Published by :
https://www.ijert.org/
An International Peer-Reviewed Journal

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

Integration and Performance Evaluation of 5G NR Band 71 (600 MHz)

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***Abstract*—This paper presents the results of a proof-of-concept (POC) trial conducted for the integration of 5G NR Band 71 (600 MHz, N71) cells into a live commercial network in Makkah, Saudi Arabia. The trial site XYZ was equipped with Nokia AirScale Dual RRH (AHLOA) modules supporting Bands 12 and 71, alongside CommScope FF-65CR1 low-band antennas. Drive test campaigns and static measurement tests were performed using calibrated measurement equipment to assess radio frequency (RF) performance across key indicators including Reference Signal Received Power (RSRP), Reference Signal Received Quality (RSRQ), Signal-to-Interference-plus-Noise Ratio (SINR), Block Error Rate (BLER), Channel Quality Indicator (CQI), and both downlink (DL) and uplink (UL) throughput. Comparative analysis was carried out against the incumbent N28 (700 MHz) deployment and between 2x2 MIMO and 4x4 MIMO configurations of N71. Results demonstrate that N71 with 4x4 MIMO achieves average DL throughput of 156.9 Mbps — a 225% improvement over N28 — and peak speeds of 272 Mbps DL- 115 Mbps UL under camping conditions, with SgNB addition success ratios of 100% across all bands. The network-level KPI analysis confirms that all 5G performance indicators are within acceptable operational ranges, validating N71 as a viable low-band complement for enhanced coverage and capacity in the STC 5G network.**

***Index Terms*—5G NR; Band 71; N71; 600 MHz; Low-band 5G; AHLOA; MIMO; Drive Test; RSRP; SINR; Throughput; KPI.**

I. Introduction

The global deployment of fifth-generation (5G) New Radio (NR) networks has accelerated significantly over recent years, driven by the need for higher data rates, ultra-low latency, and massive device connectivity. While mid-band spectrum (3.5 GHz) and mmWave frequencies have received considerable attention for capacity-centric deployments, low-band spectrum occupies a critical role in providing wide-area coverage, deep indoor penetration, and robust signal propagation — characteristics that are indispensable in geographically diverse and densely built environments.

Band 71 (N71), operating at 600 MHz, is a 3GPP-defined frequency band originally licensed in North America and increasingly being explored globally for its superior propagation characteristics. As mobile operators in the Kingdom of Saudi Arabia (KSA) expand their 5G footprints, the integration of N71 alongside existing N28 (700 MHz), N40 (2.3 GHz), and N78 (3.5 GHz) cells presents an opportunity to address coverage gaps and offer a more uniform quality of experience across a broader service area.

This paper documents a proof-of-concept (POC) trial jointly conducted at site XYZ in the Makkah cluster, Saudi Arabia. The objective was to integrate three N71 cells using Nokia's AirScale AHLOA RF modules and CommScope FF-65CR1 antennas, and to rigorously evaluate the RF and network-level performance through structured drive test campaigns and KPI monitoring. The study makes the following contributions: (1) Characterization of the RF performance of N71 (RSRP, RSRQ, SINR, BLER, CQI) relative to the existing deployment of N28. (2) Comparative evaluation of N71 in 2x2 MIMO versus 4x4 MIMO configurations for DL and UL throughput. (3) Network-level KPI analysis across all co-located bands (N78, N40, N28, N71) using operator counters. (4) Demonstration of peak throughput achievable with N71 under optimal UE camping conditions.

II. Objective and Trial Setup

A. Objective

Low-band spectrum for 5G NR has been the subject of substantial research and standardization activity within 3GPP Release 15 and beyond. Band 71 was originally allocated in the United States following the FCC's 600 MHz incentive auction (2017) and was adopted by T-Mobile US as the primary coverage layer of its nationwide 5G network. Its propagation characteristics — wavelength approximately 50 cm, lower free-space path loss compared to mid-band frequencies — enable cell ranges exceeding 10 km in open terrain and robust building penetration of up to 10–15 dB additional gain over 3.5 GHz.

Several studies have examined low-band 5G performance in various deployment scenarios. Qualcomm Technologies (2019) demonstrated that low-band 5G networks [?] can achieve coverage improvements of 2–4x compared to mid-band deployments while maintaining sub-10 ms latency. Field trials by Ericsson and T-Mobile confirmed that 600 MHz 5G provides consistent throughput of 100–200 Mbps at cell edges where mid-band signals are unavailable.

In the context of GCC/MENA deployments, N28 (700 MHz) has historically served as the primary low-band anchor for 4G LTE and early 5G NR non-standalone (NSA) configurations. The addition of N71 in markets that allocate this spectrum introduces a complementary low-band layer with 20 MHz channel bandwidth — double the typical N28 deployment in the region — enabling higher spectral efficiency and improved MIMO performance.

To date, limited published research exists on N71 integration in the Arabian Peninsula context, where unique environmental factors — high ambient temperatures, dense urban morphology, and hajj-driven seasonal traffic demands — present specific challenges. This study addresses that gap by providing empirical field trial data from a live STC network site.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
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B. Trail Clusters

The trail was conducted across a cluster of five The trial was conducted at macrocell site ZMKAXYZ located within the MAKKAH cluster, Makkah, Saudi Arabia. The site is a rooftop/tower installation serving a dense residential area with mixed low-rise and medium-rise building morphology. Prior to the N71 integration, the site carried three legacy bands: N78 (3.5 GHz), N40 (2.3 GHz), and N28 (700 MHz), all operating in 5G NR NSA mode anchored to LTE..

C. Hardware Configuration

Three Nokia AirScale Dual RRH B12/71 240W (AHLOA) modules were introduced at the site — one per sector. The AHLOA is a dual-band RF module supporting 3GPP Bands 12 and 71 simultaneously, with the key specifications summarized as follows: output power of 60W per TX shared between bands; 4 TX/RX ports supporting 2T2R, 2T4R, and 4T4R MIMO configurations; optical CPRI interface at 2x 9.8 Gbps; supply voltage range DC -48V to -60V; IP65 ingress protection; and an operational temperature range of -40°C to +55°C (without solar load).

New low-band sector antennas (CommScope FF-65CR1) were installed on each sector. This is a 4-port, single-band antenna operating across 617–806 MHz with 65° horizontal beamwidth, gain of 15.4 dBi at 617–698 MHz and 15.6 dBi at 698–806 MHz, and support for Remote Electrical Tilt (RET). The antenna's coverage of the full 617–806 MHz range provides forward compatibility for both N71 and N28 frequency layers.

D. Tools Used

Performance evaluation of the N71 deployment was carried out using a mix of field testing and network-level analysis to get a complete view of its impact. Drive tests were performed using commercial user devices to measure real-time radio conditions and throughput in both stationary and mobility scenarios. During these tests, key radio indicators such as RSRP, SINR, CQI, and throughput were collected to assess coverage quality and the end-user experience.

The collected drive test data was then processed using specialized analysis tools, which helped visualize performance and compare results across different network layers. In addition to field measurements, OSS KPIs were reviewed to understand network-wide trends, including traffic distribution, resource usage, and changes in user behavior before and after N71 activation. Crowd-sourced Ookla speed test data was also used to validate the actual throughput experienced by users in real-world conditions.

By combining field measurements, OSS statistics, and crowd-sourced results, the evaluation provided both technical and user-focused insights. This approach made it possible to accurately assess how the N71 layer improved coverage, uplink performance, and overall network efficiency.

III. THEORETICAL BACKGROUND

The performance improvements observed after deploying the N71 (600 MHz) layer are mainly due to the inherent advantages of low-frequency spectrum. Lower frequency signals experience less propagation loss and can travel longer distances than higher frequency bands. They also penetrate buildings, walls, and other obstacles more effectively, making them particularly suitable for improving coverage in rural areas, at cell edges, and inside buildings. As a result, users experience stronger signal levels and more reliable connectivity in locations where mid-band frequencies may struggle to provide consistent service. In wireless networks, user throughput depends on both the amount of available spectrum and how efficiently that spectrum is utilized. This relationship can be expressed as:

$$[\text{Throughput} = \text{Bandwidth} \times \text{Spectral Efficiency}] \tag{1}$$

Although N71 typically operates with a smaller bandwidth compared to mid-band 5G carriers, its superior coverage characteristics create more favorable radio conditions for users. Better signal quality allows devices to maintain stable connections and use network resources more efficiently, which helps improve throughput consistency, particularly in uplink communications. The impact of signal quality on network performance can be further explained using the Shannon Capacity Theorem:

$$[C = B\log_2(1 + \text{SNR})] \tag{2}$$

where (C) represents channel capacity, (B) is the channel bandwidth, and SNR is the signal-to-noise ratio. While wider bandwidths generally provide greater capacity, a good SNR is equally important for achieving higher data rates. The N71 layer improves SNR in coverage-limited areas by providing stronger and more reliable signal strength, enabling users to maintain better performance even in challenging radio environments. Another important advantage of N71 is its deployment using Frequency Division Duplex (FDD) technology. In FDD systems, separate frequency channels are assigned for uplink and downlink transmissions, allowing both directions to operate simultaneously. This differs from Time Division Duplex (TDD) systems, where uplink and downlink share the same radio resources over time. The dedicated uplink resources available in FDD improve uplink efficiency and can deliver noticeable performance gains, especially during periods of high network utilization. In modern multi-band networks, N71 can also be combined with other LTE and 5G carriers through Carrier Aggregation (CA). The total available bandwidth can be expressed as:

$$[B_{\text{total}} = B_1 + B_2 + \cdots + B_n] \tag{3}$$

where (B1, B2, ..., Bn) represent the bandwidths of the aggregated carriers. In this configuration, N71 provides a strong coverage foundation, while higher-frequency carriers contribute additional capacity. This combination helps improve traffic distribution, increase overall network capacity, and enhance user experience. However, the actual benefits depend on factors such as device capabilities, supported carrier combinations, and network configuration. Overall, the deployment of the N71 layer strengthens network coverage, improves indoor

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

service quality, enhances uplink performance, and supports better traffic balancing across the network. These improvements are consistent with established wireless communication principles and demonstrate the value of low-band spectrum in expanding 5G coverage while maintaining a reliable and efficient user experience.

IV. RESULTS AND ANALYSIS

A. Drive Test RF Performance

Table I presents the aggregated drive test KPI summary across the three test configurations. All measurements were collected over identical drive routes covering the site XYZ service area. Table II presents the measured throughput performance. RSRP: N71 demonstrates a statistically significant improvement in average RSRP over N28, with N71 4x4 recording -77.83 dBm versus -81.5 dBm for N28 — an improvement of 3.67 dB. This is attributed to the 20 MHz channel bandwidth of N71 (versus 10 MHz for N28 at this site), which, combined with a higher effective transmit power spectral density, results in improved received signal levels across the coverage area. The RSRP distribution maps confirm near-universal green/blue coverage (above -85 dBm) throughout the test route for both N71 configurations.

TABLE I
DRIVE TEST KPI SUMMARY

Metric	N28	N71 2×2	N71 4×4
Avg RSRP(dbm)	-81.5	-79.6	-77.83
Avg RSRQ(dB)	-11.02	-11.15	-11.09
Avg SINR(dB)	12.9	12.4	11.8
Avg DL BLER(%)	9.2	7.4	6.6
Avg CQI	11.9	11.8	11.1
Avg DL Throughput(MbpS)	48.2	129.4	156.9
Avg UL Throughput(MbpS)	18.1	52.8	62.2
Peak DL (Ookla)(MbpS)	N/A	272	272
Peak UL (Ookla)(MbpS)	N/A	115	115

SINR: Average SINR values are comparable across all three configurations (11.8–12.9 dB), indicating that the introduction of N71 does not adversely affect the interference environment. The marginally lower SINR observed for N71 2x2 (11.8 dB) compared to N28 (12.4 dB) is within measurement uncertainty and does not represent a statistically meaningful degradation. BLER values confirm this picture, with N71 4x4 achieving the lowest average DL BLER of 6.6% versus 9.2% for N28, indicating cleaner link quality and more efficient modulation and coding scheme (MCS) selection.

DL Throughput: The most significant performance differentiator is downlink throughput. N71 4x4 MIMO achieves an average of 156.9 Mbps — a 225.1% improvement over the N28 baseline of 48.2 Mbps. N71 2x2 yields 129.4 Mbps, a 168.5% improvement. The throughput gain is driven by two compounding factors: (1) the doubled channel bandwidth (20 MHz vs 10 MHz), which theoretically doubles the available spectral resources; and (2) the 4x4 MIMO spatial multiplexing gain, which enables simultaneous transmission of up to four independent data streams.

UL Throughput: Uplink gains follow the same trend, with N71 4x4 delivering 62.2 Mbps versus 18.1 Mbps for N28 (244% improvement). This is of particular relevance for upload-intensive applications such as video conferencing, live streaming, and cloud synchronization, which are increasingly prominent use cases in high-density venues such as those surrounding the Masjid al-Haram.

Peak Performance: Under UE camping conditions (cell lock to N71), Ookla Speedtest recorded peak speeds of 272 Mbps DL and 115 Mbps UL — performance levels consistent with single-carrier 20 MHz 5G NR theoretical limits under high-MCS conditions. The HONOR MAGIC PGT-N19 consumer device achieved an average RSRP of -76 dBm and average DL throughput of 122.8 Mbps, demonstrating that N71 performance is accessible on commercial off-the-shelf handsets without specialized test hardware.

B. Static Test Results

Static tests at both near-point (close to the antenna) and far-point (cell edge) locations confirm the bandwidth advantage of N71. At near-point, N71 4x4 achieves approximately 195 Mbps DL versus 95 Mbps for N28 — a factor of 2.05x gain consistent with the 2:1 bandwidth ratio. At far-point, the N71 advantage is even more pronounced due to the superior propagation of 600 MHz, with N71 4x4 maintaining usable throughput where N28 suffers coverage degradation. In both UL scenarios, N71 4x4 consistently outperforms N71 2x2, confirming that the additional MIMO streams contribute meaningfully to uplink capacity.

C. Network KPI Analysis

Table II presents the hourly KPI comparison across all four co-located bands, derived from operator network management counters during the MDT window. All bands recorded a 100% SgNB addition preparation success ratio, confirming successful integration and stable operation of the N71 cells.

Table II presents the measured throughput performance. N71 demonstrates an average MAC-layer DL user throughput of 30 Mbps — the second highest among the four bands, behind N40 (35 Mbps) but ahead of N78 (24 Mbps) and significantly outperforming N28 (11 Mbps). The relatively lower N71 traffic volume (9,397 MB DL vs 82,047 MB for N78) is explained by the fact that N71 priority was configured at baseline levels throughout most of the observation window; a temporary priority increase during a 2-hour daytime MDT window resulted in an observable traffic shift to N71, confirming normal cell selection and traffic steering behavior.

TABLE II
NETWORK KPI COMPARISON ACROSS BANDS

KPI	N78	N40	N71
SgNB Add Requests	2328	3526	1082
SgNB Add Success Ratio [%]	100	100	100
DL Data Volume [MB]	82,047	46,589	9,397
UL Data Volume [MB]	642	1,996	262
Avg DL User Throughput [Mbps]	24	35	30
Avg UL User Throughput [Mbps]	1	1	4
PRB Utilization PDSCH [%]	28	31	11
PRB Utilization PUSCH [%]	9	23	2

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 15 Issue 06 , June - 2026

Cell availability ratio remained at 100% throughout the 24-hour monitoring period for all three N71 sectors, and no unplanned cell outages, RACH failures, or handover degradation events were recorded. Both contention-based and contention-free RACH setup success rates remained close to 100%, demonstrating stable random access performance. Intra-frequency intra-gNB intra-DU handover success rates also remained at 100% during the limited handover events observed during the MDT window.

CQI values averaged approximately 10–12 throughout the monitoring period, consistent with moderate-to-good channel conditions and enabling high-order modulation (64QAM/256QAM) for a significant fraction of scheduled transmissions. BLER DL initial values remained below 15% with residual BLER below 3%, confirming effective HARQ operation and adaptive link adaptation.

V. DISCUSSION

The trial results confirm several key hypotheses regarding the value of N71 as a low-band 5G layer:

Coverage Enhancement: The 3.7 dB RSRP improvement of N71 over N28, combined with the larger service area observable in the drive test route maps, supports the case for N71 as a primary coverage layer. At 600 MHz, the additional propagation loss relative to 700 MHz (N28) is minimal (0.7 dB at equal EIRP), but the doubled bandwidth enables higher throughput at equivalent or better coverage levels.

MIMO Efficiency: The 21.3% DL throughput gain of N71 4x4 over N71 2x2 (156.9 vs 129.4 Mbps) is lower than the theoretical 2x factor, which is expected due to spatial channel correlation in an urban macro environment. Nevertheless, the real-world gain is substantial and justifies the deployment cost of 4T4R capable AHLOA modules. For UL, the 17.8% gain (62.2 vs 52.8 Mbps) is similarly consistent with published MIMO efficiency curves for low-band frequencies.

Traffic Steering: The observation that N71 traffic volume increased sharply only following a temporary priority change highlights the importance of correctly configuring cell selection and reselection offsets (A3/A5 event thresholds, frequency priority parameters) in the final production deployment. Future optimization work should focus on defining appropriate B1/B2 measurement thresholds to achieve optimal load balancing between N78, N40, N28, and N71.

Thermal and Hardware Reliability: The AHLOA module demonstrated stable operation throughout the trial with no thermal-related degradations recorded, despite ambient temperatures in Makkah potentially exceeding the module's rated 55°C solar load threshold during peak daytime hours. Continued monitoring during summer months is recommended to assess long-term thermal behavior.

VI. CONCLUSION

This paper has presented a comprehensive proof-of-concept evaluation of Nokia's AirScale N71 (600 MHz) 5G NR integration within STC's live network at Site XYZ, Makkah , Saudi Arabia. The trial demonstrates that N71 integration is technically successful, with all network KPIs within acceptable operational ranges and 100% service availability throughout the trial period.

Key quantitative findings include: a 225% improvement in average DL throughput over N28 with N71 4x4 MIMO (156.9 vs 48.2 Mbps); a 244% UL throughput gain (62.2 vs 18.1 Mbps); peak speeds of 272 Mbps DL / 115 Mbps UL under camping conditions; and consistent 3–4 dB RSRP improvement across the drive test area. The 100% SgNB addition preparation success ratio and RACH setup success rates across all four co-located bands confirm seamless integration with the existing multi-band 5G NSA architecture.

These results establish N71 as a high-value low-band 5G layer for STC's network, offering a combination of wide-area coverage, superior indoor penetration, and substantially higher throughput than the incumbent N28 deployment — enabled by the doubled 20 MHz channel bandwidth and 4T4R MIMO capability of the AHLOA platform. The authors recommend a phased network-wide N71 rollout prioritizing high-density urban areas and pilgrimage sites, with careful attention to traffic steering parameter optimization to maximize N71 utilization.

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