Science and Technology Publishing (SCI & TECH)
ISSN: 2632-1017
Vol. 7 Issue 4, April - 2023

Evaluation Of Data Delivery Success Ratio For Lora-Based Sensor Node

Edemeka, Victor Usiere[1]
Department of Electrical/Electronic Engineering Technology
Akwa Ibom State Polytechnic, Ikot Osurua , Akwa Ibom State

Amadi Chibuzor Henry[2]
Department of Electrical and Electronic Engineering
Imo State University Owerri, Imo State

Uduaka Etim Udoka[3]
Department of Computer Engineering
Akwa Ibom State Polytechnic
Ikot Osurua, Ikot Ekpene Akwa Ibom State

***Abstract*— In this paper, evaluation of data delivery success ratio for LoRa-based sensor node is presented. The analytical expression for computing the required signal to noise ratio (SNR), bit error probability (BER), data delivery success ratio, successfully delivered data packet sizes for different payload sizes were presented. Some numerical computations for the analysis are performed for a bandwidth of 125 kHz, coding rate of 1 and payload size ranging from 10 to 50 bytes. The results showed the spreading factor, SF of 12 with the best sensitivity (lowest sensitivity value of) of -137 dBm has the lowest required SNR value of -20 dBm. On the other hand, the results show that the lowest Eb/No value of 5.072 dBm occurred for Spreading Factor, SF of 10 and this resulted in SF of 10 having the worst (or highest) bit error value of 1.76E-02. The results of data delivery success ratio, R_{Succ} (%) versus Spreading Factor, for payload size of 10, 20, 30, 40 and 50 bytes show that the SF of 10 has the lowest data delivery success ratio and this also reflected in the lowest successfully delivered data packet results for SF of 10. In essence, SF of 10 is the worst LoRa transceiver configuration when it comes to bit error probability and data delivery success ratio. In any case, for a given bit error rate, the data delivery success ratio decreases with increases in payload size.**

Keywords:* *Data Delivery Success Ratio, LoRa Transceiver, Sensor Node, Receiver Sensitivity, Bit Error Probability

1. Introduction

As LoRa transceiver technologies continues to attract the attention of wireless sensor network designers and researchers due to its long range and low power capabilities [1,2,3,4,5,6,7,8,9,10,11,12], it is essential to properly understand some aspect of the transceiver that may impact on the quality of service of such transceivers. Notably, for any give LoRa transceiver spreading factor and bandwidth there is a specific receiver sensitivity which can be used to determine its bit error performance [13,14,15,16,17,18]. Furthermore, available published research articles have also presented analytical formulas which can be used to determine the data delivery success ratio for any gibe bit error probability [19,20,21,22]. As such, this paper applied the ideas from the various published research articles to presented analytical models for evaluating the data delivery performance of LoRa transceiver-based sensor node. Specifically, the paper seeks to examine the impact of spreading factor and payload size on the bit error performance and also on the data delivery performance. Some numerical computations are used to demonstrate the applicability of the models for a case study LoRa transceiver operating in 125 kHz bandwidth and coding rate of 1. The detail analytical models, the results and discussion of the results are presented in the paper.

2. Methodology

The study is focused on how the spreading factor and payload size affect the bit error rate and data delivery for a LoRa transceiver-based wireless sensor node. Let denote the LoRa sensitivity, BW denotes bandwidth with possible values of 125 kHz, 250 kHz and 500 kHz, NF denotes noise figure with value of 6 and SNR is the signal to noise ratio, then the bit error probability or bit error rate (BER) is determined as follows;

$$S_{LoRa} = -174 + 10\log_{10}(BW) + NF + SNR \quad (1)$$

Hence;

$$SNR = S_{LoRa} + 174 - 10\log_{10}(BW) - NF \quad (2)$$

$$\left.\frac{E_b}{N_0}\right|_{dBm} = SNR - 10\log_{10}(SF) - 10\log_{10}\left(\frac{4}{4+nCR}\right) + 10\log_{10}(2^{SF}) \quad (3)$$

$$E_b/N_O = 10^{\left(\left.\frac{E_b}{N_0}\right|_{dBm}/10\right)} \quad (4)$$

Where nCR is the coding rate with possible values of 1,2,3 and 4.

$$\text{BER} = \frac{1}{2}\left[1 - erf\left(\left(\frac{\log_{12}(SF)}{\sqrt{2}}\right)\left(E_b/N_O\right)\right)\right] \quad (5)$$

When the bit error probability or bit error rate (BER) is known, the data delivery success ratio, R_{Succ} is given as;

$$R_{Succ} = \frac{B_{pldb}}{B_{payL}} = \left((1-\text{BER})^{\left(\left(\frac{5}{4}\right)(B_{dataL} - B_{headL})\right)}\right)(1 - P_{coll}) \quad (6)$$

Where Pcoll denotes the probability of collision at the media access control layer. In this study $\boldsymbol{P_{coll}} = 0$. Also, B_{payL} denotes the payload data

B_{pldb} denotes the successfully delivered payload data

B_{headL} denotes the packet header and it has a value of 20-bits or 2.5 bytes

B_{dataL} denotes the total packet which consists of the payload and all the overhead data and it is defined as;

$$B_{dataL} = \boldsymbol{B_{payL}} + 13 \qquad (7)$$

$$B_{headL} = 20\ bits = 2.5\ bytes \qquad (8)$$

Then;

$$R_{Succ} = \left((1-\text{BER})^{\left(\left(\frac{5}{4}\right)(\boldsymbol{B_{payL}}+13-2.5)\right)}\right)(1-P_{coll}) \qquad (9)$$

$$R_{Succ} = \left((1-\text{BER})^{\left(\left(\frac{5}{4}\right)(\boldsymbol{B_{payL}}+10.5)\right)}\right)(1-P_{coll}) \qquad (10)$$

3. Results and discussion

Some numerical computations for the analysis are performed for a bandwidth of 125 kHz, coding rate of 1 and payload size ranging from 10 to 50 bytes. The results of Bit Error Rate (BER), Required SNR (dBm) and Eb/No (dBm) versus Spreading Factor, SF are shown in Table 1. Also, Table 1 and also Figure 1 show the LoRa receiver sensitivity for the various spreading factors considered. According to the LoRa receiver sensitivity values in Table 1 and Figure 1 SF of 12 has the best sensitivity of -137 dBm. The results of the required SNR (dBm) in Table 1 and figure 2 show that SF of 12 has the lowest required SNR value of -20 dBm.

The results of the Eb/No (dBm) versus Spreading Factor, SF in Figure 3 and Table 1 show that the lowest Eb/No value of 5.072 dBm occurred for Spreading Factor, SF of 10 and this resulted in SF of 10 having the worst (or highest) bit error value of 1.76E-02, as shown in Figure 4 and Table 1. The results of data delivery success ratio, R_{Succ} (%) versus Spreading Factor, SF are shown in Table 2 and Figure 5 for payload size of 10, 20, 30, 40 and 50 bytes. The results show that in all the payload sizes considered, the SF of 10 has the lowest data delivery success ratio. This also reflected in the lowest successfully delivered data packet results shown in Table 3 and Figure 6. In essence, SF of 10 is the worst LoRa transceiver configuration when it comes to bit error probability and data delivery success ratio. In any case, for a given bit error rate, the data delivery success ratio decreases with increases in payload size.

Table 1 The results of Bit Error Rate (BER), Required SNR (dBm) and Eb/No (dBm) versus Spreading Factor, SF

SF, Spreading Factor	LoRa Receiver sensitivity (dBm) for BW = 125 kHz	Bit Error Rate (BER)	Required SNR (dBm)	Eb/No (dBm)
7	-124	5.78E-03	-7	6.590
8	-127	8.97E-03	-10	6.021
9	-130	1.29E-02	-13	5.519
10	-133	1.76E-02	-16	5.072
11	-135	5.92E-03	-18	5.668
12	-137	1.28E-03	-20	6.3009

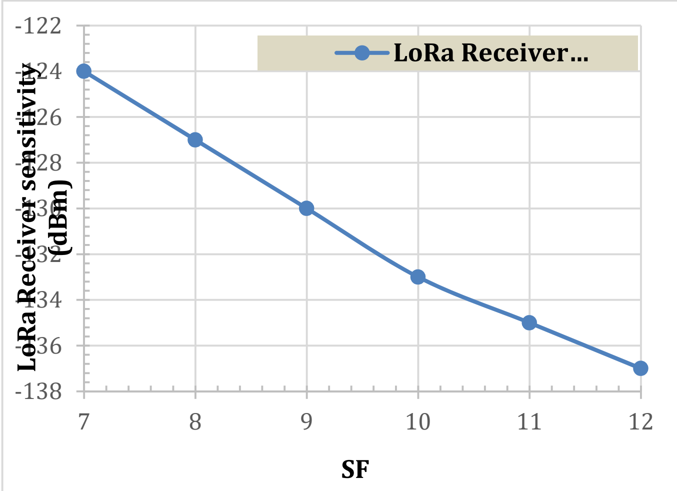

Figure 1 The graph of LoRa receiver sensitivity versus Spreading Factor, SF

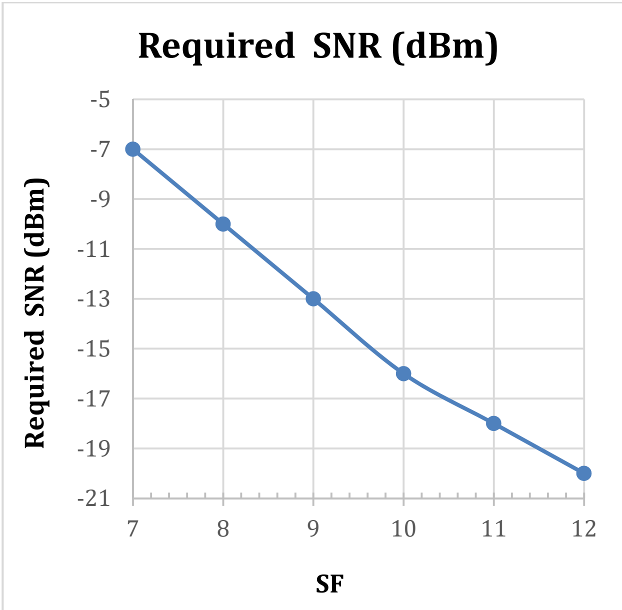

Figure 2 The graph of required SNR (dBm) versus Spreading Factor, SF

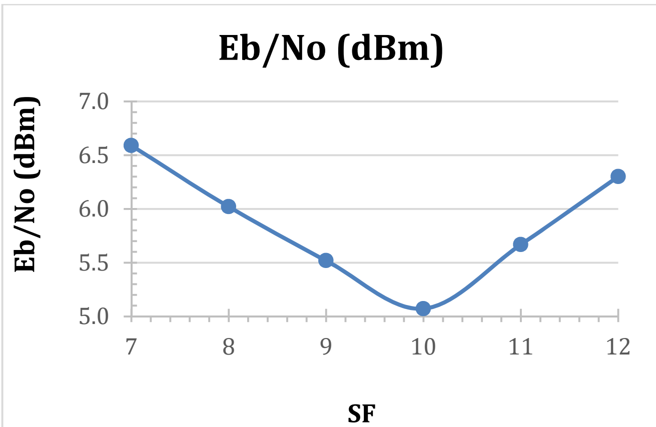

Figure 3 The graph of Eb/No (dBm) versus Spreading Factor, SF

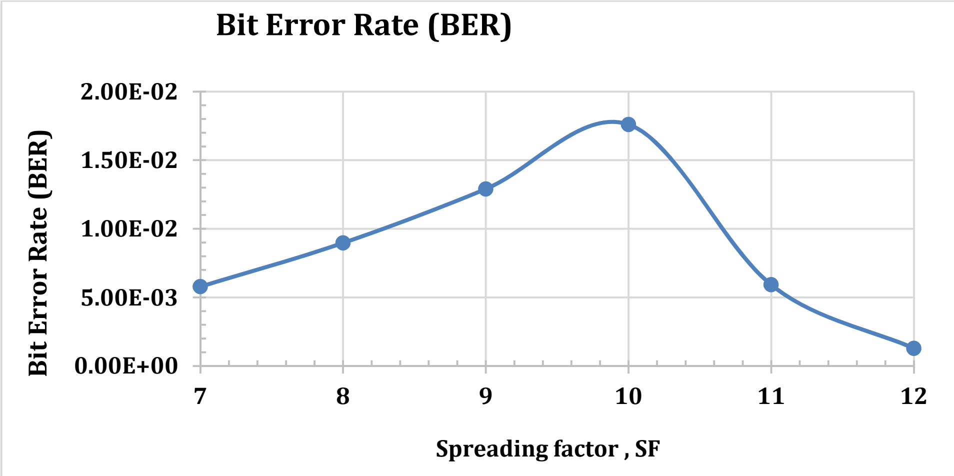

Figure 4 The graph of **Bit Error Rate (BER)** versus Spreading Factor, SF

Table 2 The results of data delivery success ratio, R_{Succ} (%) versus Spreading Factor, SF

Spreading Factor , SF	Ruscc (%) for payload of 10 bytes	Ruscc (%) for payload of 20 bytes	Ruscc (%) for payload of 30 bytes	Ruscc (%) for payload of 40 bytes	Ruscc (%) for payload of 50 bytes
7	0.861978	0.801736	0.745703	0.693587	0.645113
8	0.793852	0.709303	0.633759	0.566261	0.505951
9	0.716455	0.608904	0.517499	0.439815	0.373792
10	0.634897	0.5087	0.407586	0.326571	0.261658
11	0.858838	0.797394	0.740345	0.687378	0.638201
12	0.967799	0.952469	0.937382	0.922535	0.907922

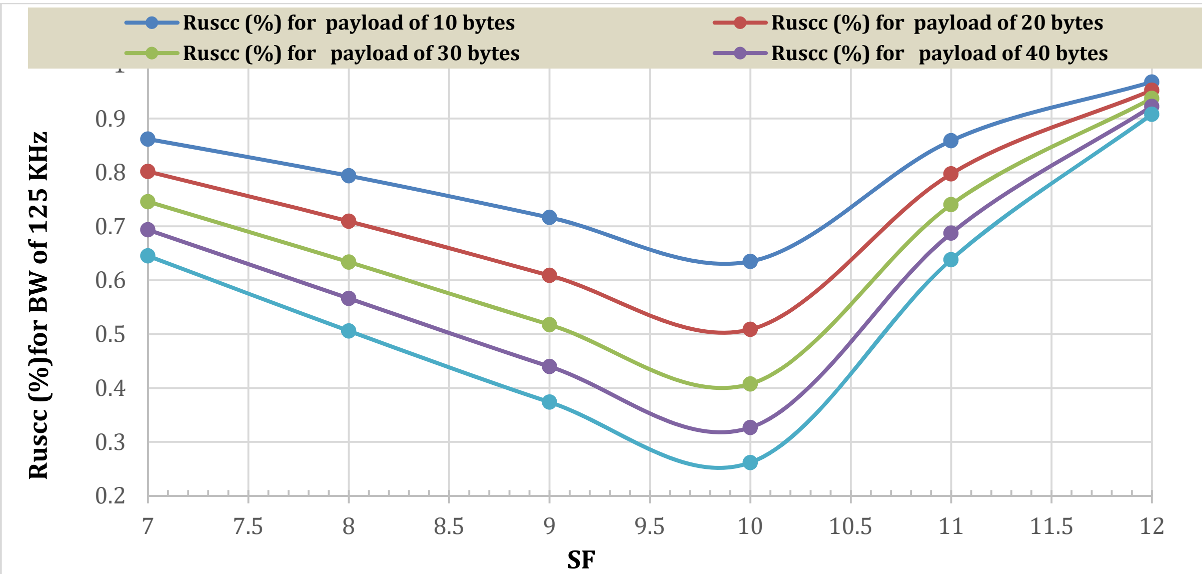

Figure 5 The graph of data delivery success ratio, R_{Succ} (%) versus Spreading Factor, SF

Table 3 The results of successfully delivered payload data, Bpldb (bytes) versus Spreading Factor, SF

SF, Spreading Factor	Bpldb (byte) for payload of 10 bytes	Bpldb (byte) for payload of 20 bytes	Bpldb (byte) for payload of 30 bytes	Bpldb (byte) for payload of 40 bytes	Bpldb (byte) for payload of 50 bytes
7	8.620	16.035	22.371	27.743	32.256
8	7.939	14.186	19.013	22.650	25.298
9	7.165	12.178	15.525	17.593	18.690
10	6.349	10.174	12.228	13.063	13.083
11	8.588	15.948	22.210	27.495	31.910
12	9.678	19.049	28.121	36.901	45.396

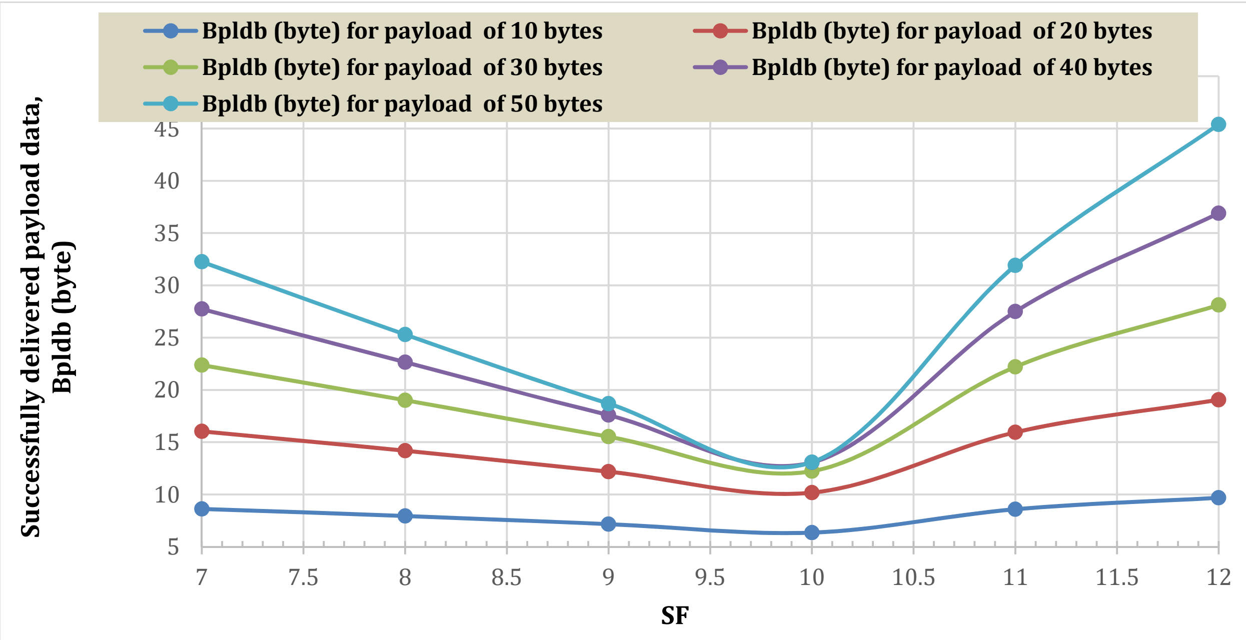

Figure 6 The graph of Successfully delivered payload data, Bpldb (bytes) versus Spreading Factor, SF

4 Conclusion

Analysis of the effect of spreading factor and payload size on bit error performance and data delivery performance of wireless sensor node using LoRa transceiver for its data transmission is presented. Numerical computations for a bandwidth of 125 kHz show that the spreading factor of 10 has the worst bit error performance and data delivery performance. Also, for a given bit error rate, the data delivery success ratio decreases with increases in payload size.

References

1. Khalifeh, A., Mazunga, F., Nechibvute, A., & Nyambo, B. M. (2022). Microcontroller Unit-Based Wireless Sensor Network Nodes: A Review. *Sensors*, *22*(22), 8937.
2. Garg, R. K., Bhola, J., & Soni, S. K. (2021). Healthcare monitoring of mountaineers by low power wireless sensor networks. *Informatics in Medicine Unlocked*, *27*, 100775.
3. Ogbonna Chima Otumdi , **Ozuomba Simeon,** Philip M. Asuquo (**2020**) Device Hardware Capacity And Rssi-Based Self Organizing Map Clustering Of 928 Mhz Lorawan Nodes Located In Flat Terrain With Light Tree Densities ***Science and Technology Publishing*** *(SCI & TECH) Vol. 4 Issue 9, September - 2020*
4. Kalu, C., **Ozuomba, Simeon**. & Udofia, K. **(2015).** Web-based map mashup application for participatory wireless network signal strength mapping and customer support services. ***European Journal of Engineering and Technology,*** *3 (8)*, 30-43.
5. Abdollahi, A., Rejeb, K., Rejeb, A., Mostafa, M. M., & Zailani, S. (2021). Wireless sensor networks in agriculture: Insights from bibliometric analysis. *Sustainability*, *13*(21), 12011.
6. Zion, Idongesit, **Simeon Ozuomba**, and Philip Asuquo. **(2020)** "An Overview of Neural Network Architectures for Healthcare." *2020* ***International Conference in Mathematics, Computer Engineering and Computer Science (ICMCECS).*** IEEE, 2020
7. Samuel, Wali, **Simeon Ozuomba,** and Philip M. Asuquo **(2019).** EVALUATION OF WIRELESS SENSOR NETWORK CLUSTER HEAD SELECTION FOR DIFFERENT PROPAGATION ENVIRONMENTS BASED ON LEE PATH LOSS MODEL AND K-MEANS ALGORITHM. EVALUATION, 3(11). ***Science and Technology Publishing*** *(SCI & TECH) Vol. 3 Issue 11, November - 2019*

8. Atakpo, F. K., Simeon, O., & Utibe-Abasi, S. B. (2021) A COMPARATIVE ANALYSIS OF SELFORGANIZING MAP AND K-MEANS MODELS FOR SELECTION OF CLUSTER HEADS IN OUT-OF-BAND DEVICE-TO-DEVICE COMMUNICATION. *Journal of Multidisciplinary Engineering Science Studies (JMESS).*
9. **Simeon, Ozuomba. (2020).** "APPLICATION OF KMEANS CLUSTERING ALGORITHM FOR SELECTION OF RELAY NODES IN WIRELESS SENSOR NETWORK." ***International Multilingual Journal of Science and Technology*** *(IMJST) Vol. 5 Issue 6, June - 2020*
10. Samuel, W., **Ozuomba, Simeon,** & Constance, K**. (2019).** SELF-ORGANIZING MAP (SOM) CLUSTERING OF 868 MHZ WIRELESS SENSOR NETWORK NODES BASED ON EGLI PATHLOSS MODEL COMPUTED RECEIVED SIGNAL STRENGTH. ***Journal of Multidisciplinary Engineering Science and Technology*** *(JMEST) Vol. 6 Issue 12, December - 2019*
11. **Simeon, Ozuomba. (2020).** "Analysis Of Effective Transmission Range Based On Hata Model For Wireless Sensor Networks In The C-Band And Ku-Band." ***Journal of Multidisciplinary Engineering Science and Technology*** *(JMEST) Vol. 7 Issue 12, December - 2020*
12. Ogbonna Chima Otumdi , **Ozuomba Simeon**, Kalu Constance **(2020).** Clustering Of 2100 Mhz Cellular Network Devices With Som Algorithm Using Device Hardware Capacity And Rssi Parameters ***Science and Technology Publishing*** *(SCI & TECH) Vol. 4 Issue 2, February – 2020*
13. Mujumdar, O., Celebi, H., Guvenc, I., Sichitiu, M., Hwang, S., & Kang, K. M. (2021, April). Use of LoRa for UAV remote ID with multi-user interference and different spreading factors. In *2021 IEEE 93rd Vehicular Technology Conference (VTC2021-Spring)* (pp. 1-7). IEEE.
14. Andersen, F. R., Ballal, K. D., Petersen, M. N., & Ruepp, S. (2020, June). Ranging Capabilities of LoRa 2.4 GHz. In *2020 IEEE 6th World Forum on Internet of Things (WF-IoT)* (pp. 1-5). IEEE.
15. Sağır, S., Kaya, İ., Şişman, C., Baltacı, Y., & Ünal, S. (2019, May). Evaluation of low-power long distance radio communication in urban areas: LoRa and impact of spreading factor. In *2019 Seventh International Conference on Digital Information Processing and Communications (ICDIPC)* (pp. 68-71). IEEE.
16. Raychowdhury, A., & Pramanik, A. (2020). Survey on LoRa technology: solution for internet of things. *Intelligent Systems, Technologies and Applications: Proceedings of Fifth ISTA 2019, India*, 259-271.
17. Ben Temim, M. A., Ferré, G., & Tajan, R. (2022). A New LoRa-like Transceiver Suited for LEO Satellite Communications. *Sensors*, *22*(5), 1830.
18. Pashchenko, A. K., & Bombizov, A. A. (2022, November). Estimating Data Transmission Range in a Wooded Area via the Lora Channel. In *2022 International Siberian Conference on Control and Communications (SIBCON)* (pp. 1-4). IEEE.
19. Bouguera, T., Diouris, J. F., Chaillout, J. J., Jaouadi, R., & Andrieux, G. (2018). Energy consumption model for sensor nodes based on LoRa and LoRaWAN. *Sensors*, *18*(7), 2104.
20. Maudet, S., Andrieux, G., Chevillon, R., & Diouris, J. F. (2021). Refined node energy consumption modeling in a LoRaWAN network. *Sensors*, *21*(19), 6398.
21. Ramli, A. F., Shabry, M. I., Abu, M. A., & Basarudin, H. (2021). A Study on the Impact of Nodes Density on the Energy Consumption of LoRa.
22. Singh, R. K., Puluckul, P. P., Berkvens, R., & Weyn, M. (2020). Energy consumption analysis of LPWAN technologies and lifetime estimation for IoT application. *Sensors*, *20*(17), 4794.