

Analysis and Results from the Verizon 5G NR Launch

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Is 5G Real?

Does mmWave really work?

WAY BACK IN OCTOBER 2018



- Evaluated the 5GTF Fixed Wireless Verizon Deployment in Houston, TX
- Both Outdoor and Indoor CPE Used in LOS and NLOS testing
- Six 100 MHz Channels utilized in the 28 GHz band

6 months later...



DIFFERENTIATION OF SRG TESTING VS. CLICK-BAIT TESTING

- TESTING WAS DONE IN THE MINNEAPOLIS AND CHICAGO MARKETS WHERE WE OBSERVED 77 AND 88 UNIQUE 5G NR PCIs.
- For the tests we conducted, we used a combination of UDP and TCP data transfers with each data transfer lasting up to five minutes.
- In our walk and **drive tests**, we looped the test scenario, and several individual tests ran 20 minutes or longer.





TEST SETUP

- WE USED THREE HIGH-BANDWIDTH SERVERS LOCATED DIFFERENT DATA CENTERS TO SUPPLY TWELVE CONCURRENT STREAMS (2 GBPS TOTAL) AND A MAX MTU SEGMENT SIZE OF 1,454 BYTES OVER A 10 GBPS BACKHAUL CONNECTION.
- WE ESTIMATE WE TRANSFERRED CLOSE TO 1 TB OF DATA OVER 5G NR AND LTE IN THE TWO MARKETS WITH THE TWO MOTOROLA Z3 SMARTPHONES.
- EACH INDIVIDUAL MMWAVE CARRIER AND LTE BAND WERE CAPTURED USING ON THE UE AND INDEPENDENTLY WITH A RF SCANNER.

5G CELL SITE AND MORE



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- 5G NR FR2 SITES ARE PART OF THE VERIZON SMALL CELL DENSIFICATION.
 - FOUR 100 MHz CHANNELS IN 28 GHz BAND
 - ERICSSON MARKET USING THE AIR 5121 GNB
 - 46 DBM EIRP PER BEAM
 - 8 BEAMS PER PANEL
 - 4 PANELS
 - 12° HORIZONTAL & VERTICAL BW
- THIS INCLUDES LTE SMALL CELLS AND LAA IN MANY OF THE SITES.



5G PHONE



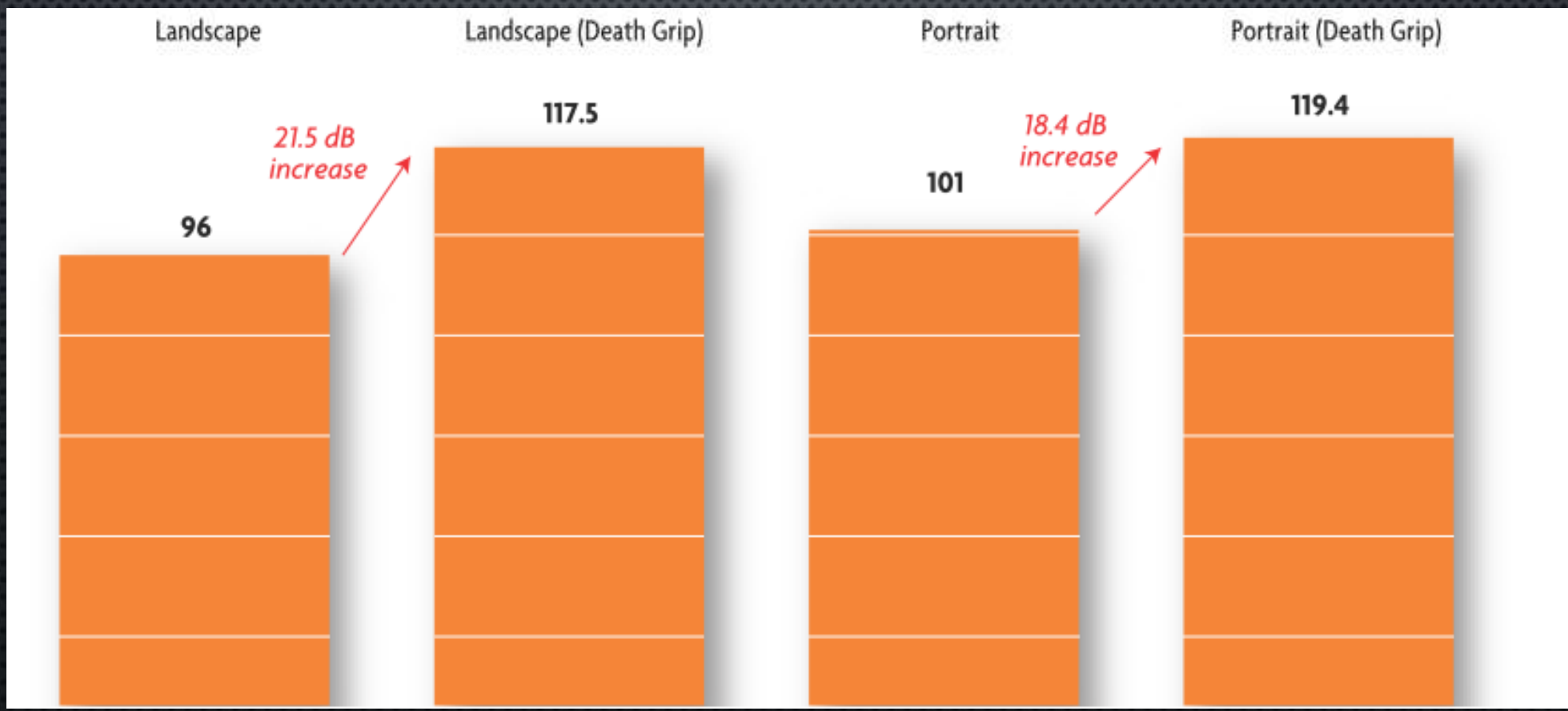
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- SRG USED TWO MOTOROLA Z3 WITH THE 5G NR MOD
- THE ADDITION OF THE MOTO MOD PROVIDED NR AND ALLOWED US TO ACHIEVE 5CC IN CHICAGO WITH 3CC OF LAA
 - FOUR 1x4 MMWAVE ANTENNA ARRAY MODULES (DUAL POL)
 - ARRAYS LOCATED ON SIDES, BACK AND FRONT FACING (TOP BUMP)
 - 8 DBM PER PORT (THEORETICAL MAX)
 - PROXIMITY DETECTOR WAS ENABLED LIMITING PEAK POWER



Image Source: Verizon

DEVICE PATHLOSS PERFORMANCE





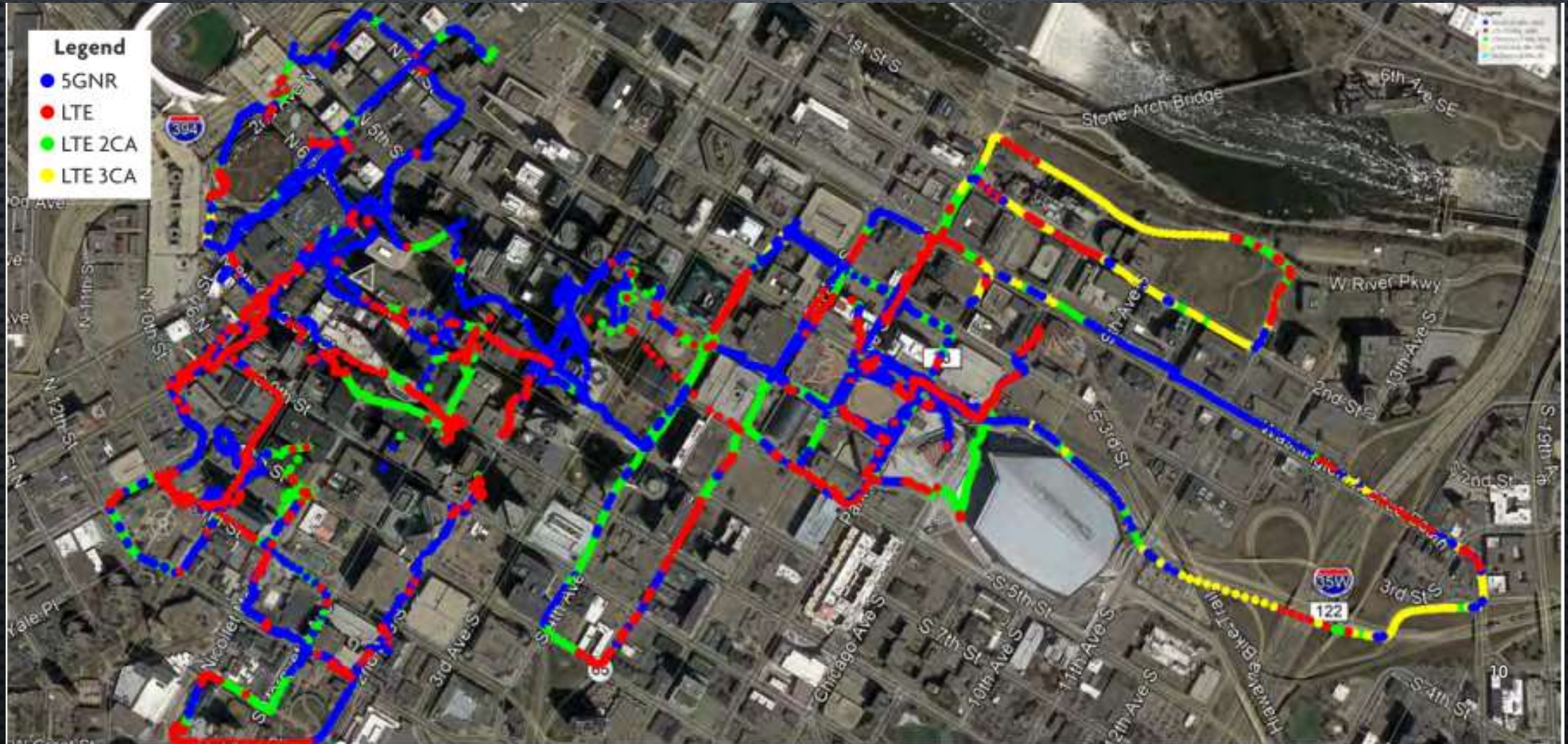
MORE PHONE “WONKINESS”



- “5G UWB” (ULTRA-WIDEBAND) ICON ON THE SMARTPHONE WAS VERY INCONSISTENT IN ACCURATELY DISPLAYING WHETHER DATA WAS RECEIVED OVER NR OR LTE.
 - UE DISPLAYED A STEADY 5G UWB ICON, YET THE LTE RADIO BEARER CARRIED THE DATA TRAFFIC
 - UE 5G UWB ICON FLASHED BETWEEN 5G UWB AND 4G LTE, RRC CONNECTION TIME WASN'T LONG ENOUGH TO SEND MUCH DATA OVER 5G AND LTE DATA WAS MUCH LOWER
 - UE DISPLAYED 4G LTE, BUT IT WAS USING THE 5G RADIO BEARER
- THE USER EXPERIENCE IS ALSO IMPACTED BY HOW THE SMARTPHONE IS HELD AND WHETHER IT IS IN LANDSCAPE OR PORTRAIT ORIENTATION.



RRC CONNECTIONS BY TECHNOLOGY



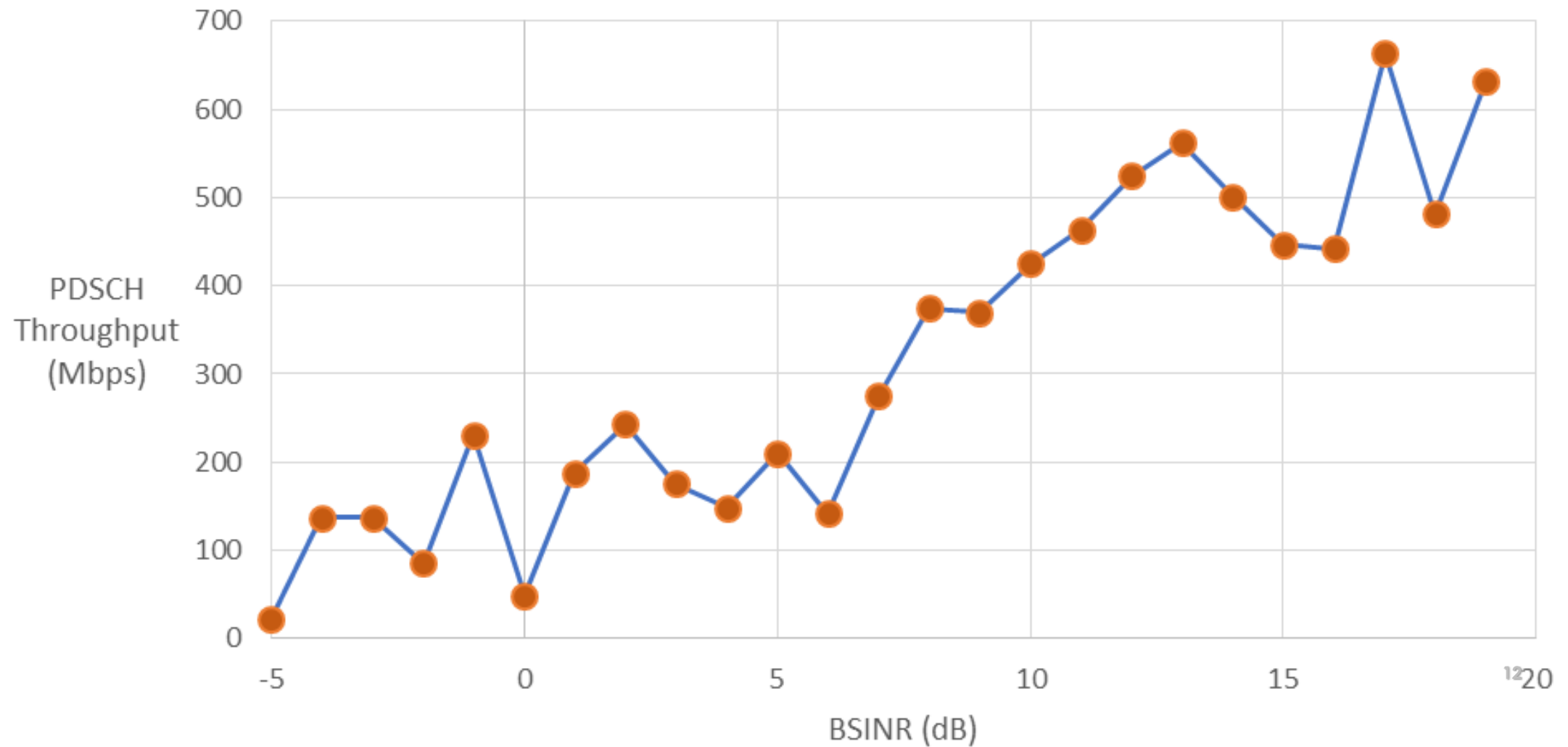


EYE CANDY

[NR 5G] RSRP	-93.2 dBm
[NR 5G] SINR	13.2 dB
[NR 5G] Tx Pwr	6.0 dBm
[NR 5G] PDSCH TP.	1102.69 Mbps
[NR 5G] Rx Bler	14.0 %
[NR 5G] NR ARFCN	2073333

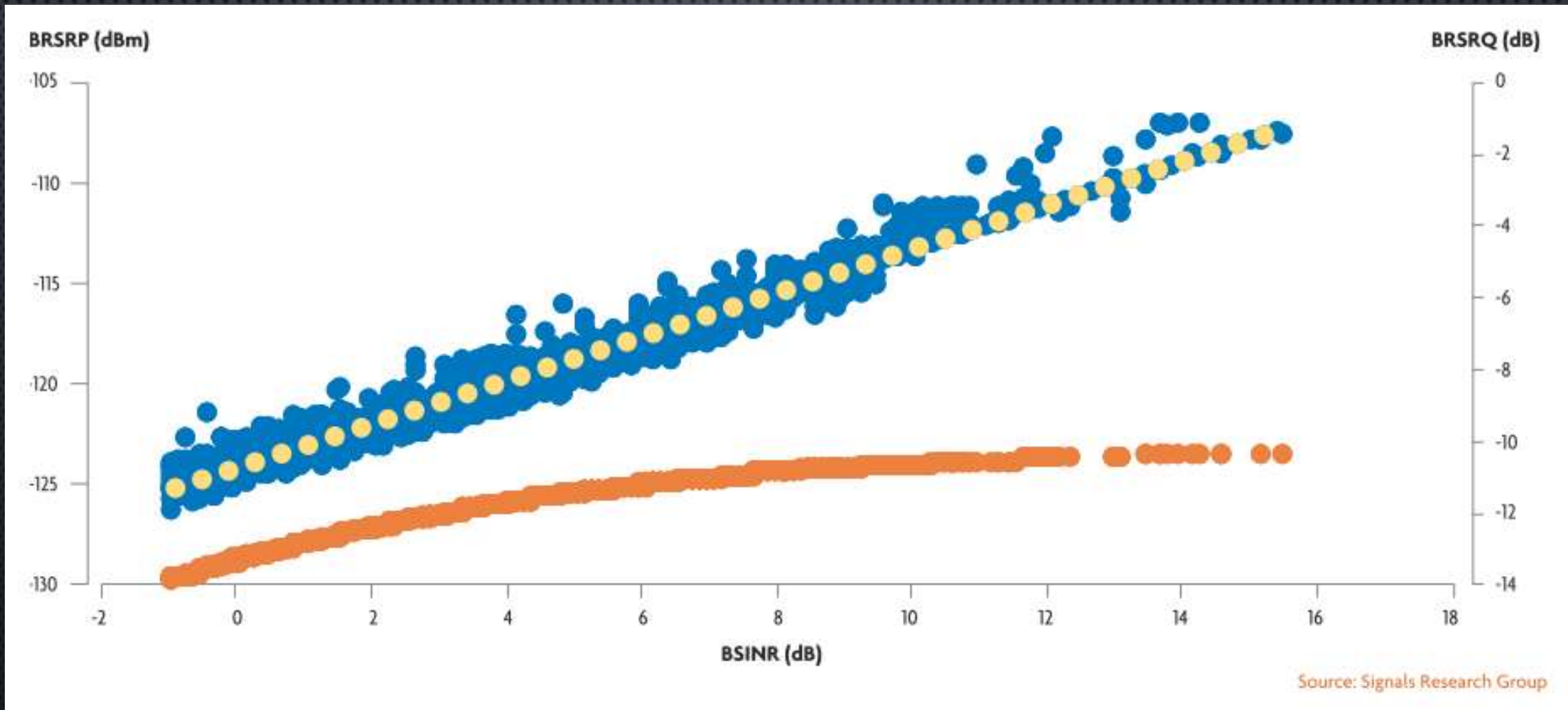


MMWAVE DATA PERFORMANCE



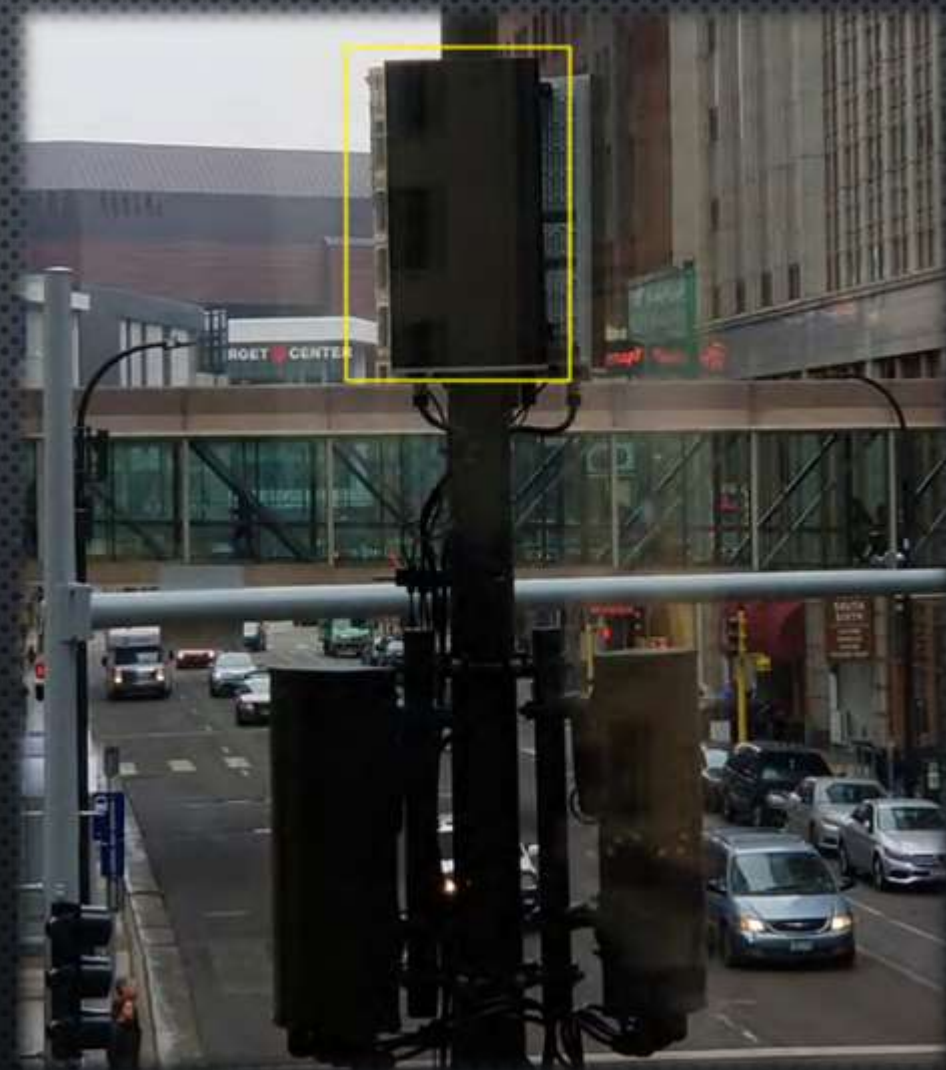


MMWAVE PERFORMANCE





INTERESTING DEPLOYMENT





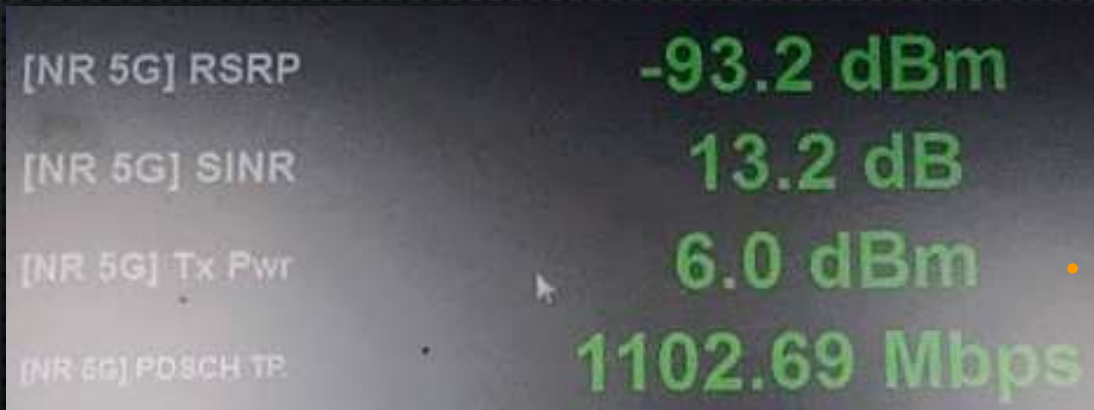
WHAT ELSE DID WE FIND?

5G NR MESSAGING CAPTURE

- THE CURRENT VZW 5G NR NETWORK IS CONFIGURED TO SEND ALL UL DATA VIA LTE
 - MASTER CELL GROUP IS SET TO '0'
 - THRESHOLD SET TO INFINITE

```
[5G-NR RRC_F40 DATA] :  
VALUE RADIOBEARERCONFIG ::=  
  DRB-TOADDMODLIST  
  PDCP-CONFIG  
  MORETHANONERLC  
  PRIMARYPATH
```

HOWEVER...



cellGroup 0
ul-DataSplitThreshold infinity

What's this all about?

GOING DEEP INTO EXTRA INNINGS



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- With no downlink data the UE is still transmitting 6 dBm at nearly 2 Mbps in near and far cell conditions
- This appears to be the Uplink Control Information (UCI) which contains Channel State Info (CSI), HARQ, CQI and Scheduling Requests (SR).
 - Looking even deeper this is sent over 2 Resource Blocks
 - 6 dBm spread over 2.88 MHz...

[NR 5G] PCI	5
[NR 5G] RSRQ	-10.9 dB
[NR 5G] PDSCH TP.	0.05 Mbps
[NR 5G] Rx Bler	0.0 %
[NR 5G] PUSCH TP.	1.97 Mbps

5G NR MESSAGING CAPTURE

[PUCCH-CONFIGCOMMON

nRB-CQI 2 CCH-SHIFT DS1,

nRB-CQI 2



LAST THOUGHTS

- WE OBSERVED PHYSICAL LAYER DATA SPEEDS OF 1-1.2 GBPS (PEAKS UP TO 1.5-1.8 GBPS) ARE READILY ACHIEVABLE IN THE NETWORK, INCLUDING THESE SPEEDS AT DISTANCES OF UP TO 140 METERS IN SOME INSTANCES.
- THESE ARE EARLY DAYS SO THERE NEEDS TO BE SOME OPTIMIZATION DONE. WE FOUND THE 5G NR NETWORK AND THE MILLIMETER WAVE PERFORMANCE TO BE PREDICTABLY UNPREDICTABLE.
- WE OBSERVED THAT LOW DATA SPEEDS AND/OR THE PHONE'S INABILITY TO GET ASSIGNED AND REMAIN CONNECTED TO A 5G NR RADIO BEARER DIDN'T NECESSARILY MEAN THE QUALITY AND STRENGTH OF THE MILLIMETER WAVE SIGNAL WAS POOR.
 - BEAM MANAGEMENT, INCLUDING THE ABILITY OF THE MOBILE DEVICE TO SUPPORT INTER-CELL AND INTER-BEAM (INTRA-CELL) HANDOVERS ISN'T SUPPORTED, OR AT LEAST IT DOESN'T WORK LIKE WE WOULD EXPECT.
- MILLIMETER WAVE ALSO REQUIRES A PARADIGM SHIFT IN THINKING ABOUT HOW CELLULAR NETWORKS WORK AND HOW THEY SHOULD PERFORM. FR2 DEPLOYMENTS WILL ALWAYS NEED 5G NR/LTE NETWORKS IN THE LOWER BANDS TO PROVIDE SEAMLESS CONNECTIVITY. THE CELL SITE DENSIFICATION REQUIRED TO SUPPORT MILLIMETER WAVE IS ALSO RELATIVELY SIGNIFICANT



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THANK YOU

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