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Implementation of an LTE Network designed for downtown of Gharyan city using Mentum Planet based on PGM & Q9 models

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Abstract

With the growing demand for fast and reliable telecommunications infrastructure, deploying a Long-Term Evolution (LTE) network has become a necessity to support both economic and social development. This paper presents three proposed layouts for designing an LTE network in the downtown area of Gharyan, which represents the city's central and most densely populated zone. The project was motivated by the uneven distribution of coverage across the area, where several locations experience either a complete lack of service or very weak signal reception. The aim is to support the city's digital transformation by improving access to mobile internet and data services, which in turn enhances business performance, emergency response, public service efficiency, education, remote learning, telemedicine, and remote work opportunities. To implement this plan, the design process relied on Mentum Planet software, a tool specialized in mobile network planning, using real-world terrain and signal data provided by Almadar Company. Three different network layout designs were simulated using two built-in propagation models: the Planet General Model (PGM) and the Q9 model. These simulations were conducted to assess signal strength and coverage across the study area. The analysis showed that one of the layouts provided significantly better signal quality and broader coverage compared to the others. Moreover, the Q9 model proved more reliable in predicting signal behavior in densely built urban settings. Based on these findings, a set of technical recommendations has been developed to guide the future implementation of LTE networks in similar environments, while also addressing challenges such as terrain variations, signal interference, and infrastructure limitations. In conclusion, this work contributes to enhancing telecommunications services in Gharyan and supports broader efforts toward innovation and digital inclusion across key sectors in the region.

Keywords: LTE, 4G, Q9, PGM, Mentum Planet

1. Introduction

Telecommunication technology has witnessed remarkable advancements over the past decades, evolving from the first generation (1G), which was limited to voice communication, to the fourth generation (4G), which introduced high-speed data transmission and low latency. This transformation was driven by the growing demand for modern applications that require fast and reliable connections, such as high-definition video streaming, online gaming, and augmented and virtual reality applications. In this context, 4G LTE technology has become a cornerstone of modern digital infrastructure, offering enhanced performance and greater flexibility, particularly in densely populated areas. [1]

Despite these capabilities, several technical challenges remain especially those related to coverage quality, efficient resource distribution, and signal loss that continue to affect overall network performance. The core research problem lies in the need for accurate models capable of predicting signal losses (Path Loss) in 4G networks, which is crucial for improving network planning and operational efficiency. Relying on unsuitable or randomly selected models may lead to weak coverage, increased interference, and a significant decline in network

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performance. The importance of this study stems from the widespread reliance on 4G networks, particularly in regions that have not yet transitioned to fifth-generation (5G) systems. As a result, any enhancement in the design of 4G networks has a direct impact on service quality and communication reliability, especially in the face of rising demand for wireless connectivity. Furthermore, the outcomes of such studies can serve as a foundational reference when planning for future network generations.

This study primarily aims to develop an efficient and well-structured coverage plan for a 4G network within the target area, with a focus on optimizing coverage distribution and minimizing signal losses. As part of this objective, four different mathematical models will be applied to calculate path loss. The process involves substituting data into each model's equations to compare the outcomes and identify the model that results in the smallest possible cell radius ensuring efficient network design. Following this theoretical phase, the study will move to the practical simulation stage using the Mentum Planet software, where the Q9 and PGM models will be employed to simulate the network's real-world performance. The results will then be presented and discussed in detail in the Results and Discussion section, followed by the Conclusion, which summarizes the key findings and offers recommendations for improving future network planning.

2. Planning a 4G LTE Networks

The process of planning a 4G LTE networks is a vital step in achieving optimal performance and ensuring the necessary coverage, required capacity, and expected quality for end users. This planning process relies on analyzing a range of technical and operational factors, such as identifying optimal locations for base stations, analyzing technical requirements, and assessing user behavior patterns. The tool used in this study is "Mentum Planet," which is considered one of the leading tools in the field of wireless network planning. This tool provides a range of functions that assist in designing, analyzing, and optimizing 4G LTE networks. For the theoretical models for Path Loss, the signal strength decreases due to the path distance, operating frequency, weather conditions, indoor environments, reflection, diffraction, scattering, free space loss, and absorption by environmental objects. It is also affected by different environments (such as urban, suburban, and rural areas, forests, seas, etc.). Differences in the height of the transmitting and receiving antennas also result in losses. [2]. This is where theoretical models for signal attenuation come into play, as they are an essential part of the planning process for 4G LTE networks. These models describe the behavior of the signal as it is transmitted from the transmitter to the receiver [2], helping to estimate signal loss. From this, one can gain insights into permissible path loss and the maximum cell range. There are several models used to calculate path loss, this paper discusses only four models, which are:

1. Free Space Path Loss Model [3].
2. Okumura-Hata Model [4].
3. Cost 231 Hata Model [5].
4. Lee Model [5].

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For comparison of Signal Loss Estimation Models**,** Table 1 presents the results related to Path Loss derived from the preceding headings and the distance between the transmitter and receiver, with the received power fixed at $-90\ dB_m$. This value is considered excellent for achieving good coverage in the downtown city. Additionally, the calculations are based on the following parameters: $f = 1800\ MHz$, $transmitter\ power = 46\ dB_m$, height of the base station $(h_t) = 24\ m$, and height of the receiver $(h_r) = 1.5\ m$ It is also taken into account that the city is urban. In the following table, P_r denotes the received power.

Table 1: Path Loss and Distance Measurements for Urban Coverage

Models	$\boldsymbol{d = 0.75\ Km}$	$\boldsymbol{d = 1.03\ Km}$	$\boldsymbol{d = 2.89\ Km}$
Okumura-Hata	$P_r = -85.15\ dB_m$	$P_r = -90.09\ dB_m$	$P_r = -106.16\ dB_m$
Cost 231-Hata	$P_r = -90.10\ dB_m$	$P_r = -95.04\ dB_m$	$P_r = -111.11\ dB_m$
Lee	$P_r = -68.46\ dB_m$	$P_r = -73.53\ dB_m$	$P_r = -90.02\ dB_m$

It is noted that the COST 231-Hata model predicts the highest loss among the models mentioned earlier, followed by the Okumura-Hata model and then the Lee model. Therefore, in this paper, the COST 231-Hata model will be taken into account to ensure the best possible coverage.

3. Simulation and Calculations

Simulation is a vital tool in network planning, allowing engineers to understand network behavior under various conditions and assess potential performance. the simulation process using Mentum Planet, a powerful tool in the field of wireless network planning, as shown in figure 1, which shows the main interface of Mentum Planet presenting the map of downtown of Gharyan city.

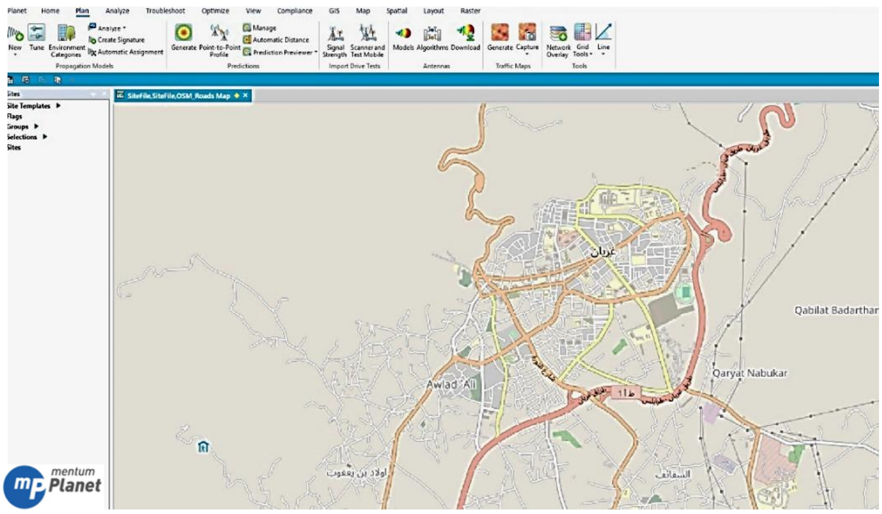

Figure 1: Main Interface of Mentum Planet showing map of downtown of Gharyan city

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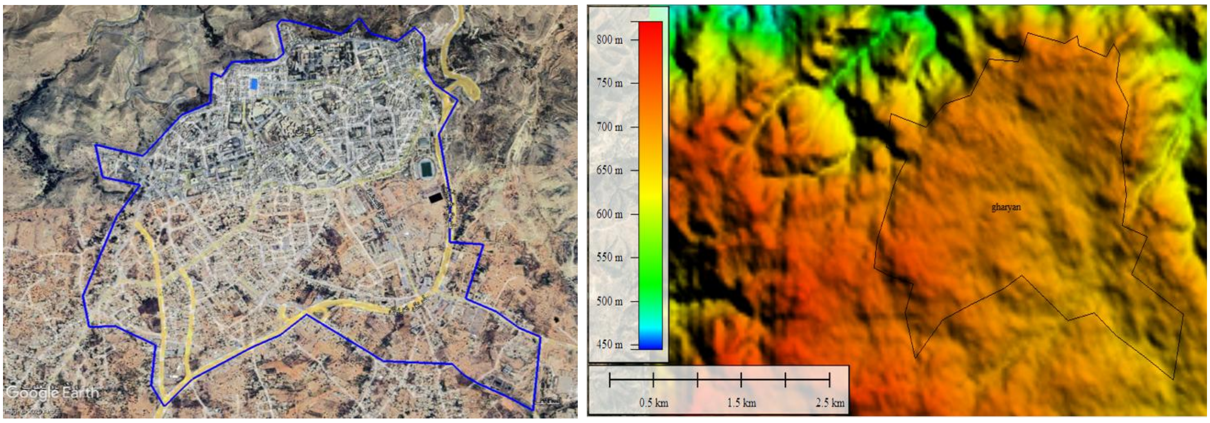
- **Study Site Survey:**

The downtown area is located in the middle of Gharyan city, characterized by high population density, especially during peak hours around noon. While its area is approximately 6.13 Km^2. By implementing three different scenarios of a 4G network for the central area downtown of the city and comparing the results derived from them. Figure 2 (a) shows the downtown map as captured from Google Earth, While the Figure 2 (b) illustrates the elevation of the study area using Global Mapper.



(a) (b)

Figure 2: (a) Map of city downtown via Google Earth, (b) Digital Elevation Grid Format in Global Mapper

By assuming the radius (R) of the antenna, based on the results of the Cost 231-Hata model, which is 0.75 Km, the number of antennas needed can be calculated easily by calculating the area covered by an antenna with 3 scatterers, using the following formula: [6]

$$A = \frac{9*\sqrt{3}}{8} * R^2 \qquad (1)$$

In this case:

$$A = \frac{9*\sqrt{3}}{8} * (0.75)^2 = 1.096Km^2$$

From this, and from the approximate area of downtown (6.13 Km^2). It is possible to determine how many antennas are needed to cover the area, as shown:

$$No. of\ attenas = \frac{6.13}{1.096} = 5.593 \approx 6 \qquad (2)$$

From the comparison between the previous used models, Cost 231 Hata model was found to be the most accurate in predicting path loss. For enhancing the network efficiency, its results were taken into account by using the distance it predicted when the received power was -90 dBm. However, Simulations will not be conducted using this model; instead, other existing models from Mentum Planet, which are more complex, realistic, and continuously evolving, will be used. These models include:

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- **Planet General Model (PGM):**

The Planet General Model is a vital tool for cellular network planning, operating within a frequency range of $150\ to\ 2000\ MHz$. It is effective for distances from $1\ to\ 100\ km$, with base station antenna heights ranging from $30\ to\ 1000\ meters$ and mobile station antenna heights between $1\ and\ 10\ meters$. This model contributes to estimating signal propagation, ensuring adequate coverage, and optimizing antenna locations based on terrain profiles, making it an ideal choice for cellular network design and given as [7]:

$$P_{RX} = P_{TX} + K_1 + K_2 \log(d) + K_3 \log(H_{eff}) + K_4 Diffraction + K_5 \log(H_{eff}) \log(d) + K_6(H_{meff}) + K_{CLUTTER} \quad (3)$$

Where:

$\boldsymbol{P_{RX}}$ is the receive power in dBm.
$\boldsymbol{P_{TX}}$ is the transmit power (ERP) in dBm.
$\boldsymbol{K_1}$ is the constant offset in dB.
$\boldsymbol{K_2}$ is the multiplying factor for $\log(d)$.
$\boldsymbol{K_3}$ is the multiplying factor for $\log(H_{eff})$. It compensates for gain due to antenna height.
$\boldsymbol{K_4}$ is the multiplying factor for diffraction calculation.
$\boldsymbol{K_5}$ is the Okumura-Hata type of multiplying factor for $\log(H_{eff}) \log(d)$.
$\boldsymbol{K_6}$ is the correction factor for the mobile effective antenna height gain $(K_6 H_{meff})$.
$\boldsymbol{d}$ is the distance, in meters, of the receiver from the base site.
$\boldsymbol{H_{eff}}$ is the effective height of the base site antenna from the ground.
$\boldsymbol{Diffraction}$ is the value calculated for loss due to diffraction over an obstructed path. The value produced is a negative number, so a positive multiplication factor, K_4 is required.
$\boldsymbol{K_{CLUTTER}}$ is the gain in dB for the clutter type at the mobile position in Planet DMS. In Mentum Planet, $K_{CLUTTER}$ represents a loss.
$\boldsymbol{H_{meff}}$ is the mobile effective antenna height.

- **Q9 Model:**

The Q9 model is used to estimate expected path loss between the transmitter and receiver based on terrain profiles. This model is based on the Okumura-Hata model and is particularly effective for frequencies ranging from $150\ to\ 2000\ MHz$ and distances from $0.2\ to\ 100\ km$ and given as [8]:

$$L_b = HOA + mk[mobile] + \sqrt{(a * KDFR)^2 + (JDFR)^2} \quad (4)$$

$$HOA = A_0 + A_{11} + A_2 \log(HEBK) + A_3 \log(d) \log(HEBK) - (3.2\,[\log\,(11.75hm)]^2 + g(F)) \quad (4)$$

$$A_{11} = A_1 * \log d \quad (5)$$

$$g(F) = 44.49 \log F - 4.78(\log F)^2 \quad (6)$$

Where:

$\boldsymbol{L_b}$ is the pathloss.
$\boldsymbol{mk}[\boldsymbol{mobile}]$ is the land use code at the mobile in dB.
$\boldsymbol{a}$ is a parameter related to the knife-edge diffraction.
$\boldsymbol{KDFR}$ is the contribution from knife-edge diffraction in dB.

$JDFR$ is the diffraction loss due to the spherical earth in dB.
HOA (Hata Open Area) is a variant of Okumura-Hata's equation in dB.
$HEBK$ is the effective antenna height in meters as defined in the Q9 propagation model.
d is the distance from the base antenna to the mobile in Km.
A_0, A_1, A_2, A_3 are Q9 model tuning parameters.

Two scenarios are taken inconsideration, each using one model (PGM or Q9 model). Additionally, there will be three layouts with the same antenna height, bandwidth, and receiver height, while differing in the location, number, and angles of the sectors. Table 2 presents the input data used.

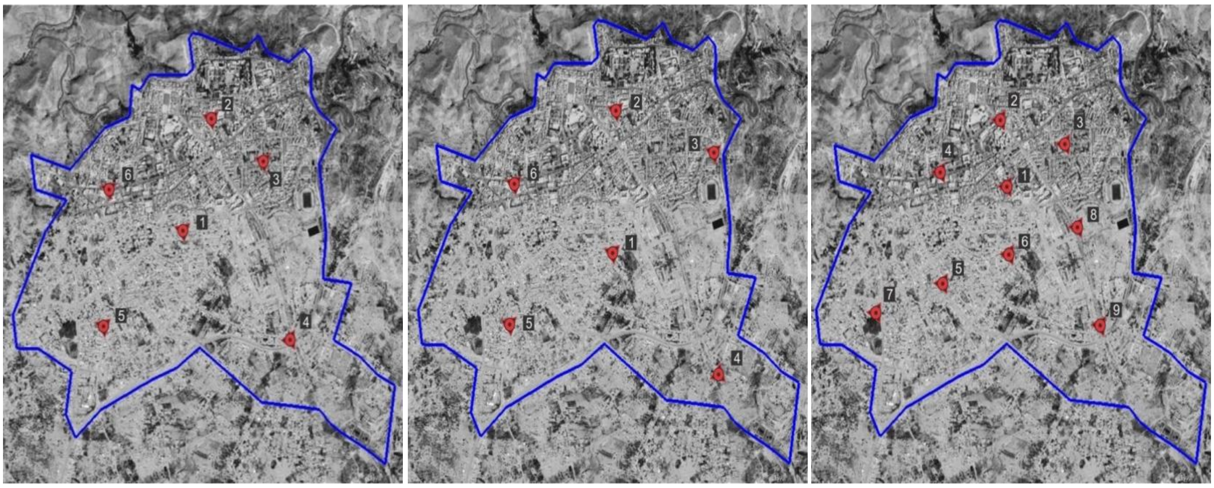
Table 2: Input data

Frequency	Base station height	Receiver height
1800 MHz	24 m	1.5 m

Layout 1: In this layout, six antennas were utilized and distributed to cover the entire study area, as shown in Figure 3 (a). The angles of each sector were adjusted to avoid interference, as detailed in Table 3.

Layout 2: This layout focused on the upper part of the area, which has the highest population density and a greater number of buildings, using six antennas as illustrated in Figure 3 (b). The angles of each sector were also adjusted as indicated in Table 3.

Layout 3: The number of antennas was increased to a total of nine to strengthen coverage not only in the upper area but across the entire study area, as shown in Figure 3 (c). This layout can be utilized in the future when obstacles increase and capacity needs to be expanded. The angles of each sector were adjusted as shown in Table 3.



(a) (b) (c)

Figure 3: Antenna Distribution of (a) Layout 1 (b) Layout 2 (c) Layout 3

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The following table shows the angles of each sector adjusted to avoid interference for all three layouts.

Table 3: Sector Angles for each of Layout 1, Layout 2 & Layout 3

No. of antennas	Layout 1			Layout 2			Layout 3		
	Azimuth			Azimuth			Azimuth		
1	50	170	290	50	170	290	50	170	290
2	50	170	290	50	170	290	50	170	290
3	50	170	290	50	170	290	50	170	290
4	10	120	285	40	140	290	50	170	290
5	50	170	290	50	170	290	50	170	290
6	50	170	290	50	170	290	50	170	290
7							50	170	290
8							50	170	290
9							50	170	290

4. Results and Discussion

PGM Scenario: In this scenario, simulations were conducted using PGM for all layouts, and the results of each layout were presented in an image that illustrates the signal strength across the area with color codes as shown in figure 4. Additionally, there is an accompanying image that features a table displaying the received power percentage for each range throughout the entire area.

Q9 Scenario: this scenario, simulations were conducted using the Q9 model for all layouts, and the results of each layout were presented in an image that uses color coding to illustrate the signal strength across the area as shown in figure 5. Additionally, there is a subsequent image that features a table detailing the received power percentage for each range throughout the entire area.

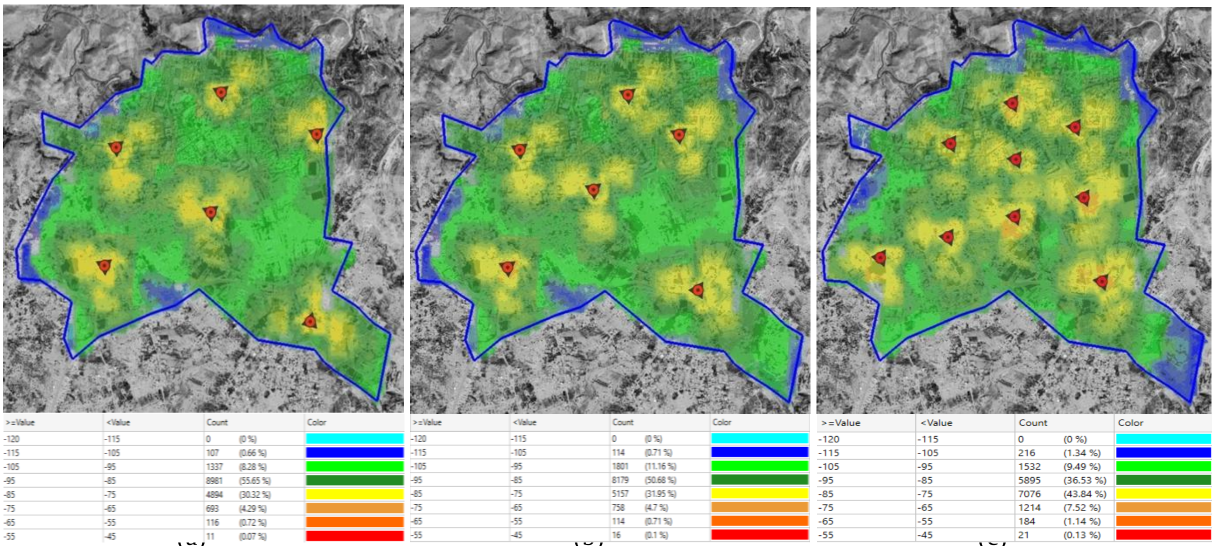

Figure 4: Coverage by Signal Level According to PGM model for (a) Layout 1 (b) Layout 2 (c) Layout 3

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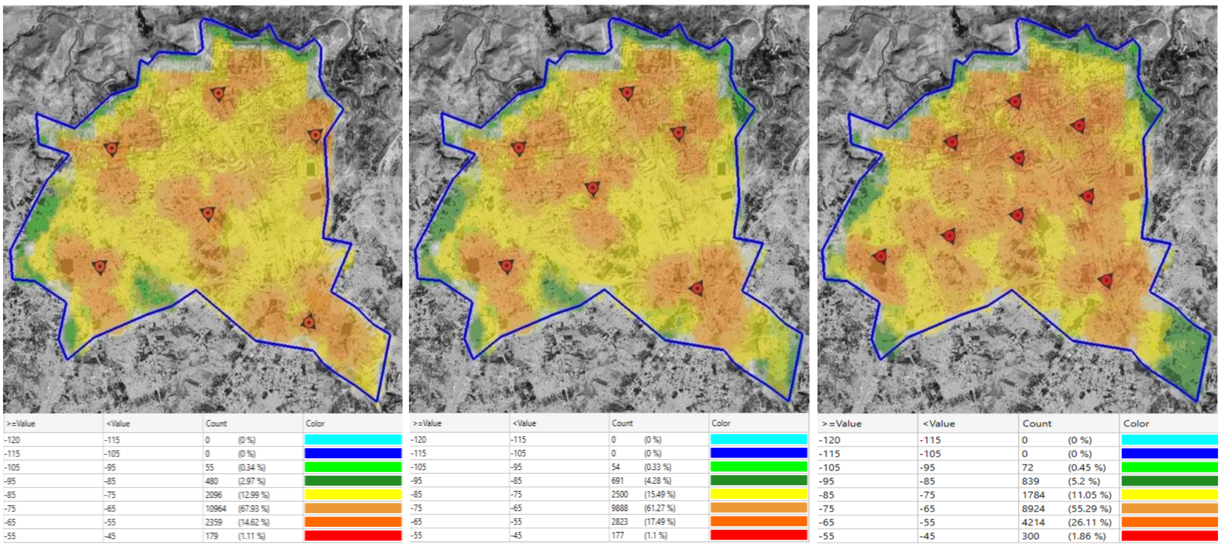

(a) (b) (c)

Figure 5: Coverage by Signal Level According to Q9 model for (a) Layout 1 (b) Layout 2 (c) Layout 3

Overall, the PGM was the most accurate in predicting losses. There were differences between the results of the first and second layouts, despite using the same number of antennas and having very similar antenna locations. The following tables illustrates the percentage of received power between $-95\ dB_m$ and $-115\ dB_m$ for each layout (The values were taken based on the previous mention that the minimum acceptable value for the received power is $-90\ dB_m$. Therefore, a comparison was made between the smaller values)

Table 4: Comparison Between Layouts in Terms of Signal Level According to both models

	Planet General Model		Q9 Model	
	$-95\ dB_m$ & $-105\ dB_m$	$-105\ dB_m$ & $-115\ dB_m$	$-95\ dB_m$ & $-105\ dB_m$	$-105\ dB_m$ & $-115\ dB_m$
Layout 1	8.28 %	0.66 %	0.34 %	0 %
Layout 2	11.16 %	0.71 %	0.33 %	0 %
Layout 3	9.49 %	1.34 %	0.45 %	1 %

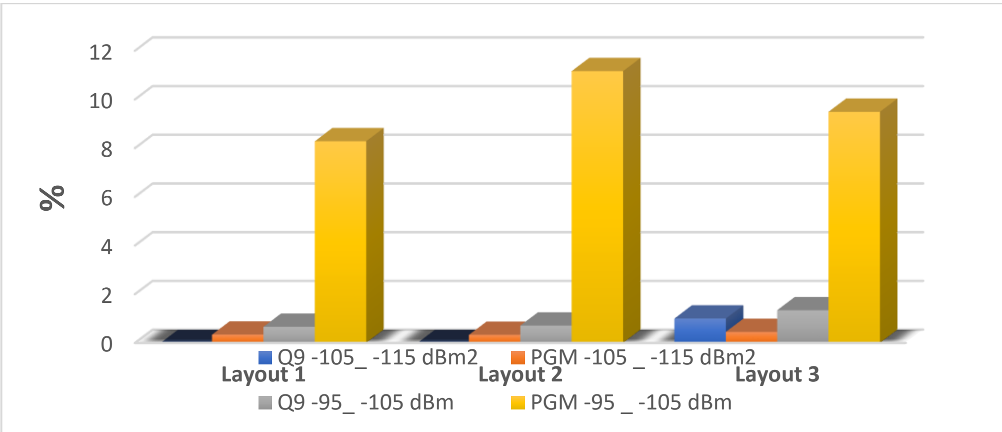

Figure 6: Error Rate Comparison Across Layouts and Signal Conditions for PGM and Q9 Models

The results predicted by the Q9 model were also quite good for all layouts, where the percentage of received power above $-95\ dB_m$ was very low. The best design is layout 1 in terms of the PGM, which is slightly better than layout 2 and also less costly than layout 3, which used more antennas than necessary. As shown in figure 6, the comparison was made based on the percentage of received power between $-95\ dB_m$ and $-115\ dB_m$, where values below $-95\ dB_m$ are considered very good. There is a significant difference between the Cost 231 Hata model and the results from the models used by Mentum Planet, with the Q9 model being the closest to the Cost 231-Hata model.

In conclusion, one might wonder why the capacity was considered as well. The answer to this question is that the goal of this paper is to provide good receiver power throughout the study area downtown of Gharyan city. Additionally, the OFDMA technology is capable of providing substantial capacity, this means that it can be relied upon in terms of capacity.

5. Conclusion

The objective of this paper has been achieved, as it was able to provide a comprehensive plan for the downtown area of Gharyan city to ensure excellent coverage with the least number of antennas. By concluded that the location, height, and number of antennas, as well as the direction of each sector, all affect coverage and the level of loss in received power. It is also shown that the increasing of number of antennas is not always the solution. When three antennas were added, representing a significant increase, the total became nine antennas; however, the results were not as expected. The received power levels did not improve significantly within the optimal range of $-45\ dB_m$ to $-65\ dB_m$. This emphasizes that good planning and thorough study of the area to identify the best possible locations for antennas is crucial, and it can save a lot of money by minimizing the number of antennas used.

One of these planning models could serve as a foundation upon which a company may build and improve to ultimately achieve the optimal network design.

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