Prediction of signal attenuation value caused by weather changes on cellular communication networks using backpropagation algorithm

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***Abstract*—The value of signal attenuation by the resulting weather changes may differ at any time. The collection of signal power data with different times, weather, humidity, rainfall, and temperatures using the drive test method in Malang area will be processed using machine learning methods and backpropagation algorithms. The process is carried out using Matlab software. In this study, data collection is carried out on four BTS ranges. In addition to these data, it is also necessary to calculate the value of signal attenuation by weather changes in order to find out whether the weather category is good or bad for telecommunications activities. When the weather is sunny and cloudy it has an RSSI range value of -85 dBm to -75 dBm, while in cloudy and rainy weather it has an RSSI range of -104,2 dBm to -87 dBm. Data from the results of the drive test measurements obtained the signal attenuation value by the largest weather change of 40.49718 dB and the largest rainfall of 681.8 mm / hour. Based on the test data, the signal attenuation value when the weather is sunny and cloudy is worth 0.096164 dB to 8.61604 dB, and in cloudy and rainy weather it has a greater attenuation value, from 12.3466 dB to 21.0098 dB. Using the backpropagation algorithm, the accuracy rate in this prediction reaches 99.7 %.**

Keywords*— *Signal Attenuation, Weather Changes, Drive Test, Machine Learning, Backpropagation, RSSI

I. INTRODUCTION

In cellular telecommunications networks, information signal transmitted from the Base Transceiver Station (BTS) received by mobile phones and vice versa. Without the information signal, there will never be communication with each other. In the process of exchanging signals, there are problems that users may not have been directly aware of. These problems can be in the form of noise interference, fading, interference, and attenuation. These disturbances can reduce the power output received by users from the center and hinder performance that should be able to run smoothly. In addition, interference can also be caused by the weather situation when communicating and the surrounding environmental conditions [1].

Unstable weather can cause various kinds of problems when electromagnetic waves transmit and receive information. Indonesia has high rainfall, both in the rainy and dry seasons. The amount of rainfall can reduce the signal power level, because rain particles that undergo a polarization and scattering process on the signal wave interfere with electromagnetic signal waves that send and receive information signals or vice versa [2]. Electromagnetic waves do not require a medium for their propagation and propagate through several characters, such as wavelength, amplitude, frequency, and speed. The higher the energy level in a source, the lower the wavelength of the energy produced, but the higher the frequency [3].

Weather changes in cellular communications can result in reduced signal power quality sent and received, resulting in attenuation. Signal attenuation due to weather changes can also vary from time to time. Meanwhile, deep learning is used to determine the level of a signal or power received by the user under different weather conditions, humidity, rainfall, and temperature, so that providers can adjust signal power quality planning in the future. Machine learning [4] or deep learning [5] has various algorithms, one of which is backpropagation. Backpropagation is a machine learning algorithm that is useful for reducing the error rate by adjusting its weight based on the difference in output and the desired target [6].

Backpropagation used in [7] to classify the weather with the used input parameters are temperature, pressure, humidity, wind speed, rain, and clouds. Meanwhile, the output parameters are brightness, clouds, and rain. The data used in this research is 1600 data (80%) for training and 400 data (20%) for testing. The accuracy results obtained are 99% [7].

In [8] many cases found that the results of weather forecasts in the same city differ, depending on the radius and require a precise and accurate algorithm to determine it. The authors used backpropagation and bayessian regularization algorithms. The accuracy value of the backpropagation algorithm for the rainy season is less than 78.33% compared to the dry season which is 87.57%. In contrast, the bayessian regularization algorithm in the rainy season has the greatest accuracy value of 99.70% and decreases in the dry season by 99.06%.

An accurate classification method between the four rainfall intensities (no rain, drizzle, moderate rain, and heavy rain) is calculated based on the three Received Signal Level (RSL) features of 4G/LTE. The method used shows good performance, so that the overall correct classification rate is 96.7% [9].

Rain attenuation effects on cellular communications are evaluated in [10 – 15]. The studies show that rain attenuation has quite significant effect on the performance of communication network. However, there are other aspects on weather that might be contribute on the performance of communication. These aspects were not evaluated yet.

In this study, signal power data was taken with the weather, different humidity, precipitation, and temperature using the drive test method in the Malang City area which will be processed using the deep learning method and backpropagation algorithms because it is simple, yet precise. Process will be done using the Matlab software. Data retrieval performed on four Base Transceiver Station (BTS) ranges. In addition to these data, the calculation of the signal attenuation by weather changes is good or bad for telecommunications activities. The timing of this process is during the morning, afternoon, and evening with sunny, cloudy, and rainy weather.

II. METHOD

Fig. 1 is a flowchart of the research design that will be made.

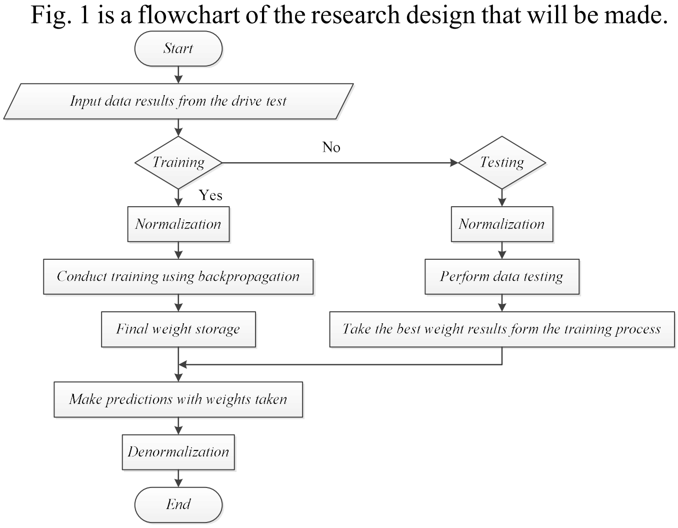

Figure 1. Research Design Flowchart

The process of this system are determine the location point, time, and weather that will be used to do the drive test. Then measure temperature, humidity, precipitation, and Received Signal Strength Indicator (RSSI) at the time of the drive test. The preprocessing stage is used to clean up some data which have the same value and result. Invoke normalized training data then initializes bias and weight values along with parameters that used during training, i. e. maximum iteration, target error, and training rate [7]. Matlab software will run the feedforward stage, backpropagation, and calculation of the weight changes. Matlab will conduct training until the target error or iteration is reached maximum. If it has been achieved, the training process will be stopeed and continued on the storage of the final weight of the training stage [8].

Entering input data that will be the input at the stage of testing. Those input data values will be normalized automatically by the system that has been created. Take the best weight gained from the training pricess that has been done before. The best weights will be feedforwarded before being denormalized, so that at the final stage will display the results of this predictions [9]. Enter input data from the drive test measurement results. Conducting the training process, namely by normalizing the data before training with the backpropagation method. Perform the testing process by normalizing the data before conduct testing with the best weight value from the training data. For the last step, make predictions of the weights that have been taken and then denormalize that data before it is displayed.

The stages of this research to be finished is shown in Figure 2.

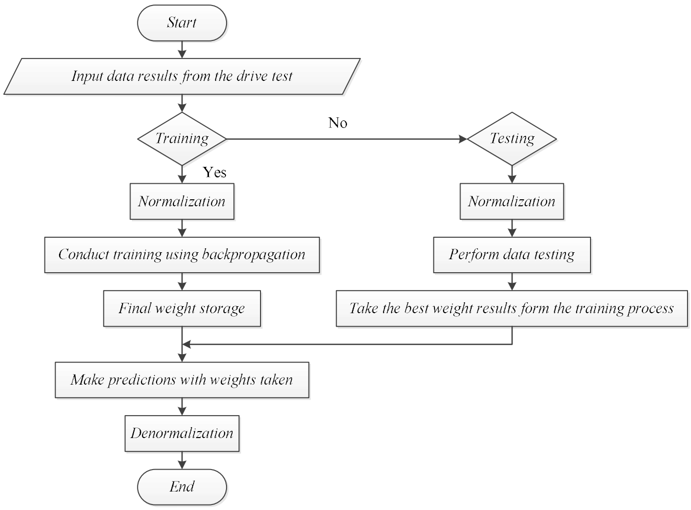

Figure 2. Training Flowchart

The process of this system are determine the location point, time, and weather that will be used to do the drive test. Then measure temperature, humidity, precipitation, and Received Signal Strength Indicator (RSSI) at the time of the drive test. The preprocessing stage is used to clean up some data which have the same value and result. Invoke normalized training data then initializes bias and weight values along with parameters that used during training, i. e. maximum iteration, target error, and training rate. Matlab software will run the feedforward stage, backpropagation, and calculation of the weight changes. Matlab will conduct training until the target error or iteration is reached maximum. If it has been achieved, the training process will be stopeed and continued on the storage of the final weight of the training stage.

Entering input data that will be the input at the stage of testing. Those input data values will be normalized automatically by the system that has been created. Take the best weight gained from the training pricess that has been done before. The best weights will be feedforwarded before being denormalized, so that at the final stage will display the results of this predictions. Enter input data from the drive test measurement results. Conducting the training process, namely by normalizing the data before training with the backpropagation method. Perform the testing process by normalizing the data before conduct testing with the best weight value from the training data. For the last step, make predictions of the weights that have been taken and then denormalize that data before it is displayed.

III. RESULTS AND DISCUSSION

The value of signal attenuation by weather changes calculated based on the data drive test results that have been measured, taken, and collected [10]. Attenuation calculation is done using a wide variety of variables and a fixed constant derived from the attenuation formula itself.

From all the calculation of the signal attenuation by the weather changes obtained the final result as shown by the table below in Table 1.

TABLE I
SIGNAL ATTENUATION RESULTS

Site	*Time*	*Weather*	*Temperature* (°C)	*Humidity (%RH)*	*Precipitation (mm/h)*	*A*
1	Morning	Cloudy	27.5	51	0	
	Noon	Cloudy	33.3	36	0	
	Evening	Overcast	31.7	34	0	
	Noon	Clear	32.1	39	0	
	Evening	Clear	31.5	39	0	
	Noon	Overcast	31	42	0	
	Evening	Cloudy	31.3	43	0	
	Evening	Rainy	28.4	66	89,4	
2	Morning	Cloudy	28.1	47	0	
	Noon	Cloudy	32.5	34	0	
	Evening	Overcast	28.9	37	0	12.07
	Noon	Clear	32.8	37	0	2.07
	Evening	Clear	30.3	40	0	6.07
	Noon	Overcast	30.9	39	0	13.37
	Evening	Cloudy	31.2	43	0	1.97
	Evening	Rainy	30.1	87	84.9	8.27
3	Morning	Cloudy	29	49	0	7.4
	Noon	Cloudy	32.6	36	0	9.1
	Evening	Overcast	30	40	0	23.4
	Noon	Clear	31.6	36	0	13.7
	Evening	Clear	29.8	40	0	12.2
	Noon	Overcast	30	39	0	22.9
	Evening	Cloudy	28.2	43	0	12.9
	Evening	Rainy	27.1	76	11.7	30.9
4	Morning	Cloudy	33.8	43	0	4.38
	Noon	Cloudy	38	31	0	3.58
	Evening	Overcast	28.3	42	0	15.28
	Morning	Clear	35.5	32	0	5.78
	Noon	Clear	30.8	37	0	3.58
	Evening	Clear	29.4	43	0	4.88
	Noon	Overcast	30.3	39	0	14.28
	Evening	Rainy	26.5	51	2.7	15.58

From the table above which shows the results of the calculation of signal attenuation by weather changes can display the graphic according to weather changes such as in the chart below at Fig. 2. The graph contains a site, time, weather, temperature, humidity, precipitation, and attenuation of different signals based on Table 1.

The result of the signal attenuation value in the weather the lowest cloudy medium is at Site 2 during noon with results the signal attenuation value is 0.67 dB. As for the result of the signal attenuation value the highest was found at Site 3 in the evening with the result of the signal attenuation value 12.9 dB.

The result of the signal attenuation value in the weather the lowest overcast medium located at Site 2 in the evening with results the signal attenuation value is 12.07 dB. Meanwhile, for the result of the signal attenuation value the highest signal is located at Site 3 in the evening with the result of the signal attenuation value 23.4 dB.

The result of the signal attenuation value in the weather the lowest clear medium is found at Site 1 during noon with the resulting value signal attenuation of 0.75 dB. As for the result of the signal attenuation that the highest is located at Site 3 during the noon with a signal attenuation value 13.7 dB.

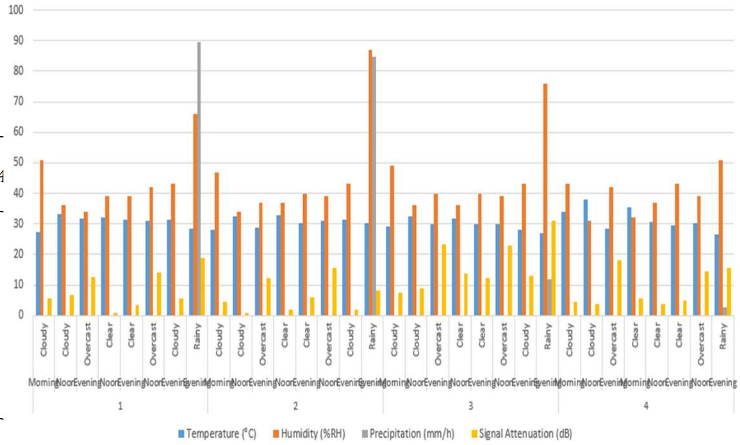

Figure 2 Signal Attenuation Graph

The result of the signal attenuation value in the weather the lowest moderate rain is located at Site 2 in the evening with a resulting value signal attenuation 8.27 dB. Meanwhile, for the result of the signal attenuation value the highest is located at Site 3 in the evening with the result of the signal attenuation value 30.9 dB.

Data testing uses 12 selected data at each time and weather. The data has been calculated manually using the formulas of backpropagation algorithm, Microsoft Excel, and Matlab. The following are 12 selected data in full with their signal attenuation values.

As data shown at Table 2, test results of 12 data have the difference attenuation based on where those data had retrieved and took places. Moreover, it can also be influenced by exactly when the data is collected. The weather at the time of data collection is also very important because of the possibility of differences in the value or number of electromagnetic waves received when the weather is sunny, cloudy, overcast, and rainy.

TABLE II
TEST RESULTS OF 12 DATA

Time	Weather	Temperature (°C)	Humidity (%RH)	Precipitation (mm/h)	RSSI (dBm)	Signal Attenuation Calculation (dB)	Signal Attenuation Testing (dB)
Morning	Cloudy	27.6	51	0	-82.4	7.54	8.61
Morning	Cloudy	28.9	48	0	-75	5.69	6.38
Noon	Cloudy	33.4	35	0	-79.4	4.64	4.00
Noon	Cloudy	32.4	35	0	-81.9	4.06	4.45
Evening	Clear	31.6	39	0	-79.7	5.52	5.90
Noon	Overcast	31	42	0	-88.9	20.7	21.00

Time	Weather	Temperature (°C)	Humidity (%RH)	Precipitation (mm/h)	RSSI (dBm)	Signal Attenuation Calculation (dB)	Signal Attenuation Testing (dB)
Evening	Overcast	31.6	34	0	-88	13.8	12.34
Noon	Clear	32.1	39	0	-75.5	1.32	0.09
Evening	Cloudy	31.3	43	0	-93	6.52	5.07
Evening	Rainy	26.5	51	2.7	-80.5	15.07	15.67
Morning	Clear	33.7	32	0	-81	2.08	1.89
Morning	Clear	33.6	32	0	-75	2.67	2.56

Meanwhile in Fig. 3 is the graphic of the test results of 12 data. The graphic will be shown below.

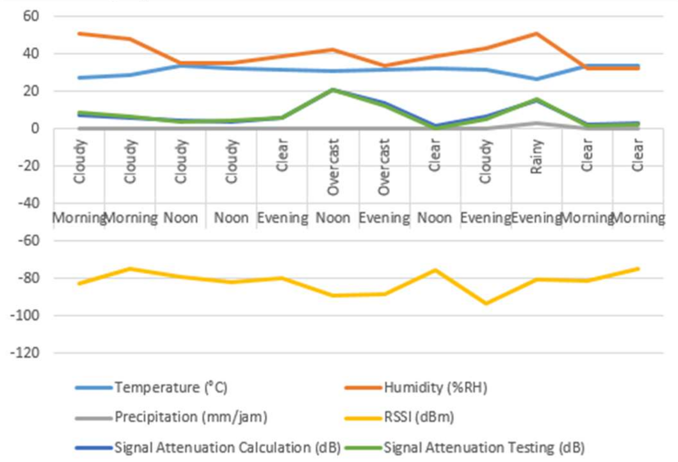

Figure 3. Graph of Test Results 12 Data

In the tables and graphs, the results of the machine learning can be seen the effect of the weather on the signal quality received by Mobile Station (MS) antenna. When the weather is overcast or rainy, the received RSSI gets smaller, which is betweenn -88.9 dBm to -80.5 dBm, and the resulting signal attenuation is also getting bigger, which is in the range of 12.34 dB to 21.00 dB. Meanwhile, if the weather is sunny and cloudy, the received RSSI is even greater, which is between -82.4 dBm to -93 dBm, and the resulting signal attenuation is also getting smaller, which is in the range of 0.09 dB to 8.61 dB.

Meanwhile, the percentage of error obtained from 12 data resulting from the calculation of signal attenuation and signal attenuation testing by weather changes as shown in Table 3. The measurement results of the drive test as a determination of the signal attenuation value by weather changes obtained the largest signal attenuation value of 40.49718 dB and the largest rainfall precipitation value is 681.8 mm/h. While the results obtained on the calculation data analysis of the signal atenuation and machine learning is used for calculates the overall error for the first data by using formulas as follows:

$$Error = \frac{calculation\ result - machine\ learning\ result}{calculation\ result} \times 100\%$$

$$Error = \frac{7.54898 - 8.61604}{7.54898} \times 100\%$$

$$Error = \frac{1.06706}{7.54898} \times 100\%$$

$$Error = 0.0805114793 \times 100\%$$

$$Error = 14.13\%$$

TABLE III
ERROR PERCENTAGE OF 12 DATA FROM SIGNAL ATTENUATION VALUES BY WEATHER CHANGES

Data	Time	Weather	Temperature (°C)	Humidity (%RH)	Precipitation (mm/h)	Signal Attenuation Calculation (dB)	Signal Attenuation Testing (dB)	Error (%)
1	Morning	Cloudy	27.6	51	0	7.54898	8.61604	14.13
2	Morning	Cloudy	28.9	48	0	5.69718	6.38501	12.07
3	Noon	Cloudy	33,4	35	0	4.64898	4.0069	13.81
4	Noon	Cloudy	32.4	35	0	4.0675	4.45781	9.59
5	Evening	Clear	31.6	39	0	5.52498	5.9059	6.89
6	Noon	Overcast	31	42	0	20.72498	21.0098	1.37
7	Evening	Overcast	31.6	34	0	13.82498	12.3466	10.69
8	Noon	Clear	32.1	39	0	1.32498	0.096164	9.27
9	Evening	Cloudy	31.3	43	0	6.52498	5.07929	22.1
10	Evening	Rainy	26.5	51	2,7	15.079	15.6777	3.97
11	Morning	Clear	33.7	32	0	2.0879	1.89787	9.1
12	Morning	Clear	33.6	32	0	2.6779	2.5618	4.35

IV. CONCLUSION

Data from the measurement results of the drive test obtained the signal attenuation value by the largest weather change, which was 40.49 dB and the largest rainfall precipitation was 681.8 mm/h. Based on the data test, the signal attenuation value when the weather is sunny and cloudy is 0.09 dB to 8.61 dB, and in overcast and rainy weather the attenuation value is greater, from 12.34 dB to 21.00 dB. By using the backpropagation algorithm in this study, an error in the training process is 0.65% and an error in the testing process is 1.86%. Thus, the level of accuarcy in this algorithm is 99.7%. This research can be developed by using different types of of data and other machine learning algorithm.

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