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Wireless Repeater Bridge Enable Wireless Interconnection on 4G-LTE Network

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Abstract. Wireless Distribution System (WDS) is a wireless network system that provides a connection between one base station and another base station or expands the network between base stations using two or more base stations. This WDS network usually no longer requires cables as a connection between backbone networks to connect them. This research was based on a case study for blank spot areas and karst or mountainous areas that have a high risk of attenuation. WDS can function several active devices such as modems or certain hotspots that work cooperatively into an ad-hoc network system as a solution if there is a barrier or non-line-of-sight (NLOS) on an existing base station. This study aims to conduct a measurement result on the modeling of the Bridge Wireless Repeater (BWR) implemented in the 4G long term evolution (LTE) Network. The trial location will be carried out in the Maros Pangkep Karst Area (KKMP) with a karst tower type covering an area of ± 46,200 ha in which the existing eNode-B of LTE base station's position is behind or across the karst. BTS placement by operators is generally on the main highway so that cellular customers in the KKMP cluster will have difficulty reaching adequate signals. The size of this karst barrier, in addition to having an impact on large attenuation, will also result in a decrease in the reference signal received power (RSSP) upto -105 dBm below, and cover 73.2% for poor the reference signal received quality (RSRQ). The measurement results shown the cooperative BWR on air indicate the RF power strength -67 dBm (Tx) and -69 dBm (Rx) are optimized. Based on the QoS test indicated all the performances get overall Good which remarks the system is well configured.

INTRODUCTION

The Maros Pangkep Karst Area (KKMP) is renowned for its stunning natural landscapes and has been designated as a national protected area by UNESCO, recognized as the 4th most beautiful karst cluster globally [1]. Some of the most well-known karst sites include Bulusaraung/Bantimurung, Leang-leang, and Rammang-rammang. These three locations have become popular tourist destinations in South Sulawesi, contributing significantly to the region's creative economy and supporting local businesses and industries.

The population around KKMP is quite large, and with the presence of industrial mines and tourist attractions, the region has significant potential for a high number of cellular users. KKMP is a favored destination for local, domestic, and international tourists (especially given its proximity to Makassar City), making it essential to have reliable telecommunications network facilities. However, based on Drive Test (DT) measurements, the cellular radio access system for 4G long term evolution (LTE) in this karst area is very weak [2]. The primary issues are that both residents and tourists struggle to communicate and face challenges in capturing live moments due to subpar cellular access [3]. Cellular radio signals are disrupted by multipath interference and signal loss, with base transceiver stations (BTS) located outside the karst area. The line of sight (LOS) is obstructed by karst mountains, creating barriers to direct wave signals [4][5], resulting in many bad and blank spots within the tourist areas. Figure 1 shows the pre-Drive Test results for the Rammang-rammang karst area from one exist cellular operator (Telkomsel), indicating poor network performance. The key performance indicator (KPI) for the reference signal received quality (RSRQ) is 73.2%,

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indicating very weak/poor signal, while the reference signal received power (RSSP) is 66.3%, or below -105 dBm, reflecting poor signal strength. Overall, 4G LTE network coverage is challenging to establish throughout the area.

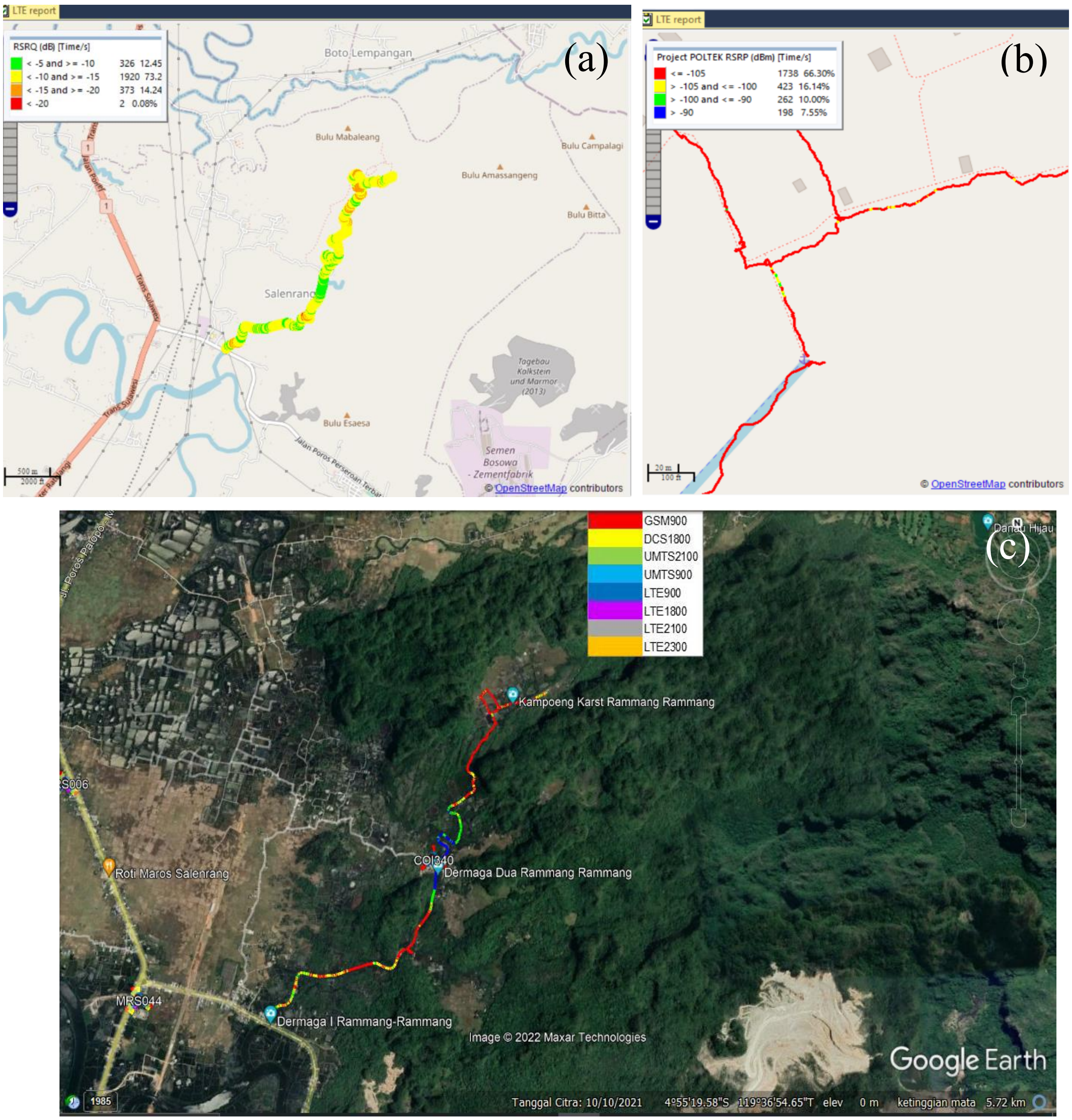

FIGURE 1. (a) RSRQ, (b) RSRP and (c) Network Serving displays in the Rammang-rammang area. Map images reproduced from Google Earth, © Google 2025 [6].

The 4G multiple input multiple output (MIMO) technology, through the enhancement of spatial multiplexing, generates multiple sub-streams, enabling interference and distortion cancellation at each BTS during processing to solve bad coverage problems [7]. This study forms the foundation for solving layer mapping and pre-coding operation methods involving LTE Physical Layer (LTE-PHY) processes. Additionally, to achieve high spectral efficiency, MIMO performance is impacted by the Tx/Rx antenna configuration, the use of multiple sub-streams to increase bandwidth capacity and the quality of the radio frequency range [8]. Similarly, the cooperative wireless radio technique, such as the bridge wireless method, serves as a relay access strategy that optimizes signal hopping over specific areas [9-10]. Both technological approaches provide practical solutions for application in the KKMP region.

To extend the signal coverage, the wireless distribution system (WDS) allows wireless interconnections on access paths within the IEEE 802.11 network, including the LTE network [11]. WDS is commonly used as a wireless repeater that expands networks without the need for network cables as data transmission media, instead enabling interconnection between each Access Point (AP) device within a single wireless network environment. In both wireless networks (local area networks and cellular), WDS can be easily deployed using an AP device without the need for a wired backbone to connect Tx and Rx devices [12]. The key advantage of WDS technology is its ability to integrate all APs into a unified network in an ad-hoc manner, offering high mobility and reliability. However, the repeater function of the AP requires additional frames on the same radio channel, which can result in increased network traffic [13-14].

The aim of this study is to evaluate the performance of a WDS-based Wireless Repeater Bridge scenario implemented within the 4G LTE network in the KKPM region. The WDS interconnection will function cooperatively, allowing each node to operate as both Tx and Rx without the need for significant additional frames. Two key KPIs, RSSP and RSRQ, will be used as reference metrics for measurement [15]. The testing model will include network speed tests and Quality of Service (QoS) evaluations to assess the connection performance.

The novelty of this research lies in developing a solution to address the issue of weak cellular signals in the target area. A future advancement in digital wireless transmission infrastructure will focus on green-BTS RF-GHz technology, aiming to minimize the use of cables to preserve the natural beauty of the karst landscape. Additionally, this approach will facilitate the use of environmentally friendly, ultra-low-power cellular radios (mWatt transmitters).

METHODS

This research focuses on fundamental studies of BWR modeling in a controlled laboratory setting, followed by field measurement tests. The workflow is illustrated in Fig. 2. A site audit was carried out using DT measurement to assess RSSP and RSRQ levels. Subsequently, the BWR installation mapped the Tx/Rx according to the specified scenario (Fig. 4). The performance measurements were conducted through speed tests and QoS evaluations once the radio link was activated.

FIGURE 2. Research Procedure

The BTS network optimization was carried out through Drive Testing measurements. This process includes a site audit and evaluation of radio quality using DT tools, with additional analysis conducted via Nemo Handy. The 4G KPIs were be conceptually assessed, following the RF optimization procedures shown in Fig. 3.

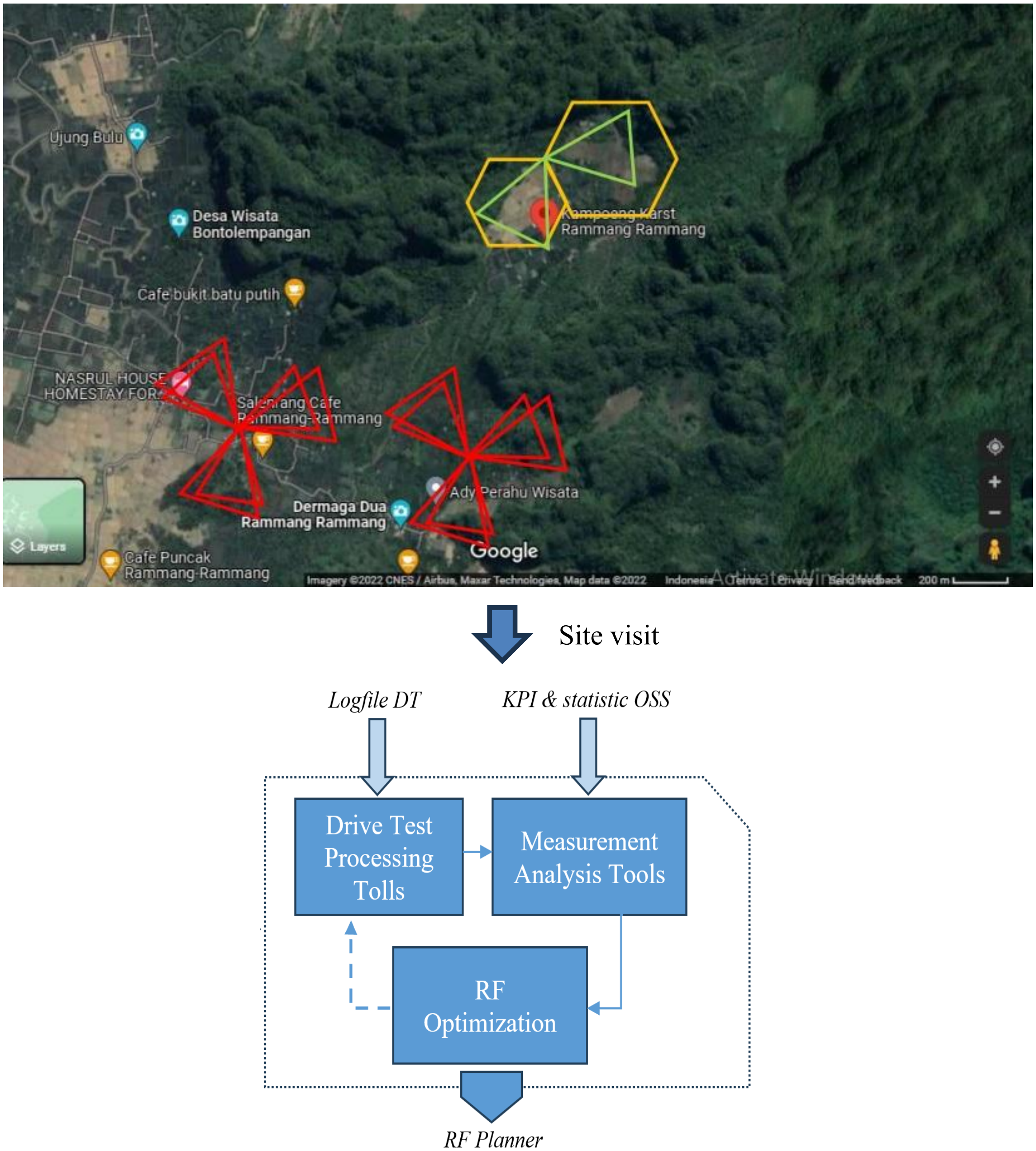

FIGURE 3. RF Optimization on the BTS cell target through Drive Test analysis. Red color shows two closer existed BTSs and Yellow/Green is the target measurement area. Map image reproduced from Google Earth, © Google 2025 [6].

The BWR modeling scenario presented in Fig. 4 illustrates the installation configuration process and the setup of the test bench. Cellular network optimization and BTS cell coverage will be evaluated in the Rammang-rammang karst region by installing Tx and Rx antenna beams along with modems. The data obtained from these measurements will enhance the KPI parameters (RSRQ and RSRP) and their post-test results (speed and QoS), helping to identify the most suitable radio system solution for this specific karst environment.

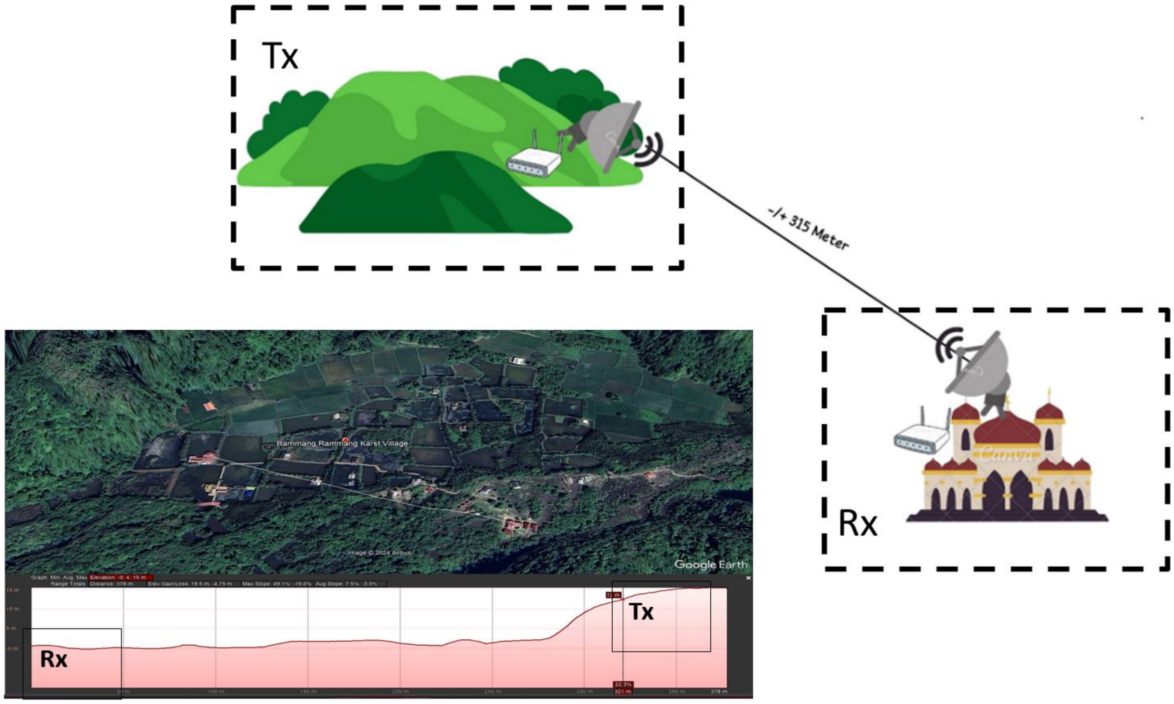

FIGURE 4. BWR modeling scenario. Map image reproduced from Google Earth,© Google 2025 [6].

RESULTS AND DISCUSSION

Fig. 5 illustrates the successful installation of the antenna, while Fig. 6 displays the main menu for the Tx-antenna at Point A (Rammang-rammang Tx, RM-Tx), confirming that the antenna has been configured as a transmitter. Following this, the next step involves configuring the Rx-antenna and positioning it at Point B (Rammang-rammang Rx, RM-Rx), ensuring a distance of 400-500 meters between the two antennas. The results show an improvement in both download and upload speeds (by Ookla), reaching 51.6 Mbps for download and 15.9 Mbps for upload.

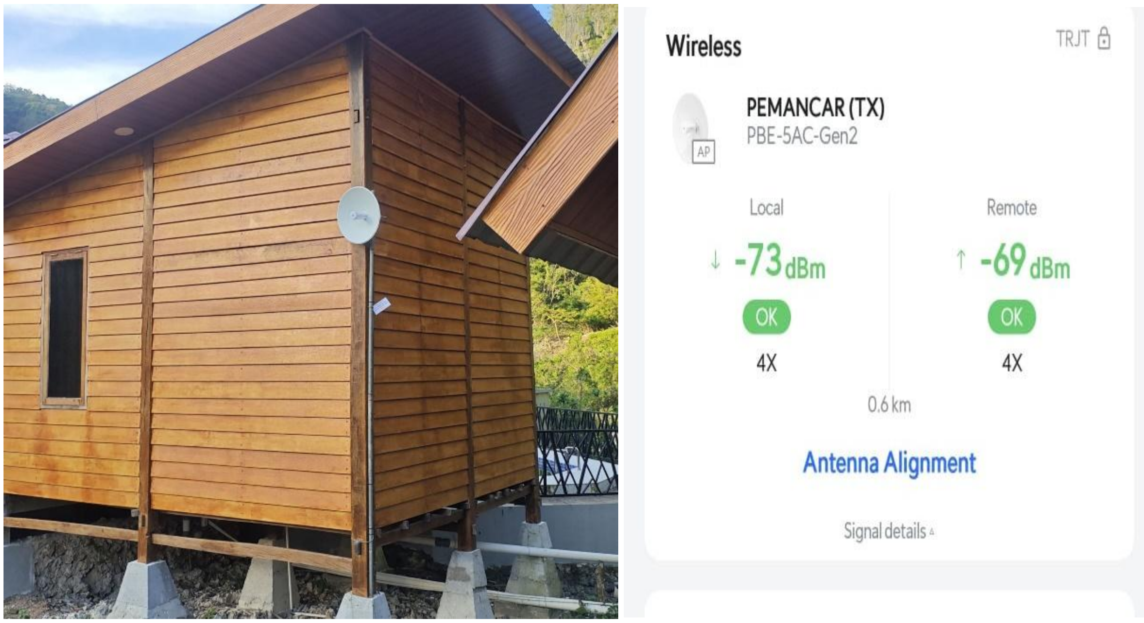

FIGURE 5. RM-Tx and its antenna configuration.

FIGURE 6. RM-Rx and its antenna configuration

Internet servers equipped with Tx/Rx antennas are tested for Internet network QoS in accordance with the TIPHON standard. This standard addresses QoS parameters such as Throughput, Jitter, Delay, and Packet Loss. The testing process ensures high-quality telecommunications services in an environment that integrates traditional telecommunications technology with IP technology. Below is an explanation of how the TIPHON standard interprets these parameters:

1) Throughput refers to the amount of data that can be transmitted over a network at a given time. The TIPHON standard may establish guidelines for bandwidth allocation to ensure that each service or application receives sufficient throughput for optimal performance. This could involve prioritizing specific services and implementing mechanisms to prevent traffic congestion, which can negatively impact overall throughput [16].
2) Jitter refers to the variation in the timing of data packet arrival at the destination. The TIPHON standard can manage jitter by coordinating packet transmission and ensuring stable delivery times, particularly for services that rely on time consistency, such as voice and video applications. This approach helps minimize the negative impact of jitter on the overall user experience.
3) Delay refers to the time it takes for a data packet to travel from its source to its destination. For real-time services like voice and video, minimizing delay is crucial for maintaining smooth communication. The TIPHON standards may include guidelines or regulations that define the maximum allowable delay for various types of services.
4) Packet loss happens when data packets fail to reach their destination across a network. This can significantly affect service quality, particularly for voice and video applications. The TIPHON standards may establish acceptable packet loss thresholds and employ control mechanisms like retransmission or redundancy to mitigate its impact.

TABLE 1. QOS Categories and TIPHON Standards

Category	*Throughput (kbps)*	*Packet Loss (%)*	*Delay (ms)*	*Jitter (ms)*	*Index*
Very Good	> 100	0	< 150 *ms*	< 0 *ms*	4
Good	< 75 - 100	2	150 – 300 *ms*	0 – 75 *ms*	3
Currently	< 50	15	300 – 450 *ms*	75 – 125 *ms*	2
Bad	< 25	25	> 450 *ms*	125 -225 *ms*	1

In all the cases mentioned above, the TIPHON standard seeks to establish a network environment that ensures high-quality service by maintaining sufficient throughput, effectively managing jitter and delay, and reducing packet loss, as illustrated in Table 1. The outcomes of the model test are presented in Table 2.

TABLE 2. QoS Results

Troughput	*Packet Loss (%)*	*Delay*	*Jitter*
87 Kbps (Good)	0,0038 (~0%) Very Good	8,3124 *ms* (Very Good)	8,3465311 *ms* (Good)

Based on the QoS measurements shown in Table 2, it can be concluded that the results meet TIPHON standardization. The throughput parameter is rated as Good, Packet Loss is rated as Very Good, Delay is rated as Very Good, and Jitter is rated as Good. Overall, the system is well-configured[17-18].

CONCLUSION

The Bridge method simplifies the integration of wireless radio and streamlines network management and monitoring. Additionally, it allows for quick and easy implementation. The network installation at the Rammang-rammang area was successfully completed, providing Internet access to the village, as indicated by the overall Good results from the network QoS test. Speed tests also showed a significant improvement in download and upload speeds, with bandwidth configured for each user after the installed network was distributed via WiFi.

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Chemical Engineering Laboratory. Map image reproduced from Google Maps, © Google 2025. All rights reserved. Used under fair use for educational and illustrative purposes.

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