

Analyzing 5G Deployments in Urban Environments Through QualiPoc Data Integration with SigCap

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INTRODUCTION

- Initial 5G deployments in 2019 primarily relied on limited millimeter-wave (mmWave) deployments, dynamic spectrum sharing (DSS), and narrow low-band channels
- We measured **AT&T, T-Mobile, and Verizon 5G deployments** in the Chicago Loop to **evaluate the progress of network expansion, spectrum deployments, and uplink enhancements**

MATERIALS & DATA INTEGRATION

- Utilized Samsung (S24+/S25+) and Google Pixel (8/9 Pro) smartphones across the three major carriers
- Data were collected with the following measurement tools: **QualiPoc, SigCap, Network Signal Guru (NSG), and Qtrun AirScreen**
- Since the data exported from these tools were not compatible with each other, we developed a feature allowing researchers to import the CSV's directly into **SigCap** for **joint analysis**

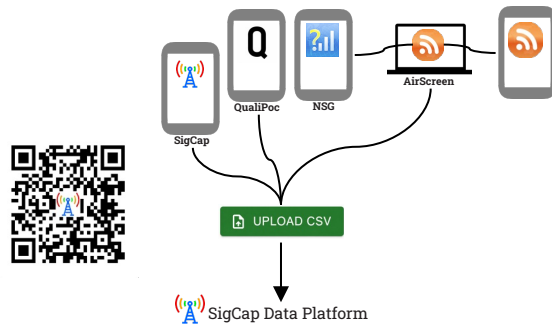


Figure 1. Visualization of data integration

COVERAGE & DEPLOYMENT OVERVIEW

Mid-band (FR1)

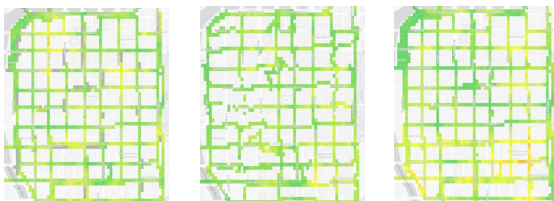


Figure 2. RSRP plot of AT&T n77, T-Mobile n41, and Verizon n77 (from left to right)

- Carriers shifted to deploying **mid-band time-division duplex (TDD)** bands, especially n41 and n77, which provide **better coverage** than mmWave and **higher capacity** compared to low-band
- Since limited initial C-band launches by AT&T and Verizon in 2022, all carriers have achieved full mid-band along the tested route

Millimeter Wave (FR2)

- Compared to a similar study conducted in 2022 [2], AT&T n260 coverage increased, resulting from **new mmWave deployments**
- Verizon is observed to have **deactivated some mmWave nodes**, especially along Michigan Ave., which are now replaced by n77 Small Cell installations
- T-Mobile's recent n258 deployments focus on areas that attract large crowds, such as Grant Park and Navy Pier



Figure 3. RSRP plot of AT&T n260, Verizon n260, and Verizon n261 (from left to right)



Figure 4. RSRP plot of T-Mobile n258 in the Loop (left), n258 in Grant Park (top), and n258 in Navy Pier (bottom)

SPECTRUM DEPLOYMENT

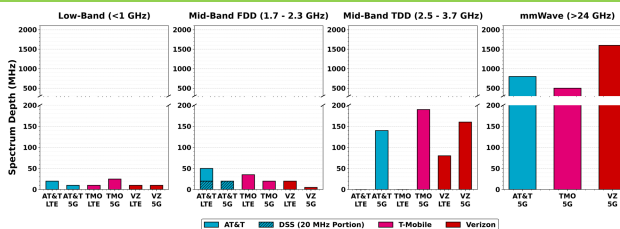


Figure 5. Aggregated bandwidth on LTE vs. 5G

- The higher amount of full-division duplex (FDD) spectrum allocated to LTE suggests there is still a significant LTE user base and/or deployments lacking 5G
- Because AT&T received n77 AMBIT (3.5 GHz) licenses after the initial n77 C-band (3.7 GHz) deployments, only **4 out of 54** n77 PCIs were observed with n77 AMBIT
- An aggregated bandwidth of 400 MHz or below was commonly observed on AT&T and Verizon mmWave deployments instead of the full 800 MHz possible



UPLINK CASE STUDY



- Uplink throughput was measured while walking around a T-Mobile macro near the Harold Washington Library using **n41 UL-MIMO, n41 1Tx, and CA_n41AA_n25AA** configurations
- Significant performance gains were observed with UL-MIMO and UL-CA configurations, even with non-line-of-sight sections
- The UL-MIMO configuration exhibited **increased spectral efficiency** compared to 1Tx
- Higher Tx Power usage was observed during UL-MIMO and UL-CA trials, leading to **higher rates of UE battery drain**

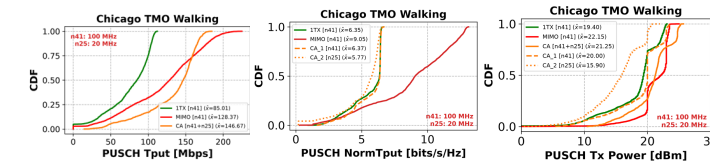


Figure 6. n41 RSRP plot (top left), uplink throughput (left), uplink spectral efficiency (middle), PUSCH Tx power during uplink load (right)

CONCLUSION & FUTURE WORK

- Extensive deployment of mid-band 5G has made 5G access ubiquitous, while mmWave access varies by carrier
- Additional network capacity can be added with undeployed licensed spectrum, such as AT&T n77 AMBIT, T-Mobile n77 C-Band, and additional channels of mmWave
- NR Standalone is widely available for T-Mobile and Verizon subscribers, including the SIM cards used for this study
- While 5G Standalone is active on AT&T's network nationwide, a staged rollout to select customers is still in progress, which did not include the AT&T postpaid SIM used for this study

Future work

- Using physical-layer metrics to evaluate UL-MIMO and UL-CA as ways to improve end-user uplink experience
- Analyze the correlation between uplink Tx power and path loss across mid-band and mmWave

REFERENCES

- [1] <https://sigcap.crc.nd.edu>
- [2] A. Narayanan et al., "A comparative measurement study of commercial 5G mmWave deployments," in Proc. IEEE INFOCOM, 2022, pp. 800–809