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5G cellular network planning in Parepare City

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ABSTRACT

The telecommunications industry is rapidly advancing, particularly in cellular network communications that use air as the transmission medium, with 5G new radio (NR) emerging as a key global technology including in Indonesia. Defined by enhanced mobile broadband (eMBB) offering speeds up to 10 Gbps, ultra-reliable low-latency communications (URLLC) with latency below 1 millisecond, and massive machine-type communications (mMTC) supporting large-scale internet of things (IoT) connectivity, 5G plays a crucial role in modern digital infrastructure. This study focuses on the city of Parepare in South Sulawesi, an area driven by trade, port operations, fisheries, shipbuilding, and natural tourism highlighting the need for high-speed and reliable data services. The research aims to develop a comprehensive 5G NR network plan for Parepare through coverage and capacity analyses evaluating synchronization signal-reference signal received power (SS-RSRP), signal-to-interference-plus-noise ratio (SS-SINR), and throughput performance. Using Atoll software to design and map next-generation Node B (gNodeB) placements, the study offers a scientific approach to optimizing 5G deployment and supporting the city's economic growth and tourism potential.

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1. INTRODUCTION

The city of Parepare, located in the South Sulawesi Province of Indonesia, is a coastal city renowned for its bustling trade, vibrant port activities, and thriving fisheries and shipbuilding industries. These economic pillars have long established Parepare as a key commercial hub within the region, playing a critical role in the economic landscape of South Sulawesi [1]. In addition to its commercial significance, Parepare also boasts significant tourism potential. The city's natural beauty, which includes stunning beaches, picturesque hills, and a variety of surrounding islands, attracts visitors from all over, contributing to its growing tourism sector. The combination of economic activities and tourism potential makes Parepare a dynamic and vital part of South Sulawesi's economy [2].

As Indonesia continues to advance technologically, there is an increasing demand for specialized services such as robust internet networks [3]. These networks are essential for enhancing public services in major cities, thereby supporting the country's economic growth and improving the quality of life for its citizens. The internet has become an integral component of daily life, facilitating academic activities, enabling social media engagement, and supporting a wide range of work-related tasks [4]. In recognition of this, the Indonesian government has prioritized the development of advanced internet infrastructure to meet the needs of its growing digital economy. A robust internet infrastructure is critical for the country's progress in the digital era, enabling various sectors to operate more efficiently and connect with the global market [5].

On May 24, 2021, Indonesia took a significant step forward by officially launching commercial 5G network services. The advent of 5G technology marked the beginning of a new era in network development, with major cities across the country, including Parepare in South Sulawesi, earmarked for 5G implementation. Parepare's strategic importance as a key trade and port hub made it a prime candidate for the rollout of this next-generation network [6]. The 5G cellular network technology, designed as the successor to 4G, aims to deliver superior service through three primary specifications: enhanced mobile broadband (eMBB) with download speeds of up to 10 Gbps, ultra-reliable and low latency communications (URLLC) with latency under 1 millisecond, and massive machine type communications (mMTC), which provides large-scale connectivity to manage millions or even billions of internet of things (IoT) devices within a single coverage area [7]-[9].

The deployment of 5G in Parepare is expected to bring numerous benefits. eMBB will provide high-speed internet access, facilitating seamless streaming, gaming, and other data-intensive activities [10]. URLLC will enable real-time applications such as autonomous driving and remote surgery, while mMTC will support the growing number of IoT devices, driving innovation in various sectors including healthcare, agriculture, and smart cities [11]. These capabilities will not only enhance the digital experience for individuals but also transform industries by enabling new applications and services that were previously not possible [12], [13].

This research aims to plan the 5G new radio (NR) cellular network in Parepare, a strategic city in South Sulawesi designated for the deployment of 5G networks in Indonesia. Given its commercial significance and growing technological needs, meticulous planning is required to develop a 5G network that can serve as a viable solution for implementation while also providing a reference for future development in other regions of Indonesia. The objective of this study is to design an optimal 5G NR network through site mapping simulations using Forsk Atoll software, involving analysis of coverage and capacity to support planning and implementation. The use of Forsk Atoll enables detailed simulations, ensuring that the network design is efficient and effective in meeting the city's needs. The outcome is expected to offer valuable insights for relevant companies in their efforts to implement the 5G network in Parepare, helping stakeholders make informed decisions about deployment and ensuring that the network delivers high-quality service to residents and businesses alike [14]-[16].

In addition to the technical aspects, this study also considers the socio-economic impacts of deploying 5G in Parepare. The selection of the 3.5 GHz frequency and 100 MHz bandwidth is justified based on Indonesia's regulatory framework, spectrum availability, and the increasing demand for high-speed connectivity. The 3.5 GHz band is globally recognized as a key mid-band spectrum for 5G, offering an optimal balance between coverage and capacity. Additionally, the 100 MHz bandwidth ensures sufficient network capacity to support low-latency, high-speed applications, aligning with international best practices and future spectrum allocation plans in Indonesia. Improved internet connectivity through 5G deployment can lead to significant socio-economic benefits for Parepare. In education, students and teachers will gain better access to online resources and e-learning platforms, improving learning outcomes [17]. The healthcare sector will also benefit, with telemedicine and remote diagnostics becoming more feasible, particularly in underserved areas. Businesses can leverage high-speed internet to enhance operations, reach new markets, and drive innovation. Moreover, the improved network infrastructure is expected to support smart city initiatives, enhance public services, and contribute to overall economic growth. Thus, the successful implementation of 5G in Parepare is expected to not only enhance connectivity but also drive substantial social and economic transformation for the community [18].

The implementation of 5G in Parepare represents a significant advancement in the city's technological infrastructure. This research aims to facilitate this process by providing a detailed and scientifically rigorous network design, leveraging advanced simulation tools to optimize coverage and capacity. The insights gained from this study will not only benefit Parepare but also serve as a valuable reference for the broader deployment of 5G networks across Indonesia. As the country continues to embrace digital transformation, the successful implementation of 5G in Parepare will play a crucial role in driving economic growth and improving the quality of life for its residents. By laying a strong foundation for future technological advancements, Parepare can position itself as a leading city in the digital age, attracting investment and fostering innovation. This research underscores the importance of strategic planning and the potential of 5G to transform societies, making it an essential contribution to Indonesia's technological and economic development.

This paper is organized as follow: section 2 is Parepare City profile. Section 3 is method that is divided into four parts: first is the specification for 5G NR cellular network design, second is coverage planning, third is capacity planning and fourth is simulation using the Atoll Application. In section 4 presents result that is devided into three parts: first is technical analysis, second is capacity planning and three is network design simulation. Last section 5 is conclusion.

2. PAREPARE CITY PROFILE

The city of Parepare is one of the Level II regions in South Sulawesi. The city covers an area of 99.33 km² and has a population of approximately 140,000 people, distributed across four districts comprising 22 sub-districts, with an average population growth rate of 1.85%. Astronomically, Parepare is located between 3°57’39” and 4°04’59” South Latitude and between 119°36’24” and 119°43’40” East Longitude. Geographically, the city is bordered by Pinrang Regency to the north, Barru Regency to the south, Sidenreng Rappang Regency to the east, and the Makassar Strait to the west [19].

As one of the important cities in South Sulawesi, Parepare serves as a central hub for trade and port activities, with most residents running their own businesses to sustain their daily needs. Given its economic significance and urban landscape, this research utilizes the 3.5 GHz frequency, categorized as a medium-frequency band, with a bandwidth of 100 MHz. This frequency offers a favorable balance between coverage and capacity, making it suitable for site placement in business districts, government areas, and urban communities. The choice of the 3.5 GHz frequency band with a 100 MHz bandwidth also aligns with Indonesia's national spectrum policy, which has designated the 3.3–3.6 GHz band for 5G deployment as per the Ministry of Communication and Informatics (KOMINFO). This frequency range is considered optimal for urban areas like Parepare, ensuring efficient network performance while meeting regulatory requirements. Additionally, the 100 MHz bandwidth was selected based on ITU recommendations for eMBB applications, providing sufficient throughput and spectral efficiency to handle high user demand in urban environments. This allocation supports higher data rates, reduced latency, and improved network performance, aligning with Indonesia’s 5G roadmap and ensuring seamless connectivity in Parepare’s growing digital ecosystem. The frequency falls within the FR1 frequency range, specifically n78. Below is Figure 1, which is a map of Parepare City.

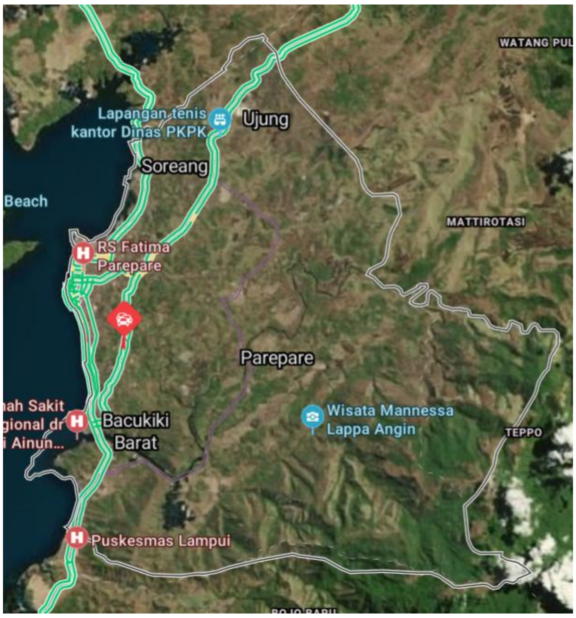


Figure 1. Parepare City area map [19]

3. METHOD

3.1. The specification for 5G NR cellular network design

Based on the profile of Parepare City, the necessary specifications and parameters for the 5G cellular network design were identified. These specifications take into account various factors such as population density, geographical area, and projected network demand. The detailed parameters for the network design are presented in Table 1, providing the foundation for the planning and deployment of 5G infrastructure in the city.

Table 1. Specific design

Parameter			5G NR (3.5 GHz)	
Region	Area size (km^2)	Propagation model	Bandwidth	Power transmitter
Parepare	99.33	Urban macro (UMa)	100 MHz	49

3.2. Coverage planning

In the coverage planning, two scenarios, namely scenario 1 and scenario 2, are considered to determine the minimum number of gNodeBs required while ensuring optimal coverage and performance. This process takes into account the specified area size and the path loss between gNodeBs and user terminal (UT) devices [20], [21]. The planning process begins with identifying the research area's size and characteristics, followed by defining the system design specifications. A link budget calculation is then performed to estimate the maximum allowable path loss (MAPL) using relevant parameters. Once the link budget value is determined, the appropriate propagation model is selected based on ETSI 138.901, which categorizes environments into UMa, urban micro (UMi), and rural macro (RMa) models [22].

In this study, the UMa propagation model was chosen based on a comprehensive analysis of Parepare's urban characteristics, including population density maps and urban morphology. While some areas of Parepare exhibit characteristics of dense urban pockets, the overall city layout primarily consists of moderate-density residential and commercial areas with mid-rise buildings and open spaces. This structure aligns more closely with UMa rather than UMi, which is typically applied to high-density city centers with closely packed buildings and narrow streets.

An urban morphological analysis further supports the selection of the UMa model, as Parepare features a mix of open roads, mid-rise buildings, and green areas. These characteristics make UMa the more suitable choice, providing wider coverage and better outdoor signal propagation compared to UMi, which is optimized for environments with dense multipath effects and the need for small-cell deployment. Additionally, the UMa model offers a better trade-off between coverage and capacity, ensuring efficient network planning with fewer gNodeBs while maintaining adequate signal quality across the city. By selecting the UMa propagation model, this study ensures an optimal balance between coverage and capacity, allowing for an efficient deployment of gNodeBs while minimizing infrastructure costs. After choosing the propagation model, the next step involves determining the coverage area per gNodeB, optimizing placement, and ensuring seamless connectivity across Parepare in accordance with Indonesia's 5G regulatory framework [23]-[25].

3.3. Capacity planning

Capacity planning considers both quality and capacity in a design, enabling the determination of cellular network planning requirements, including the number of users, traffic demand, and data rate [26]. The capacity planning process begins with estimating the number of users for the coming years using the Bass model calculation [27]. Next, the data rate calculation is performed to determine the data on the combination of frequency bands for the operator. Finally, the traffic demand calculation is conducted to determine the density of cellular network users [28].

The Bass model is a valuable mathematical framework for forecasting the adoption of novel technologies, such as 5G, by distinguishing between two primary user segments, who are early adopters driven by external influences like advertising and media campaigns without relying on social validation, and imitators, who adopt the technology after observing [27]. By analyzing the respective coefficients of innovation and imitation, the Bass model provides a robust projection of future user growth curves, which is pivotal for network planning as it furnishes the foundational data required to compute necessary data rates and traffic demands, ultimately determining the cellular network density needed to ensure optimal quality of service (QoS) as the user base expands [28].

3.4. Simulation using the Atoll application

In this study, a simulation of the 5G NR cellular network planning at a 3.5 GHz frequency was conducted using Atoll software. The purpose is to map gNodeBs based on the coverage and capacity planning scenarios [29], [30]. The version of Atoll used in this study is Atoll 3.4.0. Figure 2 shows the Atoll software.

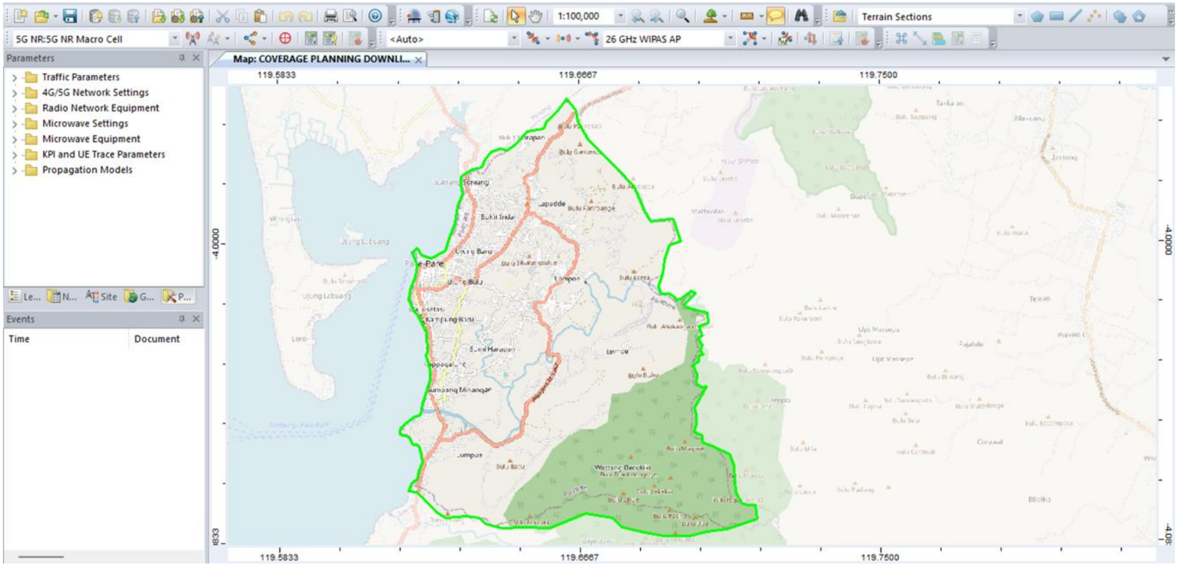


Figure 2. Online maps and zone of Parepare City using Atoll software

4. RESULTS
4.1. Technical analysis
The coverage-based planning aims to estimate the minimum number of gNodeBs required to cover the Parepare City area. The coverage analysis begins with calculating the link budget to determine the MAPL value, which is used to find the maximum cell radius between the transmitter and receiver, following the ETSI 138.901 propagation model, specifically Uma. This planning considers the geographical conditions and area types, such as rural, suburban, urban, and dense urban. The cell radius value is used to determine the number of cells needed in the Parepare area, resulting in the minimum number of gNodeBs required. Coverage calculation is influenced by link budget parameters can be seen in Table 2.

The link budget parameters in Table 2 are used to determine the thermal noise and subcarrier quantity values. These values are then applied to calculate the minimum number of gNodeBs. The results for both scenarios can be seen in Table 3.

Table 2. Parameter of link budget

Parameters	Scenario 1 (Downlink)	Scenario 2 (Uplink)	Parameters	Scenario 1 (Downlink)	Scenario 2 (Uplink)
gNodeB transmitter power (dBm)	49	49	Rain/ice margin (dB)	0	0
Resource block	273	273	Slow fading margin (dB)	7	7
10 log 10 subcarrier quantity	3276	3276	UE antenna gain (dB)	0	0
gNodeB antenna gain (dBi)	2	2	Bandwidth (MHz)	100	100
gNodeB cable loss (dB)	0	0	Boltzmann's constant (k) (mWs/k)	1.38×10^{-20}	1.38×10^{-20}
Penetration loss (dB)	26.85	26.85	Temperature (Kelvin)	293	293
Folliage loss (dB)	19.59	19.59	Thermal noise power (dBm)	-153.93	-153.93
Body block loss (dB)	3	3	UT noise figure (dB)	9	9
Interference margin (dB)	6	2	Demodulation threshold SINR (dB)	-1.1	-1.1

Table 3. gNodeB minimum calculation results

Parameters	Scenario 1 (Downlink)	Scenario 2 (Uplink)	Parameters	Scenario 1 (Downlink)	Scenario 2 (Uplink)
MAPL	99,436 dB	103,436 dB	Large of area	99.330.000 m	99.330.000 m
d_{3D} (hypotenuse)	562,341 m	707,945 m	C_A (cell three sectoral)	820753 m	1307640 m
d_{2D} (cell radius)	561,849 m	707,552 m	Number of gNodeB	121 sites	76 sites

4.2. Capacity planning
The planning based on capacity planning begins by considering the population or number of users, data rate, and traffic demand. This capacity planning is based on the population to project the number of

inhabitants seven years into the future, using 2023 as the starting year and 2030 as the final year. This population projection will determine the number of 5G users in the city of Parepare. Based on data from the *Badan Pusat Statistik* (BPS) regarding the population in the city of Parepare, specifically in the districts of Bacukiki, Bacukiki Barat, Ujung, and Soreang [18], the forecasted population and annual growth through 2030 can be seen in Table 4.

The data from Table 4 is then used to determine the number of 5G users in Parepare City by taking into account the data from 2023. This calculation considers user data from 2023 and utilizes data from ITU development statistics to obtain imitational and innovational data used in estimating the number of users. Additionally, the data provides the data rate and traffic demand, which refer to the amount of traffic generated by users can be seen in Table 5.

Table 4. Population forecast and annual growth 2022 to 2030

No	Subdistrict	Total population			Difference in years	Population growth percentage 2028-2029 (%) difference from 2028 to 2029	Difference between 2029 to 2030	Predictions in 2030
		2022	2028	2029				
1	Bacukiki	28,129	42,702	45,776	1	0.071987	1	49071.29
2	Bacukiki Barat	45,934	47,599	47,880	1	0.005903	1	48162.66
3	Ujung	33,758	33,113	33,003	1	-0.003321	1	32893.37
4	Soreang	47,033	46,799	46,760	1	-0.000833	1	46721.03
					Total			176848.3

Table 5. Parameters of capacity planning

No	Parameters	Value
1	Estimating the number of users $N(t)$	55,858 users
2	Data rate	1249.11 Mbps
3	Traffic demand ($G(t)$)	54 bps

4.3. Network design simulation

The purpose of conducting the network planning simulation is to map the minimum number of gNodeB needed to cover the Parepare City area. After simulating the network design using Atoll software, the average values for the synchronization signal-reference signal received power (SS-RSRP), signal-to-interference-plus-noise ratio (SS-SINR), and throughput parameters were obtained. This simulation provided plot results that estimated the number of sites based on a radius, totaling 327 sites for both scenario 1 and scenario 2 evenly distributed across Parepare City.

However, the plot results mapped some sites in hilly areas where there are no population and no available electricity supply. Therefore, the calculation results were manually entered to examine the relationship between the simulation results and the calculations that had been performed. The site locations based on the plot from the Atoll software are shown in Figure 3.

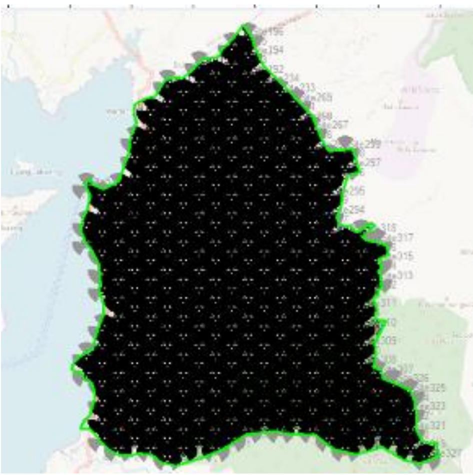


Figure 3. Sites based on Atoll recommendations

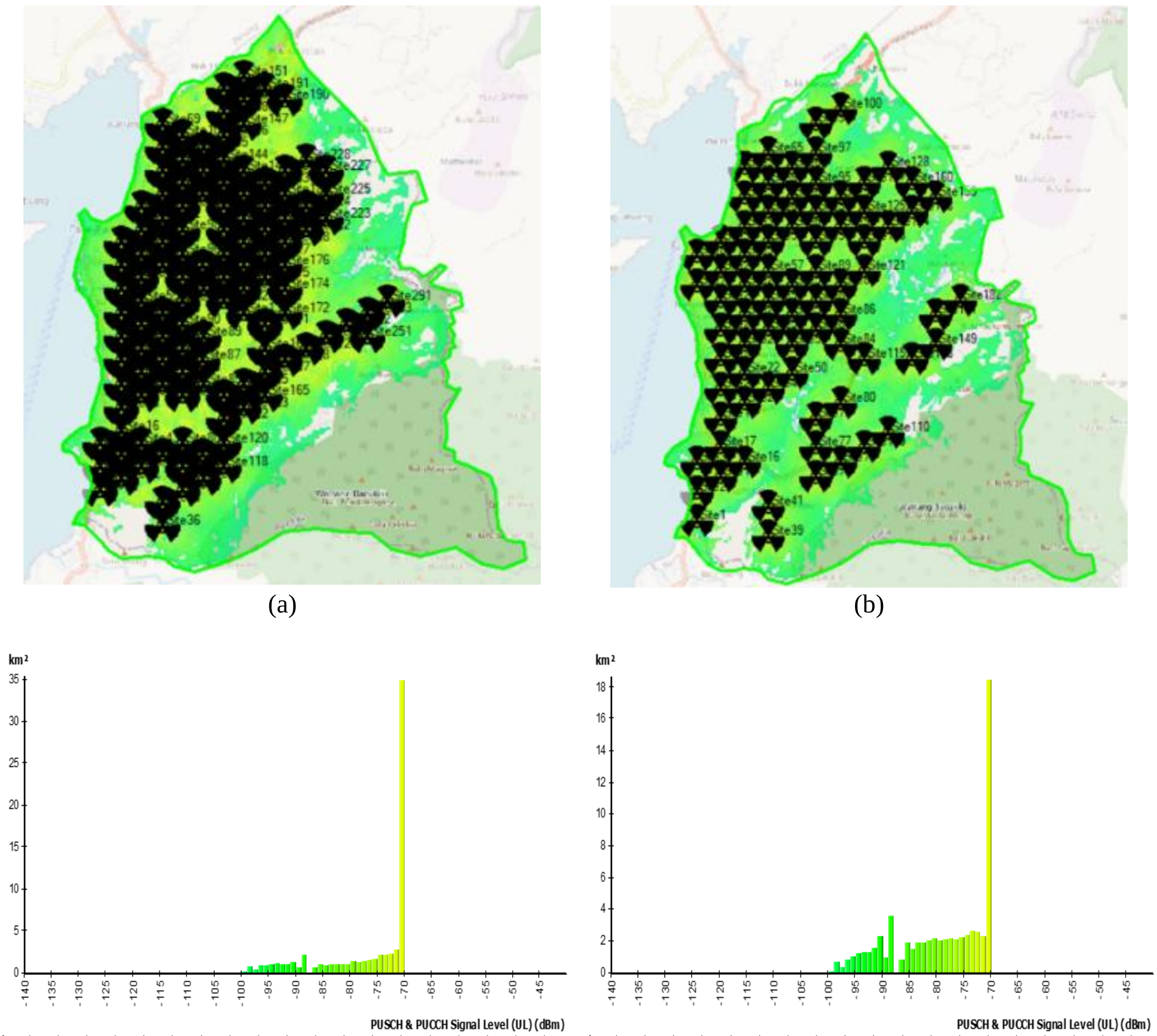
4.4. Simulation result of coverage planning

The results of the 5G cellular network planning in Parepare City for the coverage planning scenario, based on the simulations and calculations performed, can be seen in Table 6 and Figure 4. This table presents an overview of the site distribution and key parameters assessed during the planning process. The data serves as a basis for evaluating the efficiency and performance of the network design in various areas of the city.

The prediction of the SS-RSRP parameter is used to determine the signal strength that can be received by the UE with the placement of 121 sites for scenario 1, as shown in Figure 4(a), and 76 sites for scenario 2, as shown in Figure 4(b), at the planning location. Based on Figure 4(c), the average SS-RSRP value obtained has met the key performance indicators (KPI) standard of -75 to -65, categorized as very good. Based on Figure 4(d), the average SS-RSRP value obtained has met the KPI standard of -95 to -75, categorized as good. Therefore, it can be concluded that both simulation scenarios are satisfactory and can be implemented for 5G network planning.

Table 6. Simulation results and coverage planning calculations for all scenarios

Parameter	Scenario 1	Scenario 2
Number of gNodeB	121	76
SS-RSRP (dBm)	-75	-79



(a) (b) (c) (d)

Picture 4. SS-RSRP parameter prediction for all scenarios: (a) site distribution for scenario 1 (57 gNodeB Sites), (b) site distribution for scenario 2 (76 gNodeB Sites), (c) SS-RSRP coverage result for scenario 1, and (d) SS-RSRP coverage result for scenario 2

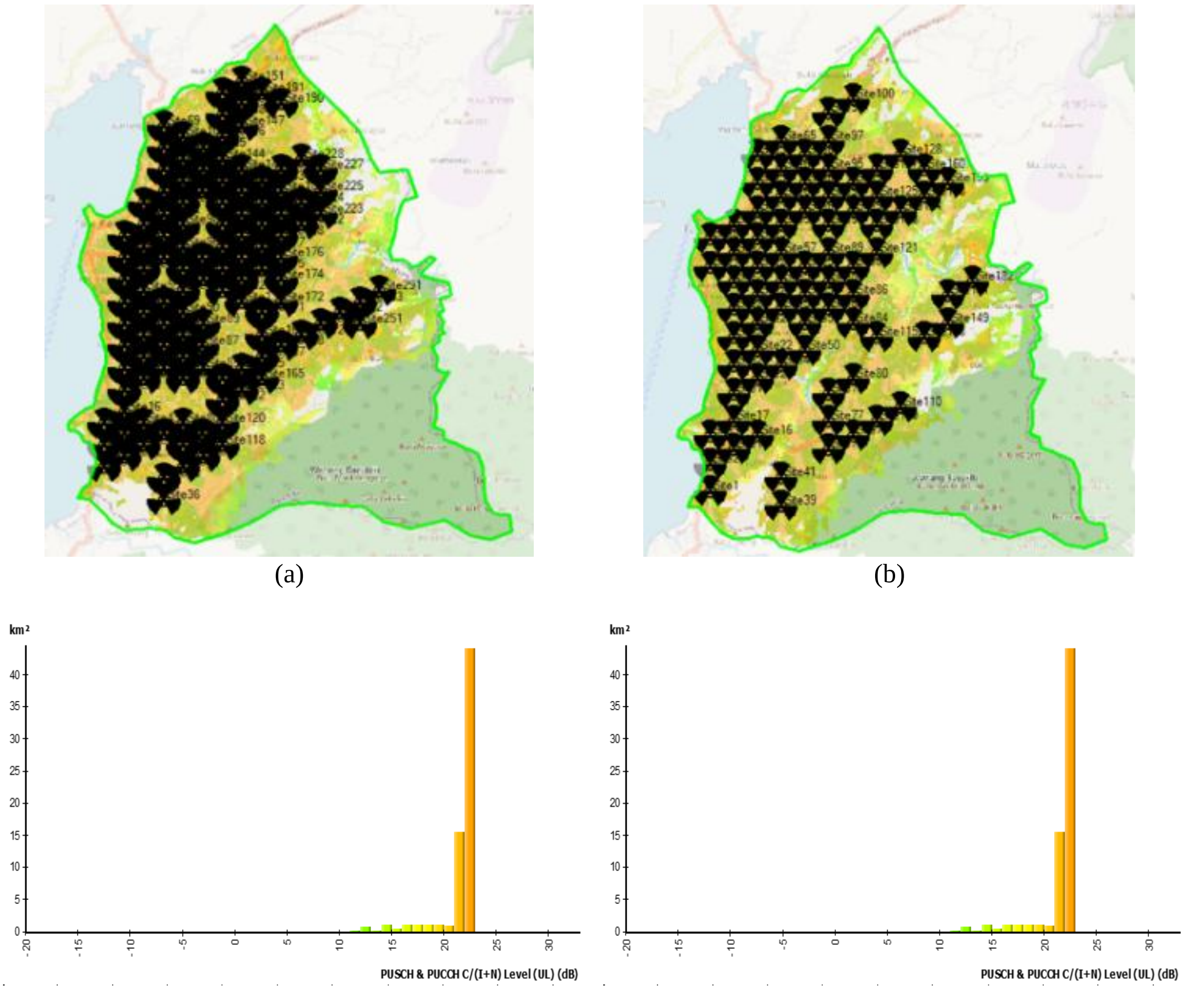
4.5. Simulation result of capacity planning and throughput parameter prediction

The 5G cellular network planning results for Parepare City in the capacity planning scenario are shown in Table 7 and Figure 5. These results are based on simulations and calculations. The results of the throughput parameter prediction simulation can be seen in Figure 6.

Table 7. Simulation results and capacity planning calculations for all scenarios

Parameter	Scenario 1	Scenario 2
Number of gNodeB	121	76
SS-SINR (dB)	21,93	21,66
Throughput (Mbps)	61	50

Figure 5(a) shows the predicted SS-SINR parameter, which indicates signal quality and the signal power ratio received to the interference and noise power received by the UE with 121 sites in scenario 1. Figure 5(b) shows the placement of 76 sites in scenario 2. These figures provide a detailed view of how the signal quality varies with different site placements. Figure 5(c) shows that the average SS-SINR value meets the KPI standard, ranging from 20 to 30, categorized as very good. Based on Figure 5(d), the average SS-SINR value also meets the KPI standard, ranging from 20 to 30, categorized as very good. The predicted throughput parameter in all scenarios can be seen in Figure 6.



(a) (b)

(c) (d)

Picture 5. SS-SINR parameter prediction for all scenarios: (a) SS-SINR prediction for scenario 1 (121 gNodeB Sites), (b) SS-SINR prediction for scenario 2 (76 gNodeB Sites), (c) average SS-SINR result for scenario 1, and (d) average SS-SINR result for scenario 2

The predicted throughput parameter indicates the data transmission speed received by the UE, with the placement of 121 sites in scenario 1 in Figure 6(a) and 76 sites in scenario 2 in Figure 6(b) at the designated planning locations. Figure 6(c) shows an average simulation result of 61 Mbps in scenario 1, while Figure 6(d) shows an average simulation result of 82 Mbps in scenario 2. The throughput values achieved are in accordance with the IMT-2020 capability recommendation, which sets the standard at 100 Mbps. These simulation results are satisfactory and can be used for 5G network planning.

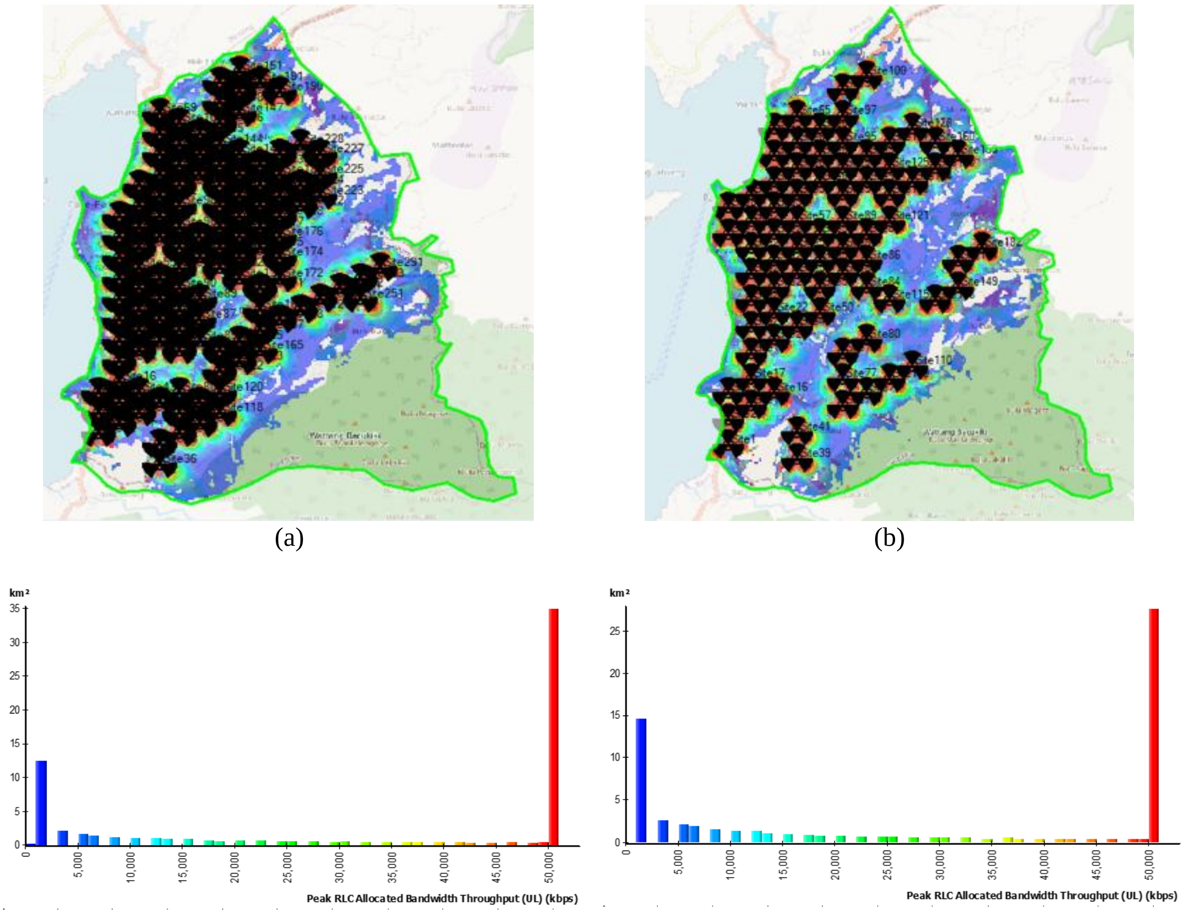


Figure 6. The predicted throughput parameter in all scenarios: (a) throughput simulation result for scenario 1 (121 gNodeB Sites), (b) throughput simulation result for scenario 2 (76 gNodeB Sites), (c) average throughput result for scenario 1 (61 Mbps), and (d) average throughput result for scenario 2 (82 Mbps)

Based on the calculations and simulations conducted using Atoll software with two different scenarios, where each scenario has a different number of sites, new site additions were made to cover the city of Parepare in a 5G network. The gNodeB site mapping was carried out based on coverage planning and capacity planning calculations, utilizing a 3.5 GHz frequency in the medium frequency band category and a 100 MHz bandwidth. The placement of gNodeB sites was determined by the efficiency of the covered areas, such as business, government, and urban communities, while also considering the population distribution in the city of Parepare.

Based on the discussion, this study illustrates the capacity aspect of the trade-off between coverage and capacity. The presented data compares two planning scenarios with different numbers of gNodeBs, which clearly demonstrates a direct correlation between the number of gNodeBs and throughput, a key metric for network capacity. Specifically, scenario 1, which includes 121 gNodeBs, achieves an average throughput of 61 Mbps. In comparison, scenario 2 with a significantly smaller number of gNodeBs (76), yields a lower average throughput of 50 Mbps.

These results convincingly support the fundamental principle of modern network planning: cell densification through the addition of gNodeBs effectively increases network capacity. While the document does not explicitly present a scenario where coverage is sacrificed for capacity, the available data clearly validates that an increased number of gNodeBs is crucial for enhancing capacity. Thus, this finding is consistent with the fundamental logic that in a dense 5G network environment, the primary focus is on increasing capacity to accommodate high data demands.

In this study, several significant contributions to the field of 5G network planning, particularly in the context of coastal city implementation. In this study, present a detailed comparative analysis distinguishing two network planning scenarios, which effectively highlights the trade-off between the number of gNodeBs and network throughput, while also providing practical insights for future optimization.

Uniquely, this research integrates the Bass Model calculation to project population growth in Parepare City. This approach serves as a foundation for more realistic and proactive capacity planning to anticipate future traffic demands. Finally, demonstrate the practical application of the Atoll network planning and optimization software to simulate and analyze 5G network performance. The use of this software in the specific context of a coastal city in Indonesia provides a replicable model for similar studies in other geographical regions.

5. CONCLUSION

In the results of the coverage scenario and capacity scenario calculations, there were 121 sites for scenario 1 and 76 sites for scenario 2. The placement of gNodeB sites was based on the efficiency of the covered area, considering the population distribution. The simulation results obtained were able to cover various planning areas such as business, government, and urban communities, and meet the targets of the KPI and IMT-2020. The parameters generated from the design simulation include the average values of SS-RSRP, SS-SINR, and Throughput. The average SS-RSRP simulation result for scenario 1 was -75 dBm, and for scenario 2, it was -79 dBm. The average SS-SINR simulation result for scenario 1 was 21.93 dB, and for scenario 2, it was 21.66 dB. The average Throughput simulation result for scenario 1 was 61 Mbps, and for scenario 2, it was 50 Mbps. Based on these values, it can be concluded that the simulation results are feasible for 5G network planning in Parepare City. Based on the research on the 5G NR cellular network planning at a 3.5 GHz frequency in Parepare City, further development is needed for this study. Future research should include the use of different frequencies and wider bandwidths, along with different research areas, to ensure continuous advancement in 5G cellular network planning.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Sulwan Dase	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		
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Sandryones Palinggi	✓		✓	✓			✓		✓	✓	✓		✓	✓

C	:	**C**onceptualization	I	:	**I**nvestigation	Vi	:	**Vi**sualization
M	:	**M**ethodology	R	:	**R**esources	Su	:	**Su**pervision
So	:	**So**ftware	D	:	**D**ata Curation	P	:	**P**roject administration
Va	:	**Va**lidation	O	:	Writing - **O**riginal Draft	Fu	:	**Fu**nding acquisition
Fo	:	**Fo**rmal analysis	E	:	Writing - Review & **E**diting			

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest related to the completion of this research. This study was made possible through collaborative efforts among PNUP, POLIBOS, and UKI Toraja, whose support greatly contributed to the success of the research. Appreciation is also extended to the Parepare City Government and the Parepare City Statistics Agency (BPS) for providing the essential data used in this work. Furthermore, the research received financial support from the BLU Funding of the Polytechnic State of Ujung Pandang, Makassar, Indonesia.

INFORMED CONSENT

We declare that informed consent was obtained from all individuals involved in this study, ensuring that each participant fully understood the purpose, procedures, and use of the data collected.

ETHICAL APPROVAL

This study received ethical approval from the appropriate institutional review authorities, ensuring that all research procedures complied with established ethical standards and guidelines. All methods were conducted responsibly, with careful consideration for participant rights, data privacy, and overall research integrity.

DATA AVAILABILITY

All data used in this study are available upon reasonable request, including datasets obtained from the Parepare City Statistics Agency (BPS Kota Parepare) and the Parepare City Government. These external data sources have been properly cited and referenced in the manuscript. Additional supporting data generated during the research can be accessed through the corresponding authors, in accordance with standard data-sharing policies and ethical guidelines.

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