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Optimization of Delay Using Killer Whale Algorithm (KWA) on NB-IoT

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Abstract: NB-IoT is designed to connect IoT devices with low-power, wide-area coverage and efficient costs. Ensuring optimal data transmission delay is a challenge in NB-IoT implementation. Inadequate coverage can hinder IoT adoption. Optimization balances energy saving and delay trade-off. The Killer Whale Algorithm (KWA) optimizes delay by adjusting repetition variables. KWA addresses dimensions, variable limits. Applying KWA in NB-IoT optimizes transmission, enhancing QoS. Optimizing delay involves reducing latency in uplink data transmission using repetition variables. This study applies KWA to optimize NB-IoT delay. Analysis in Table 4 shows non-linear repetition-distance correlation. Interestingly, delay outcomes exhibit a contrasting relationship. Still, delay remains advantageous, remaining under 1 second even at 10 km, specifically 9.2674 ms (0.0092674 seconds). This thesis aims to optimize delay in NB-IoT network transmission using the Killer Whale Algorithm (KWA), crucial for modern communication networks and IoT applications. Leveraging KWA, the research identifies solutions to reduce transmission delay, enhancing efficiency and meeting IoT communication demands for speed and timeliness.

Keywords: NB-IoT; QoS; Optimization; Killer Whale Algorithm; LPWA

INTRODUCTION

NB-IoT is a cellular network technology specifically designed to support low-power, wide-area connectivity between IoT devices, with broad network coverage and efficient implementation costs (Song & Zhuang, 2009) & (Adhikary et al., 2016). One of the challenges in NB-IoT implementation is ensuring optimal data transmission delay to support reliable communication between IoT devices. Insufficient network coverage can lead to communication failures and hinder IoT technology adoption (Chung, 2017). Hence, it is imperative to optimize the transmission of the NB-IoT network in order to reduce latency in data transfer.

Optimization algorithms are one of the approaches used to find the best solutions in specific contexts (Hu et al., 2015). To find the optimal variables for reducing latency based on repetition, the Killer Whale Algorithm (KWA) is employed in this research. In KWA, the optimization problem consists of the dimensionality of space, minimum and maximum limits of variables (Biyanto et al., 2017). The application of KWA in optimizing delay in NB-IoT holds the potential to enhance Quality of Service (QoS) in telecommunications networks. In this context, optimizing delay in network transmission means finding the optimal repetition variables to reduce latency in uplink data transmission, thereby providing good quality of service to connected IoT devices.

Previous research has proposed various methods to optimize delay in NB-IoT networks, such as the Parameter Optimization of Power Saving Mode (PSM) model that offers maximum energy savings

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while minimizing communication delay through multi-objective optimization techniques (Bello et al., 2019) r optimal frequency selection methods (Prajanti et al., 2018). However, there is still ample room to optimize delay in NB-IoT networks by leveraging optimization algorithms. The objective of this research is to apply the KWA algorithm in optimizing delay in NB-IoT networks.

LITERATURE REVIEW

Literature review in this research was conducted on previous studies that discussed topics related to the implementation of NB-IoT, specifically focusing on optimizing coverage enhancement in the Narrowband Internet of Things (NBIoT) network within the time range from 2017 to 2023. The literature study was conducted to understand the optimization approaches that have been used in previous research, such as optimal eNodeB location selection, transmission delay optimization, transmission power adjustment, and signal strengthening strategies. Additionally, this literature study revealed the challenges and constraints faced in optimizing the NBIoT network coverage, such as interference, environmental uncertainty, transmission latency, and energy efficiency.

According to (Raza et al., 2017) n the context of meeting diverse requirements of Internet of Things (IoT) applications, traditional cellular and short-range wireless technologies alone are deemed insufficient. Low-power wide-area networking (LPWA) technology offers advantages unavailable in other wireless systems, such as long-range connectivity with low power consumption and low data rates on devices. The potential market size for LPWA is substantial. From a technical standpoint, addressing the challenge of connecting a significant number of IoT and M2M devices necessitates novel solutions from LPWA providers

In the study by (Lauridsen et al., 2017) titled "Coverage comparison of GPRS, NB-IoT, LoRa, and SigFox in a 7800 km2 area," researchers conducted simulations to investigate coverage areas in the Northern Denmark region, comprising 7800 km2 of rural areas, predominantly farmland, forests, smaller villages, and a combined urban area of 147 km2. NB-IoT exhibited superior performance compared to SigFox and LoRa based on the Maximum Coupling Value (MCL) of 164 dB and only <10% of NB-IoT devices experienced outages.

(Biyanto et al., 2017) The killer whale meta-heuristic algorithm is developed from the behavioral and life pattern analysis of killer whales. Its basis lies in how killer whales pursue prey and interact socially within their groups. This algorithm also incorporates killer whales' memory abilities, making it distinct. Killer whales, apex predators in the ocean, are categorized into two main groups: Resident Fish Eaters and Transient Mammal Hunters. The former hunt in consistent locations, while the latter track prey migrations.

METHOD

This research applies a case study method as an experimental approach. The research process involves a series of steps as outlined below:

1. In the initial step, the research objectives and issues are identified. In this context, the objective is to optimize transmission delay in NB-IoT networks, focusing on open area conditions. The approach used involves implementing the Killer Whale Algorithm (KWA) to achieve minimal latency, with the aim of improving Quality of Service (QoS).
2. Literature review: This stage involves a literature review related to the research topic, including previous studies conducted and the methods used in those studies.
3. Data collection: The data used in this research consists of simulation parameters derived from previous research conducted by (Ravi et al., 2019) with some modifications and adjustments made to the parameter configurations in this study.
4. Analysis and simulation: Parameters are configured and analyzed through methods such as applying the Okumura-Hata model (for open areas) to calculate path loss, assessing SINR, and forming an objective function. This function is employed in simulations and optimized using the Killer Whale Algorithm (KWA).

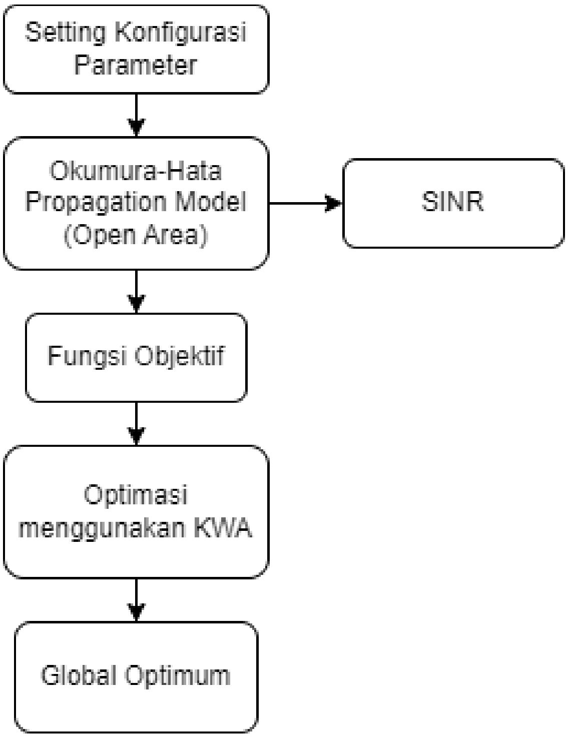


Fig. 1 Flow Of Analysis And Simulation Stages

5. Evaluation: This stage involves evaluating the global minimum results using KWA.
6. Report Writing: The final step is to write the thesis report, detailing the entire research process, findings, and overall conclusions.

The configuration parameter settings are done prior to conducting analysis and simulation. In this research, the scope of the scenario is an open area. The configuration parameter settings can be seen in Table 1.

Table 1. Parameter Configuration

Parameter	Value
Propagation model	Okumura-Hata propagation model (Open area)
Heigh base station (m)	42
Heigh mobile station (m)	1.5
Frequency Band	DL: 925 MHz, UL: 880 MHz
Tx Power	eNodeB: 46 dBm, UE: 20 dBm
Modulation Coding Scheme	12
Tone	12
Resource Unit	0
Packet Size	96 bit
Iterations	20 runs
Inter-packet interval	10 seconds
Zone length (m)	1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000

SINR

Signal-to-Interference-plus-Noise Ratio (SINR) in wireless communication is calculated using several parameters, including transmitter power, bandwidth, interference power, noise power, and pathloss. The formula for calculating SINR is as follows:

$$\mathrm{PSD_{RX}} = \frac{\mathrm{PSD_{TX}}}{\mathrm{pathloss}}$$

Received Power Spectral Density ($\mathrm{PSD_{RX}}$), $\mathrm{PSD_{TX}} = \mathrm{P_{TX}}/$ and pathloss is the result of the Okumura-Hata propagation model.

$$\mathrm{K_3} = \mathrm{P_{TX}}/(180\mathrm{kHz} \times \mathrm{N_0} \times \mathrm{pathloss})$$
$$SINR = K3 \times f \times r$$

The frequency of 180 kHz represents the bandwidth of NB-IoT, and N0 stands for noise power spectral density with units of W/Hz. The symbol 'r' represents repetition, and the symbol 'f' represents the frequency factor of the tone, which can be seen in Table 2.

Table 2. Configuration between Frequency and Tone

Tone	Bandwidth (kHz)	Frequency factor 'f'
$12 \times 15\mathrm{kHz}$	$180/\mathrm{f}$	1
$6 \times 15\mathrm{kHz}$	$180/\mathrm{f}$	2
$3 \times 15\mathrm{kHz}$	$180/\mathrm{f}$	4
$1 \times 15\mathrm{kHz}$	$180/\mathrm{f}$	12
$1 \times 3.75\mathrm{kHz}$	$180/\mathrm{f}$	48

Objective Function

In wireless communication, an objective function refers to a metric or criteria used to measure the performance or efficiency of a specific wireless communication system. This objective function plays a crucial role in formulating and evaluating optimization solutions in the design, configuration, and adjustment of wireless communication systems. The objective function in the context of wireless communication can vary significantly depending on the specific goals of the system. When optimizing the objective function, there are several common optimization algorithms used in wireless communication, such as particle swarm optimization (Lee et al., 2023), genetic algorithm (Jarrah et al., 2018) and Lagrangian methods (Ravi et al., 2019). In this research, we employ the latest optimization algorithm known as the Killer Whale Algorithm (KWA) (Biyanto et al., 2017) which aims to reduce delay and optimize latency in data transmission between NB-IoT devices.

The delay in User Equipment (UE) involves synchronization processes, the Random Access Channel (RACH), and data transmission. In this study, data transmission delay is estimated based on the variable distance between the base station (eNodeB) and the UE. Factors such as modulation and coding scheme (MCS), frequency subcarrier allocation (tone), and data repetitions significantly affect latency during data delivery. Specifically, UE uplink data transmission includes elements like Downlink Control Information (DCI), data delivery processes, actual transmission, and overall data acknowledgment.

The mathematical formula used to calculate the latency while considering the distance factor in this study is formulated as follows:

$$TL = (x_1 \times tPDCCH + tDUS + x_2 \times tone \times tPUSCH + tUDS + x_3 \times\ tACK)$$

Variabel x_1 represents the number of repetitions in the Downlink Control Information (DCI) settings, which we assume to be ($x_1 = 1ms$) and the value of $x_3 = x_1$ and the variable $x_2 = 2ms$. Based on the 3GPP standard for NB-IoT, we assume that the constant values of several parameters used are as follows:

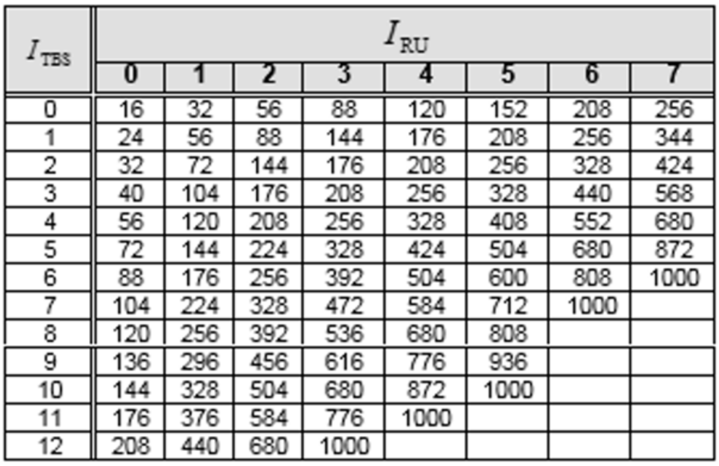
$$tPDCCH = 0.9287\ ms, tDUS = 8\ ms, tPUSCH = 0.9287\ ms, tUDS = tULACK = 0$$

After obtaining the value of transmission latency time, we then calculate the data delivery delay using the distance factor between the eNodeB and UE. The mathematical formula for this calculation can be seen as follows:

$$Delay = \frac{TL \times Packet\ size}{TBS(m,u)} + \frac{d}{v}$$

The packet size is the number of bits sent, which is 96 bits, *d* represents the distance with variable values {1000, 2000, 3000, 4000, 5000, 6000, 7000, 8000, 9000, 10000} in meters. The variable "v" denotes the speed of sound in air, assumed to be 343 m/second. The Transport Block Size (TBS) is determined by the modulation coding scheme (m) and the resource unit (u) according to the standard uplink physical layer configuration as shown in Figure 2

Table 3. TBS NPUSCH



I_{TBS}	I_{RU}							
	0	1	2	3	4	5	6	7
0	16	32	56	88	120	152	208	256
1	24	56	88	144	176	208	256	344
2	32	72	144	176	208	256	328	424
3	40	104	176	208	256	328	440	568
4	56	120	208	256	328	408	552	680
5	72	144	224	328	424	504	680	872
6	88	176	256	392	504	600	808	1000
7	104	224	328	472	584	712	1000	
8	120	256	392	536	680	808		
9	136	296	456	616	776	936		
10	144	328	504	680	872	1000		
11	176	376	584	776	1000			
12	208	440	680	1000				

Researchers can also use images, diagrams, and flowcharts to explain the solutions to these problems.

RESULT

Okumura-Hata Propagation Model (open area)

In this study, the analysis employs the Okumura-Hata propagation model assuming an open simulation area. This model predicts path loss at radio frequencies. Variations of the Okumura-Hata model exist, with the most common applied to urban, suburban, and rural settings. Path loss is then computed based on the eNodeB-UE distance utilizing the Okumura-Hata model. The formula for the Okumura-Hata model in an open area is as follows:

$$L = 69.55 + 26.16\mathbf{log}10(f) - 13.82\mathbf{log}10(ht) - (1.1\mathbf{log}10(f) - 0.7)hr + (1.56\mathbf{log}10(f) - 0.8) + 20\mathbf{log}10(d)$$

Explanation:
L stands for path loss in decibels (dB).
f is the operating frequency in Megahertz (MHz).
h_t is the height of the transmitter antenna in meters above ground level.
h_r is the height of the receiver antenna in meters above ground level.
d is the distance between the transmitter and receiver in kilometers.

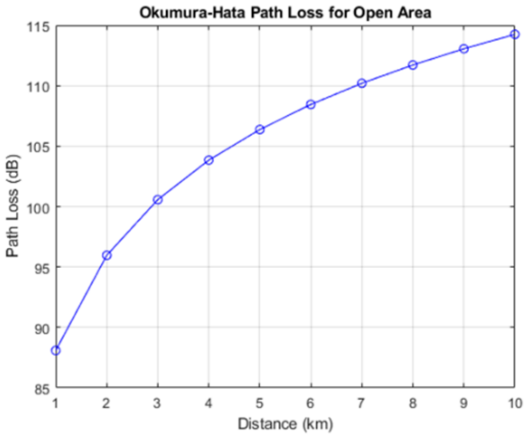


Fig. 2 Path loss Okumura-hata (Open Area)

Fig 2 visualizes the results obtained from the analysis conducted by applying the Okumura-Hata propagation model in an open area. The graph illustrates the changes that occur as the Mobile Station (MS), which is a mobile device, moves away from the Base Station (BS), acting as the main station. Specifically, it can be observed that there is a significant increase in the path loss value as the distance between the Mobile Station and the Base Station increases. An increase in path loss value indicates a reduction in the intensity of the signal received by the receiver, which in this context is the Mobile Station.

SINR Result

Within the framework of SINR (Signal-to-Interference-plus-Noise Ratio) analysis based on simulation processes using MATLAB software, evaluation is carried out by incorporating the path loss component values generated from the Okumura-Hata propagation model analysis. The Okumura-Hata propagation model is used to estimate the signal strength reduction that occurs when radio signals propagate through an environment, particularly in areas that can be considered as open areas, where the characteristics of radio signal propagation are not significantly hindered by physical obstacles. Therefore, the applied path loss values in this analysis reflect the signal strength reduction caused by distance propagation in specific environmental conditions.

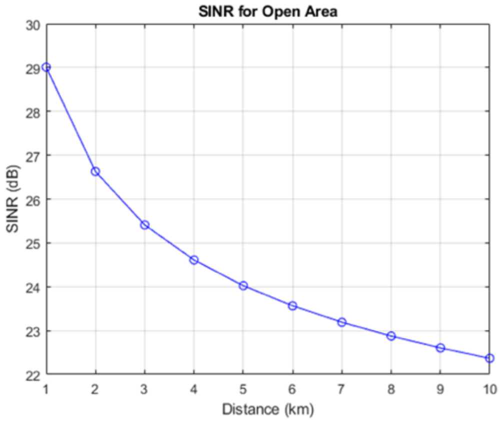


Fig. 3 SINR

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The results of SINR calculations provide insights into the quality and reliability of communication between the transmitter and receiver. This is clearly illustrated in Fig 3, where the signal strength gradually decreases as the transmission distance between the eNodeB and UE increases.

Optimization Using the Killer Whale Algorithm

The objective function based on delay was employed in the research, while the variables used in optimization are the repetitions of parameters x_1, x_2, x_3 which are assumed to have constant values. The repetition values for NB-IoT are within the interval {1, 2, 4, 8, 16, 32, 64, 128}. The modulation coding scheme parameter used is (m=12), and the resource unit is (u=0), resulting in a Transport Block Size (TBS) of 208, as depicted in Figure 2. This delay optimization consists of ten scenarios based on distances ranging from 1 km to 10 km, with a process of 20 iterations. Global minimum refers to the absolute lowest value of an objective function across its entire domain. The results of the delay optimization in search of the global minimum can be observed in Table 4.

Table 4. Optimization Results of Delay Based on Distance

Distance (Km)	Repetition Variable	Delay (ms)
1	[1,1,92.08]	9,2674
2	[1,1,62.6707]	9,2703
3	[1,1,64.3309]	9,2733
4	[1,1,59.3641]	9,2762
5	[1,1,38.0425]	9,2791
6	[1,1,76.1605]	9,282
7	[1,1,115.6076]	9,2849
8	[1,1,95.7191]	9,2878
9	[1,1,86.7077]	9,2907
10	[1,1,79.0043]	9,2937

In the repetition variable, it is evident that the optimized repetition values do not align with the intended value intervals. Therefore, the solution is to round the variable values upwards to match the intervals used in NB-IoT uplink transmissions. The analysis results in Table 6 indicate that the characteristics of the repetition variable exhibit a non-linear relationship with distance. However, the outcomes demonstrate a contrary relationship in terms of the resulting delay. Despite this, the obtained delay results remain highly favorable, staying below 1 second even at a distance of 10 kilometers. Specifically, the value is 9.2674 milliseconds, equivalent to 0.0092674 seconds.

DISCUSSIONS

This study is centered on the optimization of delay in the transmission of Narrowband Internet of Things (NB-IoT) networks through the application of the Killer Whale Algorithm (KWA). The analysis findings reveal that the principle of pathloss holds noteworthy implications within this context. The outcomes of the Signal-to-Interference-plus-Noise Ratio (SINR) analysis also suggest that, at a maximum transmission distance of 10 kilometers, the received network quality by the recipients still conforms to the threshold standard of >20 dB, thereby indicating a robust potential for substantial support in reliability and service quality within the NB-IoT network.

The optimization endeavor has yielded satisfactory delay outcomes by manipulating the repetition variables across an array of scenarios. While the repetition values do not consistently align with the anticipated value intervals, the resultant delay remains below the 1-second threshold at a 10-kilometer distance, with specific values ranging approximately at 0.0092674 seconds.

CONCLUSION

This research is conducted with the aim of optimizing delay in Narrowband Internet of Things (NB-IoT) network transmission using the Killer Whale Algorithm (KWA). NB-IoT is a crucial technology in modern communication networks, particularly for Internet of Things (IoT) applications. Transmission delay is an important factor in ensuring the expected Quality of Service (QoS).

By leveraging the Killer Whale Algorithm (KWA), this research focuses on identifying optimal solutions to reduce transmission delay in the NB-IoT environment. Through analysis, simulation, and evaluation stages, this algorithm can be applied to minimize delay and enhance data transmission efficiency. This approach holds significant potential in meeting the increasing demands for speed and timeliness in IoT communication.

REFERENCES

Adhikary, A., Lin, X., & Wang, Y.-P. E. (2016). Performance Evaluation of NB-IoT Coverage. *2016 IEEE 84th Vehicular Technology Conference (VTC-Fall)*, 1–5. https://doi.org/10.1109/VTCFall.2016.7881160

Bello, H., Jian, X., Wei, Y., & Chen, M. (2019). Energy-Delay Evaluation and Optimization for NB-IoT PSM With Periodic Uplink Reporting. *IEEE Access*, *7*, 3074–3081. https://doi.org/10.1109/ACCESS.2018.2888566

Biyanto, T. R., Matradji, Irawan, S., Febrianto, H. Y., Afdanny, N., Rahman, A. H., Gunawan, K. S., Pratama, J. A. D., & Bethiana, T. N. (2017). Killer Whale Algorithm: An Algorithm Inspired by the Life of Killer Whale. *Procedia Computer Science*, *124*, 151–157. https://doi.org/https://doi.org/10.1016/j.procs.2017.12.141

Chung, Y.-L. (2017). An Energy-Efficient Coverage Algorithm for Macrocell—Small Cell Network Systems. In *Energies* (Vol. 10, Issue 9). https://doi.org/10.3390/en10091319

Jarrah, M. I., Jaya, A. S. M., Azam, M. A., Muhamad, M. R., & Akbar, H. (2018). Minimizing thin film thickness in TiN coatings using genetic algorithms. *AIP Conference Proceedings*, *2016*(1), 20061. https://doi.org/10.1063/1.5055463

Lauridsen, M., Nguyen, H., Vejlgaard, B., Kovacs, I. Z., Mogensen, P., & Sorensen, M. (2017). Coverage Comparison of GPRS, NB-IoT, LoRa, and SigFox in a 7800 km^2 Area. *2017 IEEE 85th Vehicular Technology Conference (VTC Spring)*, 1–5. https://doi.org/10.1109/VTCSpring.2017.8108182

Lee, S.-H., Cheng, C.-H., Lin, C.-C., & Huang, Y.-F. (2023). PSO-Based Target Localization and Tracking in Wireless Sensor Networks. In *Electronics* (Vol. 12, Issue 4). https://doi.org/10.3390/electronics12040905

Prajanti, A. D., Wahyuaji, B., Rukmana, F. B., Harwahyu, R., & Sari, R. F. (2018). Performance Analysis of LoRa WAnTechnology for Optimum Deployment of Jakarta Smart City. *2018 2nd International Conference on Informatics and Computational Sciences (ICICoS)*, 1–6. https://doi.org/10.1109/ICICOS.2018.8621803

Ravi, S., Zand, P., Soussi, M. El, & Nabi, M. (2019). Evaluation, Modeling and Optimization of Coverage Enhancement Methods of NB-IoT. *2019 IEEE 30th Annual International Symposium on Personal, Indoor and Mobile Radio Communications (PIMRC)*, 1–7. https://doi.org/10.1109/PIMRC.2019.8904109

Song, W., & Zhuang, W. (2009). *Network Selection for HeterogeneousWireless Access Networks BT - Heterogeneous Wireless Access Networks: Architectures and Protocols* (E. Hossain (ed.); pp. 1–35). Springer US. https://doi.org/10.1007/978-0-387-09777-0_8