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# Measurement Based: 4G and 5G networks Analysis

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**Abstract**— The advancement of communications services requires the adoption of advanced technologies and the deployment of next generation networks. Nowadays, the Long-Term Evolution (LTE) standard is widely used. Conversely, an increasing number of mobile network operators (MNOs) are integrating the new fifth generation (5G) radio standard into their networks. This facilitates enhanced throughput, spectral and power efficiency and extended coverage, along with minimizing latency. The effectiveness of these developments is evaluated by evaluating the Quality of Service (QoS) in mobile networks. This study describes LTE-4G and NR-5G data measurements and key performance indicator (KPI) analysis based on information collected through a test drive (DT) process for two operators in Austria. Data measurements specifically target parameters that affect network strength and quality, including reference signal received power (RSRP), reference signal received quality (RSRQ), signal-to-interference-noise ratio (SINR), and received signal strength index (RSSI). And downlink - uplink data transfer rate (DL/UL throughput). Analysis of these parameters may reveal the presence of some errors when collecting data from the mobile phone network, such as errors from DT devices, errors from the network itself, errors due to weather conditions, geographical errors, etc. Identify areas of vulnerability for specialized attention to address network errors and maintain them to increase data accuracy and improve quality of services. Ultimately, analyzing KPIs and detecting errors within the collected data provides a simplified approach to managing and monitoring mobile network performance, reducing complexity, maintenance time and costs, thus enhancing customer satisfaction.

**Keywords**- Drive test, KPI, 5G, 4G, RSRP, RSRQ, SINR, MNO.

## I. INTRODUCTION *(HEADING 1)*

The rise of innovative cellular network technologies under the 5G umbrella is anticipated to serve as crucial facilitators for a range of new applications, such as industrial automation, intelligent transportation, and tactile internet. The diverse traffic requirements, spanning from ultra-reliable communications and massive connectivity to enhanced mobile broadband, highlight the critical nature of these advancements. Consequently, the increasing focus on research related to cellular network monitoring and prediction aims to guarantee a contented user base and the fulfilment of service level agreements. [1-5].

But as the user base continues to grow steadily, achieving optimization becomes a formidable challenge, emphasizing the significance of evaluating network performance. On a global scale, the projected total count of mobile devices is anticipated to reach 18.22 billion by the year 2025, representing a surge of 4.2 billion devices compared to 2020 levels. Furthermore, the number of internet users is increasing at an annual rate of 7.6%, equivalent to an average of 900,000 new users per day. As a result, the monitoring and scanning of 4G/5G networks play a crucial role in assessing mobile network statistics, essential for optimizing 4G/5G networks within a specific region [6-10].

Essentially, performance parameters, commonly known as Key Performance Indicators (KPIs), vary depending on the provided services. These KPIs encompass data that influences network coverage and capacity, including signal strength and quality, as well as download and uplink throughput. Furthermore, KPIs serve as indicators to ascertain whether a device or equipment meets the necessary criteria for successful deployment. The primary focus of mobile operators revolves around ensuring the optimal performance of cellular networks and evaluating the Quality of Service (QoS). These aspects directly impact both profitability and customer satisfaction. QoS plays a critical role in the competition for subscribers, necessitating efficient optimization of the cellular network to meet users' essential service needs [11-15]. A Key Performance Indicator (KPI) is a measurable metric used to assess the performance and effectiveness of a mobile network. KPIs aid in evaluating the network's success in achieving its objectives and goals. They are crucial for monitoring and managing the network's performance to ensure optimal functionality and user satisfaction. [11].

These Key Performance Indicators (KPIs) assist mobile network operators in overseeing and enhancing different facets of their networks to guarantee a dependable, high- quality experience for users and effectively achieve business objectives. The prioritization of specific KPIs may vary based on the distinct goals and emphasis of the mobile network operator.

The data for KPIs is gathered through the Drive Test (DT) process utilizing a set of tools, including GPS, a scanner, a laptop equipped with the Teams program, and a mobile phone with an Internet connection. Following the data collection process, a raw data file is obtained, which is then processed and filtered according to the specified parameters [16-20].

Conducting a comprehensive statistical analysis of cellular networks in Austria City, this study utilizes Key Performance Indicators (KPIs) acquired from Drive Tests conducted by two prominent cellular network operators. The measurements are categorized into five modes of transportation: bus, train, car, walking, and static. Each category's measurements are segregated, and those of each network are isolated and meticulously analyzed, with a specific focus on 4G and 5G networks known for their modern technology featuring high bandwidth, transmission rates, low latency, and error rates.

The data is thoroughly examined and visualized through charts created using Excel. Incorrect and duplicate measurements are identified and removed to ensure accurate interpretation of the results. The analysis predominantly explores the 4G-LTE network, providing an initial comprehension of LTE network coverage for the specified operators in the region. This relies on data measurements such as RSRP, RSRQ, RSSI, SINR, and Downlink (DL) Throughput.

Throughput, encompassing both Downlink (DL) and Uplink (UL), stands as a critical Key Performance Indicator (KPI) in mobile networks. It signifies the speed at which data is transferred between the user's device and the network (DL) or from the user's device to the network (UL). Throughput plays a pivotal role in determining the Quality of Service (QoS) delivered to users. Meeting or surpassing anticipated productivity levels is essential for upholding high service quality and ensuring subscriber satisfaction [21,25].

These data measurements play a vital role in network planning, feasibility studies, modelling, and overall development. Consequently, wireless network operators can leverage these measurements to effectively assess and determine appropriate KPIs for enhancing network performance. [1,26].

## 2-Related work:

[27] This work focused on the impact of handover on 4G LTE networks. The data collection method in this research uses test drive method by using pocket application terms to retrieve web data. The research findings highlight the importance of understanding how handover affects 4G LTE network performance. This method is implemented to retrieve service mobility data in ping mode by paying attention to the e-nodeB side. There has also been a failure to deliver the data mentioned in this paper due to interference with the site.

In [28] This paper presents a practical method of real-time data measurement for the 5G network, using the SIM8200EAM2 module. Moreover, different measurement methods were presented, by illustrating the dynamic and static tests carried out, which aimed to validate the relevant network parameters for 5G communication. Besides these, a series of functional tests were carried out, together with the cellular network provider, Orange Romania. These tests demonstrated the fact that the method presented in this work ensures a certain safety from the point of view of the values of the measured parameters. Figure 1 shows the method of conducting measurements made in mobility conditions.

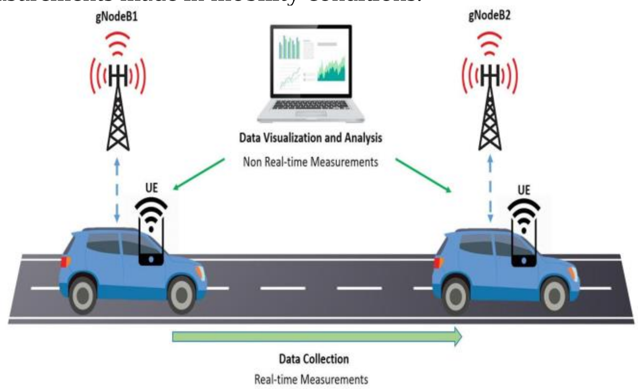


Figure 1. Real-time measurement scenario [28].

[29] This paper analyzed the Quality of Service (QoS) metrics and reference signal parameters utilized in LTE and 5G within the iPerf scenario. The data for this analysis was derived from a drive test campaign conducted by Systemics-PAB in an urban setting for four Polish Mobile Network Operators (MNOs). The findings reveal that employing the same Radio Access Network (RAN) led to comparable QoS assessments for Orange and T-Mobile. However, Plus, by utilizing the 40 MHz band at the 2.6 GHz frequency for its emerging 5G NR network, achieved higher RSRQ-5G and significantly increased throughput for Downlink (DL). Notably, the remaining MNOs lack radio resources in this particular frequency band.

[30] This paper explores the utilization of aggregated measurements from various User Equipment (UE) to predict the serving Reference Signal Received Power (RSRP) along a given route. LTE measurements gathered during drive tests in rural and urban areas were examined to analyze the dependence of data variability. The findings indicate that the precision of data-driven estimation is notably affected by variability in the underlying data, stemming from factors such as UE orientation, UE characteristics, and immediate environment. By compensating for a subset of these effects, it is possible to reduce the standard deviation of the estimation error from approximately 8 dB overall to 4 dB.

[31] This research offers a comprehensive exploration of MBB networks, encompassing deployment settings, performance metrics, and implementation scenarios. It emphasizes key criteria crucial for evaluating MBB performance. Additionally, the study includes a case analysis involving the performance of two established Mobile Network Operators (MNOs) in the Sultanate of Oman. The findings reveal that the majority of surveyed cities exhibit 4G network coverage, while 5G throughput demonstrates commendable data rates alongside reduced ping rates.

## 3- Results and discussion:

In this section, we scrutinize crucial Key Performance Indicators (KPIs) for LTE-4G and NR-5G cellular networks, presenting the outcomes of these assessments. Examined KPIs include Downlink (DL) and Uplink (UL) throughput, Received Signal Strength Indicator (RSSI), Signal-to-Interference-plus-Noise Ratio (SINR), Reference Signal Received Power (RSRP), and Reference Signal Received Quality (RSRQ). Two telecommunications operators in Austria conducted measurements for 4G/5G KPIs. The data, sourced from multiple Excel files, was consolidated and standardized based on respective categories. As mentioned earlier, the data collected through the Drive Test (DT) process encompasses five categories: car, train, bus, walking, and static. This section provides a detailed description of the analyzed KPIs. Figure 2 shows the RSRP parameter measurements for five categories of raw data. We noticed some jumps in incorrect and illogical measurements in communications systems, and there are other incorrect measurements that are not clear because the diagram was drawn for all categories together and was processed and filtered in several stages. In figure 3 shows a plot of RSRP, RSSRQ, and RSSI data measurements for two categories: car and static. And from Figure 3 we notice in the car category of the RSRQ parameter that measurements were recorded from test point 1634 to test point 3398, which is equivalent to 1764 test points, for a constant reading of -2 dB. There are other repeated periods with similar readings, and this is unreasonable in communications systems. We created statistics for the RF condition for 10000 test points for the RSRP parameter, according to the levels agreed upon by international telecommunications institutions, as shown in Figure 4. In Figure 5, we notice that the measurements for RSRP parameter of the HSPA+ network are better than the readings of the rest of the networks. Note that the diagram was drawn based on the number of readings in the HSPA+ network, which amounts to 2941 only. We also note that in the NR network there are similar readings for repeated periods, and this indicates that there is an error in recording the measurements. Figure 6 shows that the measurements in the excellent range of the RSRP and the measurements in the poor range of the RSRQ are similar over a period of approximately 300 points and for more than one period, and they occurred in the same periods and time for both parameters RSRP & RSRQ. The result of this analysis indicates that there was an error in the measurements when recording them. Table 1 shows a comparison of the statistical analysis at RSRP for two categories: car and walk, and for two operators A&B, and two technologies LTE and NR. We also show in Table 2 a comparison of the statistical analysis at RSRQ for two categories: car and walk, and for two operators A&B, and two technologies LTE and NR. The results were clear that the measurements of operator B were somewhat better than operator A.

### 4- Conclusion

In this research, we studied key performance indicators that have an important role in the process of improving the performance of 4G-5G networks because they provide useful information to facilitate network monitoring and management. Data measurements were collected via the DT process for five categories: car, train, bus, walking and static for two operators in Austria. Analysis and comparisons were made between the following parameters RSRP, RSRQ, RSSI and SINR for 4G-5G networks. The results of analysis and comparison showed that there were errors when recording measurements using the DT method. Processed and filtered to increase data accuracy to obtain better results for mobile networks when using finer data in forecasting. In future work, use machine learning models based on real data. Also, use other measurements, conduct the same context and analysis of the data, and verify the validity of the analysis. As well as obtaining higher reliability by using different data for more than one region and of a different geographical nature, such as city centers with high population density and mountainous and rural areas. When starting to deploy a 5G network, we can follow this approach to analyze data practically to ensure the best quality of service reaching customers. Researchers can rely on other 4G/5G network parameters and analyze them to demonstrate their importance in prediction.

| *Metrics* | RSRP (dBm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CAR | | | | WALK | | | |
| | LTE | | NR | | LTE | | NR | |
| | OP.A | OP.B | OP.A | OP.B | OP.A | OP.B | OP.A | OP.B |
| Median | -101 | -93 | -102 | -103 | -100 | -94 | -102 | -99 |
| Max | -72 | -53 | -70 | -61 | -57 | -60 | -66 | -66 |
| Min | -125 | -124 | -128 | -130 | -133 | -120 | -131 | -121 |
| Std | 7.96 | 12.48 | 7.37 | 8.65 | 12.6 | 9.29 | 12.05 | 9.14 |
| >90% | -82 | -59 | -85 | -78 | -65 | -68 | -70 | -74 |

**Table 1** RSRP for two categories car and walk, two operators A&B and two technologies LTE and NR

| Metrics | RSRQ (dBm) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | CAR | | | | WALK | | | |
| | LTE | | NR | | LTE | | NR | |
| | OP.A | OP.B | OP.A | OP.B | OP.A | OP.B | OP.A | OP.B |
| Median | -13 | -12 | -16 | -12 | -15 | -12 | -17 | -15 |
| Max | -5 | -2 | -3 | -2 | -6 | -6 | -8 | -4 |
| Min | -23 | -19 | -22 | -19 | -24 | -20 | -20 | -21 |
| Std | 2.67 | 3.87 | 3.24 | 3.87 | 2.11 | 1.37 | 1.95 | 3.25 |
| >90% | -7 | -2 | -7 | -6 | -9 | -9 | -11 | -7 |

**Table 2** RSRQ for two categories car and walk, two operators A&B and two technologies LTE and NR.

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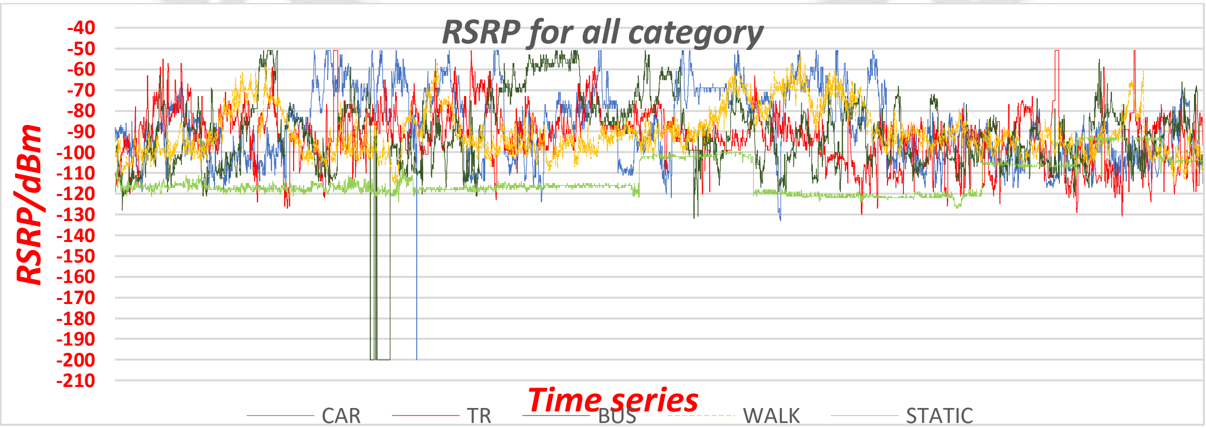


Figure 2. RSRP for five categories before the filtering process.

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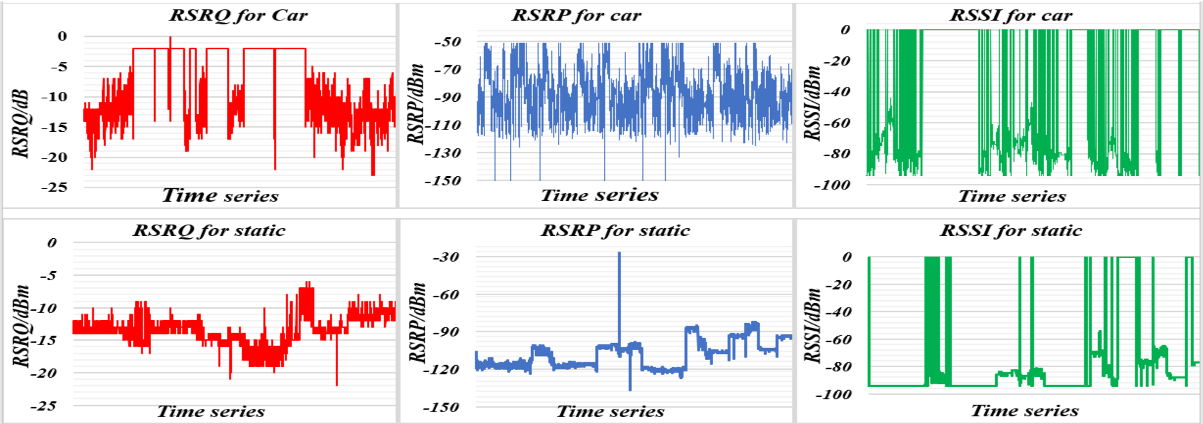
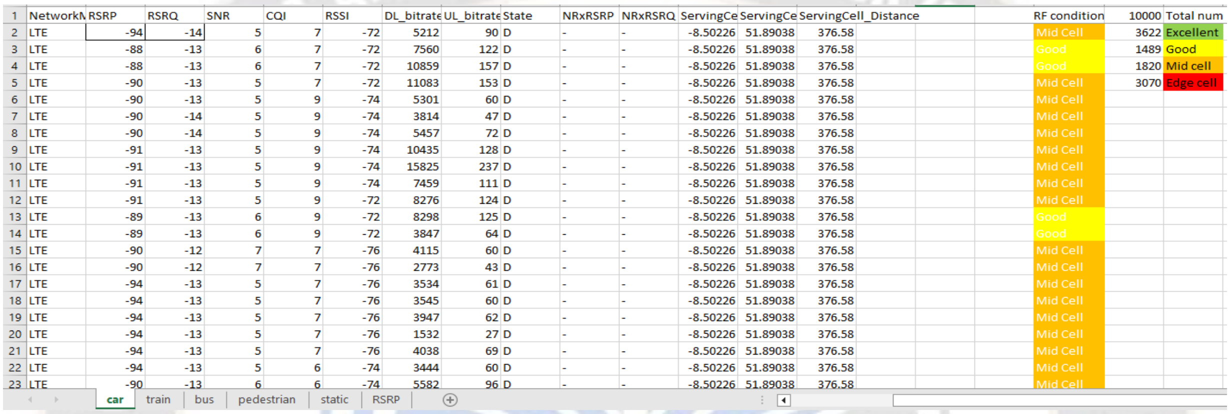



Figure 3. Analysis of raw data before the filtering process for the static and car categories.



| 1 | NetworkN | RSRP | RSRQ | SNR | CQI | RSSI | DL_bitrate | UL_bitrate | State | NRxRSRP | NRxRSRQ | ServingCe | ServingCe | ServingCell_Distance | | | RF condition | 10000 | Total num |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | LTE | -94 | -14 | 5 | 7 | -72 | 5212 | 90 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | 3622 | Excellent |
| 3 | LTE | -88 | -13 | 6 | 7 | -72 | 7560 | 122 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Good | 1489 | Good |
| 4 | LTE | -88 | -13 | 6 | 7 | -72 | 10859 | 157 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Good | 1820 | Mid cell |
| 5 | LTE | -90 | -13 | 5 | 7 | -72 | 11083 | 153 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | 3070 | Edge cell |
| 6 | LTE | -90 | -13 | 5 | 9 | -74 | 5301 | 60 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 7 | LTE | -90 | -14 | 5 | 9 | -74 | 3814 | 47 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 8 | LTE | -90 | -14 | 5 | 9 | -74 | 5457 | 72 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 9 | LTE | -91 | -13 | 5 | 9 | -74 | 10435 | 128 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 10 | LTE | -91 | -13 | 5 | 9 | -74 | 15825 | 237 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 11 | LTE | -91 | -13 | 5 | 9 | -74 | 7459 | 111 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 12 | LTE | -91 | -13 | 5 | 9 | -72 | 8276 | 124 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 13 | LTE | -89 | -13 | 6 | 9 | -72 | 8298 | 125 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Good | | |
| 14 | LTE | -89 | -13 | 6 | 9 | -72 | 3847 | 64 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Good | | |
| 15 | LTE | -90 | -12 | 7 | 7 | -76 | 4115 | 60 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 16 | LTE | -90 | -12 | 7 | 7 | -76 | 2773 | 43 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 17 | LTE | -94 | -13 | 5 | 7 | -76 | 3534 | 61 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 18 | LTE | -94 | -13 | 5 | 7 | -76 | 3545 | 60 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 19 | LTE | -94 | -13 | 5 | 7 | -76 | 3947 | 62 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 20 | LTE | -94 | -13 | 5 | 7 | -76 | 1532 | 27 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 21 | LTE | -94 | -13 | 5 | 7 | -76 | 4038 | 69 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 22 | LTE | -94 | -13 | 5 | 6 | -74 | 3444 | 60 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |
| 23 | LTE | -90 | -13 | 6 | 6 | -74 | 5582 | 96 | D | - | - | -8.50226 | 51.89038 | 376.58 | | | Mid Cell | | |

car | train | bus | pedestrian | static | RSRP

Figure 4. Statistical condition RF for RSRP.

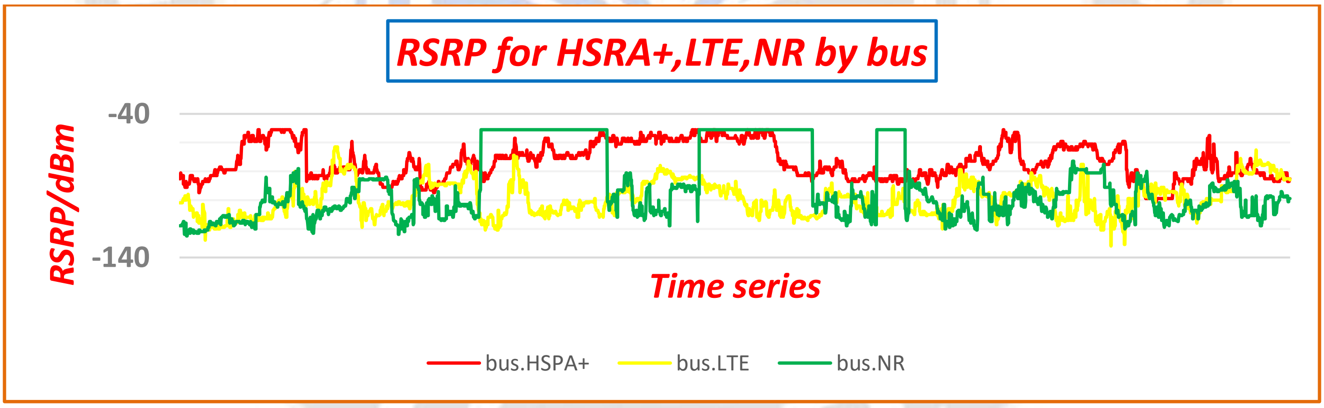



Figure 5. RSRP for HSRA+, LTE and NR technology by bus category.

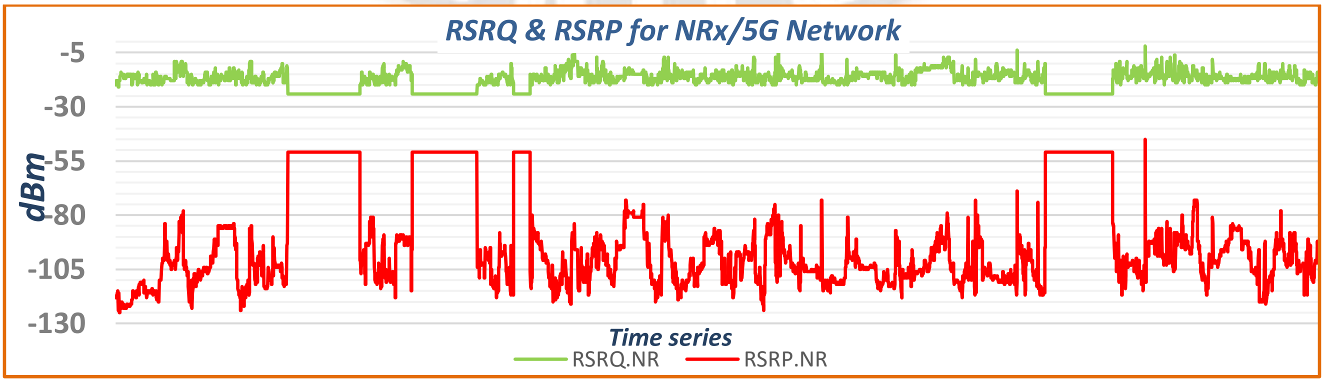



Figure 6. Comparing between RSRQ & RSRP for NRx/5G Network.