Earthquake Early Warning System Prototype Based on Lot using Backpropagation Algorithm

Adi Pranesthi
School of Electrical Engineering
Telkom University
Bandung, Indonesia
adipranesthi@student.telkomuniversity.ac.id

Budhi Irawan
School of Electrical Engineering
Telkom University
Bandung, Indonesia
budhiirawan@telkomuniversity.ac.id

Casi Setianingsih
School of Electrical Engineering
Telkom University
Bandung, Indonesia
setiacasie@telkomuniversity.ac.id

***Abstract*—Earthquakes are vibrations that occur on the earth's surface due to the sudden release of energy from the inside that creates seismic waves. An earthquake is caused by the movement of the earth's crust (the earth's plate). The frequency of a region refers to the type and size of earthquakes experienced during a period. Along with the development of early earthquake detection system technology provides a solution to minimize earthquake events. This research will discuss the system's design to determine the occurrence of earthquakes through time pattern analysis and Peak Ground Acceleration value. By using the Radial Basis Function Method, which later to minimize the loss of life from earthquakes. And help the main tools owned by the government. This study aims to determine the occurrence of earthquakes from Peak Ground Acceleration values and time analysis patterns, which are obtained from the decision of the Backpropagation method with an accuracy rate of 88%.**

Keywords—earthquake, low power wide area network, backpropagation, peak ground acceleration

I. INTRODUCTION

An earthquake is a natural phenomenon, one of which occurs due to the shifting of the plates on the earth's surface; earthquakes are destructive, so that in each event almost always gives material and immaterial losses. This is important to be developed, given the previous seismograph tools. Seismographs have the disadvantage of being too strong if vibrations make the seismograph unable to take notes because the recorder can be damaged. With this tool, it will not be the primary tool that the government will use to predict natural disasters, but it can at least help to read patterns of earthquakes through time pattern analysis and official data from BMKG. The tool will read the pattern of an earthquake based on a specific time range and the latitude and longitude of the location of the vibration, and then the data is processed using an application that will be submitted with LoRa to the database so that the data will be directly displayed on the website.

II. RELATED WORK

A. *Application of Artificial Neural Network Back-propagation to Classify the Type of Earthquake Mount Rinjani (Ishak, Bulkis Kanata, L.A Syamsul Irfan Akbar, 2016)*

This research applies a backpropagation neural network to classify the type of earthquake Sembalun Mount Rinjani, Lombok. Network Backpropagation neural network is trained to strike a balance between the system's ability to recognize patterns used during training and the network's ability to provide the correct response to the input pattern with the pattern used during training. Backpropagation neural network is used to classify the type of earthquake Sembalun Mount Rinjani, Lombok, using one year of data (1995) by dividing the data into two parts: the training data and test data [1].

B. *Analysis of Earthquake Speed Acceleration in Sumatra Using Artificial Neural Network Backpropagation Method (Toni, Widianto, 2019)*

Research has been conducted on soil acceleration analysis using Artificial Neural Networks (ANN), which aims to analyze and predict soil densities in Sumatra. This study uses ground acceleration data recorded through the accelerograph at three stations in West Sumatra, namely Padang Panjang Geophysical Station (PAPA), Ketaping Meteorological Station (PATA), and Maritim Teluk Bayur (PATU) Station. This data processor uses the backpropagation method. Data processing is done with two types of data sharing, namely data sharing with a ratio of 50:50 and a ratio of 80:20. After the training and testing process, it was found that the data sharing with an 80:20 ratio got better results than the data sharing with a 50:50 ratio. Overall, it can be concluded that ANN in the training process can predict the acceleration of the ground quite accurately, but in the testing process, the error value obtained is quite large, so ANN is not able to predict the acceleration of land data correctly. [2].

III. SYSTEM METHOD

This chapter explains what will be done and provides an overview of the equipment's design to be made. To get earthquake data, sensors that are used consist of GPS sensors and MPU-6050. The Arduino Pro Mini will then be controlled, and then the data will be sent through the LoRa network. Other modules as support and laptop as a source:

Fig. 1. Design tool.

Start with hardware design. The sensor used consists of GPS sensors and MPU -6050. Arduino will control the sensor; after that, data will be sent to the Antares server using LoRa Shield. Data will be received by Antares which contains Longitude and Latitude data, Peak Ground Acceleration

Value, around installing the equipment. After that, the data will be used to predict an earthquake's impact using the Radial Base Function algorithm with these parameters. The results will be displayed on the web.

Hardware design is one of the first steps in making sensors. Where sensors can read values and data obtained and run in the future.

1) *Installation of Sensor Devices*

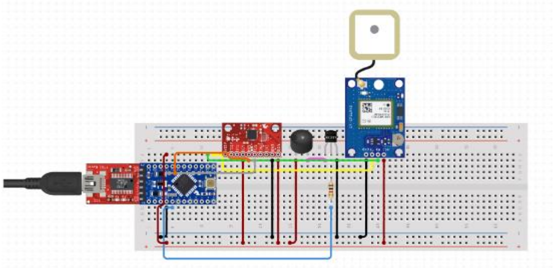

Fig. 2. Schematic tool.

In this process, the sensor that will be used is TinyGPS Neo6mv2. This sensor has four pins, namely Vcc, TX, RX, ground pins. Each will be connected to the Arduino Pro Mini, except the Vcc is connected to the Vcc MPU-6050 then to the SV Arduino Pro Mini pin. Pin TX is connected to pin D4, pin RX will be connected to pin D3 on Arduino, and finally, the ground pin will be connected to the ground pin on Arduino pro mini.

GPS sensor functions to determine longitude and latitude in the form of coordinates. And this distance data can be used in the next process, whether there is Peak Ground Acceleration in units (g) in the coordinate or close to the previous coordinate by using a time pattern analysis.

Furthermore, the second sensor is the MPU-6050 to measure the magnitude of Peak Ground Acceleration. This sensor consists of four pins, namely Vcc, ground, SDA, and SCL Vcc pins will be connected to the Arduino Pro Mini voltage source 3.3v, ground to Arduino ground and the SDA pin will be connected to the SDA pin on Arduino, and finally, the SCL pin is connected to the pin SCL on Arduino pro mini.

The buzzer is then connected to the D8 digital pin for the buzzer to tell if the parameter has passed the safe limit.

2) *Data Reading*

The sensor will read the data according to its function. GPS sensor to determine longitude and latitude. At the same time, the MPU-6050 sensor is used to measure Peak Ground Acceleration. After the data is obtained, it will be sent to the Antares platform using the LoRa network.

3) *Send Data*

The data to be sent consists of three data in the form of strings to the Antares platform. Data sent in the form of Longitude and Latitude (Longitude and Latitude), Peak Ground Acceleration with units (g). The protocol used by LoRa is LoRaWAN, with a frequency of 915 MHz. End devices function for receivers and transmitters, each gateway will be connected to the end device in its coverage area, and the gateway will forward the data to the network server, LoRa.id, and the data will be received by the Antares platform [3].

4) *Data in Antares*

The data to be displayed are longitude, latitude, and Peak Ground Acceleration data. Antares is an Internet of Thing (IoT) platform, as cloud storage is explicitly created for developing software and websites built [4].

The parameters that will be used consist of 2, namely:

1. Longitude and Latitude.
2. Peak Ground Acceleration.

In this research, the website design uses python programming language as the back end and javascript as the front end. Website appearance consists of 2 parts, namely a system decision containing the results of determinations or predictions from the model and the latest system data section that includes Antares data. Designing this application designed two different views: the YES decision page, earthquake, and NO decision.

We provide an earthquake warning system in real-time using PGA and machine learning to determine a direction from the picture below.

- Display on the web if the detected vibration is an earthquake.

Fig. 3. UI display if earthquake.

- Display on the web if the system decision is not an earthquake.

Fig. 4. UI display, if not earthquake.

In this research, the Radial Backpropagation artificial neural network method is used to make decisions that support the occurrence of an earthquake or not. Based on Longitude and Latitude, then for the final decision, Peak Ground Acceleration data is used and supporting decisions. The final decision on this system is whether an earthquake occurred or no earthquake occurred. Which is a type of binary classification? The architectural model used is as shown below:

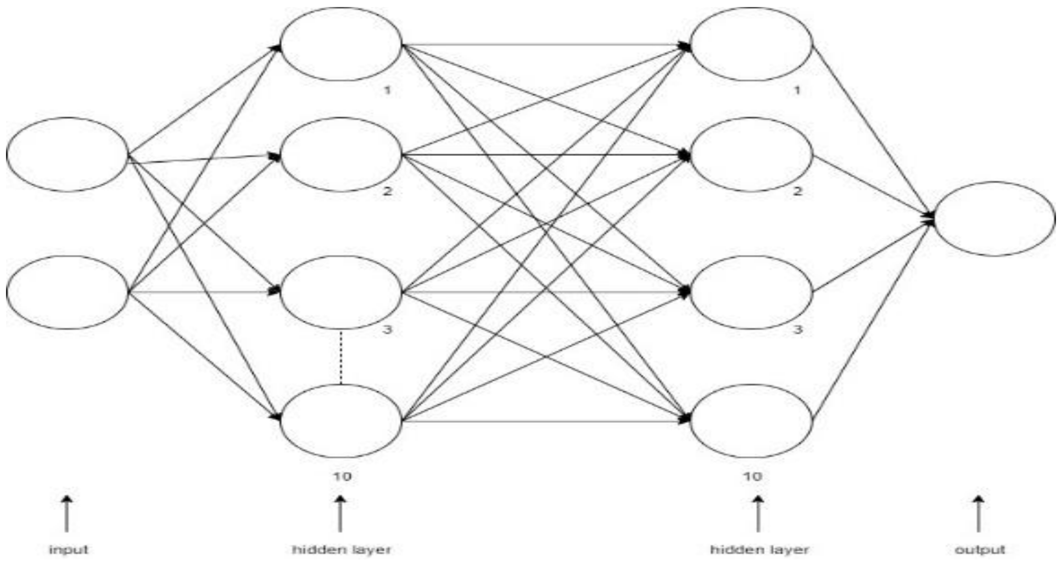

Fig. 5. Backpropagation architecture.

The backpropagation architecture consists of 4 layers, with the first layer being the input layer, the first layer composed of 2 nodes where the first input (x1) is the latitude, and the second input (x2) is longitude. The second and third layers are hidden layers where each layer has ten nodes with a Relu activation function. The Relu function changes the weight value that passes through the node to the maximum amount. And the last layer is the output layer wherein the layer of adding all the weights of the third layer occurs.

Where in general, the process starts from the preparation of data, training, until testing the model that has been built. The data preparation stages are making a dataset on BMKG data obtained in the form of excel in 2014 - 2018, into one whole file in comma-separated values. It starts by taking data from Excel, bringing together data from 2014 - 2018, filtering out invalid data where some data is not used.

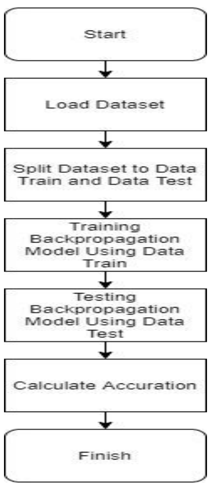

Fig. 6. Backpropagation training and testing.

The next stage is the training of the backpropagation model. In general, the process can be seen in the flow chart. Starting from taking a data set, then separating the data set into a data train and data test. Train the model using a data train, perform model testing using data sets, calculate accuracy, and save the model

The model formed is then integrated with the website application. A final decision is made in the website application, where the input model is real-time data from Antares consisting of longitude data, latitude data, and PGA. The data is received by the web server running the Website application. Then it is processed in a supporting decision model that requires longitude, latitude, and final decision of Peak Ground Acceleration data. Supporting decisions and final decisions can be explained by the pseudocode below.

IV. Implementation and Testing

Tests are carried out to determine whether the system is made to run by the original purpose. Where sensors can retrieve data correctly and test LoRa network performance. The sensor is used to retrieve data from the accelerometer sensor. For testing, the accelerometer sensor will measure the acceleration of the sensor movement. This is because the sensor used is a type of motion sensor, where the sensor only reads the value of the sensor movement itself.

1) Accelerometer Sensor Test

TABLE I. ACCELEROMETER TEST RESULT

Testing	**Gravity**	**Acc X**	**Acc Y**	**Acc Z**	**{Acc x}^2**	**{Acc x}^2**	**{Acc x}^2**
1	1	0,15	-,08	-0,98	0,0225	0,0049	0,9604
2	0,99	0,14	-0,08	-0,98	0,0196	0,0064	0,9604
3	1	0,15	0,08	-0,98	0,0225	0,0064	0,9801
4	1,01	0,15	0,07	-0,99	0,0225	0,0049	0,9604
5	1	0,14	0,08	-0,98	0,0196	0,0064	0,9604
6	1	0,15	0,08	-0,98	0,0225	0,0064	0,9604
7	1	0,15	0,07	-0,99	0,0225	0,0049	0,9801
8	1,01	0,15	0,06	-0,98	0,0225	0,0036	0,9604

The results obtained by calculating the average values on the X, Y and Z-axis will be used to get the Peak Ground Accelerometer value used as our parameter.

- Gravity calculation formula.

Information:
〖Acc x〗 ^ 2 = 0.0225
acc y ^ 2 = 0.0025
acc z ^ 2 = 0.9801
Steps taken to measure gravity
gravity = √ (0.0225 + 0.0025 + 0.9801) = 1.01

- Peak Ground Acceleration calculation formula.

PGA = | ((1.01-1.01) × 1000) / 1 | = 0
The results obtained to get a value of 0, where Peak Ground Acceleration is included in the safe parameter.

2) Lora Test Result

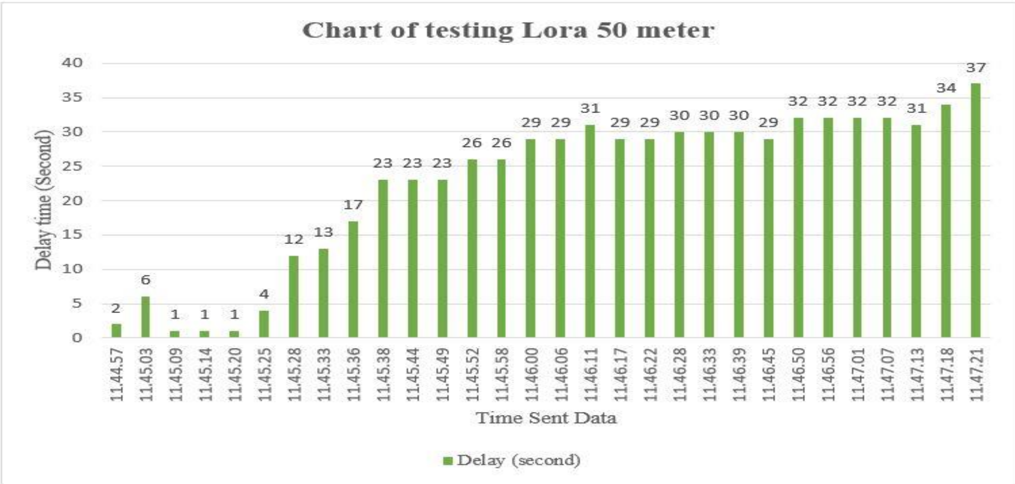

Fig. 1. Graph of 50 meter LoRa test result.

TABLE II. 50 METER LORA TEST RESULT

Testing	Start Sending	Data Sent	Delay (second)	Distance (meter)	Status
1	11.44.57	11.44.59	2	50	Sent
2	11.45.03	11.45.09	6	50	Sent
3	11.45.09	11.45.10	1	50	Sent
4	11.45.14	11.45.15	1	50	Sent
5	11.45.20	11.45.21	1	50	Sent
6	11.45.25	11.45.29	4	50	Sent
7	11.45.28	11.45.40	12	50	Sent
8	11.45.33	11.45.46	13	50	Sent
9	11.45.36	11.45.53	17	50	Sent
10	11.45.38	11.46.01	23	50	Sent
11	11.45.44	11.46.07	23	50	Sent
12	11.45.49	11.46.12	23	50	Sent
13	11.45.52	11.46.18	26	50	Sent
14	11.45.58	11.46.24	26	50	Sent
15	11.46.00	11.46.29	29	50	Sent
16	11.46.06	11.46.35	29	50	Sent
17	11.46.11	11.46.40	31	50	Sent
18	11.46.17	11.46.46	29	50	Sent
19	11.46.22	11.46.51	29	50	Sent
20	11.46.28	11.46.58	30	50	Sent
21	11.46.33	11.47.03	30	50	Sent
22	11.46.39	11.47.09	30	50	Sent
23	11.46.45	11.47.14	29	50	Sent
24	11.46.50	11.47.22	32	50	Sent
25	11.46.56	11.47.28	32	50	Sent
26	11.47.01	11.47.33	32	50	Sent
27	11.47.07	11.47.39	32	50	Sent
28	11.47.13	11.47.44	31	50	Sent
29	11.47.18	11.47.52	34	50	Sent
30	11.47.21	11.47.58	37	50	Sent

TABLE III. 150 METER LORA TEST RESULT

Testing	Start Sending	Data Sent	Delay (second)	Distance (meter)	Status
1	16.25.24	16.25.28	4	150	Sent
2	16.25.29	16.25.34	5	150	Sent
3	16.25.35	16.25.40	5	150	Sent
4	16.25.40	16.25.45	5	150	Sent
5	16.25.46	16.25.51	5	150	Sent
6	16.25.51	16.25.59	8	150	Sent
7	16.25.54	16.25.09	15	150	Sent
8	16.25.59	16.25.15	16	150	Sent
9	16.26.02	16.26.23	21	150	Sent
10	16.26.04	16.26.32	28	150	Sent
11	16.26.10	16.26.36	26	150	Sent
12	16.26.16	16.26.43	27	150	Sent
13	16.26.18	16.26.48	30	150	Sent
14	16.26.24	16.26.53	29	150	Sent
15	16.26.26	16.26.59	33	150	Sent
16	16.26.32	16.27.05	33	150	Sent
17	16.26.37	16.27.10	33	150	Sent
18	16.26.43	16.27.16	33	150	Sent
19	16.26.49	16.27.21	32	150	Sent
20	16.26.54	16.27.27	33	150	Sent
21	16.27.00	16.27.32	32	150	Sent
22	16.27.05	16.27.38	33	150	Sent
23	16.27.11	16.27.44	33	150	Sent
24	16.27.16	16.27.52	36	150	Sent
25	16.27.22	16.27.58	36	150	Sent
26	16.27.28	16.28.03	35	150	Sent
27	16.27.33	16.28.09	36	150	Sent
28	16.27.39	16.28.14	35	150	Sent
29	16.27.44	16.28.22	38	150	Sent
30	16.27.47	16.28.26	39	150	Sent

That way, you can calculate the percentage level of packet loss in sending data to Antares. To calculate the percentage of packet loss by using the following formula:

With such an accuracy obtained from sending data using LoRa within 50 meters is:

packet loss = (30 -30) / 30 × 100% = 0%.

That way, the calculation of throughput obtained from sending data using a LoRa within 50 meters is:

Throughput = (30 x 12) / 144 = 2,5bps.

Based on the above calculation, the throughput of 2.5BPS is obtained.

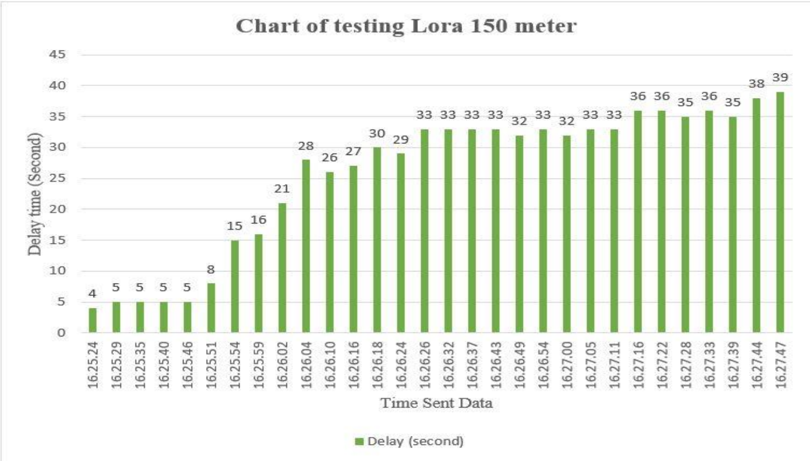

Fig. 2. Graph of 150 meter LoRa test result.

That way, you can calculate the percentage level of packet loss in sending data to Antares. To calculate the percentage of packet loss by using the following formula:

With such an accuracy obtained from sending data using LoRa within 150 meters is:

packet loss = (30 -30) / 30 × 100% = 0%

That way, the calculation of throughput obtained from sending data using a LoRa within 150 meters is:

Throughput = (30 x 12) / 143 = 2,51749 bps

Based on the above calculation, the throughput of 2.51749 bps is obtained.

TABLE IV. 250 METER LORA TEST RESULT

Testing	Start Sending	Data Sent	Delay (second)	Distance (meter)	Status
1	13.03.21	13.03.22	1	250	Sent
2	13.03.27	13.03.28	1	250	Sent
3	13.03.32	13.03.33	1	250	Sent
4	13.03.38	13.03.39	1	250	Sent
5	13.03.43	13.03.44	1	250	Sent
6	13.03.49	13.03.52	3	250	Sent
7	13.03.52	13.04.03	11	250	Sent
8	13.03.57	13.04.13	16	250	Sent
9	13.04.00	13.04.17	17	250	Sent
10	13.04.02	13.04.31	29	250	Sent
11	13.04.08	13.04.53	45	250	Sent
12	13.04.13	13.04.58	45	250	Sent
13	13.04.16	13.05.04	48	250	Sent
14	13.04.21	13.05.09	48	250	Sent
15	13.04.24	13.05.15	51	250	Sent
16	13.04.29	13.05.20	51	250	Sent
17	13.04.35	13.05.26	51	250	Sent
18	13.04.41	13.05.31	50	250	Sent
19	13.04.52	13.05.37	45	250	Sent
20	13.04.57	13.05.41	44	250	Sent
21	15.26.59	15.27.05	4	250	Sent
22	15.27.08	15.27.13	5	250	Sent
23	15.27.16	15.27.19	3	250	Sent
24	15.27.21	15.27.24	3	250	Sent
25	15.27.26	15.27.30	4	250	Sent
26	15.27.32	15.27.36	4	250	Sent
27	15.27.38	15.27.42	5	250	Sent
28	15.27.43	15.27.47	4	250	Sent
29	15.27.49	15.27.53	4	250	Sent
30	15.27.55	15.27.58	3	250	Sent

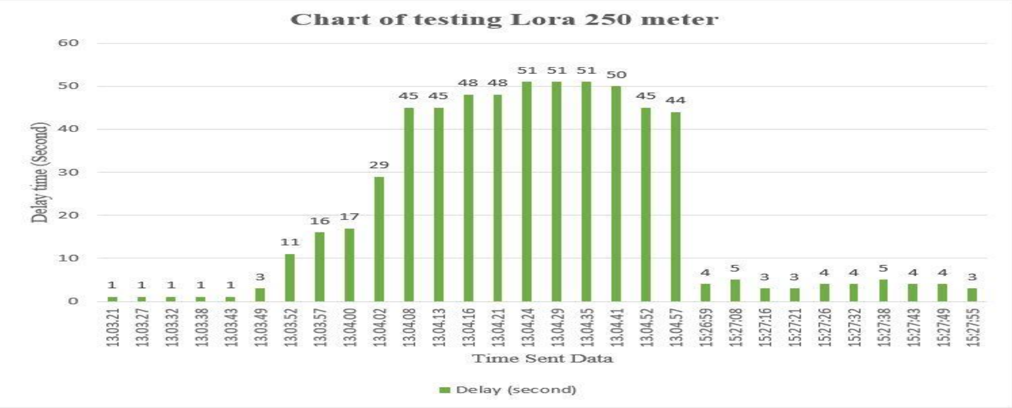

Fig. 3. Graph of 250 meter LoRa test result.

That way, you can calculate the percentage level of packet loss in sending data to Antares. To calculate the percentage of packet loss by using the following formula:
With such an accuracy obtained from sending data using LoRa within 250 meters is:

packet loss = (30 -30) / 30 × 100% = 0%.

That way, the calculation of throughput obtained from sending data using a LoRa within 150 meters is:

Throughput = (30 x 12) / 152 = 2,36842 bps.

Based on the above calculation, the throughput of 2.36842 bps is obtained.

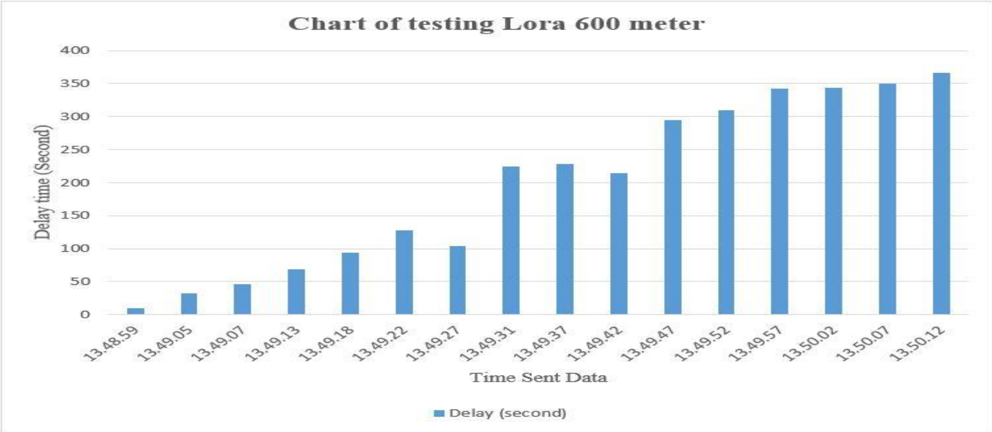

Fig. 4. Graph of 600 meter LoRa Test Result

That way, you can calculate the percentage level of packet loss in sending data to Antares. To calculate the percentage of packet loss by using the following formula:

That way, the accuracy obtained from sending data using a LoRa within 600 meters is:

packet loss = (30 -16) / 30 × 100% = 46.667%

Based on the above calculation, Packet Loss is 46.667%, which means that the data sent from LoRa is successfully sent.

From Table IV, we can calculate the throughput of data transmission to Antares. To calculate the percentage of throughput using the following formula:

That way, the calculation of throughput obtained from sending data using a LoRa within 600 meters is:

Throughput = (16 x 12) / 73 = 2,63013699 bps

Based on the above calculation, it is obtained throughput of 2.63013699 bps from 16 data that were successfully sent.

3) *Backpropagation Model Test*

Changing the variable Train set, test set, alpha, and epoch can show the highest results or accuracy done in previous research [6], [7].

TABLE V. BACKPROPAGATION MODEL TEST

No	Train Set	Test Set	Alpha	Epoch	Accurate
1	70%	30%	0,000001	1000	86%
2	80%	20%	0,000001	1000	85%
3	90%	10%	0,000005	1000	88%

Testing the Backpropagation model consists of, namely:

- *Train Set:* The part of the dataset that we train to make predictions or run functions from another ML algorithm according to their respective goals
- *Test Set:* The part of the dataset that we test to see its accuracy, or in other words, to see its performance.
- *Alpha:* Tuning parameters in the model.
- *Epoch:* Iteration Backpropagation

The highest accuracy obtained is 88% obtained from this test. This test itself was carried out to find out the right calculation to get the best results.

TABLE VI. BMKG DATA

No	Date	Time	Latitide	Longitude	Depth	Magnitudo
1	05/01/1/4	11:32:08	-6,09	105,37	5	5,2
2	12/01/1/4	10:46:50	-8,49	109,43	5	4,4
3	22/01/1/4	17:41:12	-6,79	106,76	5	4,0
4	03/11/1/4	08:56:30	-7,74	105,96	5	4,8
5	09/04/1/4	02:21:20	-7,31	106,79	8	3,3
6	06/01/1/4	01:10:09	-9,09	106,04	10	4,7
7	06/01/1/4	01:39:01	-9,58	107,07	10	4,5
8	14/01/1/4	02:27:15	-8,05	107,35	10	3,8
9	14/01/1/4	06:45:35	-7,47	107,54	10	3,3
10	17/01/1/4	02:52:51	-8,23	107,29	10	4,3
11	02/02/1/4	22:31:37	-7,67	108,61	10	3,8
12	03/02/1/4	22:36:42	-7,01	128,26	10	5,8
13	05/02/1/4	22:58:30	-6,60	105,07	10	4,1
14	06/02/1/4	23.40.00	-7,90	107,27	10	3,7
15	10/02/1/4	08:40:32	-8,43	108,59	10	4,1
16	11/02/1/4	09:32:06	-8,05	107,40	10	3,6
17	16/02/1/4	10:50:02	-7,84	106,63	10	4,6
18	21/02/1/4	07:41:03	-8,52	105,12	10	4,9
19	23/02/1/4	08:58:41	-8,11	108,30	10	4,4
20	26/02/1/5	19:41:04	-7,93	106,31	10	4,3

The table above is the official data from BMKG that we use as parameters in this research. BMKG is the Indonesian Agency for Meteorological, Climatological, and Geophysics. This data is processed using the backpropagation method as a decision-maker supporting an earthquake's occurrence, or an earthquake did not occur [5].

V. CONCLUSION

All sensors are running, but the stability is slightly disturbed due to minimal capacity, and the MPU-6050 sensor can measure Peak Ground Acceleration (m/s^2) values. The network for urban areas that we recommend is a maximum distance of 250 meters; more than that, packet loss is vast. The system is running correctly, and if the device is installed at the test site, the system cannot send data but does not enter the Antares platform due to the limited reach of the LoRa gateway. This study aims to determine the occurrence of earthquakes from Peak Ground Acceleration values and time analysis patterns, which are obtained from the decision of the Backpropagation method with an accuracy rate of 88%.

REFERENCES

[1] Kanata, B. and Akbar, L.S.I., 2018. Penerapan Jaringan Syaraf Tiruan Backpropagation Untuk Mengklasifikasi Jenis Gempa Gunung Rinjani Sembalun, Lombok. Dielektrika, 3(2 Agustus), pp.140-149.

[2] Widianto, T., Abdullah, Z. and Pujiastuti, D., 2019. Analisis Percepatan Tanah Gempa di Sumatera Menggunakan Jaringan Syaraf Tiruan Metode Backpropagation. Jurnal Fisika Unand, 8(1), pp.64-71.

[3] Lundell, D., Hedberg, A., Nyberg, C. and Fitzgerald, E., 2018, June. A routing protocol for LoRa mesh networks. In 2018 IEEE 19th International Symposium on" A World of Wireless, Mobile and Multimedia Networks"(WoWMoM) (pp. 14-19). IEEE.

[4] "ANTARES," [Online]. Available: https://antares.id/id/index.html. [Accessed 12 March 2019].

[5] Andriani, F.D., Iryanti, M. and Sari, I.L., Analisis Pola Waktu Mula Anomali Polarisasi Sinyal Sebelum Gempa Bumi Di Wilayah Aceh Dan Sumatera Utara. Wahana Fisika, 2(2), pp.118-128.

[6] Setyadi, N.A., Nasrun, M. and Setianingsih, C., 2018, December. Text Analysis For Hate Speech Detection Using Backpropagation Neural Network. In *2018 International Conference on Control, Electronics, Renewable Energy and Communications (ICCEREC)* (pp. 159-165). IEEE.

[7] Taqyudin, M.I., Irawan, B. and Setianingsih, C., 2019, August. Wood Classification Based on Fiber Texture Using Backpropagation Method. In *2019 International Conference on Sustainable Engineering and Creative Computing (ICSECC)* (pp. 245-250). IEEE.