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5G mmWave n257 Deployment with 800 MHz Carrier Aggregation

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***Abstract*—Fifth-generation (5G) millimeter-wave (mmWave) technology operating in the N257 band (26.5–29.5 GHz) represents a transformative leap in wireless broadband capacity. This paper presents a comprehensive performance evaluation of a live 5G mmWave trial deployment conducted at Site XYZ in a congested city. The trial operated in Non-Standalone (NSA) mode with LTE as the anchor layer, employing 4-component carrier aggregation (4×200 MHz) to achieve 800 MHz of total downlink bandwidth. Theoretical peak throughput calculations—based on Effective Resource Elements, 64 QAM modulation, 0.95 coding rate, 2-layer digital beamforming, and a 4:1 TDD ratio—project a maximum downlink rate of approximately 4 Gbps per cell. Live test measurements under Line-of-Sight (LOS) conditions recorded peak downlink throughputs of 1509 Mbps at near-point, 1159 Mbps at mid-point, and 944 Mbps at far-point, with corresponding uplink rates of 358 Mbps, 216 Mbps, and 186 Mbps respectively. The paper also details the NSA Secondary Cell Group (SCG) addition strategy with prioritized handoff parameters, Carrier Aggregation (CA) configuration scripts, and practical deployment constraints. Key limitations including CPE Ethernet port bottleneck at 1.5 Gbps, NLOS coverage gaps, and lack of indoor measurement scenarios are documented. The results validate the viability of mmWave 5G as a high-capacity layer for dense urban deployments while highlighting areas requiring further optimization.**

***Index Terms*—5G NR; mmWave; N257 band; carrier aggregation; Non-Standalone (NSA); throughput; SCG addition; beamforming; TDD; link budget**

I. INTRODUCTION

The global proliferation of data-intensive applications—including ultra-high-definition video streaming, augmented/virtual reality, Industry 4.0 automation, and smart city infrastructure—has placed unprecedented demand on mobile network capacity. The International Telecommunication Union (ITU) defines 5G as a system capable of delivering peak data rates of 20 Gbps in downlink [6], largely achievable through the exploitation of millimeter-wave (mmWave) spectrum bands above 24 GHz.

Among the key spectrum assets enabling ultra-high-throughput 5G services is the N257 band (26.5–29.5 GHz), which offers contiguous wideband allocations that are unavailable in sub-6 GHz spectrum.

mmWave propagation presents a unique set of challenges: higher free-space path loss, severe attenuation through obstacles, sensitivity to atmospheric absorption, and strong directionality that demands precise beam management. These characteristics necessitate careful site selection, antenna design, and RF parameter optimization to achieve adequate coverage and throughput.

This paper documents and analyzes a pilot trial deployment of 5G NR mmWave technology at Site XYZ in, using Huawei's AAU5323 massive MIMO antenna solution. The objectives of the paper were to: (i) validate theoretical peak throughput calculations; (ii) characterize DL/UL performance across near, mid, and far test points in LOS environments; (iii) demonstrate the NSA layer strategy and SCG addition mechanism; and (iv) identify deployment-specific challenges for future optimization.

The paper is structured as follows: Section II reviews background on mmWave 5G. Section III describes site configuration and link budget analysis. Section IV presents the NSA layer strategy. Section V details CA configuration. Section VI reports test results. Section VII discusses limitations and future work. Section VIII concludes.

II. BACKGROUND AND RELATED WORK

mmWave communications in the 5G context have been extensively studied. Rappaport et al. [1] provided foundational propagation measurements in urban environments at 28 GHz and 73 GHz, demonstrating that dense small-cell deployments can overcome high path loss through directional beamforming. Rangan et al. [2] formalized the system-level implications of mmWave channel models, emphasizing the importance of blockage statistics and spatial consistency.

From a standards perspective, 3GPP Release 15 introduced New Radio (NR) support for FR2 (Frequency Range 2: 24.25–52.6 GHz) [5], defining physical layer procedures—including synchronization signal blocks (SSBs), beam management, and numerology with 120 kHz subcarrier spacing—that underpin the trial described in this paper. The NSA architecture defined in Release 15 enables operators to leverage existing LTE infrastructure as the control-plane anchor while adding NR as a data-plane supplement.

Prior field trials of mmWave 5G have reported peak throughputs ranging from 1 to 4 Gbps under ideal LOS conditions, with rapid degradation beyond 200–300 m in NLOS scenarios. Polese et al. [3] highlight the importance of carrier aggregation across multiple component carriers to achieve aggregate bandwidths approaching 1 GHz. The work presented here contributes operational field data from an active commercial trial deployment in the Arabian Gulf region, a geography with limited published mmWave measurement datasets.

III. Site Configuration and Theoretical Analysis

A. *Site Selection and Physical Setup*

The site was selected based on multiple RF design criteria: a clear open-area sector with minimal obstruction, sufficient tower load capacity for an additional 4th sector, and existing BBU5900 baseband infrastructure with an available slot for the UBBP card.

The hardware deployment comprises a Huawei AAU5323 antenna unit operating in the N257 band, co-located with an RRU5909 supporting the LTE 1800 MHz anchor layer. The AAU5323 is mounted at 25 m antenna height with azimuth 120°, providing a designed cell radius of approximately 1500 m under open-area LOS conditions. Table I summarizes the hardware parameters.

TABLE I
Site XYZ Hardware Parameters

Parameter	Value
Vendor	Huawei
City	Dammam, Saudi Arabia
Site Name	XYZ
Frequency Band	N257 (26.5–29.5 GHz)
Total Bandwidth	800 MHz (4×200 MHz CA)
TX Power	36.5 dBm
Antenna Height	25 m
Antenna Type	Huawei Massive MIMO (AAU5323)
Antenna Gain	29 dBi
Designed Cell Radius	∼1500 m
Sectors	1 (Azimuth 120°)

B. *Theoretical Peak Throughput Calculation*

The theoretical single-user downlink peak rate is derived using the parametric formula adapted from 3GPP TS 38.306 [4]:

$$R_{\text{peak}} = \frac{N_{\text{RE}} \cdot B_{\text{mod}} \cdot R_c \cdot N_L \cdot \rho_{\text{DL}} \cdot N_{\text{CC}} \cdot (1 - \text{IBLER})}{T_{\text{TTI}}} \tag{1}$$

where N_{RE} is the effective resource elements per DL slot (15,389 bits), B_{mod} is the bits per RE for 64 QAM (= 6), R_c is the coding rate (0.95), N_L is the number of MIMO layers (2), ρ_{DL} is the DL ratio of TDD frame (0.8 for 4:1), N_{CC} is the number of component carriers (4), IBLER is the initial block error rate (0.10), and $T_{\text{TTI}} = 0.125$ ms.

Substituting these values into (1) yields a theoretical aggregate peak downlink rate of approximately **4 Gbps**. Table II summarizes the key configuration parameters.

IV. NSA mmWave Layer Strategy and SCG Addition

A. *Layer Strategy Overview*

The trial operates in 5G Non-Standalone (NSA) architecture, where LTE 1800 MHz serves as the Master Cell Group (MCG) anchor providing control-plane connectivity, while the NR mmWave N257 layer is added as a Secondary Cell Group (SCG) for high-throughput data-plane offload. The C-band NR N78 (100 MHz) layer acts as an intermediate SCG tier.

TABLE II
Key mmWave Configuration Parameters

Parameter	Value
Frequency Band	N257 (26.5–29.5 GHz)
Component Carriers	4 × 200 MHz
Aggregate Bandwidth	800 MHz
Subcarrier Spacing	120 kHz
TTI Duration	0.125 ms
Modulation (Peak)	64 QAM
Coding Rate	0.95
MIMO Layers	2 (Digital Beamforming)
DL:UL TDD Ratio	4:1 (DL factor 0.8)
IBLER	10%
Working Mode	NSA (LTE Anchor)
Target Peak DL Rate	∼4 Gbps

The SCG addition priority is configured to strongly prefer mmWave attachment when signal conditions are adequate: N257 SCG priority is set to 7 versus N78 priority of 1, ensuring UEs within mmWave coverage are aggressively connected to the high-throughput layer. Table III shows the full priority matrix.

TABLE III
NSA SCG Frequency Priority Configuration

RAT	Freq. Band	SCG Priority	Anchor Priority
NR	N78 (3.5 GHz)	1	N/A
NR	N257 (26 GHz)	7	N/A
LTE	L1800 20 MHz	N/A	6
LTE	L1800 15 MHz	N/A	5

B. *SCG Addition Recommended Parameters*

The SCG addition trigger uses Event B1 measurement reporting, where the UE signals the eNB when the NR secondary cell RSRP exceeds a configurable threshold. For the N257 layer, the B1 RSRP threshold (`NsaDcB1ThldRsrp`) is relaxed from the default −105 dBm to −115 dBm to maximize mmWave SCG addition probability within the coverage footprint. The B1 Time-to-Trigger is set to 512 ms for connection stability. The SCG DL frequency priority is planned with N78 = 1 and N257 = 6 to enforce mmWave preference.

V. Carrier Aggregation Configuration

A. *Intra-Band CA Architecture*

To achieve 800 MHz aggregate downlink bandwidth, four 200 MHz component carriers are aggregated using intra-band contiguous CA within the N257 band. NR DU cells (NrDuCellId 50, 54, 58, 62) are enabled with both downlink and uplink CA switches (`INTRA_BAND_CA_SW` and `INTRA_BAND_UL_CA_SW`).

The Primary Component Carrier (PCC) serves as the scheduling anchor, with three Secondary Component Carriers (SCCs) added using a blind SCC configuration strategy (`SCC_BLIND_CONFIG_SW`), which avoids measurement gap overhead and accelerates full-bandwidth aggregation. The A2 RSRP threshold is -109 dBm and A5 RSRP threshold is -105 dBm.

B. CA Frequency Group Configuration

The four component carriers are configured as CA frequency group `CaFreqGroupId = 1` with the following NARFCNs: 2055833, 2059165, 2062497, and 2065829, with corresponding SSB positions at 2054825, 2058157, 2061489, and 2064821 respectively. All carriers use 120 kHz subcarrier spacing consistent with FR2 numerology. A representative extract of the radio configuration commands is shown in Listing 1.

Listing 1. Extract of CA Configuration Commands (NrDuCellId 50)

```
// Enable NRDUCELL CA switch
MOD NRDUCELLALGOSWITCH:
  NrDuCellId=50,
  CaAlgoSwitch=INTRA_BAND_CA_SW-1
             &INTRA_BAND_UL_CA_SW-1;

// Enable SCC blind config
MOD NRCELLCAMGMTCONFIG:
  NrCellId=50,
  CaA2RsrpThld=-109,
  CaA5RsrpThld2=-105,
  CaA6Offset=2,
  CaStrategySwitch=SCC_BLIND_CONFIG_SW-1;

// Configure CA frequency group
ADD GNBCAFREQUENCY:
  CaFreqGroupId=1,
  DlNarfcn=2055833,
  SsbFreqPos=2054825;
```

VI. TEST SETUP AND RESULTS

A. Test Setup

Field measurements were conducted using a CPE Win device positioned at three representative test locations—near-point, mid-point, and far-point—along the azimuth 120° main lobe of Site ZND897's mmWave sector, all under open-area LOS conditions. The transport network employed a 10G PON backhaul via an OLT and PE aggregation node, providing adequate backhaul capacity for mmWave peak throughput tests.

MAC layer padding tests were first conducted to characterize the maximum MAC-layer throughput per component carrier. Results confirmed that each 200 MHz CC achieves approximately 1 Gbps maximum MAC throughput, aligning with theoretical predictions and validating CA configuration integrity.

B. DL/UL Point Measurement Results

Table IV presents the measured DL and UL throughput results at each test point under LOS conditions.

The near-point DL result of 1509 Mbps represents the maximum throughput achievable by the CPE Win device, which is limited by its Ethernet interface to 1.5 Gbps. MAC Padding tests confirm actual air-interface throughput exceeds this ceiling. The UL peak of 358 Mbps is consistent with the 4:1 TDD ratio allocating approximately one-fifth of frame resources to the uplink.

TABLE IV
DL AND UL THROUGHPUT RESULTS – LOS CONDITIONS (SITE ZND897)

Test Point	DL Throughput (Mbps)	UL Throughput (Mbps)
Near	1509	358
Mid	1159	216
Far	944	186

* CPE Ethernet port limits DL to 1.5 Gbps max.

Throughput degrades gracefully with distance in the LOS scenario: DL reduces from 1509 to 944 Mbps (-37.4%) from near to far, while UL reduces from 358 to 186 Mbps (-48.0%). This degradation is attributable to increasing path loss, reduction in received RSRP, and corresponding MCS adaptation to lower-order constellations to maintain link reliability.

C. Discussion

The results confirm that mmWave 5G N257 with 800 MHz CA can deliver multi-gigabit throughput at practical deployment distances in LOS environments. The near-point throughput of 1.5 Gbps with a single 2R CPE terminal, combined with the 4 Gbps theoretical maximum, demonstrates the technology's capacity advantage over sub-6 GHz 5G in dense deployment scenarios.

The NSA architecture with elevated N257 SCG priority (7 vs. 1 for N78) and relaxed B1 RSRP threshold (-115 dBm) demonstrated effective preferential mmWave attachment. The blind SCC configuration strategy minimized CA activation overhead, enabling rapid multi-carrier aggregation without measurement gap delays.

VII. LIMITATIONS AND FUTURE WORK

Several deployment-specific constraints were encountered during the trial:

- **CPE Ethernet Port Bottleneck:** The CPE Win device's Ethernet interface imposes a 1.5 Gbps ceiling, preventing measurement of full air-interface capacity. Future trials should use multi-gigabit (10GbE) test equipment to remove this bottleneck.
- **UE Mobility Limitations:** The CPE is designed for stationary operation; signal instability during mobility tests rendered drive-test measurements unreliable. 5G NR mmWave handset terminals with full beam tracking are required to characterize mobility performance.
- **Indoor Measurement Gap:** No buildings were located within the sector coverage footprint, preventing characterization of indoor penetration loss—a critical factor where typical building losses of 15–30 dB substantially reduce indoor coverage.

- **NLOS Coverage Characterization:** NLOS measurement locations could not be identified due to device limitations. Dedicated NLOS propagation measurements using directional spectrum analyzers are recommended.

Future work should include: (i) NLOS and indoor propagation modeling using ray-tracing simulations calibrated against field measurements; (ii) multi-user MIMO performance evaluation with beamformed spatial multiplexing; (iii) handover performance assessment between mmWave, C-band, and LTE layers; (iv) capacity and coverage trade-off analysis for dense urban small-cell grid planning; and (v) SA (Standalone) mode activation to evaluate native 5G core network performance.

VIII. CONCLUSION

This paper has presented a detailed performance evaluation of a 5G NR mmWave trial deployment at Site ZND897 in Dammam, Saudi Arabia, operating in NSA mode on the N257 band with 4-component carrier aggregation delivering 800 MHz of aggregate bandwidth. Theoretical analysis projects a peak downlink throughput of approximately 4 Gbps per cell, while live field measurements recorded 1509 Mbps DL and 358 Mbps UL at the near-point under LOS conditions.

The NSA SCG addition framework with elevated mmWave priority (N257 = 7) and relaxed B1 RSRP threshold (-115 dBm) demonstrated effective preferential mmWave attachment. The blind SCC configuration strategy minimized CA activation overhead and enabled rapid multi-carrier aggregation.

The trial validates mmWave 5G as a viable ultra-high-throughput capacity layer for urban 5G deployments, infrastructure objectives. The documented limitations provide a clear roadmap for subsequent phases of mmWave network optimization and expansion. These findings contribute to the growing body of field-validated mmWave 5G measurement data and offer practical guidance for network engineers deploying high-frequency 5G installations in the 5G network.

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