK	0	0
	OOK	0	0

The following performance analysis is to calculate the delay. The delay shows the length of time sent and received. Based on the test results in LOS conditions, OOK modulation has the lowest delay value, namely 0.00272 s, while the highest delay with a value of 0.03713 s in the LoRa modulation. Table 4 shows the performance analysis of the delay.

Table 4. Performance analysis of delay value.

Distance (m)	Modulations	Delay (s)	
		LOS	NLOS
50	LoRa	0.03713	0.0371212
	FSK	0.00282	0.0028044
	OOK	0.00272	0.0027192
100	LoRa	0.03712	0.0371204
	FSK	0.00283	0.0027224
	OOK	0.00272	0.0027224
150	LoRa	0.03713	0.0371194
	FSK	0.00280	0
	OOK	0	0
200	LoRa	0.30708	0.0371192
	FSK	0	0
	OOK	0	0
250	LoRa	0.03713	0.037124
	FSK	0	0
	OOK	0	0

The lowest NLOS delay condition with a value of 0.0027192 s appears in OOK modulation, while the highest delay is in LoRa modulation with a value of 0.037124 s. OOK modulation has the best delay because the speed of this modulation in sending data is better than other modulations.

The subsequent performance analysis is to calculate the transfer speed. The transfer rate shows what speed it takes for data to be sent and received. Based on the transfer speed test results, in the LOS conditions, the highest transfer rate is in the OOK modulation with a value of 3.98365 kbps, while the lowest transfer rate is in the LoRa modulation with a value of 0.29213 kbps. In NLOS conditions, the highest transfer rate is in OOK modulation, with a value of 3.98595 kbps. In contrast, the lowest transfer rate is in LoRa modulation, with a value of 0.29217 kbps. OOK modulation has the advantage of high transfer speed. Table 5 shows the performance analysis of the transfer speed value.

Table 5. Performance analysis of transfer rate value.

Distance (m)	**Modulations**	**Transfer Rate (kbps)**	
		LOS	**NLOS**
50	LoRa	0.29213	0.29217
	FSK	3.84201	3.86507
	OOK	3.98365	3.98595
100	LoRa	0.29216	0.29218
	FSK	3.83674	3.85376
	OOK	3.98245	3.98132
150	LoRa	0.29214	0.29218
	FSK	3.86692	0
	OOK	0	0
200	LoRa	0.29223	0.29219
	FSK	0	0
	OOK	0	0
250	LoRa	0.29211	0.29215
	FSK	0	0
	OOK	0	0

The following performance analysis is to calculate the throughput value as listed in Table 6. Several factors determine throughput in terms of microcontroller device, data size, data type, modulation, transfer speed, and bandwidth used.

Table 6. Performance analysis of throughput value.

Distance (m)	**Modulations**	**Throughput (%)**	
		LOS	**NLOS**
50	LoRa	0.23370	0.2337
	FSK	3.07361	3.0921
	OOK	3.18692	3.1887
100	LoRa	0.23372	0.2337
	FSK	3.06939	3.0830
	OOK	3.18596	3.1851
150	LoRa	0.23371	0.2337
	FSK	3.09353	0
	OOK	0	0
200	LoRa	0.23378	0.2336
	FSK	0	0
	OOK	0	0
250	LoRa	0.23369	0.2336
	FSK	0	0
	OOK	0	0

Based on the performance analysis results, in the LOS condition, OOK modulation has the highest throughput percentage with a value of 3.18692%. At the same time, the lowest percentage is in the LoRa modulation, with a value of 0.23369%. In NLOS conditions, the highest percentage of throughput is in OOK modulation with a value of 3.1887%, while the lowest percentage is in the LoRa modulation with a value of 0.2336%. The transfer speed greatly influences the percentage of throughput. OOK modulation has the highest throughput percentage due to its high transfer speed.

The following performance analysis is to calculate the packet loss value. Packet loss shows the percentage of data lost in the data transmission process. Several factors influence the packet loss value in terms of the barrier conditions between the transmitter and receiver, the modulation used, and the distance between the transmitter and receiver. Based on the test results under LOS conditions, the modulation with the best packet loss percentage is LoRa modulation with a value of 0%. In NLOS conditions, the modulation with the best packet loss percentage is LoRa modulation with a value of 0%. LoRa has the ability to send data and receive data very well. In addition, LoRa is more resistant to noise and interference. Table 7 shows the analysis of the packet loss value performance.

Table 7. Performance packet loss value.

Distance (m)	Modulations	Packet Loss (%)	
		LOS	NLOS
50	LoRa	0	0.06
	FSK	1.46	0.60
	OOK	1.78	0.03
100	LoRa	0	0
	FSK	2.03	0.32
	OOK	77.5	2.14
150	LoRa	0.06	5.81
	FSK	7.74	100
	OOK	100	100
200	LoRa	36.61	24.66
	FSK	100	100
	OOK	100	100
250	LoRa	21.72	68.17
	FSK	100	100
	OOK	100	100

5. Conclusions

The attendance system based on LoRa was successfully developed. LoRa modulation is the best modulation for distance testing. LoRa modulation sends and receives data to the farthest point in both LOS and NLOS conditions.

The proposed LoRa device uses parameters with SF7 value, 125 kHz bandwidth, 4/5 coding rate, and 5469 bits/sec bitrate value. FSK modulation is able to send and receive data better in LOS conditions. OOK modulation has the lowest capability of sending and receiving data.

The best RSSI value in LOS conditions is -73.4 dBm using LoRa modulation, while in NLOS conditions, the best RSSI value is -87.9 dBm using LoRa modulation. The best delay value in NLOS conditions is 0.0027192 s using OOK modulation.

In the LOS condition, the best delay value is 0.00272 s using OOK modulation. The best transfer rate in NLOS conditions was 3.98595 bits/sec using OOK modulation, while the best transfer rate for LOS conditions was 3.98245 bits/sec using OOK modulation.

The best throughput in NLOS conditions was 3.1887% using OOK modulation, while in LOS conditions, the best throughput value was 3.18692% using OOK modulation.

The best packet loss in NLOS conditions is 0% at a distance of 100 m using LoRa modulation, while in LOS conditions, the best packet loss is 0% at a distance of 50 m and 100 m using LoRa modulation.

Abbreviations

FSK	Frequency Shift Keying
IoT	Internet of Things
LoRa	Long Range
LOS	Line Of Sight
LPWAN	Low Power Wide Area Network
NLOS	Non-Line Of Sight
OOK	On-Off Keying

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