JURNAL IPTEK
MEDIA KOMUNIKASI TEKNOLOGI
homepage URL : ejurnal.itats.ac.id/index.php/iptek

Utilizing Compact 4G LTE Mobile Stations to Enhance Network Coverage in Rural Low-Signal Areas

Sirmayanti Sirmayanti[1], Muh. Ilham Ihsary[2], and Ichsan Mahjud[3]*

Department of Electrical Engineering, Politeknik Negeri Ujung Pandang[123]

ARTICLE INFORMATION

Jurnal IPEK – Volume 29 Number 2, December 2025

Page:
145 – 158
Date of issue:
December 30, 2025

DOI:
10.31284/j.iptek.2025.v29i2.7732

ABSTRACT

A bad spot is an area where signal quality fails to meet Key Performance Indicator (KPI) standards, due to factors such as limited channel capacity, BTS malfunctions, long distances from the BTS, or topographical interference. This study investigates a 4G LTE bad spot case in the rural area of Romanglasa Subdistrict where RSRP levels range from -100 dBm to -120 dBm. Although several e-nodeBs are present around the area, physical obstructions like trees and buildings continue to degrade signal quality. The objective of this study is to effectively implement a Compact Mobile Station (COMBAT), analyze the installation process, and evaluate the network's performance after deployment. The methods used include drive testing, BTS site surveys, simulations, and network design. The installation was carried out in collaboration with Telkomsel using Combat-571 as the cell ID. Following deployment, network quality measurements and post-drive testing were conducted. The results showed significant improvements: download throughput reached 47.6 Mbps, upload 28.4 Mbps, jitter decreased to 7 ms, packet loss dropped to 0%, and latency was reduced to 21 ms. Post-installation RSRP also improved to between -80 dBm and -100 dBm, categorized as good to fair according to KPI standards.

Keywords: *Combat; RSRP; RSRQ; bad-spot; drivetest*

E-MAIL

sirmayanti.sirmayanti@poliupg.ac.id
ilhamihsary22@gmail.com
ichsan_mahjud@poliupg.ac.id

*Corresponding author:
Sirmayanti Sirmayanti
sirmayanti.sirmayanti@poliupg.ac.id

ABSTRAK

Bad spot adalah wilayah dengan kualitas sinyal yang tidak memenuhi standar Key Performance Indicator (KPI), disebabkan oleh keterbatasan kanal, gangguan pada BTS, jarak yang jauh dari BTS, atau interferensi topografi. Penelitian ini mengkaji kasus bad spot jaringan 4G LTE di wilayah rural Romanglasa dengan RSRP berkisar antara -100 dBm hingga -120 dBm. Meskipun terdapat beberapa e-nodeB di sekitar lokasi, hambatan fisik seperti pepohonan dan bangunan menyebabkan sinyal tetap buruk. Penelitian ini bertujuan mengimplementasikan Compact Mobile Station (COMBAT) secara efektif, menganalisis proses instalasinya, dan mengevaluasi performa jaringan setelah pemasangan. Metode yang digunakan meliputi drive test, survei lokasi BTS, simulasi, dan perancangan jaringan. Instalasi dilakukan bersama Telkomsel dengan ID Combat-571. Setelah implementasi, dilakukan pengukuran kualitas jaringan dan post-drive test. Hasilnya menunjukkan peningkatan signifikan: throughput unduh mencapai 47,6 Mbps, unggah 28,4 Mbps, jitter turun ke 7 ms, packet loss menjadi 0%, dan latency 21 ms. RSRP pasca-instalasi juga membaik ke kisaran -80 dBm hingga -100 dBm, sesuai kategori baik hingga sedang menurut KPI.

Kata Kunci: *Combat; RSRP; RSRQ; bad-spot; drivets.*

PUBLISHER

LPPM- Adhi Tama Institute of Technology Surabaya
Address:
Jl. Arief Rachman Hakim No. 100, Surabaya 60117, Tel/Fax: 031-5997244

INTRODUCTION

With technological advancements, society now views technology as a necessity rather than a luxury. This shift has marked humanity's entry into the digital era, where the Internet plays an essential role in everyday life for people of all ages [1],[2]. According to the Indonesian Internet Service Providers Association (APJII), as of 2024, over 221 million Indonesians aged 13 and above were connected to the Internet [3]. The primary reasons for Internet use include accessing social media, gaming, reading news, working or studying from home, and utilizing public services. However, a major reason for limited Internet use in some areas is the absence of network coverage or poor signal quality, commonly referred to as a *bad spot* [4].

A bad spot occurs when a location's signal quality fails to meet Key Performance Indicators (KPIs), often due to limited channel capacity from high user density or equipment issues [5]. Signal degradation or loss is typically caused by geographical and weather factors, which hinder BTS signal transmission [6].

Regional characteristics vary based on classifications such as urban, suburban, rural, and metropolitan areas [7]. The term *urban* refers to areas with high population density and built-up environments. *Suburban* areas typically combine features of both urban and rural settings. *Rural* describes small settlements located outside city boundaries, while *metropolitan* areas emerge when several adjacent cities or administrative regions merge into a large urban zone [8]. Topography and terrain contours are often major contributors to poor network quality, especially in agricultural lands, open green spaces, forests, and mountainous regions. In addition, weather conditions can also significantly affect network performance, potentially resulting in bad spots or even blank spots [9].

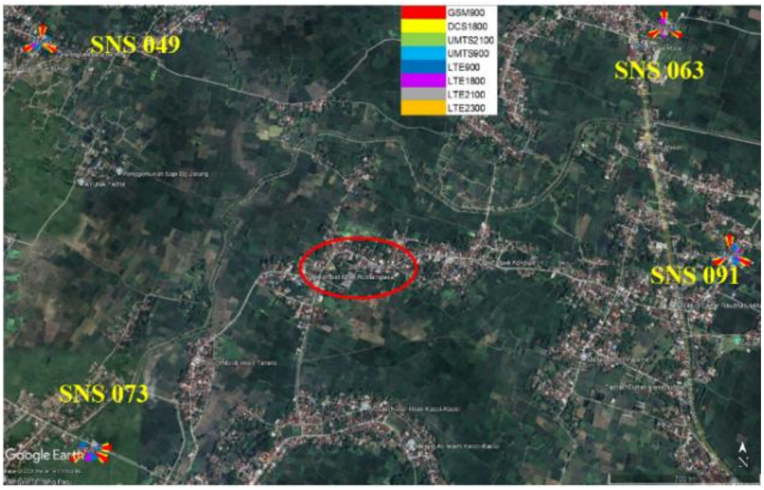


Figure 1. Location of Romanglasa Subdistrict (red circle) and surrounding existing Telkomsel's BTS SNS 073, SNS 091, SNS 049, and SNS 063.

As shown in Figure 1, Romanglasa Subdistrict, located in Bontonompo District, Gowa Regency, was selected as the research site due to the absence of reliable Internet and cellular network access. This is largely attributed to its rural topography, characterized by lowland areas dominated by rice fields and plantations. A field audit revealed that although the area is within the coverage of several Telkomsel BTS sites (Telkomsel, a leading cellular operator in Indonesia, offers broad network coverage and diverse digital services to users nationwide), however the received signal strength remains very weak. The figure also shows several Telkomsel Base Transceiver Station (BTS) sites located near the targeted research area, specifically sites Site Number Series (SNS) 073, SNS 091, SNS 049, and SNS 063. Based on the field site audit, it was found that Romanglasa is primarily covered by site SNS 073. However, the signal from SNS 073 that reaches the Romanglasa is very weak or poor. At site SNS 073, there is only one sectoral Long-Term Evolution (LTE) antenna directed towards this area, operating at a frequency of 2100 MHz; however, this site only covers a small portion of Romanglasa's zone. Site SNS 091 has three sectoral LTE antennas aimed at this area, operating at frequencies of 900 MHz, 1800 MHz, and 2100 MHz. Unfortunately, the signal that reaches Romanglasa remains very poor due to obstructions such as buildings and tall trees that block or weaken the signal, especially for the 1800 MHz and 2100 MHz frequencies, which are more easily blocked and whose transmission power settings are not sufficiently high. At SNS 049, there is one sectoral LTE antenna directed towards Romanglasa operating at 2300 MHz. The signal transmitted to Romanglasa is also very weak because the coverage range is relatively short, around 1–2 km in areas with dense trees. Meanwhile, site SNS 063 does not have any sectoral LTE antennas directed toward Romanglasa.

A cellular network is a wireless network designed to enhance the functionality of mobile devices. LTE is a network technology introduced by the 3rd Generation Partnership Project (3GPP). LTE represents an advancement of the third generation (3G) Wideband Code Division Multiple Access (WCDMA) and Universal Mobile Telecommunications System (UMTS) technologies and is often referred to as a 4G technology [10].

BTS is a key component in GSM/CDMA networks that connects directly to the Mobile Station (MS) via the air interface and is linked to the Base Station Controller (BSC) through the A-bis interface. The BTS functions as the signal transceiver for communication between the MS and the network, as well as connecting the MS to other network elements such as the BSC, Mobile Switching Center (MSC), Short Message Service (SMS), and Intelligent Network (IN). In 4G LTE networks, the role of the BTS is replaced by a more advanced entity called The eNodeB (Evolved Node B) [11],[12].

The SNS 073 site has only one 4G-LTE sectoral antenna directed toward Romanglasa, offering limited coverage. Meanwhile, other sites such as SNS 091, SNS 049, and SNS 063 face challenges due to physical obstructions and restricted signal reach. As a result, residents experience difficulties in communication and accessing vital information.

A Compact Mobile Station (Combat) is a type of temporary BTS tower used to address communication traffic congestion and connectivity issues in hard-to-reach areas. It also serves as a trial to determine whether a permanent BTS installation is warranted. Through careful planning and deployment of the Combat unit, it is expected that Romanglasa can gain access to improved network connectivity, allowing the community to benefit from enhanced Internet services. Therefore, comprehensive research and precise radio frequency planning are required to resolve the bad spot conditions and ensure adequate telecommunications infrastructure in Romanglasa.

The installation of conventional BTS in rural areas is generally considered less feasible due to several constraints, such as high investment and operational costs, the need for supporting infrastructure like a stable power supply, and low population density that results in insufficient traffic to justify the expenses for construction and maintenance. Additionally, the challenging geographical conditions of rural regions often increase logistical difficulties and transportation costs for equipment deployment. Considering these factors, the use of a Combat offers a more cost-effective and flexible solution. Combat provides significant advantages, including easy mobility, shorter installation time, and lower construction and maintenance costs compared to conventional BTS. These features make Combat highly suitable for enhancing network coverage in rural areas with limited infrastructure and resources.

A single site typically serves one cell, but it can support multiple cells. Generally, a site is placed on the ground, but in densely populated areas, its location may be on top of a high-rise building. The height of the tower is adjusted based on the requirements [13].

To date, research on the use of Combat units or similar mobile stations to expand network coverage in rural areas of Indonesia remains very limited. Most previous studies have focused primarily on optimizing the placement of conventional BTS sites or developing relay systems based on Very Small Aperture Terminal (VSAT) technology in remote regions that are difficult to reach with fiber optic cable infrastructure. For example, research result in [14] discussed methods for determining the optimal placement of fixed BTS sites using VSAT backhaul to serve isolated areas in Indonesia, with the goal of reducing blank spots.

On the other hand, the concept of Mobile BTS has started to be introduced in Indonesia; however, its implementation has mostly been focused on emergency communication needs, such as disaster response or large-scale events that require temporary network support. A study in [15] designed a Mobile BTS specifically to support communication in disaster areas. Moreover, another model of Mobile OpenBTS system aimed at improving search and rescue operations for victims in areas affected by natural disasters was studied in [16]. The authors propose using OpenBTS, an open-source GSM network solution, deployed on portable hardware to create a mobile cellular network that can be rapidly installed and moved as needed in disaster zones. However, both of these studies did not examine the potential use of Mobile BTS as a medium or long-term solution in rural regions.

Therefore, the utilization of Combat or Mobile BTS as a strategy to enhance connectivity in rural areas with limited infrastructure has not yet been thoroughly explored in Indonesia or other developing countries. This indicates a significant research opportunity to investigate more efficient, flexible, and sustainable models for deploying Combat systems to help bridge the telecommunication access gap in rural regions.

At Telkomsel, there is a Combat designed for mobility, making it easy to be relocated. Combat is used to extend coverage and improve traffic network capacity in a given area [17]. In 2015, for instance, one mobile operator improved its network quality by operating two Combat units in the Candi Arjuna Dieng area, strengthening its network across the entire Dieng region [18]. A Micro Cell is a low-power cellular network cell connected to a base station and produces a signal weaker than that of a macro cell [19].

This study uses Pathloss 5.0 software to design the transmission link planning [20], as well as Atoll software for Radio Frequency (RF) network planning and optimization. Additionally, Covmo software, a cloud-based platform that allows access via a web browser, is used for big data analysis, enabling users to observe trends, changes, and disruptions in network movement patterns [21]. The calculations performed include Fresnel Zone, Earth Curvature Factor, and Antenna Height Determination.

Tabel 1. KPI RSRP, RSRQ, and Throughput

Category	RSRP (dBm)	RSRQ (dB)	DL Throughput (Kbps)
Excellent	≥ -80	≥ -1	≥ 12.000
Good	-90 to -80	-7 to -1	≤7.200 to <12.000
Medium	-100 to -90	-14 to -7	≤1.500 to <7.200
Poor	-110 to -100	-20 to -14	≤324 to <1.500
Very Poor	< -110	< -20	< 324

Source: PT. TELKOMSEL.

Tabel 2. KPI Latency, Packet Loss, and Jitter

Category	Latency	Packet Loss	Jitter
Excellent	< 20 ms	0 %	0 ms
Good	20 – 50 ms	≥ 3 %	0 - 75 ms
Medium	50 – 100 ms	≥ 15 %	75 - 125 ms
Poor	> 100 ms	≥ 25 %	125 - 225 ms

Source: TIPHON.

KPIs are essential benchmarks for telecommunications networks, used to assess the performance of a network, whether good or bad. Accessibility, Retention, and Integrity are the three main categories used [22], [23]. The network performance KPI standards in this study follow the standards of the Telkomsel operator and the Telecommunications and Internet Protocol Harmonization Over Network (TIPHON). Reference Signal Received Power (RSRP) measures the average received power of reference signals in LTE which indicates signal strength. Reference Signal Received Quality (RSRQ) measures signal quality, combining the total power, including interference and noise. Throughput is the rate of successful data transfer over the network. In this study, Download Throughput (DL Throughput) is used to refer to the measurement of the data rate at which user equipment (UE) successfully receives data from the network over the downlink, serving as the KPI for assessing user experience and network performance under various radio conditions. Latency, Packet Loss, and Jitter are core Quality of Service (QoS) metrics that are measured and evaluated according to the TIPHON standard for assessing the end-to-end performance of IP-based networks, particularly within the core network segment of mobile systems such as in 4G-LTE and 5G. These KPIs are used to measure and optimize network performance and Quality of Experience (QoE) for users. Table 1 and Table 2 display these KPI standards.

The implementation of the Combat in Romanglasa has been specifically designed to address the connectivity challenges faced by rural areas with limited infrastructure and complex geographical conditions. This approach prioritizes flexibility and mobility, allowing the system to be deployed in locations with minimal support facilities, such as areas with restricted road access and unreliable electricity supply [24]. To replicate this model in other rural regions, several key aspects must be taken into account. First, a comprehensive assessment of existing signal coverage, population distribution, and local communication demands should be conducted to ensure effective and efficient deployment. Second, the Combat system must maintain a modular and adaptable design, enabling rapid installation and relocation, powered by portable generators or renewable energy solutions when grid power is unavailable. Third, integration with feasible backhaul options such as VSAT, microwave links, or the nearest available fiber optic network is essential to support stable connectivity. Additionally, multi-stakeholder collaboration involving mobile network operators, local governments, and the community is crucial to ensure sustainability and local acceptance. Periodic monitoring and adaptive optimization should also be implemented to align service quality with the dynamic needs of end users. This structured approach demonstrates that the Combat deployment in Romanglasa can serve as a replicable and scalable model for expanding equitable telecommunication access in other underserved rural areas, particularly in developing countries with similar constraints.

The main contribution of this study is exploring how to efficiently implement Combat and deploy it rapidly in rural environments like Romanglasa. The study also involves the installation process of Combat in Romanglasa and evaluates its performance and effectiveness after implementation, including network coverage, data speed, and service quality.

METHOD

The process of installing the Combat device in Romanglasa begins with selecting a strategic location to optimize network coverage. Once the location is chosen, initial network testing is conducted, including RSRP and RSRQ measurements, as well as a drive test to assess the condition before installation [25].

Next, simulations are carried out using Atoll and Pathloss 5.0. Atoll is used to evaluate the transmission area coverage based on RSRP, while Pathloss ensures stable microwave connectivity. After the simulations, the Telkomsel team installs the Combat device at the designated location, followed by post-installation testing to assess any changes in network quality and speed. If there is an improvement in quality, the process is considered successful. If not, further simulations and physical tuning are conducted.

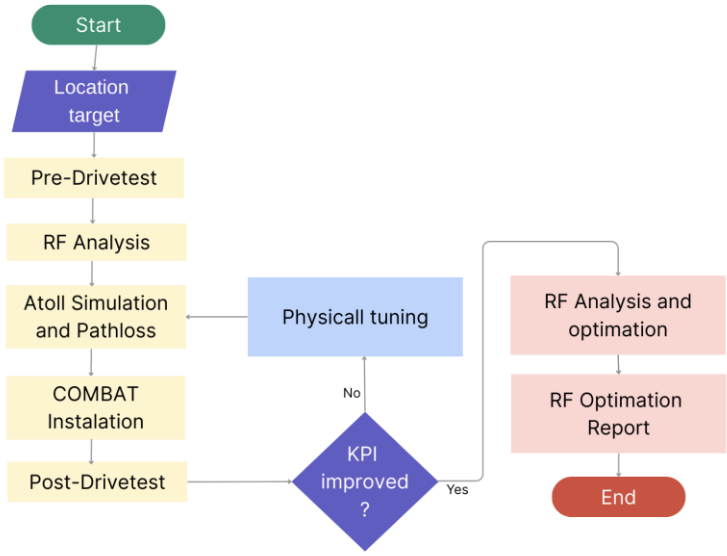


Figure 2. Flowchart of the Steps in the Combat-Cell Design System

The next step is analysis, which involves processing data from the design phase to network measurements. The final results include pre-drive test reports, post-drive test reports, network measurements before and after installation, and the productivity report for Combat-571, which serves as the conclusion of the entire process. All the steps can be seen in Figure 2.

Design Process

The design process for the Combat system begins with selecting the installation location for the device. Based on the survey results, the BTS/eNodeB device will be installed on the Masjid Al-Mukarramah tower. Figure 3 shows the Masjid Al-Mukarramah tower, where the Combat device will be installed. As a result, the Combat installation at this location is designated as site Combat-571 (COI 571-Combat MNR Romanglasa). The next step is to perform calculations for the Fresnel Zone, Earth Curvature Factor, and Antenna Height.

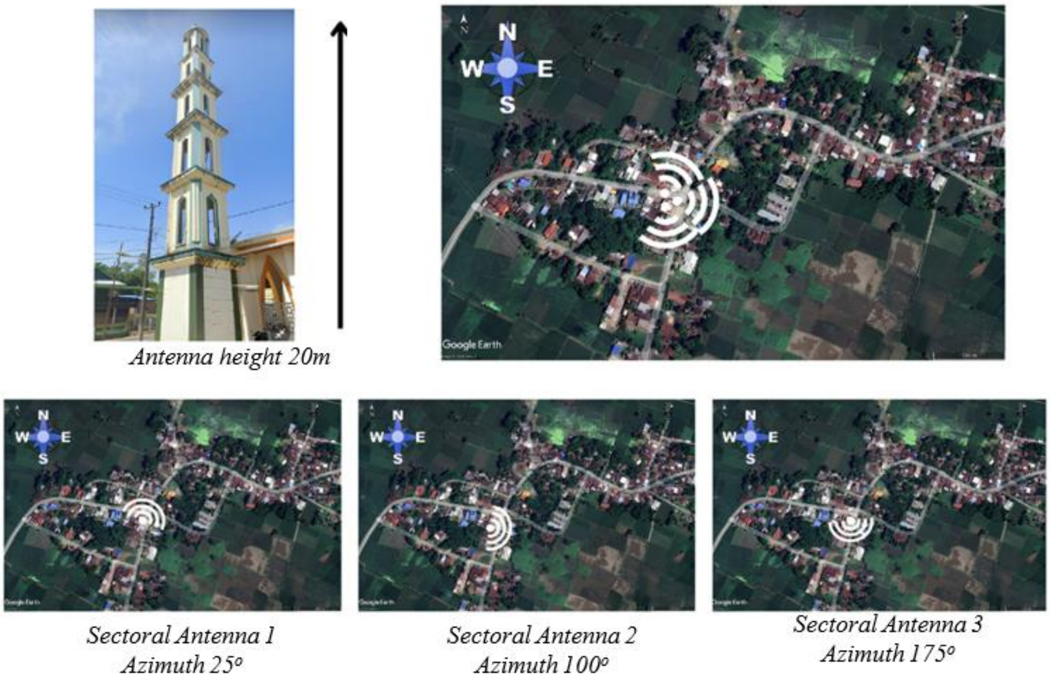


Figure 3. Antenna Placement and Orientation Design.

Fresnel Zone Calculation

Field measurement results show that the distance between Combat-571 and the SNS 063 Anugrah Payangkalan location is 2.2 km (d), with an intra-BTS frequency of 18 GHz (f). Therefore, the area of the Fresnel zone can be calculated using Equation (1) [12].

$$R_f = 17.32 \sqrt{\frac{d}{4f}} \quad \text{.....(1)}$$

Based on the calculations above, the resulting Fresnel zone area is 3 meters. The transmission signal at Combat is considered good if it reaches 60% * R_f + 3 meters, totaling 4.8 meters.

Earth Curvature Factor Calculation

The Earth curvature factor can be calculated using Equation (2) [12]. Data from the Pathloss 5.0 software simulation shows that Combat-571 is located 1.1 km (d_1) from the obstacle, while the distance from the SNS 063 Anugrah Payangkalan site to the obstacle is 0.8 km (d_2). Therefore:

$$h_{corrected} = \frac{0.079 . d1 . d2}{k} \quad \text{......(2)}$$

$$h_{corrected} = 0,05214 \ meter$$

Antenna Height Calculation

The height of the obstacle at Combat-571 and the SNS 063 Anugrah Payangkalan site is approximately 15 meters (*hobstacle*). Therefore, the Fresnel radius (F) using Equation (3) [12] can be obtained as follows:

$$F = 17.3\sqrt{\frac{n.d1.d2}{f.d}} \quad ......(3)$$

After obtaining the value of $F = 2.6$ meters, the next step is to calculate the clearance using Equation (4) [12], which is:

$$Clearance = 0.6F + h_{corrected} \quad ...... (4)$$

Once a clearance of 2.65 meters is achieved, the subsequent step involves determining the minimum antenna height required to ensure a Line of Sight (LOS) condition, as calculated using the following Equation (5) [12]:

$$h_{antenna} = h_{obstacle} + clearance \quad ......(5)$$

$h_{antenna} = 15 + 2{,}65 = 17{,}65$ meter.

The network design process is also illustrated in Figure 3, which includes mapping the equipment layout and defining the connection pathways between devices involved in the installation of the Combat-571 system.

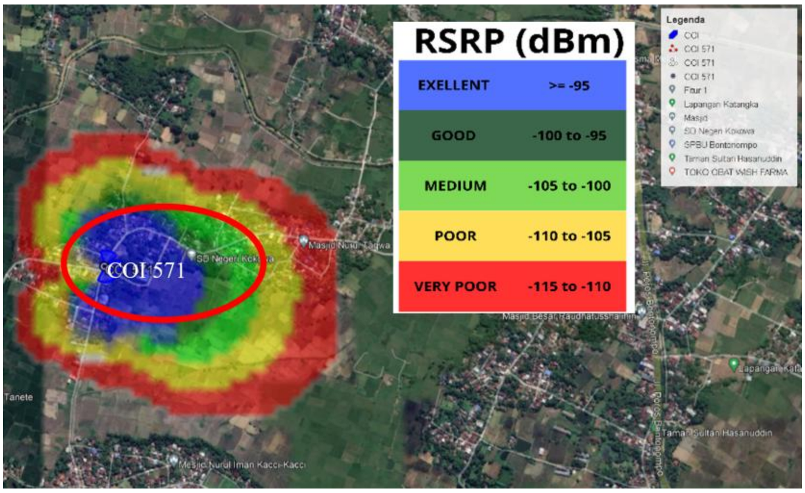


Figure 4. RSRP Coverage Simulation Results.

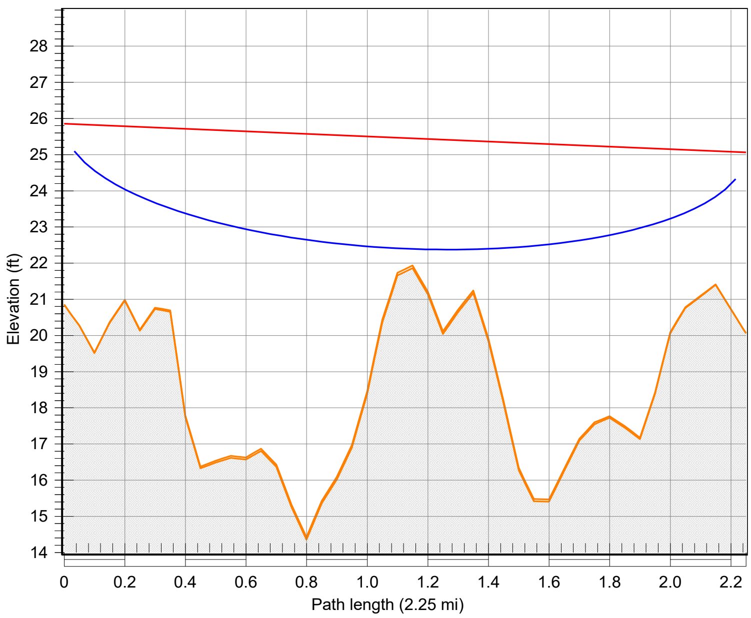


Figure 5. Microwave Link Simulation Results.

The next step involves conducting a coverage area simulation using RSRP in Atoll software. Figure 4 shows the simulation results for coverage by RSRP. The simulation indicates that previously identified bad spot areas can now be adequately covered, as shown by the blue and green zones with RSRP levels ranging from -105 dBm to ≤ -95 dBm. Subsequently, a microwave antenna link simulation is performed, as shown in Figure 5. This antenna functions to transmit and receive radio signals between the BTS and the BSC, or between multiple BTS units. This enables communication between the BTS and other components within the network.

The Fresnel zone and clearance factor along the link between Combat-571 and SNS 063 are unobstructed, as shown in Figure 5. This favorable condition having a clear Fresnel zone and no obstacles that helps to minimize multipath fading on the link.

Following this, frequency planning is conducted for the Combat-571 system. Telkomsel operates on four frequency bands: 900 MHz (2G & 4G), 1800 MHz (2G & 4G), 2100 MHz (4G), and 2300 MHz (4G & 5G). Given an estimated 750 users requiring basic internet services such as web browsing and social media access, the 1800 MHz band (DCS) is allocated for 2G technology, while the 1800 MHz and 2100 MHz bands (LTE) are used for 4G technology.

Installation Process

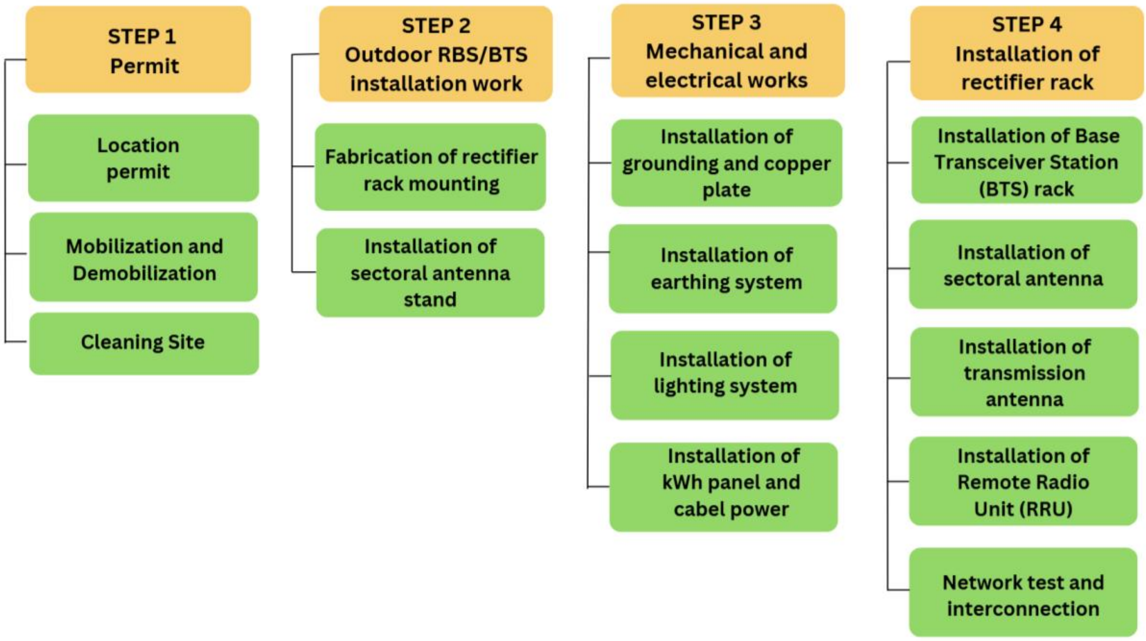


Figure 6. Block Diagram of Combat-571 Installation.

The installation and assembly process of the Combat system is illustrated in the block diagram shown in Figure 6. This involves several key stages to ensure rapid and reliable deployment. It begins with a site survey to select an optimal location with stable ground, minimal obstructions, and access to a power source such as a generator or solar panel. Once the site is prepared, the hardware components are assembled, including erecting a collapsible mast or pole, mounting sector or omnidirectional antennas, and positioning the GPS antenna for timing synchronization. The COMBAT unit (often a compact) all-in-one system is then installed, with RF cables securely connected to the antennas. Power is supplied through DC or AC sources, with backup batteries or UPS for reliability. The system is then connected to the core network using a suitable backhaul link, such as satellite, microwave, or fiber. Software configuration follows, where network parameters such as frequency, PLMN ID, and bandwidth are set via a management interface. After synchronization with the core network elements, the system undergoes testing to verify signal quality, coverage, and KPIs for connection stability.

RESULTS AND DISCUSSION

Pre-Installation Analysis

Performance testing was conducted to assess the quality of the Telkomsel network in Romanglasa prior to the installation of the Combat-571 system. The objective of this measurement was to evaluate the RSRP and RSRQ parameters, as well as to analyze the throughput, jitter, packet loss, and latency of the existing network in the area before any improvements were made.

The application G-NetTrack Pro was utilized to measure RSRP, RSRQ and DL Throughput, while SpeedTest by Ookla was used to measure throughput, jitter, packet loss, and latency. Before the installation of Combat-571, the area of Romanglasa was covered by BTS SNS 049 (eNodeB: 598049). Based on the measurement results, the RSRP value was -133 dBm, which falls into the Very Poor category according to Telkomsel's KPI, while the RSRQ value of -11 dBm is classified as Medium. These baseline measurements highlight the need for infrastructure improvements, which are addressed through the deployment of the Combat-571 system.

As the consequency, the measurement of throughput, jitter, packet loss, and latency could not be performed due to the poor network connectivity in the area. A drive test was carried out to measure signal strength and quality in Romanglasa, and to identify areas with weak signals, interference, or other issues that could impact network performance. Figure 7(a) displays the KPI targets based on the drive test results in Romanglasa prior to the installation of Combat-571, using the G-NetTrack Pro application.

The third evaluation involves User Experience Assessment. This assessment was conducted by testing several applications commonly used by end users. The applications selected for this evaluation were YouTube and Instagram. In general, the network conditions in Romanglasa before the installation of Combat-571 were poor. The SpeedTest application could not be used due to weak and unstable signal quality, which indicated very low data speeds and an unsatisfactory user experience. Most areas showed very weak signal strength, with dominant RSRP values around -110 dBm. This highlights the urgent need for improvements to the network infrastructure in the area.

Post-Installation Analysis

The first measurement involved assessing signal quality using the G-NetTrack Pro and SpeedTest by Ookla applications. This measurement was taken to identify which BTS now covers Romanglasa after the installation of Combat-571.The RSRP value is -85 dBm, which, according to Telkomsel's KPI, falls into the Excellent category. The RSRQ value is -9, which is categorized as Medium but slightly more developed in Telkomsel's KPI. Moreover, the test results show a download speed (DL throughput) of 47.6 Mbps and an upload speed of 28.4 Mbps, with jitter of 7 ms, packet loss of 0%, and latency of 21 ms.

A comparison of the network quality measurements before (pre-drive test) and after the installation (post-drive test) of the Combat device can be seen in Table 3.

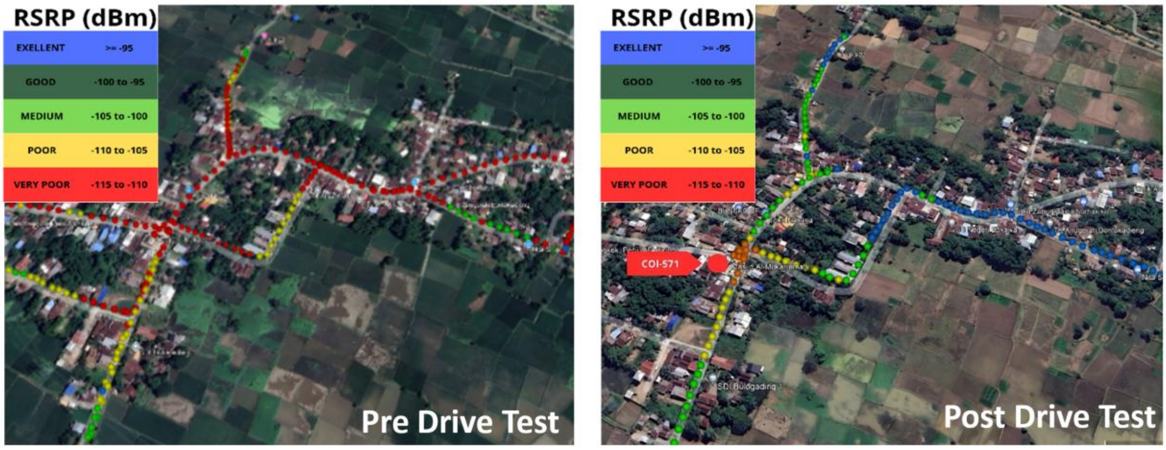
The second measurement involves a drive test. The purpose of the drive test is to measure the signal strength and quality in Romanglasa, identify areas with weak signals, interference, or other issues that could impact network performance.

Table 3. Comparison of Network Measurement Results

Parameter	Measurement Before Combat Implementation (Pre-Drivetest)		Measurement After Combat Implementation (Post-Drivetest)	
	Value Level	KPI Standard	Value Level	KPI Standard
RSRP	-133 dBm	Very Poor	-85 dBm	Excellent
RSRQ	-11 dB	Medium	-9 dB	Medium
DL Throughput	Error	-	47,6 Mbps	Excellent
Jitter	Error	-	7 ms	Good
Packet Loss	Error	-	0,0 %	Excellent
Latency	Error	-	21 ms	Good

Figure 7(b) shows the post-drive test results for the KPIs (RSRP and RSRQ) parameter in Romanglasa, using the G-NetTrack Pro application. The drive test results, with varying RSRP values, provide an overview of the signal coverage quality in the tested area. The details are as follows:

- RSRP > -95 dBm indicates very strong signal strength. Signals of this strength typically offer the best network performance.
- RSRP -100 dBm to -95 dBm indicates good signal strength. Users in this range will experience good voice call quality, adequate speeds, and consistent service availability with reliable and stable signals.
- RSRP -105 dBm to -100 dBm indicates moderate signal quality. While services are still accessible, the service quality may start to degrade.



(a) (b)

Figure 7. (a) Pre-Drive test (b) Post-Drive Test Results. The post DT measurement shows the significant signal strength improvement after the Combat installation

Figure 8 shows the completed installation of the Combat-571 equipment. The sectoral antenna and transmission antenna are mounted on the mosque tower, while the eNodeB is installed on the BTS rack, and the backhaul equipment is placed on the rectifier rack inside the Al-Mukarramah Mosque tower. The structure of Combat-571 configuration is shown. The sectoral antenna will be connected to the Radio Remote Unit (RRU) using a coaxial or jumper cable. The RRU will then be connected to the Base Band Unit (BBU) located in the BTS rack via an optical cable. The BTS rack serves as the enclosure for housing the necessary equipment for transmitting and receiving radio signals. The BTS rack contains a cooling fan, the BBU, and a DC Power Distribution Board (DCPDB). Meanwhile, the transmission or microwave antenna will be connected to a mini link, which then connects to the Minilink Transmission Transport Node (TN) using a coaxial cable.

Overall, the network measurements in Romanglasa after the installation of the Combat-571 device show a significant improvement in signal quality and strength. The high internet speeds and drive test results, predominantly with RSRP values around -90 dBm, ensure that communication and data services in the area are running smoothly and stably. The application tests also demonstrate satisfactory performance, providing users with a good experience and high satisfaction when using various online applications.

To improve connectivity in rural areas with limited infrastructure, the Combat deployed in Romanglasa can serve as a practical model for replication in similar regions. Compared to permanent BTS installations which require high capital investment, longer construction time, and reliable power supply, so Combat provides a more flexible and cost-effective solution. Moreover, Combat has advantages over mobile repeaters and microcells, which primarily act as signal boosters and depend on existing network coverage, whereas Combat functions as a stand-alone BTS unit with its own VSAT or microwave backhaul. A comparative analysis indicates that Combat offers lower capital and operational costs, shorter deployment time, and higher relocation flexibility, making it well-suited for remote areas with low user density. Tabel 4 shows the cost-Benefit Comparison.

Tabel 4. *Comparative cost-benefit analysis for different network extension methods in rural areas.*

Parameter	Permanent BTS	Mobile Repeater	Microcell	Combat (Mobile BTS)
Initial Cost (USD)	High (~$100,000+)	Low (~$5,000–10,000)	Medium (~$20,000–40,000)	Medium (~$30,000–50,000)
Deployment Time	Long (6–12 months)	Short (days)	Short (days)	Short (1–2 weeks)
Coverage Area	Wide (10–30 km)	Small (<1 km)	Small (<2 km)	Moderate (2–5 km)
Operational Flexibility	Fixed	Portable	Fixed or semi-portable	Highly Portable
Maintenance Cost	High	Low	Medium	Medium
Best Use Case	High-traffic, permanent sites	Spot coverage or signal boosting	Small urban/rural clusters	Rural/remote with poor coverage

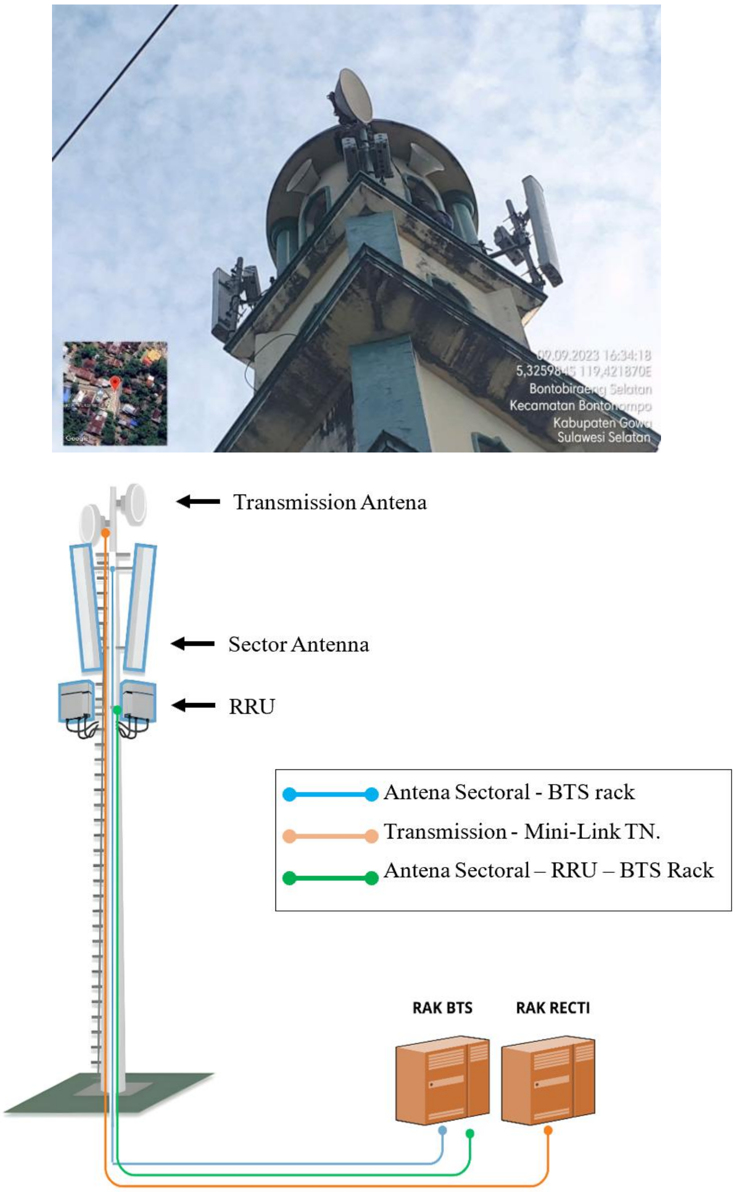


Figure 8. Installed Combat-571 Equipment.

CONCLUSION

The implementation of Combat in Romanglasa involved several design steps, including a site audit and simulations to determine the optimal radio parameters. This process included selecting the installation location and determining the required antenna height. The coverage area simulation, using Atoll, resulted in RSRP values ranging from >-95 dBm to -105 dBm. The microwave link simulation, performed using Pathloss 5.0, yielded a received signal strength of -27.04 dBm. The direction of the sector antennas was determined with azimuth angles set as follows: Sector Antenna 1 at 25°, Sector Antenna 2 at 100°, and Sector Antenna 3 at 175°.

The installation of Combat was carried out in collaboration with Telkomsel partners, starting from the design phase to the assembly, installation, and BTS configuration. Device testing was also conducted, including several drive tests (DT), to ensure that the network was active, validated, and functioning properly.

BIBLIOGRAPHY

[1] W. Setiawan, *Era Digital dan Tantangannya*. Bandung, Indonesia: Universitas Pendidikan Indonesia, 2017. ISBN: 978-602-50088-0-1.

[2] B. Tarnoff, *Internet for the People: The Fight for Our Digital Future*. London, U.K.: Verso Books, 2022.

[3] APJII, "Survei Penetrasi & Perilaku Internet 2023," [Online]. Available: https://survei.apjii.or.id/survei/. [Accessed: Mar. 2, 2025].

[4] H. W. Wardani, *et al*., "Optimasi Jaringan 3G Berdasarkan Analisis Bad Spot Di Area Jakarta Pusat," *eProceedings of Applied Science*, vol. 2, no. 3, 2016.

[5] K. A. R. Berto, "Cellular Phone and the Usage (Problems of Cellular Phone's Usage In Blank Spot Areas of Indonesia)," *Journal Studi Komunikasi dan Media*, vol. 19, no. 2, pp. 259, Dec. 2015, doi: 10.31445/jskm.2015.190209.

[6] Z. El Khaled and H. Mcheick, "Case studies of communications systems during harsh environments: A review of approaches, weaknesses, and limitations to improve quality of service," *International Journal Distribution Sensor Network*, vol. 15, no. 2, pp. 1–16, 2019, doi: 10.1177/1550147719829960.

[7] T. Pateman, "Rural and urban areas: comparing lives using rural/urban classifications," *Regional Trends*, vol. 43, pp. 11–86, 2011.

[8] D. P. Silitonga, "Tahapan perkembangan metropolitan Jabodetabek berdasarkan perubahan pada aspek lingkungan," *Journal Perencanaan Wilayah dan Kota*, vol. 21, no. 3, pp. 197–214, 2010.

[9] I. Pramulia, P. K. Sudiarta, and G. Sukadarmika, "Analisis Pengaruh Jarak Antara User Equipment Dengan eNodeB Terhadap Nilai RSRP Pada Teknologi LTE 900 MHz," *Journal SPEKTRUM*, vol. 2, no. 3, pp. 24–30, 2015.

[10] M. Ayad, S. Medjedoub, B. Mourad, K. Saoudi, and A. Arabi, "Evaluation of 4G / LTE mobile network performances based on experimental data," in *Proc. IEEE Int. Workshop Human-Centric Smart Environ. Health Well-being (IHSH)*, Boumerdes, Algeria, 2021, pp. 137–141, doi: 10.1109/IHSH51661.2021.9378732.

[11] R. A. Inojosa, P. A. Martinez, R. V. Cleff, B. Raro, and R. C. M. Pineda, "Towards the Development and Deployment of Community LTE Networks in Rural Areas," in *Proc. Int. Conf. Advancement in Technology (ICONAT)*, 2022.

[12] M. Ulfah and A. S. Irtawaty, "Optimasi Jaringan 4G LTE pada Kota Balikpapan," *Journal Ecotipe (Electronic, Control, Telecommunication, Information, and Power Engineering)*, vol. 5, no. 2, pp. 1–10, 2018.

[13] N. Ismail, M. M. Maharoni, and I. Lindra, "Analisis Perencanaan Pembangunan BTS Berdasarkan Faktor Kelengkungan Bumi dan Daerah Fresnel di Regional Project Sumatera Bagian Selatan," *Journal Istek*, vol. 9, no. 1, 2015.

[14] A. Lubis, R. S. Hardinata, and M. Seger, "Based Internet Network Design VSAT Ku-Band at Jangga Dolok Village Office," in *The International Conference on Education, Social Sciences and Technology (ICESST)*, vol. 1, no. 1, pp. 113-122, 2022.

[15] U. Prayuda, M. A. Wibisono, and T. Juhana, "Design and Implementation of SDR-Based GSM Mobile BTS for Remote and Disaster Affected Areas," in *2018 4th IEEE International Conference on Wireless and Telematics (ICWT)*, pp. 1-5, 2018.

[16] T. D. Putri, and T. Juhana, T, “Mobile-openbts implementation of natural disaster victims search,” in *2017 3rd IEEE International Conference on Wireless and Telematics (ICWT)*, pp. 149-154, 2017.

[17] A. Fauzi, “Perencanaan Kebutuhan Base Transceiver Station dan Optimasi Penempatan Menara Bersama Telekomunikasi,” *Journal Penelitian dan Pengembangan Komunikasi dan Informatika*, vol. 4, no. 3, pp. 151–158, 2014.

[18] F. H. Taqwa, N. M. Adriansyah, and U. K. Usman, “Analisis Implementasi Perencanaan Coverage Area LTE Dengan Menggunakan Combat BTS Di Alun-alun Kota Bandung,” *eProceedings of Engineering*, vol. 8, no. 2, 2021.

[19] W. Rokhmat, A. Hikmaturokhman, and M. A. Amanaf, “Perencanaan Compact Mobile Base Station Minimalis UMTS Pada Acara Music Jazz di Candi Prambanan Yogyakarta,” *Prosiding SEMNASHUMTEK*, vol. 1, no. 1, 2017.

[20] M. A. Mahathir, “Desain Micro Cell Sebagai Pengganti Macro Cell,” Bachelor’s thesis, Surabaya, 2013.

[21] S. A. Basyit, “Dimensioning of LTE Network: Description of Models and Tool, Coverage and Capacity Estimation of 3GPP Long Term Evolution Radio Interface,” M.Sc. thesis, Helsinki Univ. Technol., Finland, 2009.

[22] I. G. Made, Y. Priyandana, A. Saputra, and P. K. Sudiarta, “Analisis Hasil Drive Test Menggunakan Software G-Net dan Nemo Di Jaringan LTE Area Denpasar,” *E-Journal SPEKTRUM*, vol. 5, no. 2, pp. 216–223, 2018.

[23] J. Huang et al., “A close examination of performance and power characteristics of 4G LTE networks,” in *Proc. 10th Int. Conf. Mobile Syst., Appl., and Services*, ACM, 2012.

[24] Tognisse, I. S., Degila, J., & Kora, A. D. (2021, December). Connecting Rural Areas: A Solution Approach to Bridging the Coverage Gap. In *2021 IEEE 12th Annual Ubiquitous Computing, Electronics & Mobile Communication Conference (UEMCON)* (pp. 0873-0873). IEEE.

[25] L. Farianto, “Analisis Performa Dan Optimasi Jaringan Long Term Evolution (LTE) 2300 MHz Dengan Metode Drive Test Menggunakan Nemo Handy Di Kabupaten Brebes,” 2021.

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