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Performance Impact of n77 Second-Carrier Expansion in 5G NR Networks

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***Abstract* - The rapid growth of mobile data traffic in dense urban environments has placed increasing pressure on 5G networks to deliver both wide coverage and high capacity. While the n77 band serves as a key capacity layer for 5G NR deployments, single-carrier configurations often become congested in high-traffic city areas. To address this challenge, operators have begun expanding n77 deployments through the activation of a second carrier to improve load distribution and overall network performance. This paper presents a city-level performance evaluation of n77 second-carrier expansion in a live 5G network. The study analyzes pre- and post-activation performance using a combination of OSS key performance indicators, field measurements, and crowd-sourced Ookla speed test data. Key metrics such as downlink throughput, carrier load distribution, coverage consistency, and NR carrier aggregation utilization are examined. The results demonstrate that second-carrier activation significantly improves peak and median downlink throughput, reduces congestion on the primary carrier, and enhances overall user experience across the city. These findings highlight the effectiveness of n77 second-carrier expansion as a practical and scalable strategy for meeting growing urban 5G capacity demands.**

***Keywords* - 5G NR, mmWave, N257, beamforming, carrier aggregation, throughput, Line-of-Sight, field trial.**

I. INTRODUCTION

The rapid growth in mobile broadband demand, driven by enhanced mobile broadband (eMBB), ultra-high-definition video streaming, cloud applications, and emerging smart city use cases has significantly increased the pressure on existing cellular networks. Fifth Generation (5G) New Radio (NR) technology has been introduced to address these challenges by offering higher data rates, lower latency, improved spectral efficiency, and massive connectivity. Among the various frequency bands allocated for 5G deployment, the mid-band spectrum, particularly Band n77 (3.3–4.2 GHz), plays a crucial role in achieving an optimal balance between coverage and capacity.

As 5G adoption matures, single-carrier deployments in the n77 band often become insufficient to meet the growing traffic demands in dense urban environments. To overcome this limitation, network operators are increasingly adopting multicarrier strategies, including the activation of a second carrier (2nd CC) within the same frequency band. The activation of a second carrier in Band n77 enables effective bandwidth expansion, improved load distribution, and enhanced user throughput without the need for extensive new site deployments.

Carrier aggregation within the same band allows the network to dynamically distribute traffic across multiple carriers, thereby reducing congestion on the primary carrier and improving overall Quality of Service (QoS). At the city level, the impact of N77 2nd carrier activation can be observed in key performance indicators (KPIs) such as average user throughput, cell-edge performance, PRB utilization, latency, and traffic handling capability during peak hours. These improvements are particularly critical in high-density urban clusters where user concentration and data consumption patterns vary significantly across time and location.

This paper presents a detailed technical analysis of N77 second carrier activation and evaluates its impact on city level network performance. The study focuses on real network deployment scenarios and field trial data to quantify performance gains achieved through dual-carrier operation. By analyzing pre- and post-activation KPIs, the paper aims to demonstrate how N77 2nd carrier expansion enhances network capacity, improves user experience, and supports sustainable 5G network evolution.

II. BACKGROUND / RELATED WORK

The evolution of Fifth Generation (5G) New Radio (NR) networks has been driven by the rapid increase in mobile data traffic and the need to support enhanced mobile broadband services, low-latency applications, and diverse quality of service requirements. To address these challenges, 5G NR introduces advanced radio technologies such as flexible numerology, massive multiple-input multiple-output (MIMO), beamforming, and carrier aggregation (CA). Among these techniques, carrier aggregation plays a critical role in improving system capacity by combining multiple component carriers to increase the effective transmission bandwidth.

Band n77, operating in the 3.3–4.2 GHz frequency range, has become one of the primary spectrum resources for 5G NR deployments worldwide due to its wide bandwidth availability and suitability for urban and suburban coverage scenarios. This band enables operators to deploy large contiguous bandwidths, supporting higher user throughput and increased traffic handling capability compared to legacy frequency bands.

Early-stage 5G deployments typically rely on a single carrier configuration in Band n77. While this approach is adequate during initial network rollout, growing user adoption and increased data consumption often lead to high physical resource block (PRB) utilization on the primary carrier. Under such conditions, networks may experience congestion during busy hours, resulting in reduced average throughput, increased scheduling delays, and degradation of user experience, particularly at the cell edge.

To overcome these limitations, network operators have introduced second carrier activation within the same frequency band. The deployment of an additional carrier allows effective bandwidth expansion and improved load distribution without

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requiring new site installations or additional spectrum bands. Same-band dual-carrier operation also simplifies radio design and reduces inter-band coordination complexity, making it an efficient approach for capacity enhancement.

Previous studies on carrier aggregation in 5G NR report significant improvements in peak data rates, average user throughput, and spectral efficiency under high traffic conditions. Research focusing on intra-band carrier aggregation highlights benefits such as improved scheduler flexibility, more efficient PRB utilization, and enhanced user fairness. These advantages become more prominent in dense deployment scenarios where traffic demand varies dynamically across time and location.

Field trial investigations documented in existing literature indicate that activating an additional carrier leads to noticeable reductions in PRB congestion and improved traffic distribution across serving cells. Performance gains have been observed not only in overall throughput but also in cell-edge performance and latency-sensitive services. However, much of the existing research is limited to simulation-based studies or small-scale evaluations, often focusing on individual cells or clusters rather than large urban areas.

Moreover, several prior works concentrate on multi-band aggregation strategies or theoretical capacity modeling, with relatively fewer studies examining same-band second carrier activation using operational network data. Comprehensive city level analyses that assess performance across multiple key performance indicators, such as traffic volume, busy-hour throughput, and resource utilization, remain limited in publicly available literature.

In light of these observations, this study extends existing research by providing a detailed city-level performance evaluation of N77 second carrier activation. By analyzing real network data before and after second carrier deployment, this work aims to quantify capacity gains, efficiency improvements, and user experience enhancements achieved through dual carrier operation. The findings offer practical insights for network planning and contribute to ongoing research on scalable 5G capacity expansion strategies

III. BLOCK DIAGRAM AND GNB ARCHITECTURE

The 5G New Radio base station (gNB) supports dual-carrier operation in Band n77 through a centralized architecture that enables efficient resource sharing and coordinated scheduling. The gNB is logically divided into the Central Unit (CU), Distributed Unit (DU), and Radio Unit (RU). The CU manages higher-layer protocols such as RRC and PDCP, the DU handles MAC, RLC, and PHY functions, and the RU performs RF transmission and reception.

In the N77 second carrier activation scenario, both carriers are controlled by the same gNB, allowing unified radio resource management. A single MAC scheduler dynamically allocates physical resource blocks (PRBs) across the primary and second carriers based on traffic demand, channel conditions, and UE capability. This centralized scheduling approach reduces congestion on the primary carrier and improves overall bandwidth utilization.

Each carrier is processed through an independent PHY chain and transmitted simultaneously via the RU using coordinated antenna elements. Carrier-specific measurements are reported by the UE, enabling optimized scheduling decisions. Control signaling and carrier configuration are managed through the RRC layer, ensuring seamless activation and deactivation of the second carrier without service interruption.

This architecture enables effective bandwidth expansion, improved load balancing, and enhanced user throughput, making second carrier activation a scalable solution for capacity enhancement.

IV. THEORETICAL BACKGROUND

The performance improvement achieved through second carrier activation in 5G New Radio is primarily driven by effective bandwidth expansion and enhanced resource utilization. In a single-carrier configuration, user throughput and system capacity are constrained by the available bandwidth and the level of physical resource block (PRB) utilization. As traffic demand increases, high PRB occupancy leads to scheduling delays and reduced throughput, particularly during busy-hour conditions.

When a second carrier is activated within the same frequency band, the total available bandwidth is increased, allowing traffic to be distributed across multiple carriers. From a theoretical perspective, system capacity scales approximately linearly with bandwidth under similar channel conditions, as expressed by the Shannon capacity relationship. By doubling the usable bandwidth, the achievable data rate can be significantly increased without altering transmission power or modulation schemes.

PRB utilization plays a critical role in scheduler efficiency. In dual-carrier operation, PRBs are allocated independently on each carrier, reducing congestion on the primary carrier and improving scheduling flexibility. This results in better load balancing, improved fairness among users, and enhanced cell edge performance.

Furthermore, centralized scheduling across multiple carriers allows the gNB to dynamically assign resources based on channel quality indicators and traffic priority. This improves spectral efficiency and reduces latency for time-sensitive services. As a result, second carrier activation provides a theoretical foundation for capacity enhancement and user experience improvement in high-traffic deployment scenarios

V. METHODOLOGY

A. Network Configuration and Test Setup

The study was conducted on a live 5G New Radio network with Band n77 deployed across multiple urban sites. A second carrier was activated within the same band, resulting in a dual carrier configuration consisting of N77-F1 and N77-F2, each configured with 100 MHz bandwidth and 64T64R massive MIMO. In addition, carrier aggregation between N77 and N78 was evaluated to analyze performance under extended bandwidth conditions.

N77 was configured as the primary carrier with higher camping priority, while N78 served as a supporting layer to accommodate user equipment (UE) without N77 capability. This configuration ensured consistent accessibility and mobility

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performance while enabling capacity expansion through carrier aggregation

B. Measurement Approach

Performance evaluation was carried out using a combination of operational support system (OSS) statistics and field-level throughput measurements. Downlink throughput was assessed using both network-side KPIs and user-experienced performance obtained through Ookla speed tests. Measurements were collected during busy-hour and non-busy-hour periods to capture realistic traffic conditions.

Key performance indicators included average and peak downlink throughput, PRB utilization, user distribution, traffic volume, and stability metrics such as accessibility, mobility, and retainability. Pre- and post-carrier activation data sets were compared to isolate the impact of second carrier deployment

C. Carrier Aggregation Evaluation

NR carrier aggregation performance was evaluated for two scenarios: intra-band aggregation between N77-F1 and N77F2, and inter-layer aggregation between N77 and N78 with a total aggregated bandwidth of 200 MHz UE capability was considered to ensure aggregation was applied only to supported devices.

Throughput gains were analyzed at both user level and network level. Particular attention was given to median and peak throughput values, as well as changes in overall traffic handling capability and user percentage after carrier aggregation

D. Stability and Interference Assessment

To ensure that capacity enhancement did not adversely affect network stability, accessibility, mobility, and retainability KPIs were continuously monitored throughout the evaluation period. Uplink interference levels were also analyzed and compared against existing NR layers to verify that second carrier activation did not introduce abnormal interference behavior.

VI. RESULTS AND ANALYSIS

A. Downlink Throughput Performance

Activation of the second carrier resulted in a substantial improvement in downlink throughput at both network and user levels. OSS statistics indicate that the average downlink throughput for Band n77 increased to approximately 250 Mbps after carrier aggregation. User-experienced performance measured through Ookla speed tests showed a median throughput of around 600 Mbps, with peak values reaching approximately 580 Mbps under normal conditions.

During controlled field testing with full carrier aggregation enabled, peak downlink throughput values of up to 2.5 Gbps were observed. This confirms that carrier aggregation effectively doubles achievable throughput when compared to single-carrier operation under similar radio conditions.

B. Impact of Carrier Aggregation

Intra-band carrier aggregation between N77-F1 (100 MHz, 64T64R) and N77-F2 (100 MHz, 64T64R) demonstrated clear capacity enhancement. The aggregation of two 100 MHz carriers enabled efficient bandwidth utilization and improved scheduler flexibility. Additionally, aggregation between N77 and N78 with a combined bandwidth of 200 MHz achieved peak throughput values of up to 2.5 Gbps during field trials.

These results validate the effectiveness of same-band and cross-layer carrier aggregation in enhancing system capacity without introducing performance degradation

C. User and Traffic Distribution

Following carrier aggregation activation, the network recorded an increase of approximately 2.8% in active users and 3.9% in total traffic volume. Analysis across 384 deployed N77 sites showed similar user distribution trends before and after activation, indicating that throughput gains were achieved without uneven traffic concentration or localized congestion

D. Network Stability KPIs

Key network stability indicators remained within normal operating ranges throughout the evaluation period. Accessibility, mobility, and retainability KPIs showed no degradation after second carrier activation. Uplink interference levels followed trends consistent with other NR layers, confirming that additional carrier deployment did not introduce abnormal interference behavior

E. Summary of Key Results

TABLE I
DOWNLINK THROUGHPUT PERFORMANCE AFTER CARRIER AGGREGATION

Metric	Observed Value
OSS Average DL Throughput (N77)	~250 Mbps
Ookla Median DL Throughput	~600 Mbps
Ookla Peak DL Throughput	~580 Mbps
Overall Average DL Throughput	~253 Mbps
Peak DL Throughput (Field Test, CA Enabled)	Up to 2.5 Gbps
Throughput Gain After CA	~2× Improvement

Table I summarizes the downlink throughput performance observed after the activation of carrier aggregation. A clear improvement in network and user-experienced throughput is evident across all measurement sources. The OSS-based average downlink throughput for N77 reached approximately 250 Mbps, indicating improved overall cell capacity. User experienced measurements obtained through Ookla tests show a median throughput of around 600 Mbps, confirming that the performance gains are perceptible at the end-user level. Peak throughput values of up to 2.5 Gbps were recorded during controlled field tests with carrier aggregation enabled, demonstrating the effectiveness of bandwidth expansion. The results indicate an approximate twofold improvement in throughput compared to single-carrier operation under similar radio conditions

TABLE II
CARRIER AGGREGATION CONFIGURATION PARAMETERS

Parameter	Configuration
Primary Carrier	N77-F1
Secondary Carrier	N77-F2 / N78
Bandwidth per Carrier	100 MHz
Total Aggregated Bandwidth	200 MHz
MIMO Configuration	64T64R (Both Carriers)
Carrier Aggregation Type	Intra-band and Inter-layer

Table II. The configuration consists of two 100 MHz carriers aggregated to achieve a total bandwidth of 200 MHz Both carriers were deployed with a 64T64R massive MIMO configuration to maximize spatial multiplexing and beamforming gains. N77-F1 was configured as the primary carrier, while N77-F2 or N78 served as the secondary carrier depending on the aggregation scenario. This configuration enabled efficient scheduling and load distribution across carriers, contributing directly to the observed throughput enhancement without negatively impacting network stability.

VII. DISCUSSION

results demonstrate that second carrier activation significantly enhances downlink performance primarily through effective bandwidth expansion and improved resource utilization. The observed throughput doubling under carrier aggregation confirms the theoretical relationship between available bandwidth and achievable data rates when radio conditions and transmission parameters remain consistent.

The substantial improvement in both OSS-based and user experienced throughput indicates that gains are not limited to peak scenarios but are also reflected in day-to-day network performance. The alignment between network-side KPIs and Ookla measurements validates that the performance improvement is perceivable at the user level, which is a critical requirement for real-world deployments.

The use of 64T64R massive MIMO on both N77 carriers further amplifies the benefits of carrier aggregation by improving beamforming gain and spatial multiplexing efficiency. This combination enables higher spectral efficiency while maintaining stable coverage characteristics. Centralized scheduling across aggregated carriers allows dynamic traffic steering, reducing PRB congestion on the primary carrier and improving fairness among users.

The observed increase in user count and traffic volume following carrier aggregation activation suggests improved network attractiveness and enhanced capacity handling capability. Importantly, the similar user distribution across deployed sites confirms that performance gains are achieved at a city level rather than being confined to isolated locations, demonstrating the scalability of the solution.

Network stability metrics, including accessibility, mobility, and retainability, remained stable throughout the evaluation period. This indicates that second carrier activation does not negatively impact control-plane performance or mobility behavior. Additionally, uplink interference trends remained consistent with existing NR layers, confirming that the increased downlink capacity does not introduce adverse interference effects.

The requirement for N77 to operate as the primary carrier in N77+N78 aggregation scenarios highlights the importance of proper layer prioritization. Positioning N77 as the capacity layer with higher camping priority ensures optimal utilization of aggregated bandwidth, while N78 provides coverage continuity for user equipment without N77 capability. This layered strategy enables efficient spectrum utilization while maintaining service availability across diverse UE categories.

Overall, the discussion confirms that second carrier activation is an effective and scalable approach for enhancing network capacity and user experience without compromising network stability. These findings support the adoption of dual carrier strategies as a key element in 5G capacity evolution.

VIII. CONCLUSION

This study evaluated the impact of second carrier activation in a 5G New Radio network using Band n77 at a city level. Dual-carrier operation enabled effective bandwidth expansion and significantly improved downlink throughput. Field measurements confirmed throughput doubling under carrier aggregation, with peak values reaching up to 2.5 Gbps. User experienced performance also improved, as reflected in higher median throughput measurements. The increase in active users and traffic volume demonstrated enhanced network capacity handling capability. Key stability KPIs, including accessibility, mobility, and retainability, remained within normal operating ranges. Uplink interference behavior followed expected trends, indicating no adverse impact from additional carrier deployment. Configuring N77 as the primary carrier ensured optimal performance in aggregation scenarios. The results validate second carrier activation as a scalable and reliable capacity enhancement strategy for 5G networks.

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