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LTE Network Performance Evaluation: A Comparative Study of Planned and Deployed Networks

***Abstract**. This paper examines the comparison between the measured values and the defined interval for the selected parameters shows that they are within the acceptable range. However, differences in coverage are observed when comparing Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), Signal to Interference-Noise Ratio (SINR), and throughput, mainly due to weaker resolution maps and changes in the infrastructure that have been continuously happening in that part of Prishtina.*

***Streszczenie.** Ten artykuł analizuje porównanie między wartościami zmierzonymi a zdefiniowanym przedziałem dla wybranych parametrów, co pokazuje, że mieszczą się one w akceptowalnym zakresie. Jednakże zaobserwowano różnice w pokryciu podczas porównywania Mocy Odebranego Sygnału Referencyjnego (RSRP), Jakości Odebranego Sygnału Referencyjnego (RSRQ), Stosunku Sygnału do Zaburzeń i Szumów (SINR) oraz przepustowości, głównie z powodu słabszych map rozdzielczości oraz zmian w infrastrukturze, które ciągle mają miejsce w tej części Prisztiny. (**Ocena wydajności sieci LTE: badanie porównawcze planowanych i wdrożonych sieci**)*

Keywords: RSRP, RSRQ, SINR, throughput, LTE
Słowa kluczowe: RSRP, RSRQ, SINR, Przepustowość**,** LTE

Introduction

The planning of a communication system, particularly a radio communication system, is of utmost importance. Knowledge of terrain characteristics allows radio planning and optimization engineers to plan a radio communication system as accurately as possible with minimal losses. This is achieved by precisely placing transmitting antennas in the field and determining the transmit power of the antennas in a way that achieves the best coverage and quality of service for users [1]- [4].

A proper planning and dimensioning tool is crucial for enhancing mobile network performance [5]. The study utilized experimental evaluation with parameters such as PDSCH (Packed Data Shared Channel) modulation and BLER (Block Error Ratio).

An automatic tool for evaluation of LTE (long Term Evolution) performance was developed in Gdansk University by authors in [6]. Unlike the planning tools, the authors in [7] utilized an optimization method based on grouping cells with no mutual interference to find the optimal configuration of antenna tilt. This centralized method is guided by quality of experience criteria.

In [8], the scheduling algorithm takes into consideration delay and throughput metrics, allowing users to share the capacity based on quality-of-service parameters.

A more recent approach, investigating the use of machine learning and deep learning methods to improve LTE network performance based on downlink throughput measurement data, is presented by the authors in [9]. In [10], coverage and capacity data are also used to plan the LTE network for the Jakarta area. Using the Atoll software, an increase in the network quality is achieved after taking into consideration the parameters generated by the planning tool.

In [11], a performance evaluation of an LTE network in rural, urban, and tribal areas is conducted for video streaming and web browsing. Through extensive measurements, significant differences in cellular performance are observed among different environments.

It is well known that mobile operators tend to concentrate their services in urban areas where the number of mobile subscribers is higher. However, in [12], authors present an open-source LTE network for rural communities operating at 600 MHz This is shown as a good opportunity to promote the development of LTE networks in rural areas where mobile operators may not be as interested due to the smaller number of subscribers.

Given the changes in the environment, such as new buildings and terrain modifications, it becomes crucial for mobile operators to improve the performance of their existing mobile networks. In [13], authors have studied the improvement of network coverage in an existing network. They utilized Atoll as a software planning tool to perform measurements using its ACP (Automatic Cell Planning) tool. Based on the data generated by ACP, they concluded that a new site should be added in a specific area

An extended performance analysis of an LTE network in terms of RSRP (Reference Signal Received Power), RSRQ (Reference Signal Received Quality), and SINR (Signal-to-Interference-plus-Noise Ratio) KPIs, using drive test measurements in an urban city, has revealed a decrease in signal strength due to propagation loss [14].

A detailed study of LTE performance using the experimental evaluation of RSRP, RSRQ, RSSI, SINR and BLER is carried out by authors in [15].

To the best of our knowledge, we have not come across any publication that analyses the performance of planned and deployed networks in urban environments in terms of RSRP, RSRQ, SINR, and downlink throughput by comparing the planned and measured parameters in real network.

The rest of the paper is organized as follows. In Section II, the parameters for defining the planned LTE network are presented. In Section III, the parameters and methodology for analyzing the deployed network are explained. Results and discussion are provided in Section IV. The conclusions are presented in the last section.

Lte planed network and parameter definition

In the process of radio planning, the use of software tools is crucial in addition to the technology employed, as it enables faster and more efficient planning. Specialized software tools allow for a detailed analysis of the network, with results presented in graphical or statistical formats, facilitating the identification of coverage issues and other problems in the network areas [16]

The Atoll software tool for radio planning and optimization is a powerful platform developed by the company Forsk, known for its multi-technology capabilities that assist wireless network operators in various stages of the network lifecycle, from initial design to optimization [17]

When planning a network using a planning tool, it is indeed crucial to consider the terrain characteristics of the area where the network will be deployed. Different terrains, such as open, flat, rugged, or mountainous, can have a significant impact on radio wave propagation and network performance. In addition, built-up areas can be further categorized into three main types, as described in [18]

- Urban areas: built-up cities with large and tall objects
- Suburban areas: cities or places near cities with objects of medium height
- Rural areas: open space, small number of objects with low height"

The coverage calculation and planning for the LTE network in the urban area of "Mati 1" in Pristina, as depicted in Fig 1, has been carried out with careful consideration of the specific urban environment dependent on the resolution and layers of maps.

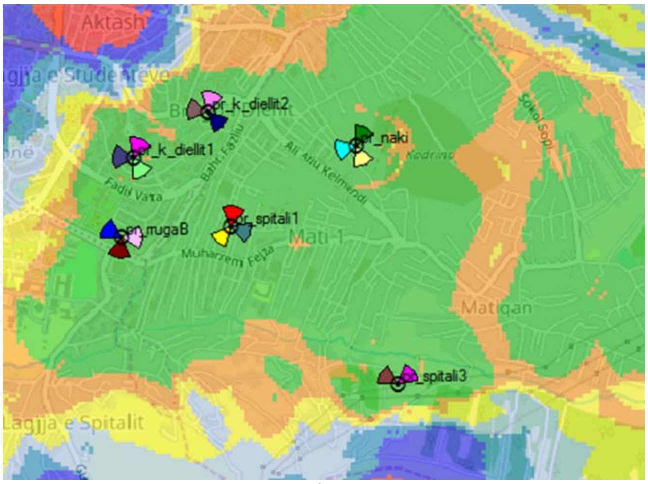

Fig 1. Urban zone in Mati 1 city of Prishtina

The levels corresponding to the colors shown in Fig 1 are presented in Table 1 as follows:

Table 1. Received signal levels and corresponding colors

Color	Signal level in dBm
	over -70
	-70 to -75
	-75 to -80
	-80 to -85
	-85 to -90
	-90 to -95
	-95 to -100
	below -10

Table 2. Base stations coordinates and heights

Technology	LTE @1800MHz
Bandwidth	20MHz
Propagation model	SPM-1800MHz-DU/U
Transmit power (dBm)	46
EPRP (Energy per resource element) (dBm)	15.4
MIMO	2x2

The colors in Fig 1 are used to visually represent these coverage levels for the LTE network in the urban area of "Mati 1" in Pristina. The main base station parameters (eNodeBs) in the selected area for coverage planning are given in Table 2

For a more accurate analysis and comparison, only a part of the "Mati 1" neighbourhood has been considered. Specifically, the area along "B" street - "C" street and "Muharrem Fejza" street has been selected in the shape of a triangle focus zone, as shown in Fig 2.

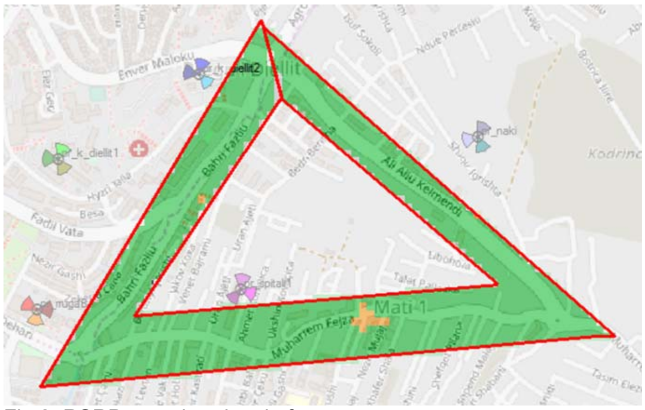

Fig 2. RSRP over the triangle focus zone

As can be seen from Fig ,2. the prediction for this 0.42 km^2 area is generally very good, with approximately 99% of the area showing received signal power levels ranging from -65 dBm to -75 dBm.

Lte deployed network and parameter definition

To evaluate the performance of the planned network that has been deployed in the specified area, drive test measurements were conducted using a Samsung S20 mobile phone with the Qualipoc software installed on it. The measurements were carried out within the triangular shape as shown in Fig 2.

Two Samsung S20 mobile phones were used for the drive test measurement:

- One mobile phone was in a "Connected" state, where there was an active connection between the User Equipment (UE) and the eNodeBs, and data and signaling messages were exchanged through logical channels. The location of the UE was known, and its mobility was managed using handover procedures,
- The other mobile phone was in an "Idle" state, where the UE was not active from the perspective of the application layer. Thus, this mobile device only observed measurements in the cell in which it was located and its neighboring cells.

The measurements were taken by a vehicle moving at a maximum speed of 40 km/h. The measurements were recorded in real-time, and the collected data was then used for analysing network performance, identifying changes, and improving service quality.

In addition to testing, QualiPoc also provides features such as displaying the exact position on the map through GPS, showing received signal strength, eNodeB characteristics, map views offered by Google Maps, graphical presentation of data, and conversion to other software platforms, as shown in Fig 3.

From Fig 3, it is evident that the received signal strength exhibits significant variations along different parts of the road axis. Weak signal strength is observed in a considerable portion of "Muharrem Fejza" road and a section of road "C". This can be attributed to various factors such as the density and height of buildings, the width of the road, hilly terrain, and suboptimal placement of base stations in relation to infrastructure changes.

Reports for predicted values (planned network) are generated using the Atoll software tool, while reports for real values (deployed network) are generated using SwissQual software. The comparison of measured and predicted values is performed using the Cumulative Distribution Function (CDF) distribution function, which allows for a quantitative assessment of the accuracy of the predicted values in relation to the measured values.

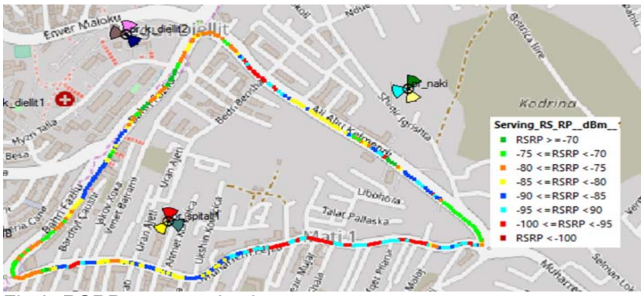

Fig 3. RSRP measured values

Result and discussion

To analyse the difference between a planned LTE network and a deployed LTE network, it is necessary to compare the Key Performance Indicator (KPI) parameters obtained from the planning tool with the actual drive test measurements. The comparison of RSRP results is shown in Fig 4, which visually represents the differences between the planned and realized network performance in terms of signal strength.

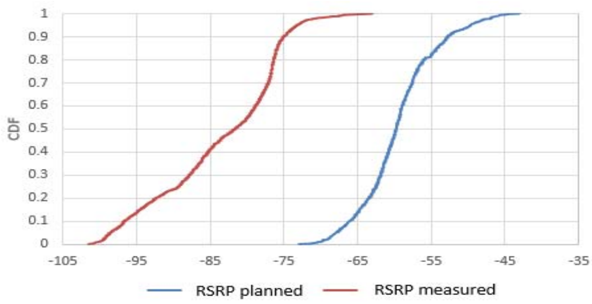

Fig 4. RSPR comparison results for LTE planned and measured network.

The analysis of the results shown in Fig 4 is carried out using the Cumulative Distribution Function (CDF). Statistical data for RSRP are shown in Table 3.

Table 3. Statistical values for RSRP

Statistical parameters	Planned value	Measured value
Maximum RSRP (dBm)	-43.01	-63
Minimum RSRP (dBm)	-72.95	-101.5
Average RSRP (dBm)	-59.5	-83.6

From the statistical data shown in Table 3, it can be observed that there is a significant difference gap between the planned and measured values of RSRP. The difference gap is larger for the minimum RSRP, which is approximately 30 dBm, compared to the maximum RSRP, which is 20 dBm. This indicates that the planned network may not have considered the most up-to-date maps with all layers, including 3D building data, in the Atoll software, leading to discrepancies between predicted and measured values. However, it is worth noting that a majority of the measured RSRP samples, specifically 57%, are greater than -80 dBm, as shown in Fig 4. This suggests that the network coverage in terms of RSRP is relatively good for the analyzed area, despite the difference gap between planned and measured values. The RSRQ comparison results are shown in Fig.5.

The difference in terms of RSRQ is 6.35 dB. In almost all the measured area, around 80% or RSRQ values are smaller than -10 dB and greater than -19.58 dB which is the borderline value for this parameters. The statistical data for RSRQ are shown in Table 4.

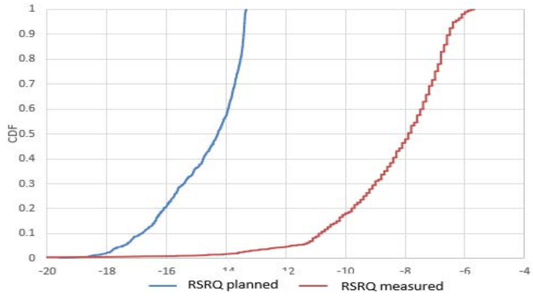

Fig 5. RSRQ comparison results for LTE planned and measured network.

Table 4. Statistical values for RSRQ

Statistical parameters	Planned value	Measured value
Maximum RSRQ (dB)	-13.33	-5.7
Minimum RSRQ (dB)	-19.58	-30
Average RSRQ (dB)	-14.77	-8.42

According to the statistical data for RSRQ shown in Table IV, it can be observed that the measured value exceeds the planned value by 7.6 dB. Although the minimum RSRQ value is lower than the planned value, it is stil within an acceptable range. The average RSRQ value differs by 6.35 dB. Moreover, in most of the covered areas where measurements were taken, approximately 80% of the samples had values greater than -10 dB.

The SINR comparison results for planned and measured network are shown in Fig 6.

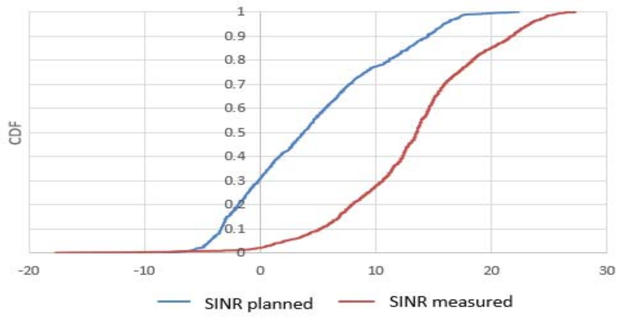

Fig 6. SINR comparison results for LTE planned and measured network.

From the data presented in Fig 6, it is evident that the planned network achieves better SINR (Signal-to-Inte-rference-plus-Noise Ratio) compared to the deployed net-work. The statistical results for SINR are shown in Table 5.

Table 5. Statistical values for SINR

Statistical parameters	Planned value	Measured value
Maximum SINR (dB)	22.34	27.2
Minimum SINR(dB)	-8.4	-17.7
Average SINR (dB)	4.51	13.16

From the statistical analysis, it is evident that the maximum measured value of Signal-to-Interference-plus-Noise Ratio (SINR) is 27.2 dB, while the predicted value is 22.34 dB. The average value for the measured SINR values is higher than that of the predicted values by 8.65 dB, indicating that the measured signal level has been better than predicted. Furthermore, half of the data generated from field measurements have SINR values above -8 dB, while half of the predicted SINR values have values above -14.3 dB.

The high SINR values observed in both cases are likely attributed to the presence of optical line of sight between the transmitter and the receiver, resulting in higher signal power compared to noise and interference. Conversely, the low SINR values observed in the considered area may be due to the lack of optical line of sight between the Base Transceiver Station (BTS) and the User Equipment (UE), obstructed by buildings and terrain changes, particularly in partially hilly terrain. This could result in reduced signal quality and performance degradation in terms of SINR.

The comparison in terms of downlink throughput is shown in Fig 7.

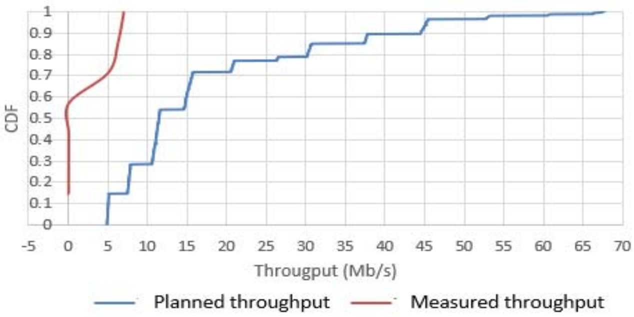

Fig 7. Comparison results for planned downlink throughput and measured downlink throughput.

The detailed statistical values for downlink throughput are given in Table 6.

Table 6. Statistical values for downlink throughput

Statistical parameters	Planned value	Measured value
Maximum thoughput (Mbps)	67.72	7.03
Minimum throughput (Mbps)	4.92	0.05
Average throughput (dB)	17.72	2.67

According to the generated statistics, overall, the planned throughput exhibits better performance compared to the measured throughput. The maximum throughput value in the planning case is 67.72 Mbps, while during measurements, a maximum value of 7.03 Mbps was observed. The minimum throughput for field measurements is 0.05 Mbps, whereas the minimum value generated by prediction is 4.92 Mbps. The average throughput for the predicted values is higher than the measured values by approximately 15 Mbps, indicating that the data transmission rate during measurements has been significantly lower compared to what was predicted.

Conclusion

This study has demonstrated that comparing the KPI parameters of RSRP, RSRQ, SINR, and DL throughput between a planned LTE network and a deployed LTE network provides valuable insights for mobile operators to identify areas for performance improvement in the current network. Based on the planning tool and measurement results, the average RSRP was observed to be 24.1 dBm higher in the planned network than in the deployed network. The average RSRQ was 6.35 dB better in the planned network than in the deployed network. The average SINR was 8.65 dB higher in the planned network than in the deployed network, and the average DL throughput was 15 Mbps higher in the planned network than in the deployed network.

Overall, the averaged KPIs indicate that the planned network outperformed the deployed network in terms of RSRP, RSRQ, SINR, and DL throughput. This difference in performance is likely attributable to the presence of new buildings in the area that were not accounted for in the resolution of the maps used by the planning tool. The findings of this study provide valuable insights for the mobile operator to make necessary adjustments and improvements to enhance the performance of the deployed LTE networks.

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