

Performance Evaluation and Optimization of JAWWAL 3G Mobile Network

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Abstract— This paper presents a case study on the planning, evaluation, and implementation of mobile networks in Hebron city, Palestine. The performance of the network is evaluated using the drive test based-on the key performance indicators (KPIs). Following the initial drive test in the region, the network analysis revealed network coverage ratio of 21.5%, service quality ratio of 11.1%, downlink throughput ratio of 6.1%, and uplink throughput ratio of 35%. These ratios indicate inadequate coverage and poor quality of service. To address these deficiencies, we propose the planning and implementation of a new cell site in the area. After the site's construction, a subsequent drive test was conducted. The results demonstrate significant improvements across all KPIs: the coverage ratio rose to 58.7%, the service quality ratio increased to 61.1%, the downlink throughput ratio improved to 69.5%, and the uplink throughput ratio increased to 74.5%.

Keywords— Mobile network planning; signal coverage; received signal code power (RSCP); signal quality; downlink throughput; uplink throughput; drive test; key performance indicators (KPIs).

I. INTRODUCTION

During the last decades, a great deal of interest has been paid to the evaluation and optimization of mobile networks [1][2][3]. In [4], the authors have provided a comprehensive study on the evaluation and optimization of JAWWAL GSM mobile network in Jenin, a city in Palestine. The key performance indicators (KPIs) from the operation support subsystem and the drive test results were evaluated and compared before and after optimizing the networks. This includes the received signal level, received signal quality, traffic channel drop rate, and handover success rate. The research work in [5] deals with practical performance monitoring and evaluation of deployed commercial mobile broadband 3G HSPA networks, considering the radio coverage and service quality aspects in typical suburban environments. The aim is to correlate cell coverage with radio link quality performance indicators in different propagation environments. The authors in [6] evaluated the quality of the signal of 3G UMTS radio access technology of three cellular networks: MTN, 9mobile, and Airtel network over two cities in Nigeria. Result shows that 40.36%, 49.55% and 82.98% of the drive test area for Airtel, 9mobile and MTN network fell below the regulatory benchmark and subscribers in this region experienced dropped calls, blocked calls, handover failures and degraded signal quality due to interference. Airtel network was

adjudged the best network while the worst network was MTN network. The authors in [7] analyzed the 3G WCDMA network in both rural and urban areas of Mwanza, Tanzania. The parameters analyzed were Received Signal Code Power (RSCP), Transmitted Power (TX), Speech Quality Index (SQI), and the ratio of received signal power to noise (E_c/N_o). The data collected shows that only 24.02% of the region had good coverage, 23.24% had poor coverage and 52.74% had fair coverage. A well-established real 3G radio network performance evaluation is presented by the authors in [8] based on RSCP and Signal-to-Interference ratio (E_c/I_o). Their focus was to analyze the live indoor network performance of a 3G network within the confines of Distributed Antenna Systems (DAS). The test was carried out by TEMS investigation, one of the most powerful tools for measuring GSM/3G/LTE mobile wireless network performance. Practical deployment has proved that the DAS is a promising technology for improving indoor coverage and capacity in 3G mobile wireless technology. The study shows how DAS can improve both RSCP and E_c/I_o which are two important key performance indicators in delivering quality 3G services that lead to better user Quality of Experience (QoE). In [9], a reliability-based performance analysis is carried out using the RxQual as the KPI. Four 2G GSM operators are considered: MTN, 9mobile, Airtel and Globacom network. In [10], the authors have examined capacity and frequency planning, as well as coverage planning, in GSM networks. As part of the process of improvement, a driving test has been conducted. In [11], the authors assess the efficiency of mobile networks, labeled as operator A, operator B, operator C, and operator D, that offer voice communication services at the University of Ilorin, located in Ilorin, Nigeria. A drive test method was utilized to collect KPIs for accessibility, retain-ability, mobility, and service integrity, in alignment with the NCC-defined target for each. The authors in [12] present the performance of 5G services by four mobile network operators (MNOs) in an urban area through a comprehensive drive test campaign. The study highlights the improvements in throughput, spectral efficiency, energy efficiency, coverage, and latency offered by 5G compared to 4G LTE. Recently in [13], the authors have evaluated the performance of the Palestinian mobile networks based on crowdsourcing measurements. The performed measurements include location information, signal level, signal quality and throughput for 3G mobile networks in Palestine.

The evaluation of these measurements reflects the relative performance of the Mobile Network Operators (MNOs).

From the literature survey above, some authors have suggested several approaches to improving the available KPIs. However, most of these approaches were not implemented and evaluated for a live 3G network. Other authors have used the drive tests to evaluate the performance of active GSM networks in terms of signal coverage and signal quality. Nevertheless, to the best of our knowledge, there are no comprehensive research works that combine both the KPIs and the drive tests to evaluate the performance of operational 3G mobile networks. In this paper, a comprehensive research study is carried out on the performance evaluation and optimization of the mobile network in Palestine. Particularly, we present a case study on the planning, evaluation, optimization, and implementation of a 3G mobile network in Hebron city, Palestine.

II. 3G MOBILE NETWORK PLANNING AND IMPLEMENTATION

The areas where customers experience issues will be identified based on complaints regarding insufficient signal coverage and decreased signal quality. Some locations called “complaint areas” are reporting no signal at all, as shown in Fig.1. In response to these complaints and to enhance service quality for users, a driving test will be conducted in the specific area of Idna village in Hebron, particularly at the site closest to the reported issues. This test will provide vital indicators and their corresponding percentages for each location.



Fig.1. Site location on the top of the hill and complaint area

By analyzing the results, we can pinpoint problem areas along with zones of signal strength and weakness. Based on the data we have, we will pursue one of the two solutions:

The first solution involves modifying the existing site by adjusting the antenna direction angles or adding a new sector. The second solution entails constructing a new site designed to meet the user needs, offering better signal coverage and improved signal quality across larger areas. The location of the new site will be determined by several factors, with the geographical area of the complaints being paramount. In urban settings, the site will be strategically positioned based on the nearby existing sites, with its height considerations favoring the tallest building in the neighborhood. In rural areas, the site selection will prioritize the geographical factors due to the

limited number of neighboring sites.

The second solution was selected based on both KPIs and the drive test results. To establish the new site, a qualification report will be generated detailing the critical parameters, including the number of sectors, longitude, latitude, antenna specifications, height above ground, azimuth, antenna tilt and radio transceiver power, as detailed in Table 1.

In Fig.2, the decided location for the new site is illustrated, positioned on a hill within in the middle of the complaint area suffering from inadequate signal coverage.

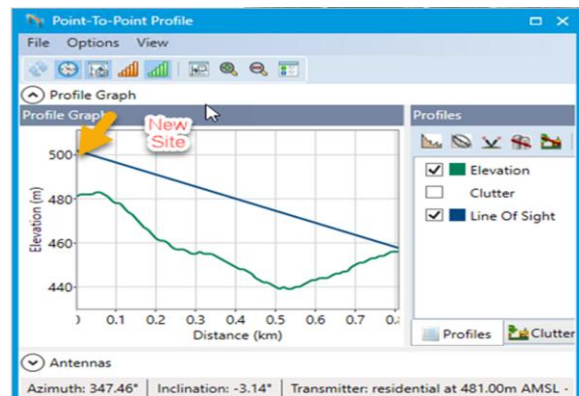


Fig.2. New site location where JAWWAL customers complaint

Fig. 3 shows the flowchart of the processes of mobile network evaluation, planning, simulation, implementation and optimization that will be carried out through this research.

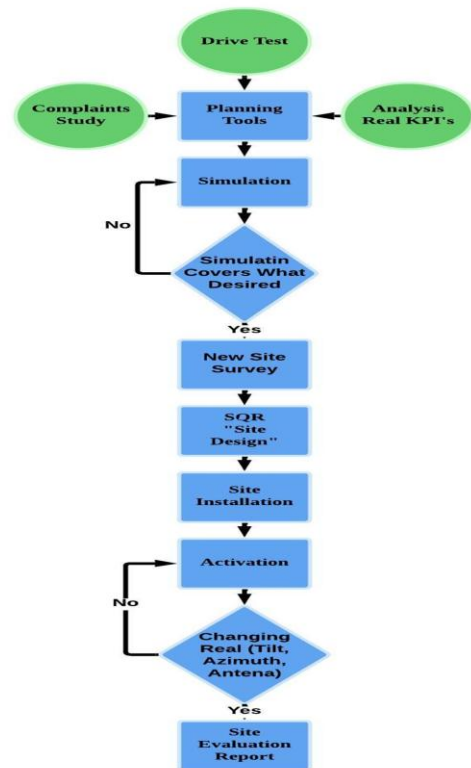


Fig.3. Flowchart of the various mobile network processes

Table 1. Site Qualification Report (SQR)

Site ID	Sectors	Longitude	Latitude	Antenna	Height (m) reference to ground	Azimuth	Antenna Tilt	Radio Transceiver Power
Site2	WCDMA1	34.972906	31.568062	45deg HBW antenna	21	60	6	Transceiver Ericsson 60 Watt
Site2	WCDMA2	34.972906	31.568062	65deg HBW antenna	21	130	9	Transceiver Ericsson 60 Watt
Site2	WCDMA3	34.972906	31.568062	33 deg HBW antenna	21	180	6	Transceiver Ericsson 60 Watt
Site2	WCDMA4	34.972906	31.568062	45deg HBW antenna	21	230	2	Transceiver Ericsson 60 Watt
Site2	WCDMA5	34.972906	31.568062	33 deg HBW antenna	21	285	4	Transceiver Ericsson 60 Watt
Site2	WCDMA6	34.972906	31.568062	45deg HBW antenna	21	340	5	Transceiver Ericsson 60 Watt

III. 3G MOBILE NETWORK EVALUATION

In order to allow for a thorough investigation, this work is separated into two stages. The first stage will investigate which KPIs are used to evaluate the performance of an operational 3G network. The second phase, which will come after this, will look at the drive test. The most important parameters obtained from the drive test are the received signal level, the received signal quality, downlink throughput, and uplink throughput.

A. Key Performance Indicators

KPIs are used to evaluate the performance of an operational 3G network. The most common KPIs are listed below:

1) Coverage-based KPIs

The capacity of a given network is measured in terms of the number of subscribers or the traffic load that it can handle. The capacity of a cell determines the number of users or simultaneous calls (in the case of speech service) the links can handle. Here, the number of calls is independent of the coverage and can be controlled by the number of carriers the operator allocates to the cell. Hence, carrier assignment is a key parameter for efficient 3G network design and must be handled carefully to ensure that the base station can cope with the offered traffic across its entire service area.

Coverage-based KPIs are essential for optimizing network performance. Key metrics include Received Signal Code Power (RSCP) and Received Signal Strength Indicator (RSSI). The RSCP stands for the received power on one code over the Control Pilot Channel (CPICH). The RSSI corresponds to the total received radio power including noise and interference. The RSCP in units of dBm is related to the RSSI in units of dBm through E_c/N_o as in equation (1):

$$RSSI [dBm] = RSCP [dBm] - \frac{E_c}{N_o} [dB] \quad (1)$$

where the quality parameter E_c/N_o stands for energy per chip over the noise plus interference power spectral density. Analyzing the data from the drive test involves evaluating four levels of RSCP strength as shown in Table 2.

Table 2. Signal Coverage RSCP levels

Strength	RSCP in dBm	Color on screen
Bad	-100 dBm	Red Color
Poor	≥ -100 dBm to < -85 dBm	Yellow Color
Good	≥ -85 dBm to < -75 dBm	Green light Color
V. Good	Above -75 dBm	Dark Green Color

2) Quality-based KPIs

In any operational communication network, Quality of Service (QoS) is a crucial concern from both customers' and providers' points of view. It is a measurable set of parameters that define the level of service that a service provider can be accountable for. QoS is defined as the collective effect of service performance, which determines the degree of satisfaction of a user of the service. QoS can also be defined as the capability of the cellular network providers to provide satisfactory service to end users. The quality of a radio network can be evaluated by examining the KPIs. Network quality in a drive test analysis focuses on the user experience while using the 3G network. It encompasses several key metrics such as E_c/N_o , SINR, throughput, and latency. Evaluating these metrics helps identify areas for improvement, ensuring a reliable and efficient network that meets user expectations. Regular monitoring and optimization based on these KPIs are essential for maintaining high standards of service quality:

$$\frac{E_c}{N_o} [dB] = 10 \log_{10} \left(\frac{RSCP}{RSSI} \right) \quad (2)$$

$$SINR = \frac{Signal Power}{Interference + Noise} \quad (3)$$

The parameter E_c/N_o is a measure of the quality of the signal and is calculated as mentioned in the above equations for the WCDMA system. SINR stands for Signal to Interference plus

Noise Ratio, which measures signal quality in-terms of the strength of the wanted signal compared to the unwanted interference and noise. Mobile network operators seek to maximize SINR at all sites to deliver the best possible customer experience, either by transmitting at a higher power or by minimizing interference and noise. Table 3 demonstrates the signal quality E_c/N_o levels in units of dB.

Table 3. Signal Quality E_c/N_o levels

Strength	E_c/N_o in dB	Color on screen
Bad	-16 Db	Red Color
Poor	≥ -16 dB to < -14 dB	Yellow Color
Good	≥ -14 dB to < -12 dB	Blue light Color
V. Good	Above -12 dB	Dark blue Color

3) 3G Downlink and Uplink Throughput

Data throughput and quality are crucial for assessing the speed and reliability of data transmission. Drive test analysis measures throughput, including upload and download speeds, to ensure a smooth user experience. 3G networks should offer speeds exceeding 2 Mbps per user. The relationship between throughput in a 3G network and the International Mobile Telecommunications-2100 (IMT-2100) standard, using Frequency Division Duplex (FDD), is vital. IMT-2100 operates in the 2100 MHz band, providing necessary bandwidth. FDD utilizes separate frequencies for uplink and downlink, reducing interference and improving transmission efficiency. This combination ensures robust and high-speed data transfer.

The IMT-2100 refers to a specific frequency range for mobile communications within the IMT-2000 series of 3G

standards established by the International Telecommunications Union (ITU). The 2100 MHz band is commonly used for the UMTS 3G system based on WCDMA.

In JAWWAL mobile operator, two channels out of the available twelve channels in the IMT-2100 band are designated for both uplink and downlink communication. Specifically, the 1920 to 1930 MHz band is used for uplink and the 2110 to 2120 MHz band is used for downlink, with each channel having a bandwidth of 5 MHz, as shown in Fig.4.

The received signal strength for both the downlink and uplink channels plays a critical role in determining data throughput, as stronger signals directly correlate with higher throughput rates measured in Kbps, as shown in Table 4. This underscores the significance of maintaining robust signal levels to ensure optimal network performance and deliver an enhanced user experience.

According to Shannon's theorem, the channel capacity (C) is determined by the bandwidth (B) and the signal-to-interference-plus-noise ratio (SINR) as follows:

$$C = B \log_2(1 + SINR) \tag{4}$$

Therefore, higher SINR values, which reflect better received signal quality, lead to higher potential throughput for both downlink and uplink channels. This relationship highlights the importance of optimizing SINR to maximize data rates and improve overall network efficiency. The bandwidth B is set to 5MHz per carrier for 3G Wideband Code division Multiple Access (WCDMA) standard.

Table 4. Received Signal Downlink and Uplink Throughput (Kbps/User) and the strength

Strength	Received Signal downlink throughput range (Kbps/User)	Received Signal uplink throughput range (Kbps/User)	Color on screen
Bad	1000 Kbps	500 Kbps	Red Color
Poor	≥ 1000 Kbps to < 2000 Kbps	≥ 500 Kbps to < 1000 Kbps	Yellow Color
Good	≥ 2000 Kbps to < 4000 Kbps	≥ 1000 Kbps to < 2000 Kbps	Turquoise Color
V. Good	Above 4000 Kbps	Above 2000 Kbps	Dark blue Color

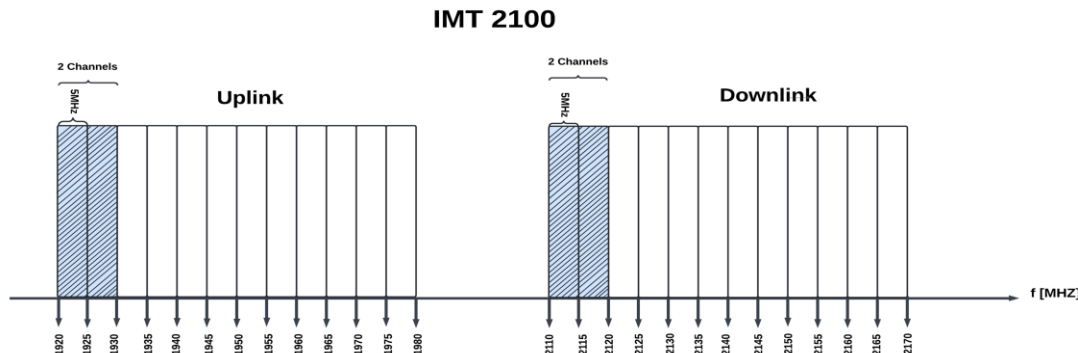


Fig.4. Allocated channels for JAWWAL mobile operator in IMT-2100 band.

B. Drive Test Analysis

Drive test analysis is a method used to evaluate the performance of mobile networks. This analysis involves collecting and analyzing data while moving through different areas using specialized testing equipment installed in a vehicle. The data collected during the drive test provides insights into the network's coverage, quality, and performance, helping network operators optimize their infrastructure and improve the user experience. Field measurements of network performance parameters consist of software installed on one or more mobile devices with a GPS receiver to place the collected samples at their corresponding coordinates on a digital map. The network and integration will be tested by conducting extensive testing to ensure that the network elements work together seamlessly. Driving tests and field measurements will be conducted to evaluate the signal strength, quality, and coverage in the complaint area. Then, driving tests will be conducted after the problem is resolved in building a new site.

We will first start with the results of the driving test through the site located in the area, then conduct a simulation to determine the location of the new site, and finally perform a test drive after placing the new site and displaying its results.

Fig. 5 and Fig. 6 show, respectively, the drive test signal coverage (RSCP) and signal quality (E_c/N_0) before the activation of the new site.

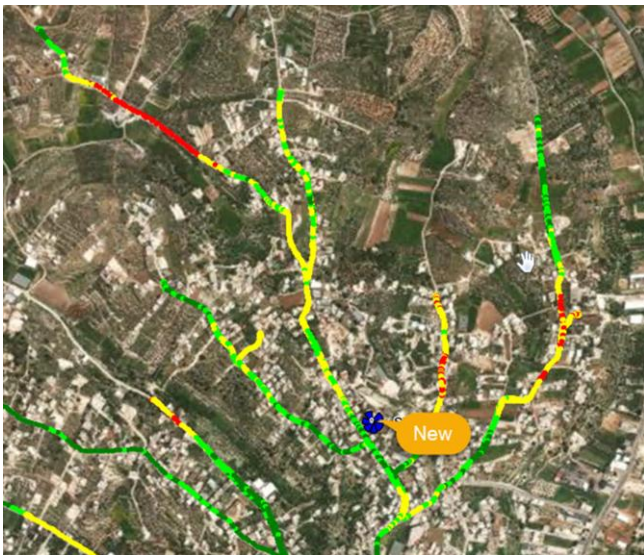


Fig.5. Drive test signal coverage before activating the new site

Data quality assesses the speed and reliability of data transmission. Drive test analysis measures data throughput, downlink, and uplink throughput. Fig. 7 indicates downlink throughput before the new site, while Fig. 8 indicates uplink throughput before the new site.

Based on the drive test, subscribers' complaints about poor coverage, signal quality, and poor downlink and uplink

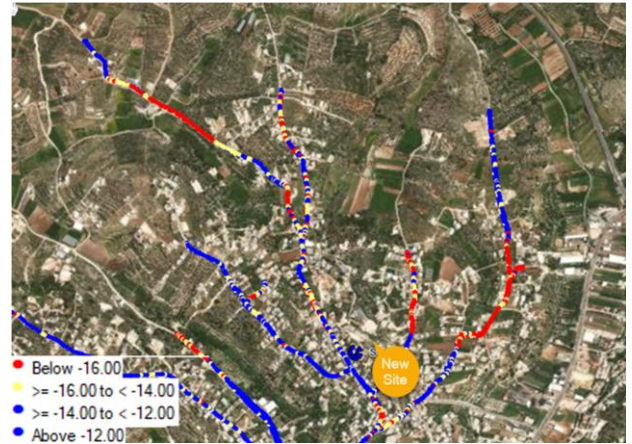


Fig.6. Drive test signal quality before activating the new Site



Fig.7. Downlink Throughput before activating the new Site2



Fig. 8. Uplink Throughput before activating the new Site2

throughput are indeed valid. As shown in Fig. 9, simulation has been created. After studying the area for coverage, noise, and throughput, we can conclude that the area needs a new resource or new site, but we must ensure optimal design and location before surveying this new site.

The best signal simulation is located in the blue category, which is from -70 dBm to -80 dBm. Additionally, the new Site2 will cover an area from Site 1; this means we have to limit Site1 there, which will decrease the handled traffic on Site1 and provide more capacity in the neighboring area.

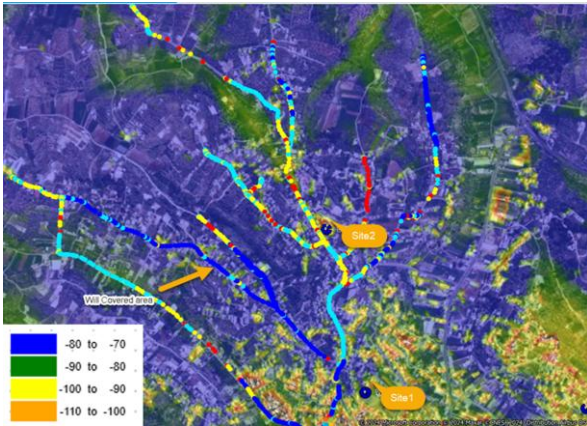


Fig. 9. New Site (Site2) simulations.

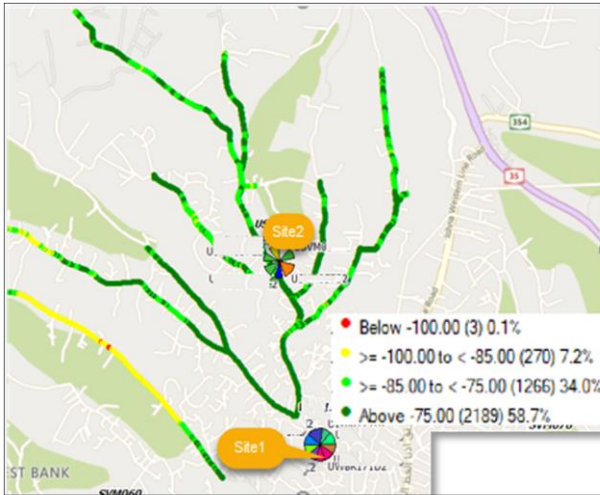


Fig.10. Drive test signal coverage after activating the new Site2

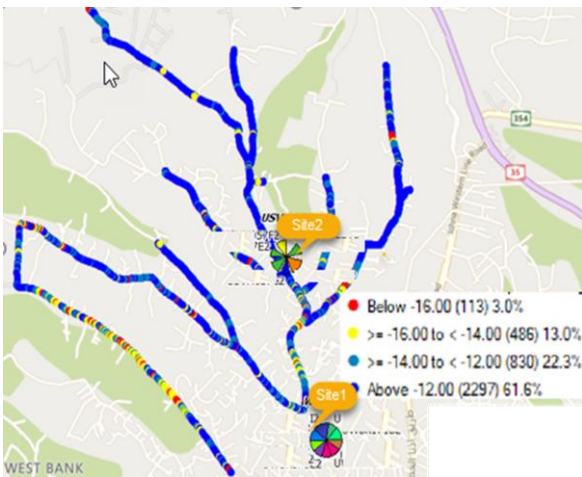


Fig.11. Drive test signal quality after activating the new Site2

As for the driving test after the new site was placed in the specified location, the result of the signal coverage and signal quality are shown in Fig. 10 and Fig. 11, respectively. Ultimately, downlink throughput and uplink throughput improved significantly, as shown in Figs. 12 and 13, respectively. From April 20th to May 7th, 2024, as shown in Fig. 14, the total downlink traffic volume for all users connected to Site2 averaged approximately 270 GBytes, while the average uplink traffic volume was around 47 GByte.

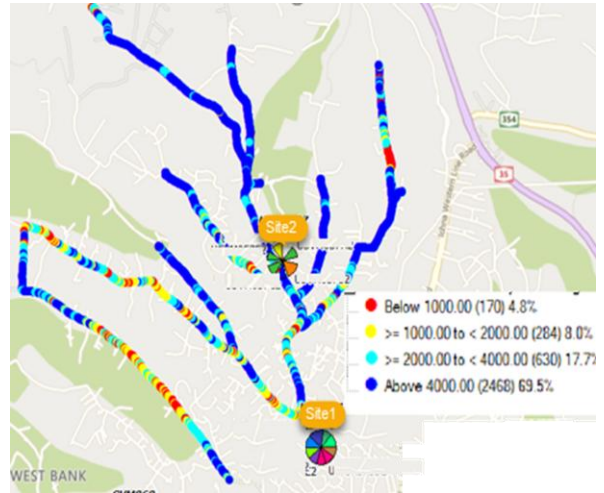


Fig.12. Downlink throughput after activating the new Site2

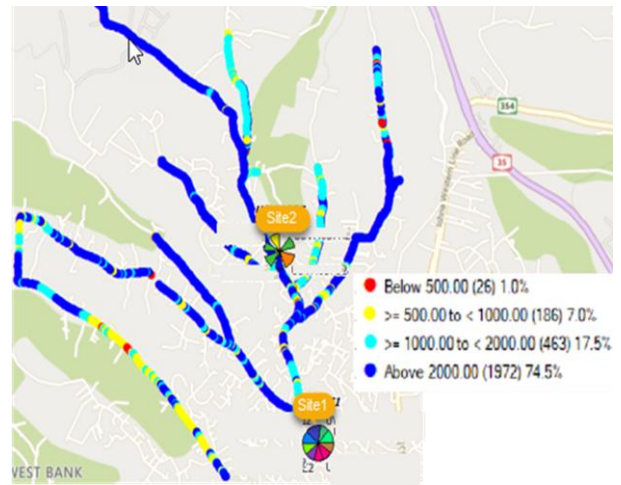


Fig.13. Uplink throughput after activating the new Site2

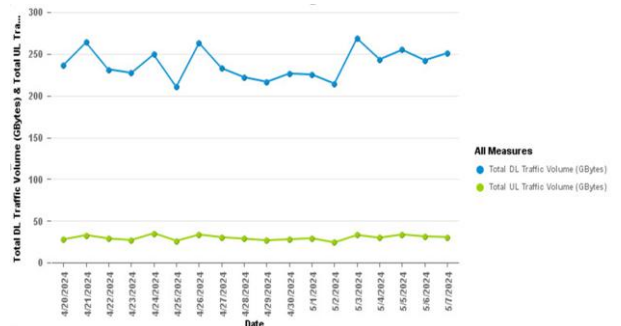


Fig.14. Total DL and UL traffic per all users connected on Site2

Fig. 15 illustrates the coverage comparison before and after the implementation of the new Site2, providing insights into the changes in network reach and performance. Fig. 16 demonstrates the quality comparison showcasing the differences in network performance before and after the deployment of the new Site2, providing a clear visual representation of the improvements or changes in quality metrics.

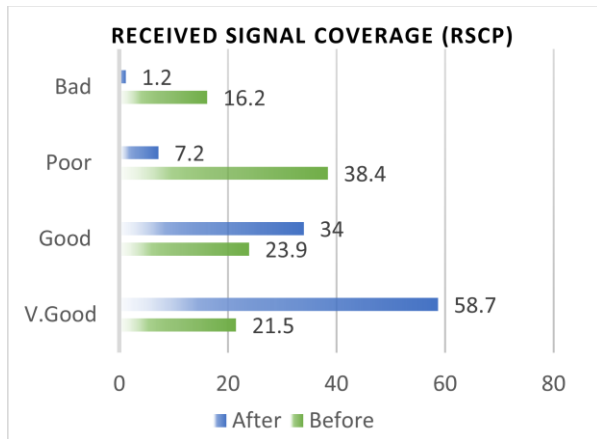


Fig.15. Percentage coverage comparison before and after Site2

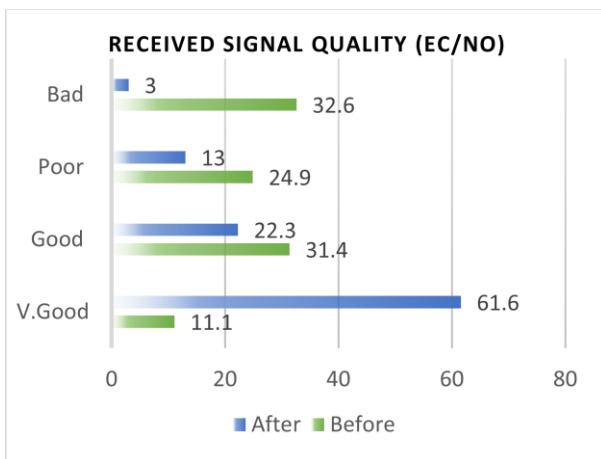


Fig.16. Percentage quality comparison before and after Site2

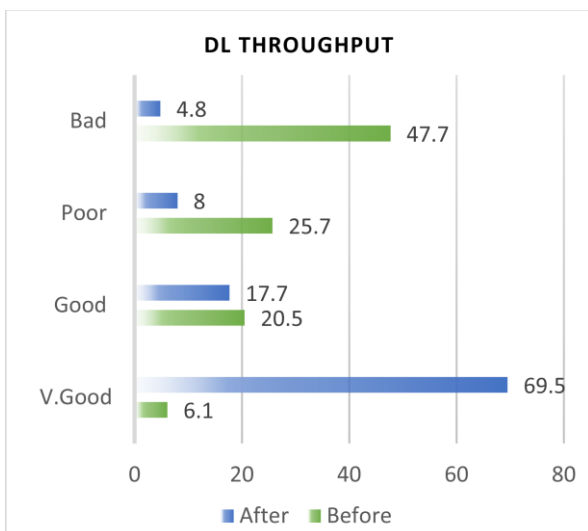


Fig.17. DL throughput comparison before and after Site 2

Fig. 17, compares downlink throughput before and after the introduction of the new Site2, showcasing any improvements or changes in data download speeds. Similarly, Fig. 18 illustrates the comparison of uplink throughput, indicating alterations in data upload speeds resulting from the implementation of the new site. Based on the ratios mentioned above and compared to those before and after installing the new site, we notice a significant improvement in terms of Received Signal Coverage (RSCP), Received Signal Quality (E_c/N_o), downlink throughput and uplink throughput.

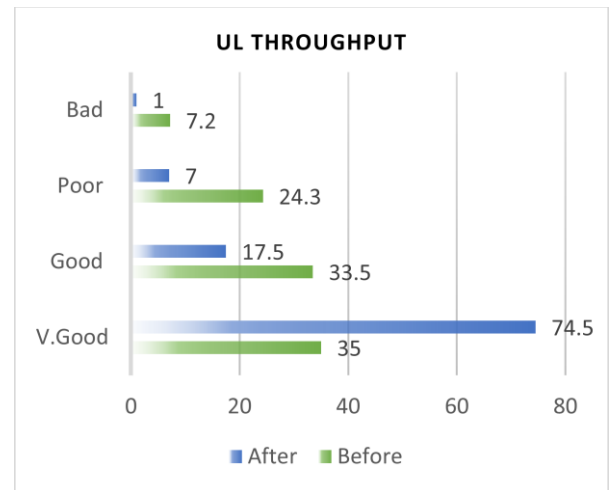


Fig.18. UL Throughput comparison before and after Site2

IV. CONCLUSIONS

This paper describes a case study on the evaluation and implementation of a 3G network in the western village of Idna in Hebron, Palestine. Two methods are used to evaluate network performance: drive tests and key performance indicators (KPIs), specifically for Received Signal Coverage (RSCP), Received Signal Quality (E_c/N_o), downlink throughput and uplink throughput. Thus, the percentages showed a noticeable improvement and a clear difference. The average network coverage rate in the region increased from 21.5% to 58.7%; the average network service quality was up from 11.1% to 61.1%, the average downlink throughput rate increased from 6.1% to 69.5%; and the average uplink throughput was up from 35% to 74.5%.

V. ACKNOWLEDGEMENTS

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VI. DECLARATION

All authors declare that they have no conflicts of interest.

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