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Performance Evaluation of River Water Quality Monitoring Using Lora Connectivity with Fuzzy Algorithm

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Abstract

This study was proposed a river water quality monitoring application, connected by sensors such as pH, turbidity and Total Dissolved Solids (TDS) sensor to measure acidity, turbidity levels and amount of dissolved solids, respectively, as well as reduce bad effect of polluted river water. This river water quality monitoring tool was able to process input data from sensors using fuzzy algorithms and determine whether the river water quality. LoRa functions as data transmission communication and Antares as a cloud service to store data obtained from sensors. Furthermore, data obtained was displayed in the Smartphone Android application. The rivers that were tested are located in Citarum river sector 6 and 21. The results showed that the accuracy of the temperature, TDS and pH sensor were 98.69%, 89.69% and 99.39%, respectively. Furthermore, the average value of RSSI Citarum sector 6 and 21 were -111,576 dB and -112,855 dB, respectively. Meanwhile The average SNR of Sector 6 was -6,46 dB and Citarum sector 21 was -12,85851 dB.

Keywords: Water Quality, Lora, Fuzzy Algorithm, Citarum River.

1 Introduction

Based on reports from the 2018 Indonesian Environmental Statistics, 25.1% of villages that has rivers experienced water pollution [1]. This data proved that the quality of river water in Indonesia is generally in a heavy polluted status and its impact is capable of damaging the river environment, as well as cause diseases that are detrimental to humans. Therefore, water quality monitoring is very important in order to maintain its good quality, keep it safe for use in daily needs and avoid the bad effect due to water pollution [2]. This study aims to create a water quality monitoring tool with sensors that are be able to provide quality data on river water such as pH, TDS, turbidity and temperature [3]. The data obtained was further processed by fuzzy algorithm to determine whether the water quality is good or not [4, 5, 6]. In addition, this tool was monitored remotely by using LoRa connectivity and the data was subsequently accessed using the application on Android.

The reference for the determination of river water quality was the Government Regulation Number 82 of 2001 concerning management of water quality and pollution control [7, 8]. The other was the Government Regulation Number 32 of 2017 concerning environmental quality standards and water health requirement on hygiene needs for sanitation, swimming pools and Solus Per Aqua [9].

Furthermore, this study was carried out based on the concept of IoT and LoRa. It is said to be a network of devices which communicates among itself using IP connectivity without human interference available anywhere, anytime, and for any purpose [10, 11]. Meanwhile, fuzzy to compression data [12, 13]. End-devices also uses it across a single wireless hop to communicate to gateways, connected to the Internet, therefore acting as transparent bridges and relaying messages between these end-devices and central network server [14, 15]. In Indonesia, LoRa operates on 923 MHz-925 MHz frequency band [16].

2 Related Works

Several studies or experiments have been carried out using the fuzzy logic method. For example, a flood detector using fuzzy logic and LoRa technology was designed by Khuen [17]. In the study by Khuen, a more reliable and robust system design.

Based on Syamsul et al. [18] was proposed control system was based on fuzzy logic, with two main parameters namely temperature and vapour pressure. It proved that controlling the nutmeg oil distillation system using fuzzy logic will improve the performance of the system i.e. accelerate the distillation time, optimal use of energy from fuel gas.

Moreover, Yi zhao et al. [19] study a fuzzy logical based algorithm was proposed to suppress the remaining ground clutter from base data of X-band Doppler weather, with the aim of controlling or improving data quality before its application.

Meanwhile, Asep [20] proposed the application of fuzzy logic methods in attempting the velocity of a hexapod mobile robot by using the Takagi-Sugeno-Kang type of its inference system. The fuzzy logic controller is used to drive a hexapod mobile robot. Zina et al. [21] study design for nonlinear uncertain system is succeeded presents a robust Fault Tolerant Tracking Control (FTTC) by Takagi Sugeno (T-S) fuzzy model. System can count from unmeasurable premise variables subject to sensor faults .

Putra et al. [22] utilized the fuzzy, which is succeeded on the scoring process of Question Answering System and increasing the accuracy level of Question Answering System. The next study was designed by Mandala and proposed an IoT digital thermometer called HI-Thermo, which implements fuzzy logic. Fuzzy system, when applied is able to set the interval to send data on continuous monitoring the energy efficiency of the system [23]. In addition, the fuzzy implementation by Alireza can use a fuzzy estimator to design a force or position tracking system in a Robot Manipulators [24].

3 System Design and Simulation

3.1 Design System

Figure 1 shows the system design of the river water quality monitoring tool. The data from this device were sent to the LoRa gateway, which was further connected to the LoRa server. The function of the LoRa server is to connect the LoRa gateway to the database and platform. After the data reached Antares, it was stored temporarily.

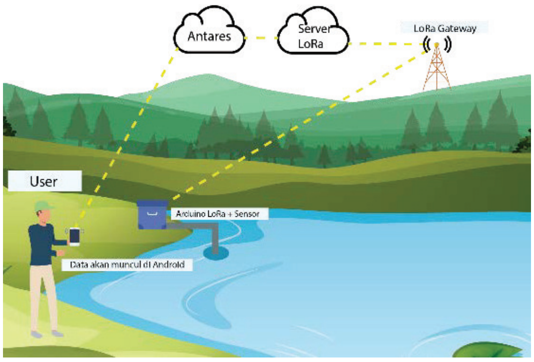


Figure 1: Design System.

Subsequently, the application made in Android that was connected to Antares retrieved the stored data. Furthermore, the data or results obtained from these sensors were shown in Real Time using an Android application called Monriv (Monitoring River) on a smartphone.

3.2 Block Diagram

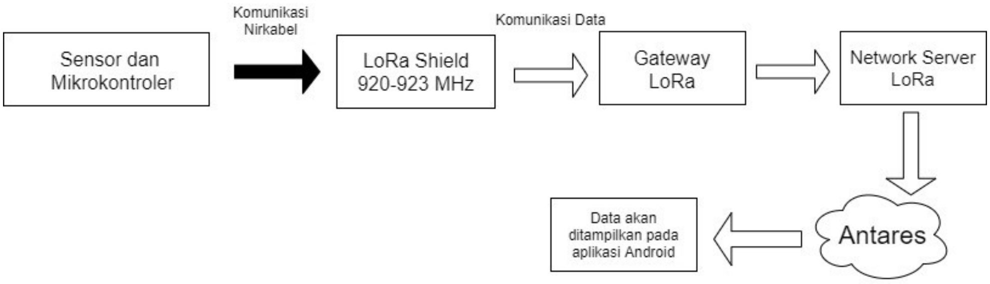


Figure 2: Block Diagram.

Figure 2 shows a block diagram of this River Water Quality Monitoring Tool. In this study, the system was designed using an Esp32 microcontroller, which was connected to several sensors to monitor and measure river water quality parameters. Furthermore, the data was sent to the LoRa gateway using a frequency of 920-923 MHz. After arriving at the gateway LoRa, it was sent to Network Server LoRa. The function of Network Server is to connect the LoRa gateway with the Platform Antares. The water quality data that was already stored in Antares was sent to the Android application that has been created and displayed on the application on the Android smartphone.

3.3 Hardware Design

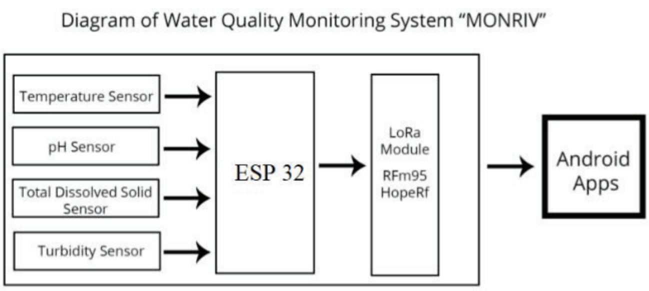
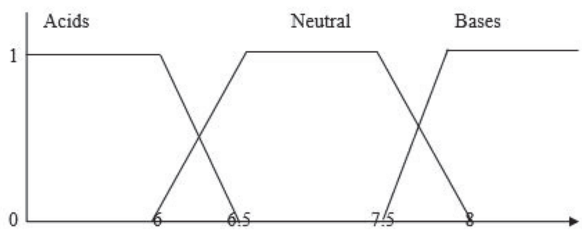


Figure 3: Hardware Design.

The Hardware Design used in this study in shown in Figure 3.The hardware design was designed to connect all 4 sensors such as Temperature, pH, Total Dissolved Solid and Turbidity Sensor to the ESP32 Board LoRa microcontroller [25, 26, 27?]. Furthermore, it was connected to LoRa Hope Rfm95 as remote communication and Antares cloud as a Database or data storage place, while the data that was earlier obtained from Antares was displayed in an application form on Android. Antares is one of the IoT platforms developed by PT Telekomunikasi Indonesia. It is able to store and send data in real time from sensors using Arduino or Raspberry Pi. Furthermore, it uses the RESTful approach in the development of API (Application Programming Interface) for easy operation and good networks by users [28, 29].

3.3.1 Fuzzy Algorithm

1. Fuzzy Variable in designing this Monriv tool, 4 variables were used as input, namely the variable pH, turbidity (in NTU), TDS (in mg / L) and temperatures (in $\circ$C).
2. Linguistic Values Four variables used in this study for linguistic values are as follows:
   (a) The pH variable, divided into 3 fuzzy sets, namely: acids, bases and neutral.
   (b) Turbidity variable, divided into 3 fuzzy sets, namely: clear, turbid and very turbid.
   (c) Variable TDS, divided into 3 fuzzy sets, namely: large, moderate and a little.
   (d) Temperature variable, divided into 3 fuzzy sets, namely: cold, hot and normal.
3. Fuzzification is the process of mapping crisp (numeric) values into a fuzzy set and determining the degree of membership. Mapping the crisp value into the fuzzy set is explained in the following figure:



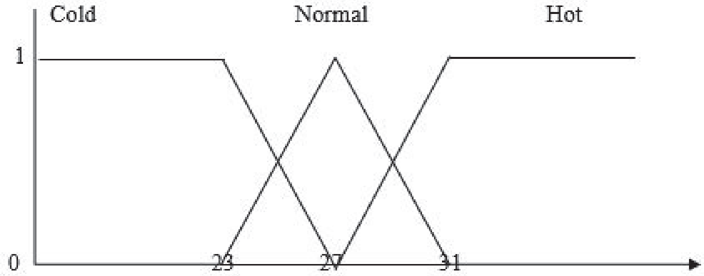
   (a) The pH variable was divided into 3, namely acids, neutral and bases from the range 0-6, 6.5-7.5 and 8-14, respectively:

$$\mu acids(x) = \begin{cases} 1, x \leq 6 \\ \frac{6,5-x}{6,5-6}, 6 < x < 6,5 \\ 0, x \geq 6,5 \end{cases}$$

$$\mu neutral(x) = \begin{cases} 1, \ 6.5 \leq x \leq 7.5 \\ \frac{x-6}{6.5-6}, 6 < x < 6.5 \\ \frac{7.5-x}{7.5-6.5}, 6.5 < x < 7.5 \\ 0, x \leq 6 \text{ atau } x \geq 8 \end{cases}$$

$$\mu bases(x) = \begin{cases} 1, x \geq 8 \\ \frac{x-7,5}{8-7,5}, 7,5 < x < 8 \\ 0, x \leq 7,5 \end{cases}$$

   (b) In the temperature membership function there were 3 linguistic variables, which include cold, normal and heat, from the range of 0-20, 21-28 and 31-100, respectively:

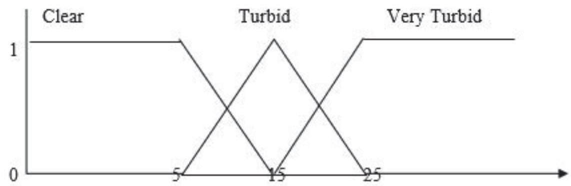


$$\mu\text{Cold}(x) = \begin{cases} 1, x \leq 23 \\ \frac{27-x}{27-23}, 23 < x < 27 \\ 0, x \geq 31 \end{cases}$$

$$\mu\text{normal}(x) = \begin{cases} 1, x = 27 \\ \frac{x-23}{27-23}, 23 < x < 27 \\ \frac{31-x}{31-27}, 27 < x < 31 \\ 0, x \leq 23 \text{ atau } x \geq 31 \end{cases}$$

$$\mu\text{hot}(x) = \begin{cases} 1, x \geq 31 \\ \frac{x-27}{31-27}, 27 \leq x < 31 \\ 0, x \leq 27 \end{cases}$$

(c) In the turbidity membership function there were 3 linguistic variables, namely clear, turbid and very turbid, ranging from 0 to 5 NTU, 6 to 25 and above 25 NTU, respectively.



$$\mu\text{Clear}(x) = \begin{cases} 1, x \leq 5 \\ \frac{15-x}{15-5}, 5 < x < 15 \\ 0, x \geq 15 \end{cases}$$

$$\mu\text{Turbid}(x) = \begin{cases} 1, x = 15 \\ \frac{x-5}{15-5}, 5 < x < 15 \\ \frac{25-x}{25-15}, 15 < x < 25 \\ 0, x \leq 5 \text{ atau } x \geq 25 \end{cases}$$

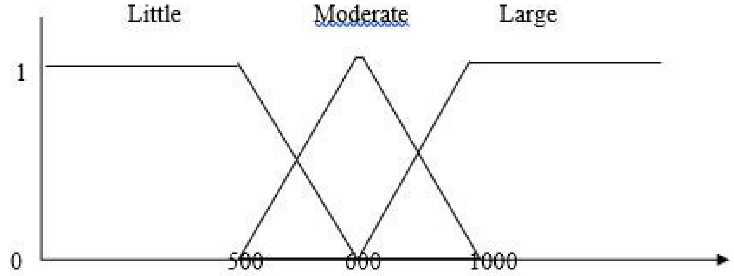
$$\mu\text{Veryturbid}(x) = \begin{cases} 1, x \geq 25 \\ \frac{x-15}{25-15}, 15 < x < 25 \\ 0, x \leq 25 \end{cases}$$

(d) In the TDS membership function there were 3 linguistic variables, namely little, moderate and large, ranging from 0 to 500 mg/L, 600 to 1000 mg/L and over 1000 mg/L, respectively.

4. Defuzzification This stage variable linguistic values were processed into crisp values as output. Data from the four water quality sensors were further divided into 4 categories namely "Excellent", "Good", "Medium" and "Poor". The data is displayed in the graph below:

   (a) Bad Category has a range of 0 to 25.

   (b) Medium category has a range of 26 to 50.



$$\mu Little(x) = \begin{cases} 1, x \leq 500 \\ \frac{600-x}{600-500}, 500 < x < 600 \\ 0, x \geq 500 \end{cases}$$

$$\mu Moderate(x) = \begin{cases} 1, x = 600 \\ \frac{x-500}{600-500}, 500 < x < 600 \\ \frac{1000-x}{1000-600}, 600 < x < 1000 \\ 0, x \leq 500 \text{ atau } x \geq 1000 \end{cases}$$

$$\mu Large(x) = \begin{cases} 1, x \geq 1000 \\ \frac{x-600}{1000-600}, 1000 < x < 600 \\ 0, x \leq 600 \end{cases}$$

(c) Good category has a range of 51 to 75.

(d) Excellent category has a range of 76 to 100.

4 Results and Analysis

This chapter discusses the Water Quality, Fuzzy Algorithm and LoRa Network Testing of the Citarum River. This was carried out in two locations, namely Citarum river sector 6 and 21 and testing LoRa network testing from Citarum to nearest gateway.

4.1 Water Quality Testing Citarum River

The water quality testing was carried out in the Citarum River Sector 6 or more precisely on Jalan Babakan Leuwi and Citarum River Sector 21 located on Sukabirus. The results obtained for

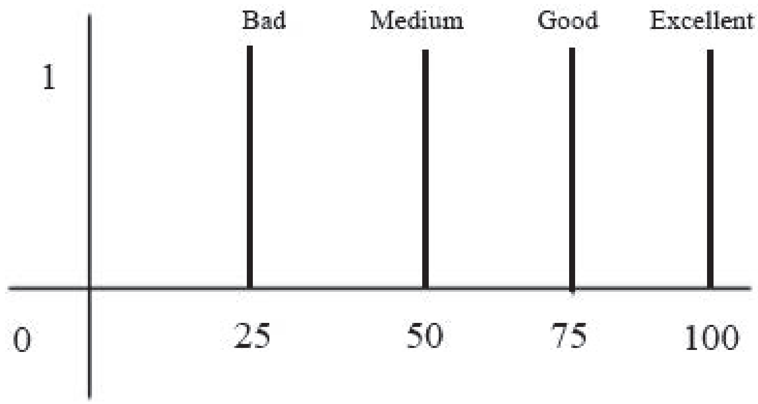


Figure 4: Defuzzification.

the quality of Citarum river water in sector 6 include:

4.1.1 Water Quality Testing

After carrying out water quality testing for about 30 minutes, the average results of the water quality of the Citarum river was obtained. In Citarum river water sector 6, the average water quality was at a pH of 9.67, TDS 300.98 mg/L, temperature 26.46 and turbidity 1281.581 NTU and were included in the bases category, little category, normal and very turbid category, respectively. Meanwhile, for the Citarum river in Sector 21, the average water quality obtained was at a pH of 8.05, TDS of 327.75 mg/L, temperature 26.38 and turbidity 1405.128 NTU and were included in the bases, little, normal and very turbid category, respectively. The conclusion was that Sector 21 has a bad quality compared to Sector 6, due to the higher TDS and turbidity value. Table 1 shows the average water quality of Citarum. River in Sector 6 and 21:

Table 1: Water Quality of Citarum River.

Water Quality of Citarum River					
No	Location	pH	TDS	Temperature	Turbidity
1	Ciatrum River Sektor 6	9,67	300,98	26,46	1281,581
2	Ciatrum River Sektor 21	8,05	327,75	26,38	1405,128

4.2 Fuzzy Algorithm Testing on River Water

4.2.1 Fuzzy Sector 6

The first test was carried out at the Citarum River Sector 6 for 30 minutes. The quality results obtained were the Citarum River in Sector 6 including "Medium" with an average fuzzy value of 50. The value of 50 was included in the "Medium" deffuzzyfication, therefore it was concluded that Citarum River Sector 6 is in the "Medium" category. The fuzzy results are shown below:

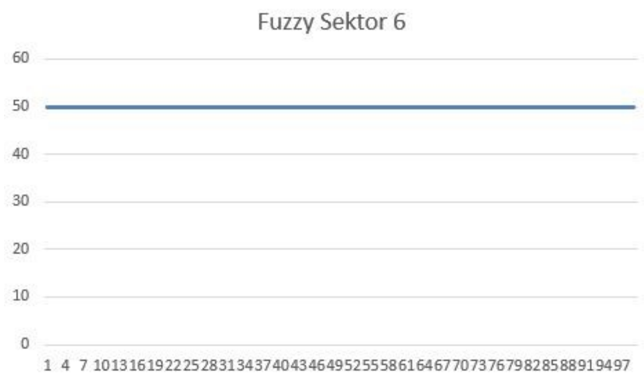


Figure 5: Fuzzy Sector 6.

4.2.2 Fuzzy Sector 21

The first test was carried out at the Citarum River Sector 21 for 30 minutes. The quality results obtained were the Citarum River in Sector 21 including "Medium" with an average fuzzy value of 50. The value of 50 was included in the "Medium" deffuzzification, therefore it was concluded that Citarum River Sector 21 is in the "Medium" category. The fuzzy results are shown below:

4.3 LoRa Network Testing

LoRa network testing was carried out by installing the RFM95W LoRa antenna to the Monriv device. The Monriv tool also acts as the LoRa network receiver from the LoRa Gateway located at Telkom STO around Bandung. This testing process was carried out by measuring RSSI, SNR, delay

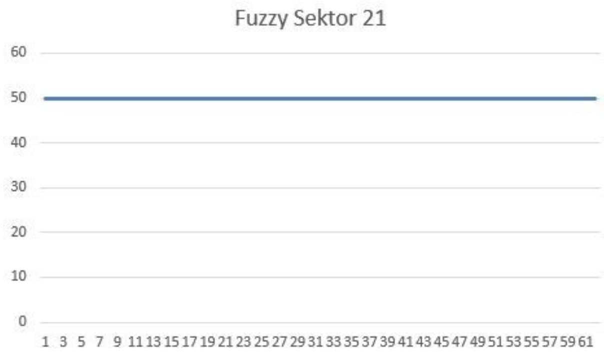


Figure 6: Fuzzy Sector 21.

and packet loss through the LoRa network within 30 minutes at the Citarum River Sector 6 and 21 locations. The test uses 923-925 mHz frequency, 125000 bandwidth and Spreading Factor of 10.

The definition of Signal Noise Ratio (SNR) is the power or signal strength received by the user with noise. The greater the value of SNR, the greater the power obtained by the user. However, if the SNR value is low then the greater the noise received. This SNR affects the quality of the network in data transmission. The definition of Received Signal Strength Indicator (RSSI) is a parameter that shows the end user's receiving power from all signals in the channel frequency band used. The further away from the beam distance, the weaker the signal strength received and the slower the data sent. The value of RSSI is closer to 0, the better the signal. The RSSI value is expressed in dBm and is a negative value. The definition of Packet Loss is the number of packets that fail to reach their destination when delivering the package. And the definition of Delay is the amount of time it takes for a package to travel from source to destination.

Table 2: Water Quality of Citarum River.

Average LoRa Network Testing					
No	Location	SNR (dB)	RSSI (dB)	Delay	Packet Loss
1	Ciatrum River Sektor 6	-6,46	-111,6	18 s	44 %
2	Ciatrum River Sektor 21	-12,86	-112,855	30 s	65 %

Table 2 shows the conclusion of the average network quality. It is seen that Citarum River Sector 6 has better average network quality compared to Citarum River Sector 21. This was proven because Sector 6 has a better SNR, RSSI, delay and packet loss compared to 21.

4.4 LoRa Network Testing from River to Gateway STO Cijawura

This test aims to analysis the performance or network quality of the LoRa from Monriv tool network data delivery, which was on the river Sector 6 and 21 to LoRa gateway in STO Cijawura and Lembong. This was carried out by obtaining sample data for about 30 minutes. Furthermore, the data in Antares was collected and either the STO Cijawura or Lembong were selected for the data to pass through. The parameters to be measured in this test include RSSI, SNR, packet loss and delay. The first test was used to measure Monriv tool to gateway STO Cijawura.

4.4.1 RSSI

The graph in Figure 7 shows that the average result for RSSI Sector 6 and 21 include -109.9 dBm and -111.8 dBm, respectively. Furthermore, RSSI sector 6 value was better compared to SNR Sector 21. This proves that apart from distance, Obstacles such as buildings and trees greatly affect the RSSI value. This was proven by the Citarum River Sector 2, which is located near the Telkom campus, consequently it has many obstacles such as high-rise buildings and housing for residents. Meanwhile, the Citarum River Sector 6 is located in a wide area. Therefore, the RSSI value obtained was better compared to 21.

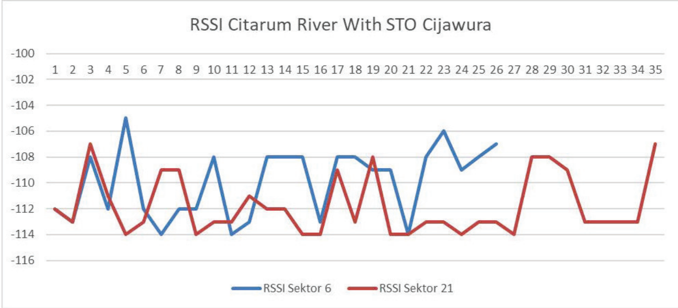


Figure 7: RSSI STO Cijawura.

4.4.2 SNR

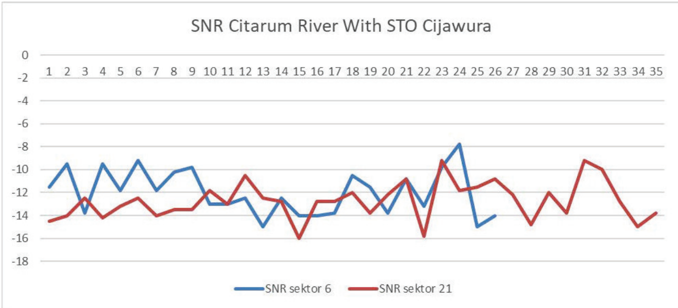


Figure 8: SNR.

The graph in Figure 8 shows that the average result for SNR in Sector 6 and 21 are -11.9731 dB and -12.731 dB, respectively. It is seen that the value of SNR for sector 6 is better compared to that of Sector 21, which proves that besides distance, obstacles such as tall buildings and trees greatly affect the SNR value. This was proven by the Citarum river Sector 21, which is located near the Telkom campus, that has many objects such as high-rise buildings and residential areas. Meanwhile, the Citarum river Sector 6 is located in a wide and spacious place. Therefore, the chances of the SNR value obtained are better compared to Sector 21.

4.4.3 Delay and Packet Loss

The Table 3 shows that the Delay and Packet Loss on Lora greatly affect distance and obstacles. The value of Delay and Packet Loss in Citarum River Sector 21 was better compared to sector 6. This is because the distance from sector 21 is closer to the STO Cijawura route. Therefore, test distance and packet loss are in direct proportion.

Table 3: Delay and Packet Loss.

No	Location	SNR (dB)	RSSI (dB)
1	Sektor 6	69 s	85 %
2	Sektor 21	47 s	77 %

4.5 LoRa Network Testing from River to Gateway Lembong

4.5.1 RSSI

The graph in Figure 9 shows that the average result for RSSI Sector 6 and 21 is -111.1 dBm and -114.27 dBm, respectively. This implies that the RSSI sector 6 value is better compared to Sector 21, which proves that apart from distance, Obstacles such as buildings and trees greatly affect the RSSI value. This was proven by the Citarum River Sector 21 which is located near the Telkom campus, consequently it has many obstacles such as high-rise buildings and housing for residents. Meanwhile,

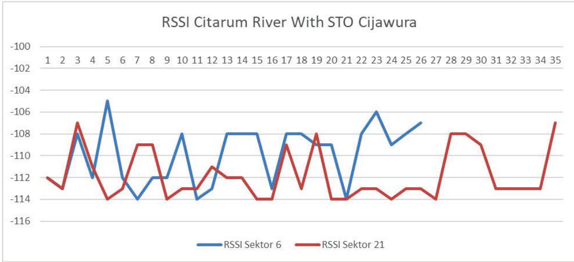


Figure 9: RSSI.

the Citarum River Sector 6 is located in a wide area. Therefore, the RSSI value obtained was better than Sector 21.

4.5.2 SNR

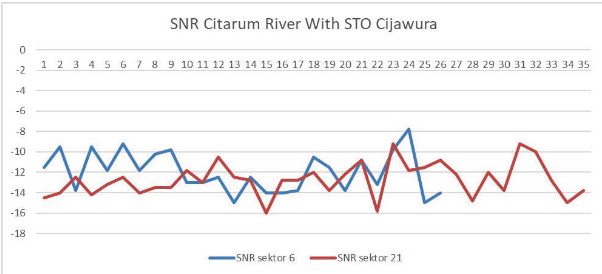


Figure 10: SNR.

Figure 10 shows that the average result for SNR Sector 6 and 21 is -3.55 dB and -12.91 dB, respectively. This implies that the value of SNR for Sector 6 is better compared to that of Sector 21, which proves that even though the gateway is different, distance and obstacle such as tall buildings and tree may affect the quality of LoRa data transmission. This is because, the Citarum Sector 21 river is located near the Telkom campus and consequently has many obstacles, such as high-rise buildings and residential housing. Meanwhile, for the Citarum Sector 6 river, which is located in a spacious place, there are no tall buildings around it, therefore the SSNR value space is better compared to Sector 21.

4.5.3 Delay and Packet Loss

Table 4: Delay and Packet Loss.

No	Citarum River	Delay	Packet Loss
1	Sector 6	69 s	78%
2	Sector 21	47 s	88%

The Table 4 shows that the delay and packet loss on Lora greatly affect distance and obstacles. The value of delay and packet loss in Citarum River in Sector 6 is compared to sector 21, due to its fewer obstacles. Apart from distance, obstacles or noise also affect the quality of data transmission.

5 Conclusion

Based on tests carried out, the water quality of Citarum River Sector 6 is better compared to that of 21, which is shown by Citarum River Sector 21 having a higher number of TDS and turbidity compared Sector 6. This was due to the closeness of Sector 21 to residential areas, which resulted to the presence of waste in River Sector 21 and in turn damaged its quality. For the results of the fuzzy calculation, these two rivers have the same number of definitions, namely 50. The value of 50 was included in the range of the river category "Medium". Therefore, it was concluded that these two rivers have a quality that is "Medium". This tool is only able to send fuzzy score to the Antares. However, it can't send the fuzzy result like "Medium" or "Good" to the Antares and application in android.

For testing the quality of the LoRa network, Citarum River Sector 6 was of better quality compared to 21, which was evident from the number of packets that were successfully sent to Antares. The number of packets successfully sent from Citarum River Sector 6 was 102 compared to Citarum River Sector 21 which only managed to send 63 data. In testing the quality of data transmission from the Citarum River to the Cijawura STO, it was seen that the quality of LoRa network data transmission is Citarum River Sector 21 as proven by the number of data packets that were successfully sent, namely 36 data compared to Sector 6 which only managed to send 27 data packets. As for the quality of data transmission from the Citarum River to STO Lembong, the river with the best data transmission quality was Citarum River Sector 6, as evidenced by the number of data packets sent successfully, namely 39 data compared to Sector 21 which only managed to send 27 data.

References

[1] Badan Pusat Statistik, "Statistik Lingkungan Hidup Indonesia (SLHI)". (2018). *Badan Pus. Stat. Indones.*, pp.1–43, 2018. R Conference paper selectivity and impact,

[2] P. N. Budiarti, A. Tjahjono, M. Hariadi, and M. H. Purnomo, "Development of IoT for Automated Water Quality Monitoring System," Proc. (2019). *Int. Conf. Comput. Sci. Inf. Technol. Electr. Eng. ICOMITEE*, 2019. vol. 1, pp. 211–216, 2019.

[3] P. Kungwalrut, V. Kongratana, T. Trisuwannawat, V. Tipsuwanporn, and A. Numsomran. (2018). "Improving the efficiency of water management system in biomass power plant using cyber-physical cloud computing," *Int. J. Intell. Eng. Syst.,* vol. 11, no. 4, pp. 188–198, 2018, doi: 10.22266/ijies2018.0831.19.

[4] M. Zangiabadi and H. R. Maleki. (2013). "Fuzzy Goal Programming Technique to Solve Multiobjective Transportation Problems with Some Non-Linear Membership Functions," *Iran. J. Fuzzy Syst.,* vol. 10, no. 1, pp. 61–74, 2013. doi: 10.22111/ijfs.2013.155.

[5] Wu, Hangyao; XU, Zeshui. Fuzzy Logic in Decision Support: Methods, Applications and Future Trends. (2020). *International Journal of Computers Communications & Control, [S.l.],* v. 16, n. 1, sep. 2020. ISSN 1841-9844. doi: https://doi.org/10.15837/ijccc.2021.1.4044.

[6] H. Patel and G. S. Thakur. (2017). "Classification of imbalanced data using a modified fuzzy-neighbor weighted approach," *Int. J. Intell. Eng. Syst.,* vol. 10, no. 1, pp. 56–64, 2017. doi: 10.22266/ijies2017.0228.07.

[7] Peraturan Pemerintah. (2001). "Peraturan Pemerintah Republik Indonesia Nomor 82 Tahun 2001," *Peratur Pemerintah Republik Indones.,* no. 1, pp. 1–5, 2001.

[8] Simo, Attila et al. Manufacturing Process Monitoring in Terms of Energy Management Improving. (2019). *International Journal of Computers Communications & Control, [S.l.],* v. 14, n. 3, p. 388-400, may 2019. ISSN 1841-9844. doi: https://doi.org/10.15837/ijccc.2019.3.3560.

[9] Menteri Kesehatan Republik Indonesia. (2017). "Peraturan Menteri Kesehatan Republik Indonesia Nomor 32 Tahun 2017 Tentang Standar Baku Mutu Kesehatan Lingkungan Dan Persyaratan Kesehatan Air Untuk Keperluan Higiene Sanitasi, Kolam Renang, Solus Per Aqua dan Pemandian Umum," *Peratur Menteri Kesehat Republik Indones.,* pp. 17–20, 2017.

[10] S. Singh and N. Singh. (2015). "Internet of Things (IoT): Security challenges, business opportunities & reference architecture for E-commerce," *Proc. 2015 Int. Conf. Green Comput. Internet Things, ICGCIoT*, 2015. pp. 1577–1581, 2016.

[11] N. A. Riski Muktiarto, D. Perdana, and R. M. Negara. (2018). “Performance analysis of mobility impact on IEEE 802.11ah standard with traffic pattern scheme,” *Int. J. Commun. Networks Inf. Secur.*, vol. 10, no. 1, pp. 139–147, 2018.

[12] S. Nosratian, M. Moradkhani, and M. B. Tavakoli. (2021). “Hybrid data compression using fuzzy logic and Huffman coding in secure IoT,” *Iran. J. Fuzzy Syst.,* vol. 18, no. 1, pp. 101–116, 2021. doi: 10.22111/ijfs.2021.5875.

[13] Costea, Claudiu Raul et al.(2015). Control System Architecture for a Cement Mill Based on Fuzzy Logic. *International Journal of Computers Communications & Control, [S.l.],* v. 10, n. 2, p. 165-173, apr. 2015. ISSN 1841-9844. doi: https://doi.org/10.15837/ijccc.2015.2.1750.

[14] A. Augustin, J. Yi, T. Clausen, and W. M. Townsley. (2016). “A study of Lora: Long range & low power networks for the internet of things,” *Sensors (Switzerland),* vol. 16, no. 9, pp. 1–18, 2016.

[15] D. Perdana, R. Munadi, and R. C. Manurung. (2017). “Performance evaluation of Gauss-Markov mobility model in hybrid LTE-VANET networks,” *Telkomnika (Telecommunication Comput. Electron. Control.*, vol. 15, no. 2, pp. 606–621, 2017, doi: 10.12928/TELKOMNIKA.v15i2.5913.

[16] P. Devi, D. Istianti, and N. Bogi. (2019). “Perancangan Dan Implementasi Device Tentang Teknologi Akses Lpwan Lora Untuk Monitoring Air Sungai Citarum Device Design and Implementation About Lpwan Lora Access Technology for Citarum River Water Monitoring.” Vol.6, No.2 2355-9365, 2019.

[17] C.K. Khuen and A. Zourmand. (2020). “Fuzzy Logic Based Flood Detection System Using Lora Technology,” *Proc. 2020 16 thn IEEE int. Colloq. Signal Process. Its Appl. CSPA (2020).* No. Cspa, pp. 40-45, 2020.

[18] Syamsul, R. Syahputra, Suherman, and Zamzami. (2018). “Control system based on fuzzy logic in nutmeg oil distillation process,” *Telkomnika (Telecommunication Comput. Electron. Control.,* vol. 16, no. 5, pp. 2254–2262, 2018.

[19] Y. Zhao, L. Yang, and Z. Xu. (2019). “Identification and Removal of Ground Clutter Using the Fuzzy Logic Algorithm,” *Proc. 2019 Int. Conf. Meteorol. Obs. ICMO 2019,* pp. 1–3, 2019.

[20] A. Najmurrokhman. (2018). “173- Design and implementation of fuzzy logic.pdf,” *2018 Electr. Power, Electron. Commun. Control. Informatics Semin.,* pp. 269–273, 2018.

[21] H. Ben Zina, M. Bouattour, and M. Chaabane. (2019). “Robust Takagi-Sugeno sensor fault tolerant control strategy for nonlinear system,” *Iran. J. Fuzzy Syst.,* vol. 16, no. 6, pp. 177–189, 2019. doi: 10.22111/ijfs.2019.5027.

[22] S. J. Putra, M. Z. Naf’an, and M. N. Gunawan. (2018). “Improving the scoring process of question answering system in Indonesian language using Fuzzy logic,” *Proc. - Int. Conf. Inf. Commun. Technol. Muslim World 2018, ICT4M 2018*, pp. 239–242, 2018.

[23] S. Mandala, N. A. S, and M. S. Mubarok. (2017). “Energy Efficient IoT Thermometer based on Fuzzy Logic for Fever Monitoring,” vol. 0, no. c, 2017.

[24] A. Naghsh, F. Sheikholeslam, and M. Danesh. (2014). “Design of an Adaptive Fuzzy Estimator for Force/Position Tracking in Robot Manipulators,” *Iran. J. Fuzzy Syst.,* vol. 11, no. 1, pp. 75–89, 2014., doi: 10.22111/ijfs.2014.1396.

[25] M. Farhan Mohd Pu’Ad, K. Azami Sidek, and M. Mel. (2020). “IoT based water quality monitoring system for aquaponics,” *J. Phys. Conf. Ser.,* vol. 1502, no. 1, pp. 2–8, 2020.

[26] C. G. Raji, V. A. Thasleena, Liloja, and M. Shahzad. (2019). “IoT Based Water Quality Monitoring with Android Application,” *Proc. 3rd Int. Conf. I-SMAC IoT Soc. Mobile, Anal. Cloud, I-SMAC 2019,* pp. 446–451, 2019.

[27] A. Singh and D. S. Sharma. (2020). “Implement Android Application for Book Donation,” *Proc. Int. Conf. Intell. Eng. Manag. ICIEM 2020,* pp. 137–141, 2020.

[28] N. K. E. Kartika, M. A. Murti, and C. Setianingsih. (2019). “Floods prediction using radial basis function (RBF) based on internet of things (IoT),” *Proc. - 2019 IEEE Int. Conf. Ind. 4.0, Artif. Intell. Commun. Technol. IAICT 2019,* pp. 125–128, 2019.

[29] D. Perdana, Sari, R. F. (2013) "Performance comparison of IEEE 1609.4/802.11p and 802.11e with EDCA implementation in MAC sublayer," 285-290. *Paper presented at 2013 5th International Conference on Information Technology and Electrical Engineering, ICITEE.* 2013, Yogyakarta, Indonesia. https://doi.org/10.1109/ICITEED.2013.6676254.

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