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Performance Analysis of 5G N71 Deployment in Live Network Environments

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Abstract - **This paper presents a detailed performance analysis of 5G N71 deployment in a live network environment, focusing on its impact on coverage enhancement, uplink performance, and overall network efficiency. Unlike mid-band 5G layers such as N78 and N40, which primarily address capacity requirements, the low-band N71 spectrum is deployed to improve coverage, particularly in indoor and cell-edge scenarios. The study was conducted across multiple sites using a 2×2 MIMO configuration, and performance evaluation was carried out using OSS-based key performance indicators (KPIs), drive test measurements, and user-experienced data including Ookla speed tests. The results indicate that N71 significantly improves coverage, with better signal propagation and deeper indoor penetration compared to higher frequency bands. In addition, uplink performance shows noticeable enhancement due to lower path loss and full-duplex operation, outperforming N40 and N78 in several scenarios. Traffic distribution analysis highlights the role of N71 in extending 5G service to areas previously dominated by LTE, thereby improving overall network accessibility. Despite limitations in carrier aggregation support and device compatibility, the deployment demonstrates stable network performance with no adverse impact on key KPIs. Overall, the findings confirm that N71 is an effective and scalable solution for enhancing 5G coverage and improving uplink performance in real-world network deployments.**

Index Terms - **Frequency Division Duplex (FDD), Indoor Coverage, Cell-Edge Performance, Carrier Aggregation, Network KPIs, Radio Performance.**

I. INTRODUCTION

The rapid growth of mobile data traffic, driven by high-definition video streaming, cloud services, and emerging digital applications, has significantly increased the demand for reliable coverage and improved user experience in modern cellular networks. While mid-band 5G deployments such as N78 and N40 provide high capacity and throughput, they often face limitations in coverage, particularly in indoor and cell-edge scenarios. As a result, ensuring consistent service quality across all environments remains a key challenge for network operators.

Low-band spectrum, such as N71, plays a critical role in addressing these coverage limitations due to its superior propagation characteristics and ability to penetrate obstacles more effectively than higher frequency bands. By deploying N71 as a coverage layer, operators can extend 5G service availability to underserved areas, including deep indoor lo- cations and regions previously reliant on LTE. This enables a more uniform user experience and supports the transition from legacy networks to 5G.

In addition to coverage benefits, low-band 5G also offers advantages in uplink performance due to its lower path loss and full-duplex operation. Compared to time division duplex (TDD) systems, frequency division duplex (FDD) operation in N71 allows simultaneous uplink and downlink transmission, resulting in more stable and efficient uplink performance. However, challenges such as limited device support for carrier aggregation and dependency on specific band combinations can impact the overall utilization of the N71 layer.

This paper presents a detailed performance analysis of 5G N71 deployment in a live network environment. The study evaluates network performance using OSS key performance indicators, drive test measurements, and user-experienced data to assess improvements in coverage, uplink throughput, and overall network efficiency. The findings aim to demonstrate the effectiveness of N71 as a coverage enhancement layer and its role in improving service quality in real-world deployment scenarios.

II. OBJECTIVE AND TRIAL SETUP

A. Objective

The primary objective of this study is to evaluate the performance impact of 5G N71 deployment in a live network environment, with a specific focus on coverage enhancement and uplink performance improvement. The study aims to analyze how the introduction of a low-band 5G layer improves signal propagation, particularly in indoor and cell-edge scenarios where mid-band layers face limitations. Another key objective is to assess the uplink performance advantages of N71, considering its frequency division duplex (FDD) operation and lower path loss characteristics.

In addition, the study evaluates the effect of N71 deployment on overall network performance, including traffic distribution, user experience, and key performance indicators (KPIs). The impact of N71 on existing 4G and 5G layers is also examined to ensure that network stability and service quality are maintained. Furthermore, the study aims to identify practical deployment challenges, such as device compatibility and carrier aggregation limitations. Overall, the objective is to validate the effectiveness of N71 as a scalable solution for extending 5G coverage and improving uplink performance in real-world network scenarios.

B. *Trial Cluster*

The trial was conducted across a cluster of ten selected sites within a live operational network environment. These sites were chosen to represent typical traffic conditions, user distribution, and varying coverage scenarios, including urban, suburban, and indoor environments. The deployment was executed in a phased manner, with antenna modifications carried out during December 2025 and the N71 layer activated in January 2026. This staged implementation enabled a clear comparison between pre- and post-deployment performance, allowing accurate evaluation of the impact of N71 integration across the cluster .

The network configuration included both LTE and 5G layers, where N71 was introduced as a low-band coverage layer alongside existing mid-band deployments such as N78 and N40. The N71 layer was configured with a 20 MHz channel bandwidth and operated using a 2×2 MIMO setup, leveraging frequency division duplex (FDD) operation to support simultaneous uplink and downlink transmission. The deployment utilized AirScale radio equipment supporting both LTE and NR technologies, ensuring seamless integration with the existing network infrastructure .

Performance evaluation was carried out using a combination of OSS-based key performance indicators (KPIs), drive test measurements, and user-experienced data. Drive testing was performed using commercial user equipment under both static and mobility conditions to capture real-world performance scenarios. In addition, throughput measurements were validated using Ookla speed tests and controlled testing environments. This comprehensive setup ensured accurate assessment of both network-level and user-level performance following the N71 deployment.

C. *Hardware Configuration*

The deployment of the N71 layer was carried out using AirScale radio equipment supporting both LTE and 5G NR technologies within a unified hardware platform. The system was configured with dual radio units capable of operating across low-band frequencies, supporting both Band 71 (NR) and Band 85 (LTE). Although the hardware supports up to 4×4 MIMO, the N71 layer was deployed using a 2×2 MIMO configuration, optimized for coverage enhancement and improved signal propagation.

The radio operated with full-band instantaneous bandwidth, ensuring efficient utilization of available spectrum resources. The transmission power was configured to support wide-area coverage, enabling improved performance in cell-edge and indoor scenarios. Advanced modulation schemes such as 1024 QAM in downlink and 256 QAM in uplink were supported by the hardware, enhancing data transmission efficiency .

Overall, the selected hardware configuration ensured seamless integration with the existing network infrastructure while providing the necessary capabilities to support low-band 5G deployment, improved coverage, and stable uplink performance.

D. *Tools Used*

Performance evaluation of the N71 deployment was carried out using a combination of field measurement tools and network-level analysis systems to ensure a comprehensive assessment. Drive testing was performed using commercial user equipment to capture real-time radio and throughput performance under both static and mobility conditions. Key radio parameters such as RSRP, SINR, CQI, and throughput were recorded during the tests to evaluate coverage and user experience.

Post-processing and analysis of drive test data were conducted using specialized software tools, enabling detailed visualization and performance comparison across different layers. In addition, OSS-based key performance indicators (KPIs) were utilized to monitor network-level performance trends, including traffic distribution, resource utilization, and user behavior before and after N71 activation. Crowd-sourced data from Ookla speed tests was also incorporated to validate user-experienced throughput in real-world conditions.

This combination of tools provided both technical and user-centric insights, ensuring accurate evaluation of the N71 layer’s impact on coverage, uplink performance, and overall network efficiency.

III. NETWORK CONFIGURATION

The network was configured in a non-standalone (NSA) architecture using Option 3x, where LTE served as the anchor layer and 5G NR carriers were deployed as secondary nodes. In this setup, multiple 5G layers including N78, N40, and N71 were integrated to support both capacity and coverage requirements. The mid-band layers (N78 and N40) were primarily utilized for high throughput and capacity, while the low-band N71 layer was introduced to enhance coverage, particularly in indoor and cell-edge scenarios .

The N71 carrier was configured with a lower priority compared to N78 and N40, ensuring that user equipment (UE) primarily camps on mid-band layers when available, and switches to N71 in areas with weaker coverage. This prioritization strategy enabled optimal utilization of available spectrum resources while maintaining consistent user experience. The interworking between LTE and NR layers was managed through EN-DC (E-UTRA NR Dual Connectivity), allowing simultaneous use of LTE and 5G resources for improved performance.

In terms of mobility and handover configuration, measurement thresholds and cell selection parameters were optimized to ensure smooth transitions between layers without service interruption. Carrier aggregation and dual connectivity configurations were also applied where supported, enabling enhanced throughput through multi-layer resource utilization. Overall, the network configuration was designed to balance capacity and coverage by leveraging the strengths of both mid-band and low-band 5G deployments.

IV. THEORETICAL BACKGROUND

The performance improvement observed with the deployment of the N71 layer is primarily driven by its low-frequency characteristics, which provide better propagation and penetration capabilities compared to mid-band frequencies. In wireless communication systems, signal propagation loss increases with frequency, making low-band spectrum more effective for wide-area coverage and indoor penetration. As a result, the N71 band is well suited for extending coverage and improving service availability in challenging radio environments such as cell edges and deep indoor locations.

TABLE I: Ookla Performance Summary

Metric	Value
Avg DL Throughput	334 Mbps
Peak DL Throughput	444 Mbps
Avg UL Throughput	44 Mbps
Peak UL Throughput	127 Mbps

From a theoretical perspective, the achievable throughput in a wireless system is directly proportional to the available bandwidth and spectral efficiency, which can be expressed as:

$$Throughput = Bandwidth \times Spectral\ Efficiency \quad (1)$$

Although the N71 layer operates with a relatively lower bandwidth compared to mid-band layers, its improved signal conditions and lower path loss contribute to more stable and consistent throughput, particularly in uplink scenarios.

The relationship between system capacity and channel conditions can be further explained using the Shannon capacity theorem:

$$C = B \log_2(1 + SNR) \quad (2)$$

where C represents channel capacity, B is the bandwidth, and SNR is the signal-to-noise ratio. While mid-band layers provide higher bandwidth, the N71 layer benefits from improved signal quality in coverage-limited areas, resulting in more reliable communication performance.

In addition, the use of frequency division duplex (FDD) in N71 allows simultaneous uplink and downlink transmission, unlike time division duplex (TDD) systems where resources are shared between UL and DL. This enables more efficient uplink performance, particularly under high load conditions. In scenarios where carrier aggregation is supported, the total effective bandwidth can be expressed as:

$$B_{total} = B_1 + B_2 + \cdots + B_n \quad (3)$$

However, practical limitations such as device compatibility and supported band combinations may restrict the full utilization of carrier aggregation involving N71. Overall, these theoretical principles explain the observed improvements in coverage, uplink performance, and network efficiency following the deployment of the N71 layer

V. OOKLA PERFORMANCE ANALYSIS

The Ookla performance analysis was conducted to evaluate user-experienced throughput of the N71 layer under real-world conditions. Multiple speed test measurements were performed using commercial user equipment in a static outdoor environment. The results indicate that the N71 layer delivers consistent and reliable downlink performance, with average throughput reaching approximately 334 Mbps and peak values exceeding 440 Mbps. Uplink performance also showed stable behavior, with average throughput around 44 Mbps and peak values exceeding 120 Mbps. As summarized in Table I, the N71 layer provides stable throughput performance across both downlink and uplink, reflecting its effectiveness in real deployment scenarios.

TABLE II: Downlink Performance Comparison

Metric	N71	N40	N78
Avg DL Throughput (Mbps)	160.3	209.4	389.8
Max DL Throughput (Mbps)	386.6	704.0	1202.6
DL SINR (dB)	6.2	10.1	14.5
CQI	10.2	9.1	9.0

In addition to standalone N71 performance, carrier aggregation scenarios were evaluated using a 5G gateway device. The results demonstrate significant throughput enhancement when N71 is aggregated with mid-band layers such as N78. Under these conditions, peak downlink throughput reached up to 930 Mbps, with average throughput exceeding 550 Mbps.

This highlights the potential of combining low-band coverage with mid-band capacity to achieve both wide coverage and high data rates in practical deployments.

Overall, the Ookla results confirm that N71 provides stable user-experienced performance and plays a critical role in extending 5G service to coverage-limited areas.

VI. DRIVE TEST RESULTS

Drive test analysis was conducted to evaluate the real-world performance of the N71 layer under both static and mobility conditions. The results indicate that N71 provides stable and reliable performance, particularly in coverage-limited scenarios. Downlink performance was observed to be consistent, with average throughput reaching around 334 Mbps and peak values exceeding 440 Mbps during static testing. As shown in Table **??**, the comparison across different bands highlights that while mid-band layers such as N78 and N40 achieve higher peak throughput due to larger bandwidth, the N71 layer maintains stable and reliable downlink performance.

In uplink performance, the N71 layer demonstrated a clear advantage over mid-band layers such as N40 and N78. Due to its lower operating frequency and FDD configuration, N71 achieved higher uplink throughput and better spectral efficiency. Average uplink throughput was observed to be around 44 Mbps, with peak values exceeding 120 Mbps. As illustrated in Table II and Table V, the N71 layer outperforms mid-band layers in uplink performance, primarily due to reduced path loss and efficient resource utilization.

Mobility test results further confirm the stability of the N71 layer, with consistent performance observed during movement across the test routes. The network maintained stable radio conditions, ensuring seamless connectivity and reliable user experience.deployment scenarios.

VII. KPI ANALYSIS

The KPI analysis was conducted to evaluate the impact of N71 deployment on overall network performance. The introduction of the N71 layer resulted in a measurable increase in user activity and signaling, indicating its active participation in the network. As summarized in Table III, key indicators such as SgNB addition attempts, NSA users, and traffic distribution show noticeable improvement following N71 activation.

TABLE III: N71 KPI Impact Summary

Metric	Value
SgNB Addition Increase	+1.3%
NSA User Increase	+1.1%
Traffic Growth	+0.5%
N71 Traffic Share	1.3%

TABLE IV: Carrier Aggregation Performance (N71 + N78)

Metric	Value
Avg DL Throughput	555 Mbps
Peak DL Throughput	930 Mbps
Avg UL Throughput	97 Mbps
Peak UL Throughput	146 Mbps

TABLE V: Uplink Performance Comparison

Metric	N71	N40	N78
Avg UL Throughput (Mbps)	68.9	43.7	42.3
Max UL Throughput (Mbps)	195.6	155.2	184.0
UL SINR (dB)	6.2	10.1	14.5
UL 256QAM Rate (%)	27.8	10.4	11.4

In terms of traffic distribution, the N71 layer contributed to overall traffic growth while extending 5G coverage to areas previously dominated by LTE. Although the traffic share of N71 remains relatively low due to device limitations, its role in improving accessibility and service continuity is significant.

The KPI results also confirm that network performance remains stable, with no degradation observed in accessibility, retainability, or mobility metrics. Overall, the analysis demonstrates that N71 enhances network efficiency while maintaining stability.

VIII. RESULT SUMMARY

Drive test analysis was conducted to evaluate the real-world performance of the N71 layer under both static and mobility conditions. The results indicate that N71 provides stable and reliable performance, particularly in coverage-limited scenarios. Downlink performance was observed to be consistent, with average throughput reaching around 334 Mbps and peak values exceeding 440 Mbps during static testing. As shown in Table III, the comparison across different bands highlights that while mid-band layers such as N78 and N40 achieve higher peak throughput due to larger bandwidth, the N71 layer maintains competitive and stable downlink performance under varying radio conditions.

From a performance perspective, N71 provides stable downlink throughput while significantly improving uplink performance compared to mid-band layers. The benefits of combining N71 with mid-band layers are further demonstrated through carrier aggregation. As shown in Table IV, the aggregation of N71 with N78 results in substantial throughput gains, achieving high peak and average data rates.

In uplink performance, the N71 layer demonstrated a clear advantage over mid-band layers such as N40 and N78. Due to its lower operating frequency and FDD configuration, N71 achieved higher uplink throughput and better spectral efficiency. Average uplink throughput was observed to be around 44 Mbps, with peak values exceeding 120 Mbps. As illustrated in Table IV, the N71 layer outperforms mid-band layers in uplink performance, primarily due to reduced path loss and more efficient resource utilization, making it highly suitable for uplink-intensive applications.

Mobility test results further confirm the stability of the N71 layer, with consistent performance observed during movement across the test routes. The network maintained stable radio conditions, including acceptable RSRP, SINR, and CQI levels, ensuring seamless connectivity and handover performance. In addition, indoor testing scenarios showed significant improvement after N71 activation, with better signal strength and noticeable throughput gains in areas previously served by LTE or weak mid-band coverage. Overall, the drive test results validate the effectiveness of N71 in enhancing coverage, improving uplink performance, and ensuring reliable user experience in real-world deployment scenarios.

IX. DISCUSSION

The results clearly indicate that the deployment of the N71 layer provides significant benefits in terms of coverage enhancement and uplink performance, complementing the existing mid-band 5G layers. While N78 and N40 are primarily designed for capacity and high throughput, their performance is often limited in indoor and cell-edge scenarios due to higher path loss. In contrast, N71, operating in the low-band spectrum, effectively addresses these limitations by providing wider coverage and better signal penetration, thereby improving overall service availability.

One of the key observations from this study is the superior uplink performance of N71 compared to mid-band layers. The use of frequency division duplex (FDD) enables simultaneous uplink and downlink transmission, resulting in more stable and efficient uplink performance. This advantage becomes particularly important for applications requiring reliable uplink communication. However, the full potential of N71 is currently limited by device compatibility and the lack of widespread support for carrier aggregation involving low-band and mid-band combinations.

Despite these limitations, the integration of N71 does not negatively impact overall network performance, as all key KPIs remain stable across the cluster. The low traffic share observed on N71 is primarily due to limited user equipment support rather than network constraints. As device capabilities evolve and support for advanced band combinations improves, the utilization of N71 is expected to increase significantly. Overall, the findings confirm that N71 serves as an effective coverage layer that enhances network reliability and complements capacity-focused 5G deployments.

X. CONCLUSION

This study presented a comprehensive performance analysis of 5G N71 deployment in a live network environment, focusing on its impact on coverage, uplink performance, and overall network efficiency. The results demonstrate that N71 effectively enhances coverage, particularly in indoor and cell-edge scenarios, enabling improved service availability in areas where mid-band layers are limited.

The deployment also shows a clear advantage in uplink performance, with N71 outperforming mid-band layers due to its low-frequency characteristics and FDD operation. Despite operating with lower bandwidth, the layer provides stable throughput and contributes to improved user experience through better signal conditions. In addition, the integration of N71 does not negatively impact network stability, as key performance indicators remain within acceptable limits.

Although current limitations such as device compatibility and restricted carrier aggregation support limit the full utilization of N71, the results confirm its effectiveness as a coverage enhancement layer. As device support evolves, the role of N71 is expected to expand further, enabling more efficient multi-layer operation. Overall, N71 deployment represents a practical and scalable solution for improving 5G coverage and uplink performance in real-world network scenarios.

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