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Improving Coverage and Signal Quality in Cellular Communications for Rural Areas

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A B S T R A C T

Base Transceiver Station (BTS) is the center in a cellular telecommunications system. However, the coverage of the BTS signal to Mobile Station (MS) is limited to certain areas. The farther away from the BTS, the smaller the signal power received by the MS. The signal power received by MS in rural area is relatively low. This research is very important to help strengthen signal power from BTS to MS and increase coverage, especially in rural areas, so that rural communities can participate in these various online activities. Efforts to increase BTS signal coverage in this paper is the use of repeaters. The results of the study indicate that the coverage and signal quality can be improved and can assist rural communities in participating in the online learning system. Repeater application is proven to increase the Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), Signal to Noise Ratio (SNR), the average Received Signal Strength Indicator (RSSI) and throughput. It also lowers the value of delay, jitter and packet loss.

Keywords: Improving Coverage, Signal Quality, Cellular

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1. Introduction

The rapid development of telecommunications technology causes the demand for communication services to increase. This is indicated by the large number of customer requests, which at first were sufficient with low-quality voice communication. Currently, voice services alone are not enough, data services are needed that continue to increase at a larger level [1].

Telecommunications technology began to develop from using wired to wireless. Wireless technology is a technology that uses electromagnetic waves as a medium for propagation. The use of wireless technology is an alternative that is widely used today for data transmission systems, because it can facilitate users by reducing the complexity of existing network installations. Data transmission is a process of sending digital or analog data through a communication medium to one or more networks or electronic devices [2][3].

One of the applications of wireless telecommunication technology is mobile cellular communication system. In the cellular communication system, BTS becomes the center of communication both between MS in one cell or with MS in another cell. A BTS can only serve MS that are within its cell range. But BTS has a limited range. The farther the position of the MS from the BTS, the weaker the signal power captured by the MS [4][5].

The COVID-19 pandemic has caused major changes in people's lives all over the world. The United Nations stated that one of the sectors affected was the world of education. Some of the Indonesian government's recommendations to suppress the spread of COVID-19 include wearing masks, avoiding crowds of people, social distancing, frequently washing hands with soap or hand sanitizer [6]. The Ministry of Education and Culture of the Republic of Indonesia has issued guidelines on technical instructions for implementing learning during the pandemic, namely through the Circular of the Ministry of Education and Culture, Directorate of Higher Education No. 1 of 2020 concerning the prevention of the spread of COVID-19 in the world of Education. In the letter, the government instructs the implementation of distance learning and advises students to study from their homes [7]. It turns out that rural areas are not yet ready to implement these regulations because the cellular telecommunication network infrastructure is very limited. And even though the pandemic is back to normal, the need for this infrastructure continues for various purposes.

Bulangan Barat Village, Pegantenan District, Pamekasan Regency is a mountainous area with limited telecommunications network facilities. This condition causes the community in the village to have difficulty carrying out the online learning process as recommended by the government [8].

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Therefore, efforts are needed to improve the coverage and quality of GSM cellular networks in rural areas [9].

There are several previous studies that develop and improve coverage in cellular communication systems. Research [10] models the coverage area of a cellular communication system based on details of the terrain, to predict signal propagation and coverage area. Paper [11] proposes the deployment of Unmanned Aerial Vehicles (UAV) to increase the coverage area and minimize interference on cellular communication networks. Paper [12] proposed the deployment of Reconfigurable Intelligent Surfaces (RIS) which passively reflect the signal in the desired direction, to increase the coverage area.

Research on the development of cellular communication networks has been carried out by many previous studies. The development of cellular communication networks can be done by increasing the channel capacity [13], increasing the coverage area and optimizing its energy efficiency [14], even by optimizing the antenna [15]. And in this study, efforts will be made to increase coverage and signal quality on GSM cellular communication networks in rural areas by using repeaters, to assist rural communities in carrying out online activities.

2. Theory

Telecommunications technology develops from one generation to the next, becoming faster, more sophisticated with an increasingly large channel capacity. Until now, telecommunications technology is already in the 5G generation towards 6G [16]. Indonesia is currently developing and preparing a 5G network. The merging of GSM cellular network systems and computer networks provides various conveniences and benefits to the network user community in helping their work in various fields. GSM is a second generation cellular system standard which was developed to solve the problem of fragmentation in Europe's first cellular system standard, and became the first cellular system to use digital modulation techniques and use a tiered service architecture. In fact, in some developing countries, 2G GSM cellular networks survive and even become the main network in these countries [17].

Cellular repeaters are generally used to repair poor cellular signal services. Cellular repeaters are applied because they are economical, user-friendly and environmentally friendly. Its working principle is similar to the cell broadcast towers used by network providers for broadcasting, but are much smaller in size and are recommended for use in certain buildings only. The system typically uses an external directional antenna to collect the best cellular signal, which is then transmitted to an amplifier unit that amplifies the signal and retransmits it locally, providing a significant increase in signal strength. More advanced models often also allow multiple cell phones to use the same repeater simultaneously, so are suitable for both commercial and home use [18].

Some of the tools commonly used in observing the performance of cellular communication signals are G-Net Track Lite, Net Tools and Speed Test. Several parameters that can be measured through the G-Net Track Lite application are RSRP, RSRQ, SNR and RSSI. RSRP is a parameter that states the level of signal strength received by the user in dBm units. RSSI is a parameter that states the overall signal power received by the user in dBm units. RSRQ is a comparison between RSRP and RSSI. While SNR is a comparison between the transmit signal power to noise. Several parameters that can be measured from the Net Tools application are delay and packet loss. Delay is the time to travel a certain distance in sending packet data. Delay can be affected by several things, including distance, physical media, and congestion. Packet loss is data packets that fail to be received in a data transmission. Packet loss can be caused by congestion or collision in a communication network. Meanwhile, several parameters that can be measured from the Speed Test application are throughput and jitter. Throughput is the amount of data actually sent per unit of time. The greater the throughput value, the more reliable the communication network is. While jitter is a variation of delay. The smaller the jitter value, the more stable the network [20].

The model for this research problem is the path loss model. Radio wave power must experience attenuation due to propagation. The received power is formulated in the following equation.

$$P_r = K \frac{P_t}{d^2} \quad (1)$$

Where,

P_r : Received Power
K : Antenna Gain
P_t : Transmitted Power
d : Distance

Meanwhile, the path loss model is formulated in the following equation.

$$P_{r(d)} = P_{r(d0)} \left(\frac{d0}{d}\right)^2 \quad (2)$$

Where,

$P_{r(d)}$: Received power at distance d
$P_{r(d0)}$: Received power at distance d_0

3. Method

This research was conducted in Bulangan Barat Village, Pegantenan District, Pamekasan Regency, because it is a mountainous area and lacks cellular network facilities. The method used in this paper to determine whether the application of repeaters on GSM cellular networks can affect the enhancement in coverage and signal quality or not is to compare the RSRP, RSRQ, RSSI, SNR, throughput, delay, jitter and packet loss data in the condition of before and after the application of the repeater on the network. RSRP, RSRQ, RSSI and SNR values are obtained from the G-Net Track Lite application. The value of delay and packet loss is obtained with the Net Tools application. While the throughput and jitter values are obtained with the Speed Test application.

The data were obtained by direct measurements. The research steps are carried out according to the following stages:

- Perform RSRP, RSRQ, RSSI, SNR, throughput, delay, jitter and packet loss data retrieval at the weakest point of receiving BTS signal power.
- Install the repeater and perform data capture until the weakest point receives signal power from the repeater.

- Compare RSRP, RSRQ, RSSI, SNR, throughput, delay, jitter and packet loss data on cellular networks between before and after repeater deployment.

4. Results and Discussion

Testing and data retrieval was carried out with G-NET Track Lite and obtained data on RSRP, RSRQ, SNR and RSSI values [19]. From the test, obtained RSRP data as shown in table 1, RSRQ as shown in table 2, SNR as shown in table 3, and RSSI as shown in table 4.

Table 1. Comparison of test results RSRP values

Distance (m)	RSRP (dBm)		Bar	
	Repeater	Non-Repeater	Repeater	Non-Repeater
20	-65	-110	5	2
50	-98	-116	4	1
90	-102	-117	3	1
130	-108	-119	2	1
170	-115	-121	1	1

Table 1 shows that the first data was taken at a distance of 20 m from the repeater, with a comparison of RSRP without a repeater of -110 dBm and RSRP using a repeater of -65 dBm. The number of bars at that point is 2 bars for conditions without repeaters and 5 bars for conditions with repeaters. The next data collection point is at a distance of 50 m and RSRP data is obtained -116 dBm in conditions without a repeater with a number of bars 4 and -98 dBm in conditions using a repeater with a number of bars 1. The next point is at a distance of 90 m and RSRP data is -117 dBm in the condition without a repeater with a number of bars 1 and -102 dBm in a condition using a repeater with a number of bars 3. The next point is at a distance of 130 m and the RSRP data is -119 dBm in a condition without a repeater with a number of bars 1 and -108 dBm in the condition using a repeater with a number of bars 2. The last point is at a distance of 170 m and RSRP data is obtained -121 dBm in conditions without a repeater with a number of bars 1 and -115 dBm in conditions using a repeater with a number of bars 1. The farther the data collection point is from the center of the repeater and at the same time from BTS, the fewer the number of bars and the smaller the RSRP value obtained, whether using a repeater or not. However, the RSRP value in the condition of using a repeater is better than without a repeater. This shows that there is an enhancement in coverage and signal quality in the application of repeater on cellular network.

Table 2. Comparison of test results RSRQ values

Distance (m)	RSRQ (dB)		Bar	
	Repeater	Non-Repeater	Repeater	Non-Repeater
20	-11	-15	5	2
50	-13	-17	4	1
90	-13	-18	3	1
130	-13	-19	2	1
170	-15	-21	1	1

As in RSRP data collection, RSRQ data collection is taken at the same points, namely at a distance of 20 m, 50 m, 90 m, 130 m and 170 m with bar conditions from 5 to 1 bar on measurements using a repeater. Table 2 shows that the RSRQ values under repeater conditions at a distance of 20 m, 50 m, 90 m, 130 m and 170 m respectively are -11 dB, -13 dB, -13 dB, -13 dB and -15 dB. These values are relatively better than the RSRQ values without repeater which are -15 dB, -17 dB, -18 dB, -19 dB and -21 dB, respectively. It shows that there is an improvement in coverage and signal quality in the addition of repeater on cellular network.

Table 3. Comparison of test results SNR values

Distance (m)	SNR (dB)		Bar	
	Repeater	Non-Repeater	Repeater	Non-Repeater
20	12.8	-6.8	5	2
50	7.8	-4.6	4	1
90	2.2	-5.4	3	1
130	2	-6.8	2	1
170	2.8	-8	1	1

Similarly, table 3 shows that the SNR value under repeater conditions at all measurement points (12.8 dB, 7.8 dB, 2.2 dB, 2 dB and 2.8 dB) is better than the SNR value without repeater (-6.8 dB, - 4.6 dB, -5.4 dB, -6.8 dB and -8 dB). This also shows that there is an increase in coverage and signal quality in the use of repeater on cellular network.

Table 4. Comparison of test results RSSI values

Distance (m)	RSSI (dBm)		Bar	
	Repeater	Non-Repeater	Repeater	Non-Repeater
20	-63	-76	5	2
50	-77	-77	4	1
90	-72	-77	3	1
130	-79	-78	2	1
170	-77	-79	1	1

In the same way, table 4 shows that the RSSI value under conditions of using a repeater at all measurement points, namely at a distance of 20 m, 50 m, 90 m, 130 m and 170 m respectively is -63 dBm, -77 dBm, - 72 dBm, -79 dBm and -77 dBm. While the RSSI values in conditions without repeaters are -76 dBm, -77 dBm, -77 dBm, -78 dBm and -79 dBm. The average RSSI value in the condition using a repeater is -73.6 dBm, relatively better than without a repeater, with an average RSSI value of -77.4 dBm.

The next observation is on the delay shown by table 5 and jitter shown by table 6.

Table 5. Comparison of test results delay values

Distance (m)	Delay (ms)		Bar	
	Repeater	Non-Repeater	Repeater	Non-Repeater
20	46	83	5	2
50	53	97	4	1
90	68	109	3	1
130	76	224	2	1
170	125	282	1	1

Table 5 shows the results of delay measurements using the Net Tools application. The delay in the condition of using a repeater is better than without using a repeater. That is, there is an improvement in the delay value from the condition without a repeater compared to using a repeater. At a distance of 20 meters, the delay value obtained in conditions without repeaters is 83 ms to 46 ms in conditions using repeaters. The bar also increased from 1 bar to 5 bars. At a distance of 50 meters, the delay also improved from 97 ms to 53 ms and the bar also increased from 1 bar to 4 bars. At a distance of 90 meters, the delay has improved from 109 ms to 68 ms and the bar has also increased from 1 bar to 3 bars. At a distance of 130 meters, the delay has improved from 224 ms to 76 ms and the bar has also increased from 1 bar to 2 bar. And for a distance of 170 meters, the delay has also improved from 282 ms to 125 ms, while the bar remains 1 bar.

Table 6. Comparison of test results jitter values

Distance (m)	Jitter (ms)		Bar	
	Repeater	Non-Repeater	Repeater	Non-Repeater
20	14	14	5	2
50	3	29	4	1
90	15	18	3	1
130	16	89	2	1
170	29	14	1	1

Table 6 shows the acquisition and comparison of jitter values in conditions of using repeaters and conditions of not using repeaters. TABLE VI shows the observed jitter values at a distance of 20 m, 50 m, 90 m, 130 m and 170 m experience ups and downs, both in conditions of using a repeater or not using a repeater. However, the average value of jitter in conditions using a repeater is better, namely 15 ms compared to conditions without a repeater, which is 33 ms.

The next discussion is on the throughput shown by Table 7 and packet loss shown by Table 8.

Table 7. Comparison of test results throughput values

Distance (m)	Throughput (KBps)		Bar	
	Repeater	Non-Repeater	Repeater	Non-Repeater
20	2520	737	5	2
50	2461	651	4	1
90	1671	470	3	1
130	909	294	2	1
170	651	263	1	1

Table 7 shows the throughput data using the Speed Test application. Throughput in conditions of use repeaters is better than without repeaters. At a distance of 20 meters, the throughput value in the condition without repeater 737 KBps increases to 2520 KBps in the condition using a repeater. At a distance of 50 meters, throughput increases from 651 KBps to 2461 KBps. At a distance of 90 meters, throughput increases from 470 KBps to 1671 KBps. At a distance of 130 meters, throughput increases from 294 KBps to 909 KBps. And at a distance of 170 meters, the throughput also increases from 263 KBps to 651 KBps.

Table 8. Comparison of test results packet loss values

Distance (m)	Packet loss (%)		Bar	
	Repeater	Non-Repeater	Repeater	Non-Repeater
20	0	0	5	2
50	0	0	4	1
90	0	0	3	1
130	0	0	2	1
170	0	20	1	1

Table 8 shows packet loss data. The data shows that the value of packet loss at all distances is zero, both in conditions of using a repeater or without a repeater. Except at a distance of 170 m, the value of packet loss in conditions without repeaters is 20%. This shows that the use of repeaters can improve the value of packet loss than without a repeater.

5. Conclusion

Some of the conclusions of this study are:

- Repeater installation on GSM cellular networks has been proven to increase coverage and signal quality by increasing the values of RSRP, RSRQ, SNR, and throughput. It also has been proven by decreasing the values of delay and jitter.
- The average value of RSSI in the condition of using a repeater is -73.6 dBm, relatively better than without a repeater, which is -77.4 dBm.
- The application of repeaters also improves the value of packet loss.

Suggestions for further research is to increase the coverage area of the repeater by optimizing the antenna and signal transmit power.

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