LoRa 920 MHz as a Green Technology in Maritime Education: Optimizing Modulation Settings for Real-Time Environmental Data

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Abstract. LoRa, as a low-power wireless communication module, offers high flexibility and energy efficiency, making it an ideal choice for sustainable monitoring in maritime environments. This study identifies optimal modulation settings for LoRa 920 MHz within a 125 KHz bandwidth across various distances, enabling real-time monitoring of oceanic environmental conditions. Key tested variables include the Spreading Factor and Coding Rate, which influence signal parameters such as RSSI, SNR, PDR, and ToA. At 250 meters (LoS), the optimal configuration is a Spreading Factor of 9 and Coding Rate of 4/7, achieving RSSI -95.60, SNR 4.80, PDR 100%, and ToA 197.63 ms. For 500 meters (LoS), the best settings are a Spreading Factor of 12 and a Coding Rate of 4/7, yielding RSSI -98.60, SNR -4.10, PDR 100%, and ToA 1351.68 ms. At 150 meters (NLoS), the ideal arrangement may be a Spreading Factor of 10 and a Coding Rate of 4/5, creating RSSI -103.80, SNR -5.40, PDR 100%, and ToA 288.77 ms. Discoveries illustrate that expanding the Spreading Calculate and Coding Rate impacts SNR and ToA. These come about to emphasize LoRa's potential to bolster economical sea natural instruction through energy-efficient, real-time information collection.

1 Introduction

The fast development of technology and information systems has brought about new possibilities and difficulties, impacting different areas such as economics, social interactions, and environmental conservation efforts that are focusing more on sustainability [1]. In marine education, it is increasingly important for students to be able to use eco-friendly technologies and digital tools to improve their knowledge of environmental issues in the maritime industry.

For the Internet of Things (IoT) system in the context of maritime education, LoRa (Long Range) which is known for its long communication range and energy efficiency is very appropriate. Using the 920 MHz frequency, LoRa operates in Indonesia and offers a wide range with minimal power consumption. In the realm of education, this technology allows a group of connected devices to collect environmental data in real-time [3, 4]. In addition to saving energy, LoRa can be integrated with existing network architectures to

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provide excellent performance even in harsh environments, such as coastal areas, making it a valuable tool for collecting relevant environmental data [4].

The optimal adjustment settings for LoRa 920 MHz in the 125 kHz range at various distances are examined in this study. The aim is to create a marine education model that utilizes green technology efficiently. Key metrics such as Received Signal Strength Indicator (RSSI), Signal-to-Noise Ratio (SNR), Packet Delivery Ratio (PDR), and Time on Air (ToA) are influenced by Spreading Factor and Coding Rate, which are important factors in this study [2, 4]. At a distance of 250 meters, the optimal configuration for Line-of-Sight (LoS) conditions is Spreading Factor 9 and Coding Rate 4/7, RSSI -95.60, SNR 4.80, PDR 100%, and ToA 197.63 are the results of this [3]. These findings demonstrate the effectiveness of LoRa in educational programs that emphasize environmentally friendly technologies by enabling efficient and energy-saving transmission of environmental information.

The real-world utilization of LoRa in schools shows how it can move forward in instructing and get understudies more included by utilizing real natural data. LoRa can work well in indoor situations, like schools, where it offers solid associations and is cost-effective, particularly in buildings with different floors [5]. In open-air settings commonly found in oceanic education—like coastal zones or separated islands—LoRa's broad run and negligible control needs make it a culminate choice for helping in exercises that center on raising mindfulness almost the environment [6, 7, 10].

Consolidating LoRa innovation into the sea instruction program not as it were energizes mindfulness of the environment but also energizes basic considering and development among understudies. LoRa permits for gathering of information in real-time utilizing exceptionally small control, which bolsters economical instruction destinations. This could be utilized for assignments like following temperature, dampness, water virtue, and discussing quality. This down-to-earth strategy of learning progresses students' get a handle on maintainability issues [6, 8, 9].

2 Methods

The methodology was developed to examine how LoRa 920 MHz can serve as an environmentally friendly technology for real-time monitoring of environmental data in maritime education. In the first phase, we conducted a review of existing literature to collect information regarding green technologies and their use in educational contexts, particularly focusing on IoT systems and the gathering of environmental data. This initial investigation was crucial for guiding the design of the LoRa-based educational device. Following the design phase, we carried out testing on the device to determine the best parameters for operating LoRa 920 MHz with a 125 kHz bandwidth under different conditions and distances relevant to maritime and coastal applications. In Fig. 1, the system framework shows two main devices: the Node Device and the Gateway Device. The Node Device, which serves as a data transmitter, is equipped with sensors suitable for monitoring marine environmental parameters, such as the DHT22 humidity sensor and the YL-69 soil moisture sensor, both of which are widely used in coastal ecology studies. The Gateway Device collects data from the Node Device and presents this information on a serial monitor, along with an indicator indicating the signal quality.

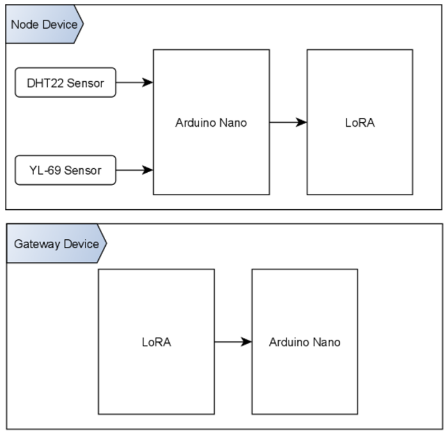

Fig. 1. Block Diagram

2.1 Modulation Parameters

The following is an explanation of the modulation parameters that will be analyzed in this paper:

1. **Spreading Factor (SF)**
   The Spreading Factor (SF) in LoRa modulation determines the number of symbols used to convey each bit of data. A higher SF, with values ranging from 7 to 12, transmits more symbols per bit, which increases the signal's ability to be detected at longer distances or in environments with interference. This increase in symbols increases the signal's robustness, making it easier to receive weak signals.
2. **Coding Rate (CR)**
   Coding Rate (CR) indicates the level of error correction applied to transmitted data in the LoRa system, with typical values ranging from 4/5 to 4/8. A higher CR adds more redundant data, allowing the receiver to correct more errors during transmission, which is particularly useful in areas with significant interference or noise.
3. **Received Signal Strength Indicator (RSSI)**
   Received Signal Strength Indicator (RSSI) measures the power level of a received signal in dBm, where a higher RSSI value (closer to 0 dBm) indicates a stronger signal and a lower RSSI (more negative) indicates a weaker signal. While a high RSSI usually correlates with good communication quality, it can be affected by factors such as the distance between the transmitter and receiver and ambient conditions.
4. **Signal-to-noise ratio (SNR)**
   The signal-to-noise ratio (SNR) measures the relationship between signal strength and noise level, expressed in dB. A higher SNR indicates a clearer signal with less interference, resulting in more reliable data transmission, while a lower (more negative) SNR implies that the signal is more difficult to distinguish from background noise, which can lead to data inaccuracies.
5. **Packet Delivery Ratio (PDR)**
   Packet Delivery Ratio (PDR) reflects the percentage of data packets that are successfully received out of the total packets sent. A PDR of 100% indicates that every packet sent is received without any loss, while a lower PDR indicates that packets are lost or corrupted during transmission, which may be caused by interference, weak signal strength, or an unsupported channel.

6. **Time on Air (ToA)**
   Time on Air (ToA) describes the total time required to complete a single transmission, including all data bits and error correction symbols. A longer ToA indicates a longer transmission duration, which can lead to increased latency and decreased energy efficiency, as the device remains active for a longer time.

3 Results and Discussion

Testing was conducted at specific distances, namely at 250 meters and 500 meters in Line-of-Sight (LoS) conditions, and at 150 meters in Non-Line-of-Sight (NLoS) conditions. These distances were chosen to replicate medium and long ranges for LoS situations, with 250 meters serving as a common operational range in accessible maritime settings, and 500 meters used to simulate long-range monitoring needs in larger coastal areas. The 150-meter distance for NLoS conditions was chosen to reflect common obstacles encountered in maritime settings, such as buildings or natural obstructions, thus aiding in the evaluation of signal performance amidst realistic interference situations.

3.1 250 Meters Distance Test (LoS - Line of Sight)

Table 1. 250 Meters Distance Test (LoS - Line of Sight)

Parameters	SF	CR			
		4/5	**4/6**	**4/7**	**4/8**
RSSI (dBm)	7	-97.90	-97.80	-96.63	-97.13
	8	-97.30	-97.56	-98.20	-96.50
	9	-99.30	-98.60	-95.60	-96.50
	10	-97.71	-99.20	-102.22	-101.20
	11	-103.10	-102.00	-101.44	-100.10
	12	-101.10	-100.80	-102.67	-100.80
SNR (dB)	7	1.10	0.70	2.63	0.25
	8	3.30	1.33	2.20	1.90
	9	2.70	1.10	4.80	3.80
	10	1.71	0.80	-7.33	-3.50
	11	-3.60	-7.30	-4.22	-0.90
	12	-1.30	-1.50	-7.00	-3.60
PDR (%)	7	100%	100%	80%	80%
	8	100%	90%	100%	100%
	9	100%	100%	100%	100%
	10	70%	100%	90%	100%
	11	100%	100%	90%	100%
	12	100%	100%	90%	100%
ToA (ms)	7	46.34	51.46	56.80	61.70
	8	82.43	90.62	98.82	107.01
	9	164.86	181.25	197.63	215.02
	10	288.77	313.34	337.92	362.50
	11	577.54	626.69	675.84	724.99
	12	1155.07	1253.38	1351.68	1449.98

Lower Spread Factors (SF), such as SF7 and SF8, result in greater Signal to Noise Ratio (SNR) and lower Time to Broadcast (ToA), thereby increasing transmission speed and energy efficiency—two important aspects of time data applications real, according to the results of Table 1. But as SF increases, especially up to SF12, the system exhibits much higher ToA, thereby reducing speed but offering more reliable transmission and higher Packet Delivery Ratio (PDR), making it suitable for possible situations experiencing interference. In addition, data integrity is influenced by the Coding Rate (CR), which ranges from 4/5 to 4/8. Higher CR values offer superior error correction but at the expense of longer ToA.

3.2 500 Meters Distance Test (LoS – Line of Sight)

The results in Table 2 show that lower SF values, such as SF7 and SF8, result in shorter Time on Air (ToA) and slightly improved Signal-to-Noise Ratio (SNR), which supports faster data transmission and is ideal for real-time applications with limited interference. However, as the SF increases to SF11 and SF12, the ToA significantly rises, indicating a trade-off where more robust coverage comes at the cost of slower transmission. The Packet Delivery Ratio (PDR) shows strong performance across various CR settings, especially at higher SFs, reflecting reliable communication. Higher CRs, particularly 4/8, provide better error resilience but lead to further increases in ToA.

Table 2. 500 Meters Distance Test (LoS - Line of Sight)

Parameters	SF	CR			
		4/5	**4/6**	**4/7**	**4/8**
RSSI (dBm)	7	-99.00	-99.00	-99.33	-98.00
	8	-99.00	-99.00	-99.00	-98.00
	9	-100.10	-99.12	-99.42	-99.00
	10	-99.14	-99.00	-99.00	-99.00
	11	-101.00	-100.00	-100.00	-99.00
	12	-99.40	-98.30	-98.60	-98.10
SNR (dB)	7	-7.11	-7.85	-8.16	-7.75
	8	-7.88	-9.70	-8.10	-6.77
	9	-9.20	-7.37	-8.85	-7.66
	10	-6.28	-7.00	-9.00	-10.00
	11	-7.00	-7.00	-7.60	-7.20
	12	-6.60	-5.60	-4.10	-5.00
PDR (%)	7	90%	70%	60%	80%
	8	80%	100%	100%	90%
	9	100%	80%	70%	90%
	10	70%	90%	100%	100%
	11	100%	90%	100%	100%
	12	100%	100%	100%	100%
ToA (ms)	7	46.34	51.46	56.58	61.70
	8	82.43	90.62	98.82	107.01
	9	164.86	181.25	197.63	214.02
	10	288.77	313.34	337.92	362.50
	11	577.54	626.69	675.84	724.99
	12	1155.07	1253.38	1351.68	1449.98

3.3 150 Meters Distance Test (NLoS – Non-Line of Sight)

The results in Table 3 show that higher SF values generally yield improved PDR, reaching up to 100% for most combinations, though with an increased ToA, indicating a trade-off between reliability and latency. For instance, SF12 consistently achieves high PDR but with a ToA extending beyond 500 ms. RSSI and SNR values fluctuate based on CR, with the highest CR (4/8) achieving relatively stable RSSI and SNR across SFs, though at the expense of increased ToA.

Table 3. 150 Meters Distance Test (NLoS – Non-Line of Sight)

Parameters	SF	CR			
		4/5	**4/6**	**4/7**	**4/8**
RSSI (dBm)	7	-103.00	-108.00	-108.00	-107.33
	8	-107.50	-103.71	-105.00	-103.44
	9	-105.00	-104.11	-104.14	-104.22
	10	-103.80	-104.50	-104.00	-103.00
	11	-106.10	-105.50	-105.10	-105.33
	12	-105.66	-104.40	-105.00	-103.40
SNR (dB)	7	-6.00	-8.00	-5.75	-7.66
	8	-4.20	-6.57	-10.83	-7.33
	9	-10.12	-8.22	-4.85	-8.22
	10	-5.40	-10.30	-13.42	-6.30
	11	-8.90	-11.40	-8.40	-13.55
	12	-12.00	-9.50	-9.30	-5.60
PDR (%)	7	10%	40%	40%	30%
	8	100%	70%	60%	90%
	9	80%	90%	70%	90%
	10	100%	100%	70%	100%
	11	100%	100%	100%	90%
	12	90%	90%	90%	90%
ToA (ms)	7	23.17	25.73	28.29	30.85
	8	41.22	45.31	49.41	53.50
	9	82.43	90.62	98.82	107.01
	10	144.38	156.67	168.96	181.25
	11	288.77	313.34	337.92	362.50
	12	577.54	626.69	675.84	724.99

4 Conclusion

In summary, LoRa 920 MHz communication testing over LoS 250, LoS 500, and NLoS 150 meters shows that proper Coding Rates (CR) and greater Spreading Factors (SF) enhance data reliability, as seen by high Packet Delivery Ratios (PDR) under various scenarios. But these settings also affect energy efficiency, which is important for real-time data monitoring, by increasing the Time on Air (ToA). With a PDR of 100%, RSSI of -103.80 dBm, SNR of -5.40 dB, and a reasonable ToA of 288.77 ms, the arrangement of SF10 and CR 4/5 at a 150-meter NLoS distance provides a balanced performance for the best real-time environmental monitoring. This configuration is appropriate for sustainable, real-time monitoring applications in the maritime industry since it offers dependable data transfer while consuming less energy.

References

1. M. J. Faber, K. M. Van Der Zwaag, W. G. V. Dos Santos, H. R. D. O. Rocha, M. E. V. Segatto, and J. A. L. Silva, IEEE Sens. J. **20**, 9480 (2020).
2. L. Beltramelli, A. Mahmood, P. Osterberg, and M. Gidlund, IEEE Trans. Ind. Informatics **17**, 3544 (2021).
3. A. P. A. Torres, C. B. Da Silva, and H. T. Filho, IEEE Access **9**, 26633 (2021).

4. J. Tapparel, O. Afisiadis, P. Mayoraz, A. Balatsoukas-Stimming, and A. Burg, IEEE Work. Signal Process. Adv. Wirel. Commun. SPAWC **2020-May**, 1 (2020).
5. L. Pocero, S. Tsampas, G. Mylonas, and D. A. Amaxilatis, IEEE Access **8**, 1 (2020).
6. Q. L. Hoang, W. S. Jung, T. Yoon, D. Yoo, and H. Oh, IEEE Access **8**, 1 (2020).
7. G. M. Bianco, R. Giuliano, G. Marrocco, F. Mazzenga, and A. Mejia-Aguilar, IEEE Internet Things J. **7**, 1 (2020).
8. Y. Astutik and R. Yusuf, Proc. 2022 12th Int. Conf. Syst. Eng. Technol. (ICSET), 31 (2022).
9. P. D. P. Adi et al., Proc. 2023 Int. Conf. Radar, Antenna, Microwave, Electron., and Telecommun. (ICRAMET), 313 (2023).
10. M. A. Arifin, N. M. N. Khamsah, N. Najati, W. Suryanto, and I. E. Prabowo, Proc. 2023 IEEE Int. Conf. Aerospace Electron. Remote Sens. Technol. (ICARES), 1 (2023).