

November 2020

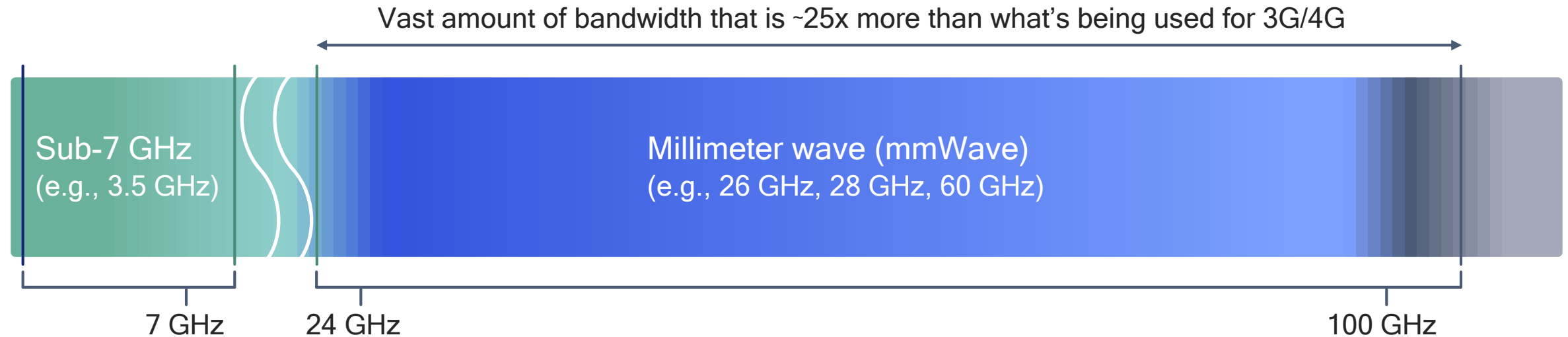
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# Deploying 5G NR mmWave to unleash the full 5G potential



# New frontier of mobile broadband – mobilizing mmWave



**Multi-Gbps data rates**

With large bandwidths (100s of MHz)

**Much more capacity**














With dense spatial reuse

**Lower latency**

Bringing new opportunities



# Global mmWave spectrum targets

	24-28GHz	37-40GHz	64-71GHz	>95GHz
	24.25-24.45GHz 24.75-25.25GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz 47.2-48.2GHz	57-64GHz 64-71GHz	>95GHz
	26.5-27.5GHz 27.5-28.35GHz	37-37.6GHz 37.6-40GHz	57-64GHz 64-71GHz	
	24.5-27.5GHz		57-66GHz	
	26GHz		57-66GHz	
	26GHz		57-66GHz	
	26GHz		57-66GHz	
	26.5-27.5GHz		57-66GHz	
	24.75-27.5GHz	40.5-43.5GHz		
	25.7-26.5GHz 26.5-28.9.5GHz 28.9-29.5GHz	37GHz	57-66GHz	
	26.6-27GHz 27-29.5GHz	39-43.5GHz	57-66GHz	
	27.9-29.5GHz			
	24.25-27.5GHz 27.5-29.5GHz	37-43.5GHz		
	24.25-29.5GHz	39GHz	57-66GHz	

# 5G NR mmWave spectrum highlights

Ready for deployment in 2020 & beyond



U.S.

Completed three mmWave auctions so far, including 24, 28, 37, 39, and 47 GHz



South Korea

28 GHz auction completed in Jun. 2018; each operator assigned 800 MHz; plan to secure additional spectrum in 2021



Japan

Assigned 28 GHz mmWave spectrum in Apr. 2019; technical rules for additional spectrum (e.g., 26.6-27 GHz and 39.5-43.5 GHz) planned for 2021



Taiwan

Auction completed in Feb. 2020 with a total of 1.6 GHz in 28 GHz band awarded to 4 operators



Italy

5G spectrum auction completed in Sep. 2018 with right of use starting January 1st, 2019



Russia

26 GHz auction completed in Q4 2018 to enable 2019+ commercial deployments



Germany

26 GHz spectrum award planned for Q4 2020

Finland, UK have also made mmWave spectrum available

# 5G Rollout Outlook

## USA

- Now ● NSA Sub-6 GHz  
● mmWave  
● Sub-6 FDD  
● Standalone
- 
- 2021 ● Sub-6 carrier aggregation  
+ Sub-6 + mmWave aggregation

## Europe

- Now ● NSA Sub-6 GHz  
● Sub-6 FDD
- 
- 2020 ● mmWave
- 
- 2021 ● Sub-6 carrier aggregation  
● Standalone

## LatAm

- Now ● NSA Sub-6 GHz  
● Sub-6 FDD
- 
- 2021 + mmWave  
+ Sub-6 carrier aggregation  
● Standalone

## China

- Now ● NSA Sub-6 GHz
- 
- 2020 ● Sub-6 FDD  
● Standalone
- 
- 2021 ● Sub-6 carrier aggregation  
+ mmWave

## India

- 2021 + NSA Sub-6 GHz  
+ mmWave  
● Standalone

## SEA

- Now ● NSA Sub-6 GHz
- 
- 2020 + mmWave
- 
- 2021 ● Standalone

## Japan

- Now ● NSA Sub-6 GHz  
● mmWave
- 
- 2020 ● Sub-6 FDD  
● Sub-6 carrier aggregation
- 
- 2021 ● Standalone  
+ Sub-6 + mmWave aggregation

## Korea

- Now ● NSA Sub-6 GHz
- 
- 2020 ● mmWave  
● Standalone
- 
- 2021 + Sub-6 FDD  
+ Sub-6 carrier aggregation  
+ Sub-6 + mmWave aggregation

## Australia

- Now ● NSA Sub-6 GHz
- 
- 2020 ● Sub-6 FDD
- 
- 2021 ● mmWave  
● Sub-6 carrier aggregation  
● Standalone



# 5G mmWave commercial devices powered by Snapdragon

## 5G smartphones



## PCs



## Modules



## Hotspots



## CPEs





# 5G NR mmWave is bringing new waves of opportunities



## For outdoor deployments...

- Significantly elevate today's mobile experiences – initially focusing on smartphones
- Deployments predominantly driven by mobile operators – initially focusing on dense urban



## For indoor deployments...

- Complementing existing wireless services provided by Wi-Fi—also expanding to new device types
- Bringing superior speeds and virtually unlimited capacity for enhanced experiences

## Creating value for the mobile ecosystem

Operators, service providers, venue owners, infra vendors, device OEMs,...

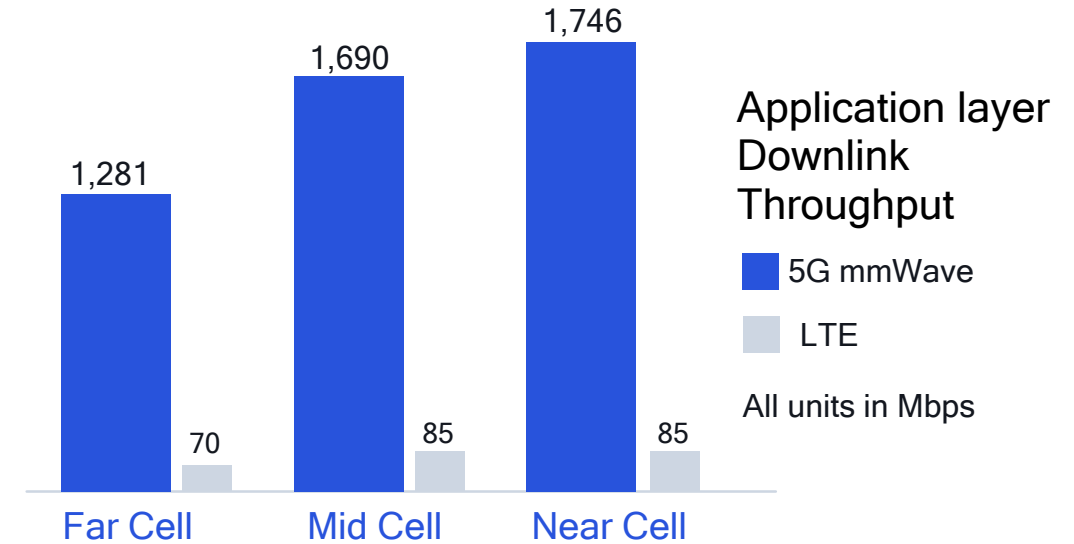


# Conducting 5G mmWave performance field tests

Tests in commercial network show 1 Gbps+ downlink sustained throughput in all scenarios



5G mmWave gNodeB



Throughput achieved\*  
**1,821 Mbps downlink**  
**96.9 Mbps uplink**

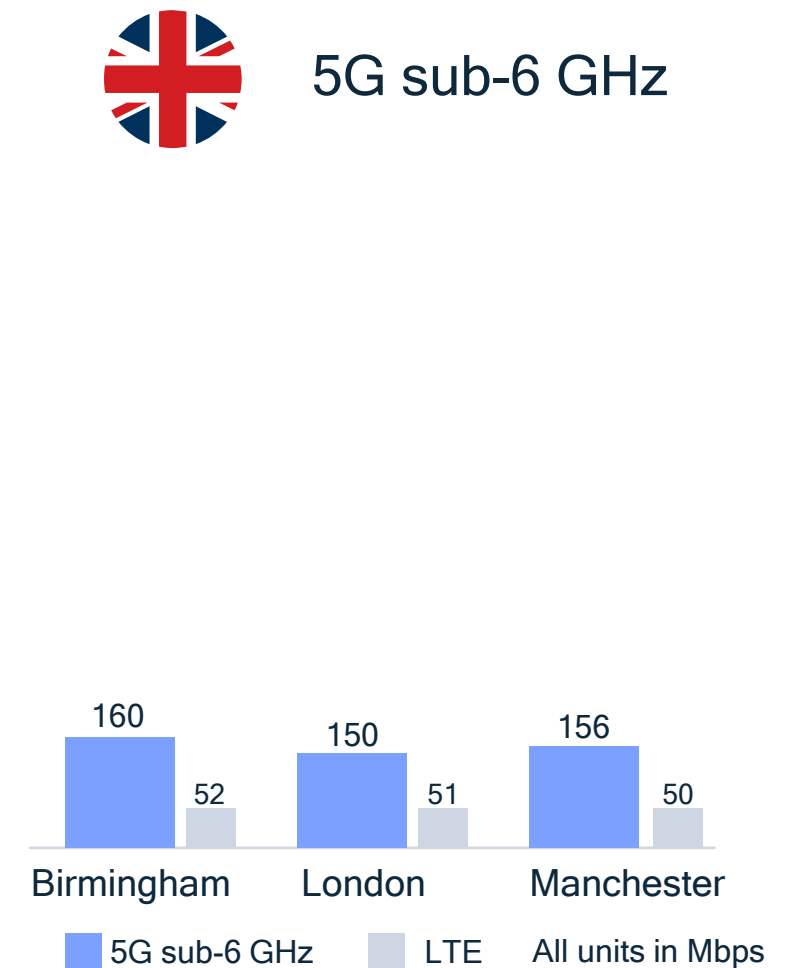
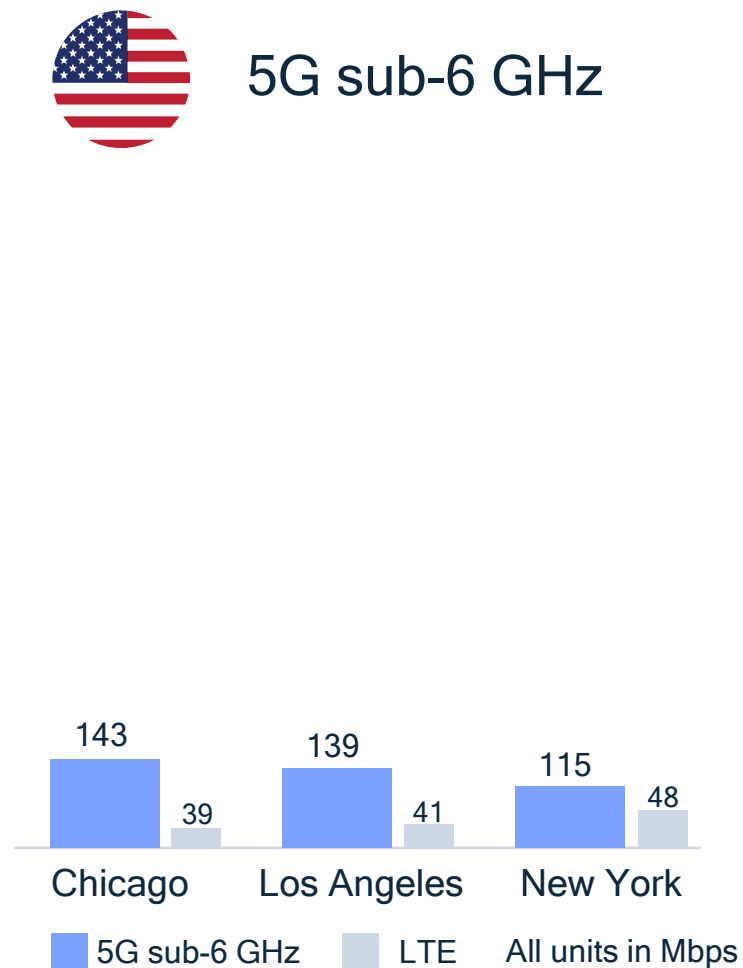
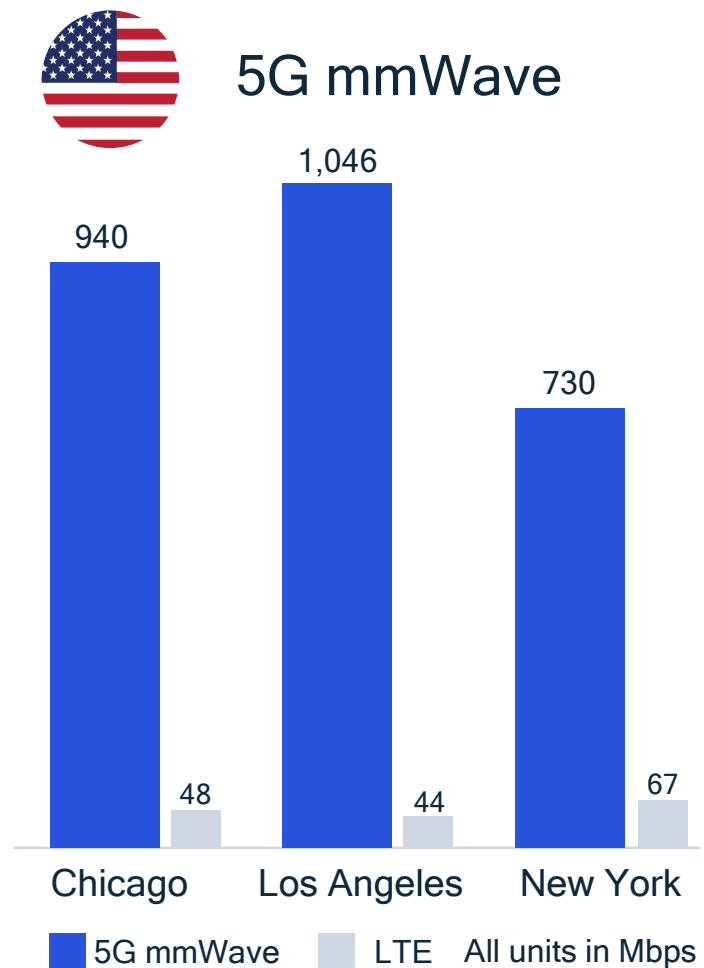


Throughput achieved\*  
**1,780 Mbps downlink**  
**73.1 Mbps uplink**

\*Measured using Ookla SpeedTest

# 5G mmWave delivers unparalleled user experience

3 Gbps in peak download speed and significant gains in average throughput observed by 5G mmWave users





## Indoor enterprises

Offices, auditoriums, manufacturing



## Indoor/outdoor venues

Conventions, concerts, stadiums



## Transportation hubs

Airports, train terminals, subway stations



## Fixed wireless access

Urban cities, suburban towns, rural villages



## Industrial IoT

Factories, warehouses, logistic hubs



# Expanding mmWave indoors, private networks, homes, IIoT



Multi-Gigabit speeds with virtually unlimited capacity



Beyond smartphones, laptops, tablets, extended reality, ...



Leveraging existing Wi-Fi or cellular by co-siting



# Testing 5G NR mobile mmWave for indoor enterprises

## Using commercial equipment

### Achieving significant coverage at 28 GHz<sup>1</sup>

- Single sector provides solid coverage in the lobby, atrium, and part of the auditorium
- Significant NLOS coverage behind the gNodeB, including the 2nd and 3rd floor

### Extreme capacity for enterprise use cases

- Downlink median burst rate<sup>2</sup> of 3.1 Gbps

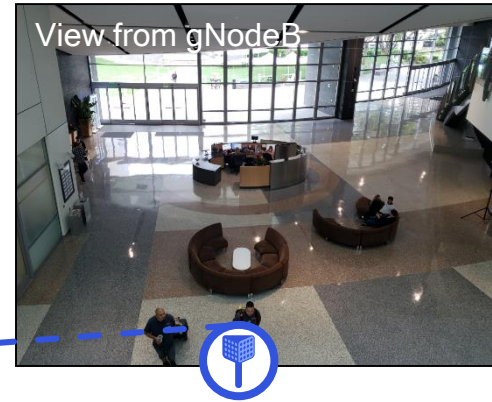
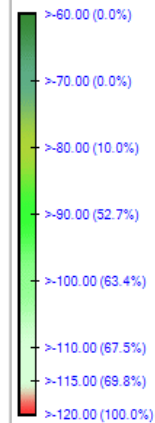


Achieving Gigabit speeds even in NLOS

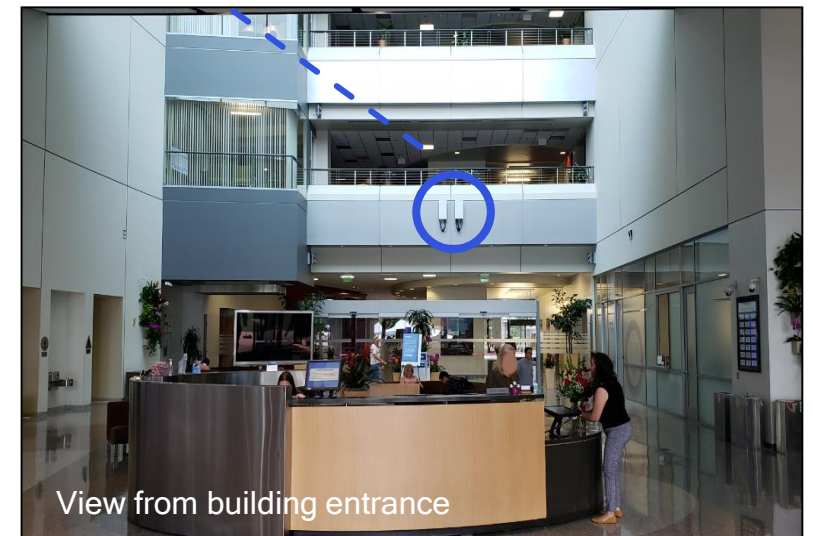
<sup>1</sup> Coverage simulation based on MAPL (maximum allowable path loss) analysis with ray tracer propagation model and measured material and propagation loss; minimum 0.4/0.1 bps/Hz for downlink/uplink data and control; <sup>2</sup> Using 400 MHz DL bandwidth



Path loss (dB)



28 GHz gNodeB  
▪ 1-sector; ~20ft. height  
▪ 400 MHz bandwidth



View from building entrance



# Bringing massive capacity and new experiences to stadiums

28 GHz band with 4x100 MHz CA – NSA with multiple LTE anchors<sup>1</sup>

98%

5G coverage in bowl seating from 8 sectors  
28 GHz with 100x4 GHz BW

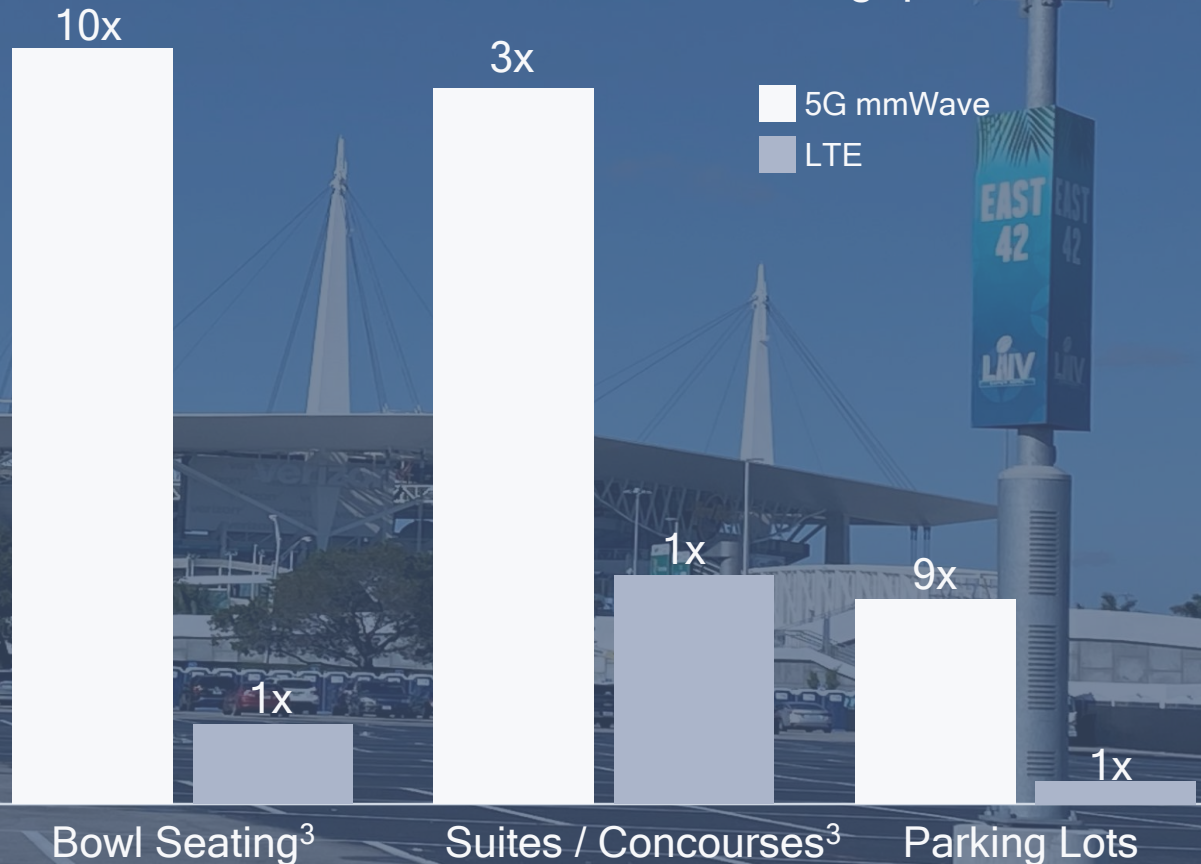
121

Bowl sectors  
100 sectors in AWS/PCS  
21 sectors in 700 MHz band

45 / 62

5G / 4G Sectors  
in parking lot

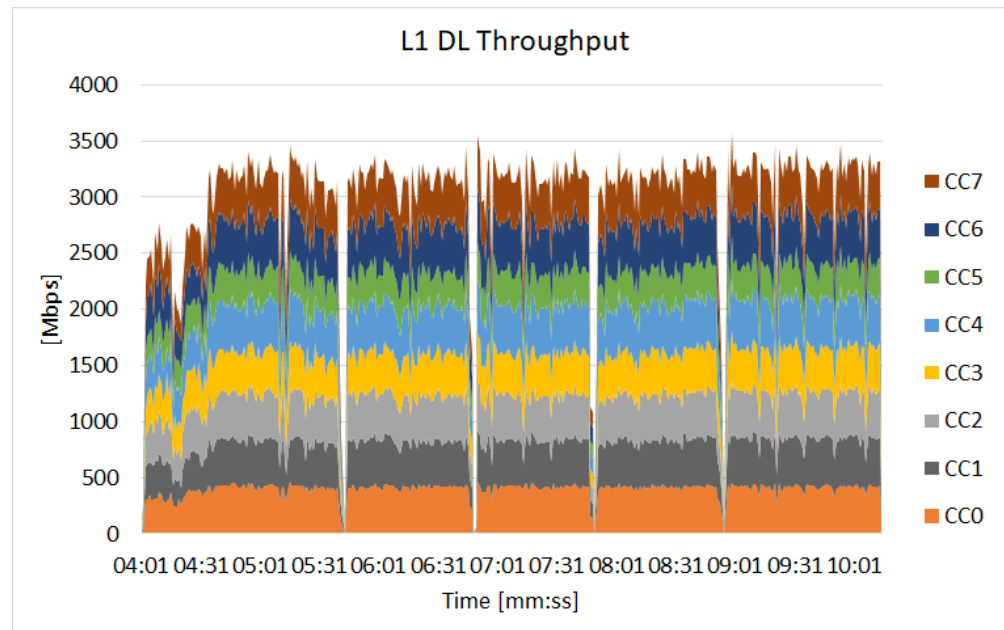
### 5G vs. 4G Downlink Throughput<sup>2</sup>



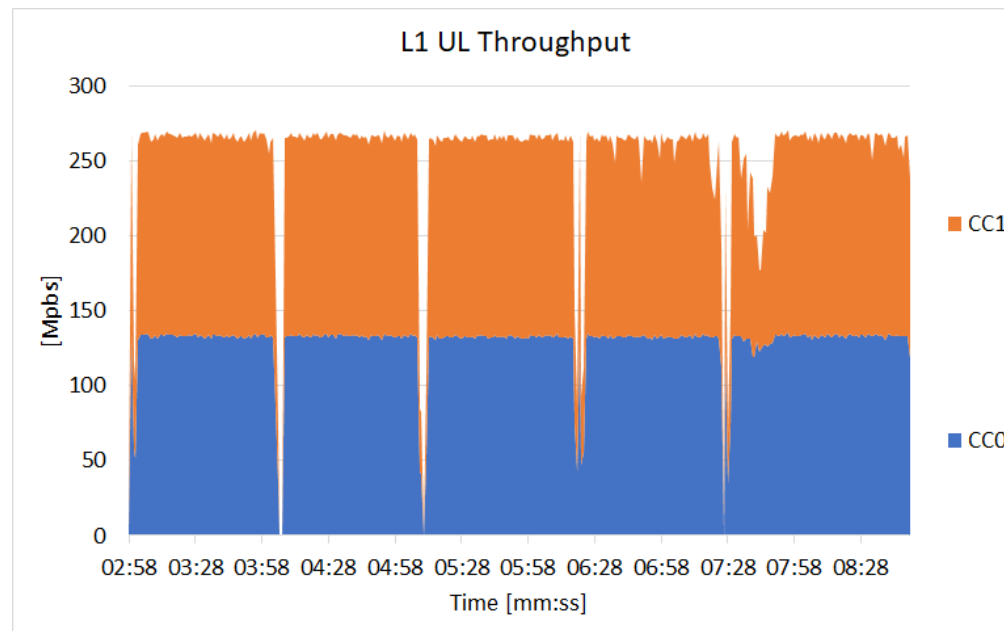
<sup>1</sup> AWS/PCS and 700 MHz bands; <sup>2</sup> Device testing from 2pm to midnight; <sup>3</sup> High 4G throughput in Bowl and Suites/concourses are due to trial CBRS sectors with 80 MHz aggregated bandwidth

# Field testing 5G mmWave in a railway station

Deploying in 28 GHz (n257) with NSA option 3x using 2.1 GHz (B1) LTE anchor



**3.6 Gbps**  
Peak downlink throughput with 800 MHz BW (8x CA)



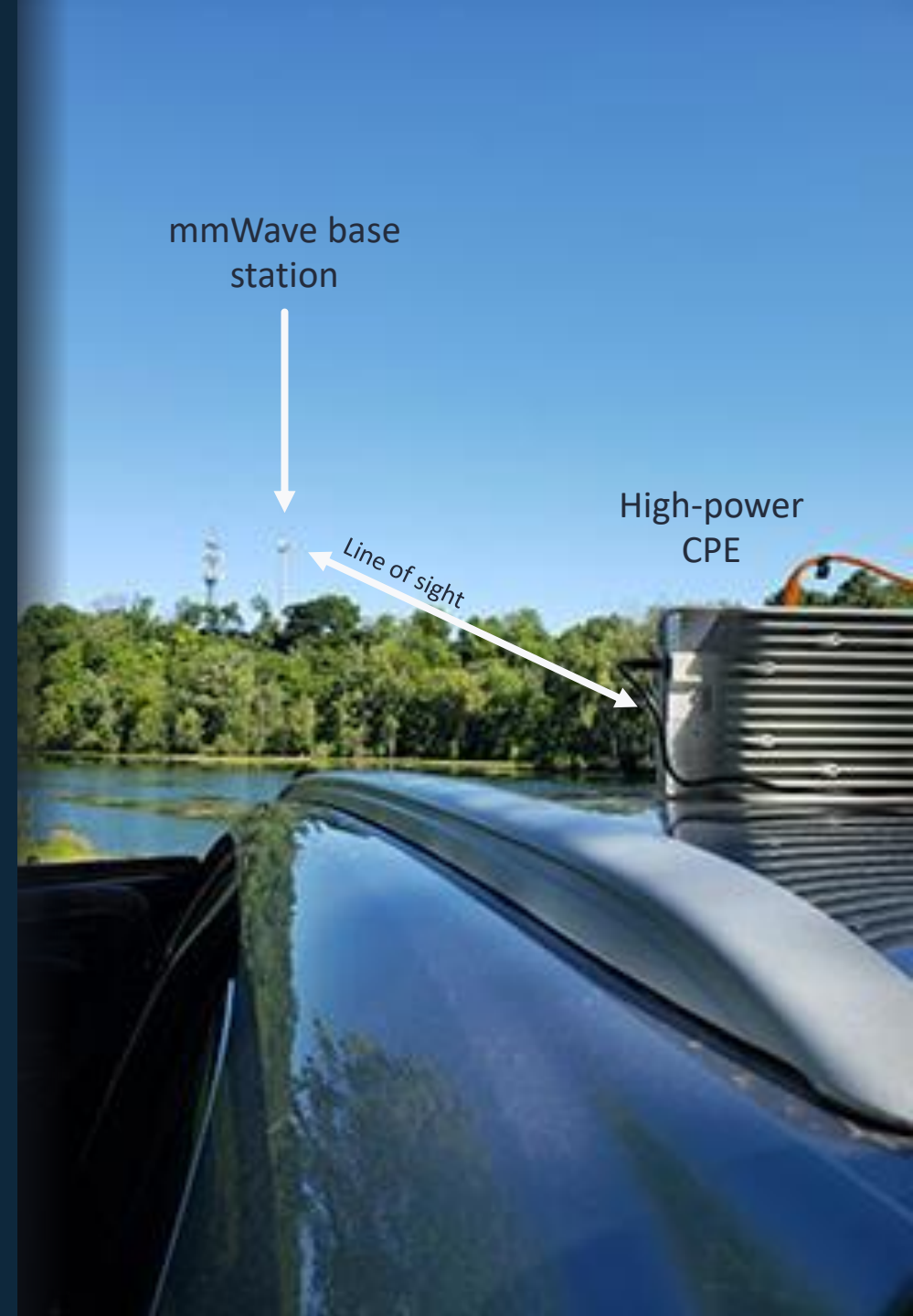
**271 Mbps**  
Peak downlink throughput with 200 MHz BW (2x CA)



# Rural America: Extended-Range mmWave delivers significant coverage improvement

Field trial collaboration with U.S. Cellular operator and Ericsson

## Test Setup



# Collaborating with ecosystem leaders to deploy 5G mmWave smart factory

## Initial use cases:



Automatic inspection of product lines via automated guided vehicle (AGV) and overhead transmission (OHT)  
– 20 Mbps DL, 120 Mbps UL



Remote augmented reality for equipment troubleshooting, maintenance, and repair  
– 25 Mbps DL, 25 Mbps UL



Immersive virtual/augmented reality for visitors of Green Technology Education Center  
– 25 Mbps DL, 2.5 Mbps UL

1 With DL and UL bandwidth of 400 MHz and 200 MHz, respectively  
Source: [https://ase.aseglobal.com/en/press\\_room/content/5g\\_smart\\_factory\\_en](https://ase.aseglobal.com/en/press_room/content/5g_smart_factory_en)

Factory manufacturing floor (~34,159 sq. ft.); 12 ft. ceiling height



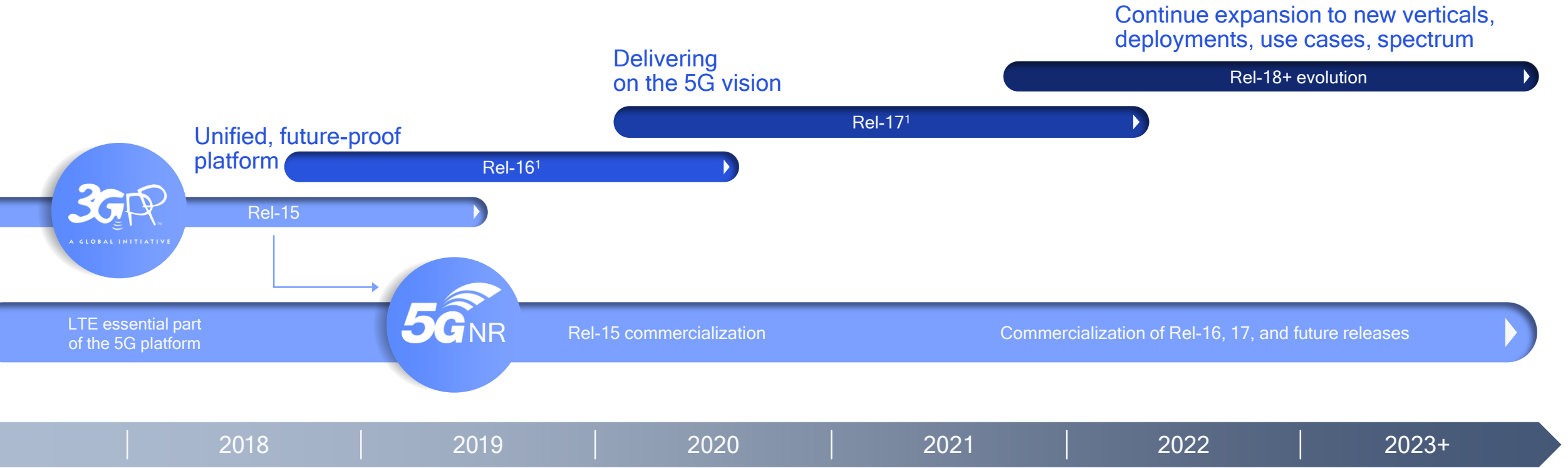
5G NR NSA network operating in 28 GHz band, achieving median throughput greater than **1.5 Gbps** in DL and **120 Mbps** in UL<sup>1</sup>



# Evolving mmWave in 3GPP Rel-16+



# Driving the 5G technology evolution



## Rel-15 eMBB focus

- 5G NR foundation
- Smartphones, FWA, PC
- Expanding to venues, enterprises

## Rel-16 industry expansion

- eURLLC and TSN for IIoT
- NR in unlicensed (NR-U)
- Positioning
- 5G V2X sidelink multicast
- In-band eMTC/NB-IoT

## Rel-17+ long-term expansion

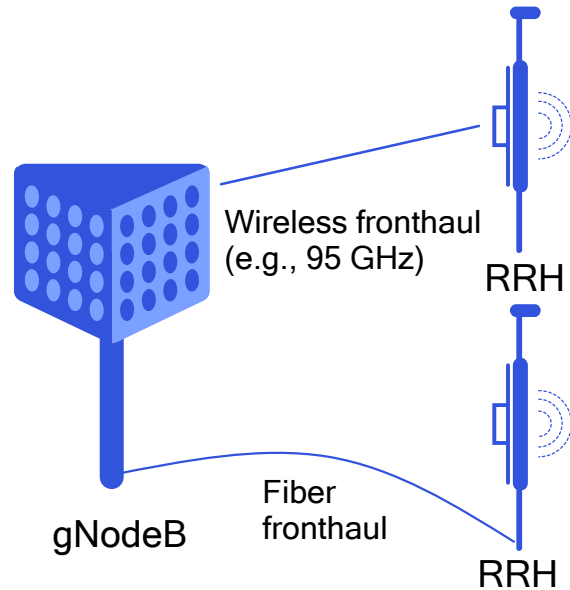
- Lower complexity NR-Light
- Boundless extended reality (XR)
- Higher precision positioning and more...

1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1



# Distributing antennas to improve robustness and coverage

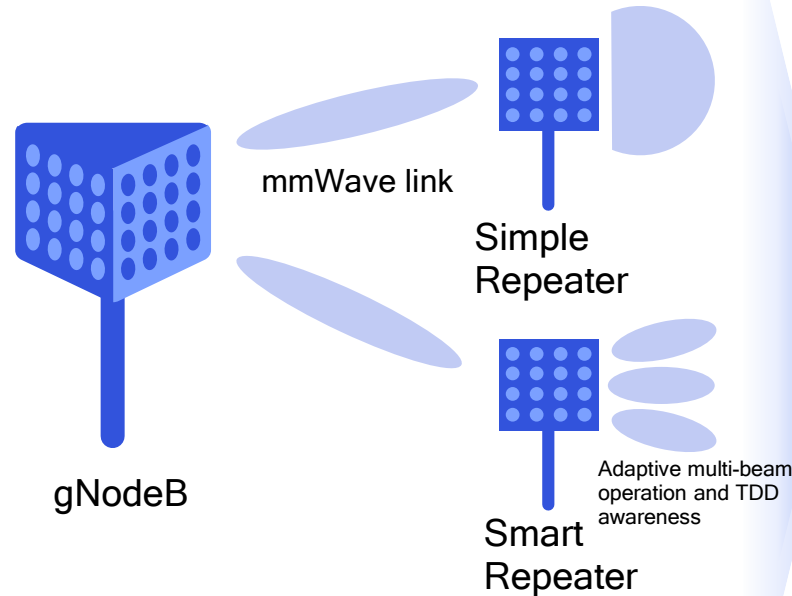
## mmWave gNodeB



5G NR mmWave gNodeB and remote radio heads (RRHs)

Beam overlap with improved angular diversity

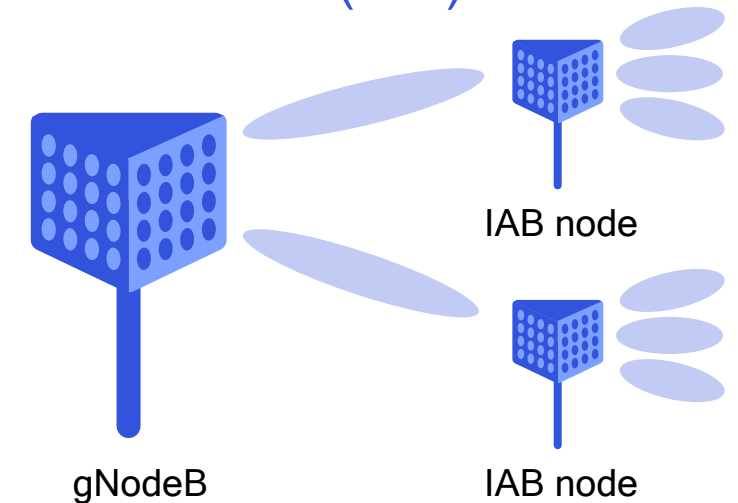
## mmWave repeaters



Extending coverage with simple repeaters, smart repeaters in Rel-17+

Flexible spatial reuse from single mmWave cell

## mmWave integrated access and backhaul (IAB)

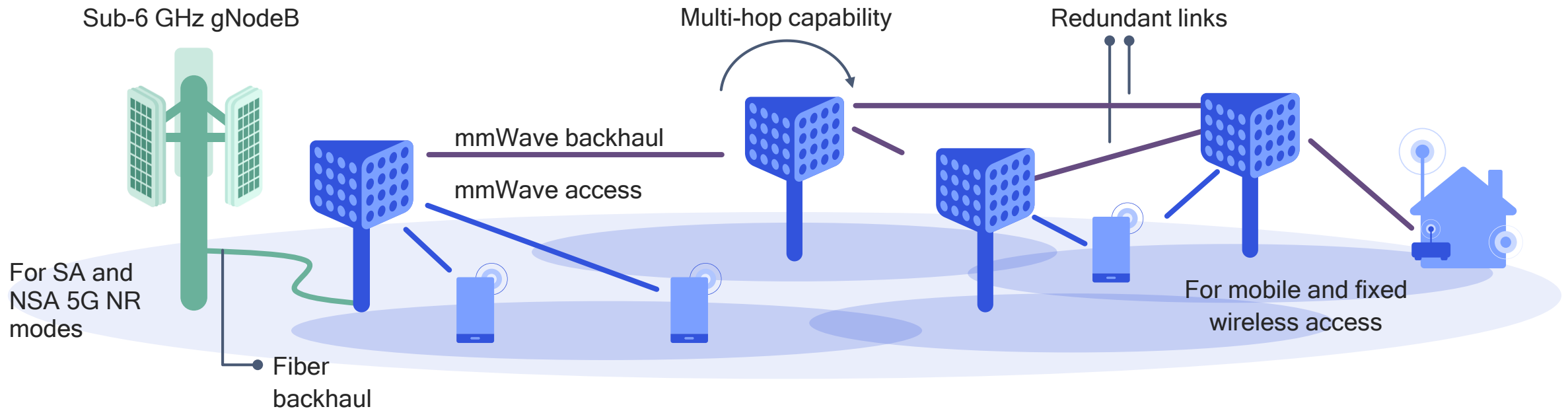


Rel-16 IAB improves coverage and capacity, further enhancements in Rel-17+

Range extension and coverage around blockages

# 5G NR mmWave IAB<sup>1</sup> for cost-efficient dense deployments

Improves coverage and capacity, while limiting backhaul cost



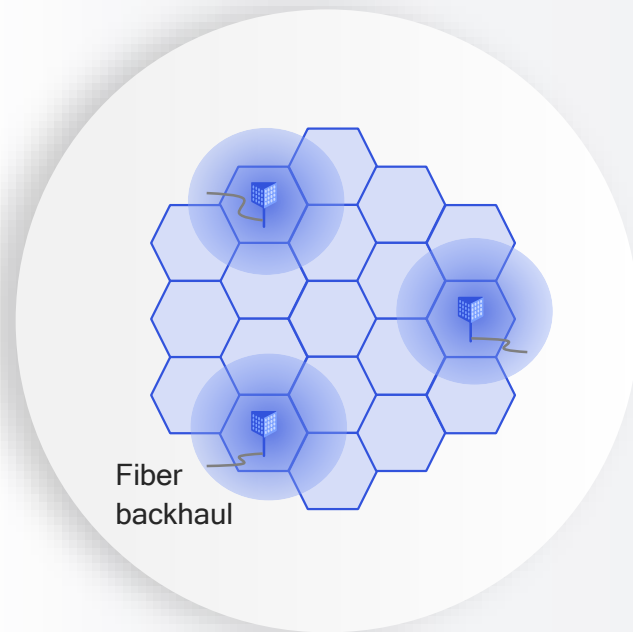
1 Integrated Access and Backhaul

Traditional fiber backhaul can be expensive for mmWave cell sites

- mmWave access inherently requires small cell deployment
- Running fiber to each cell site may not be feasible and can be cost prohibitive
- mmWave backhaul can have longer range compared to access
- mmWave access and backhaul can flexibly share common resources

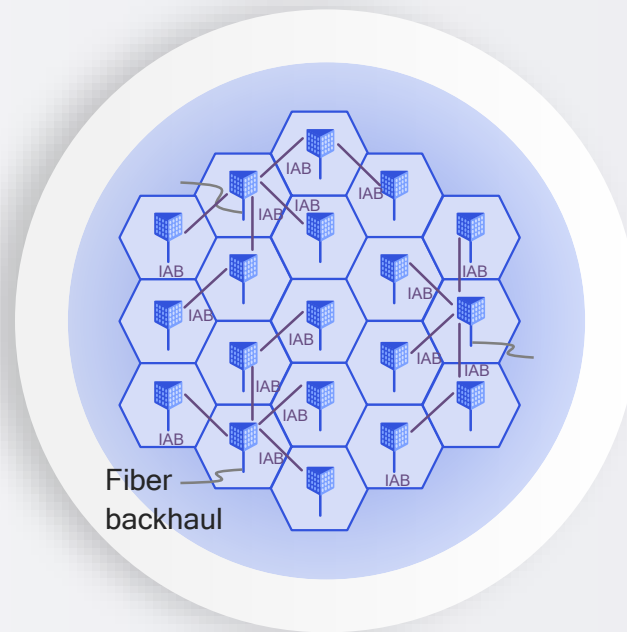
# Supporting a flexible network deployment strategy

IAB can enable rapid and cost-efficient 5G NR mmWave network buildout



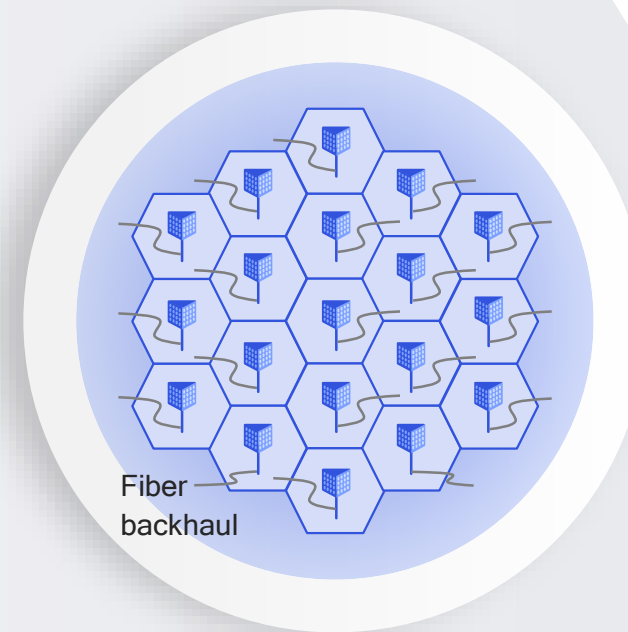
## Early 5G NR mmWave deployments based on Rel-15

Starting to connect new 5G NR mmWave base stations using limited/existing fiber links



## Widening 5G NR mmWave coverage using IAB

Incrementally deploying additional base stations with IAB still using limited/existing fiber links



## Supporting rapid traffic growth with additional fibers

Deploying new fiber links for selected IAB nodes as capacity demands increase



# Deploying IAB to expand mmWave coverage

End-to-end system simulations using 5G NR mmWave at 28 GHz

## Frankfurt, Germany

Total simulation area:

~1 km<sup>2</sup>

Total number of gNodeBs:

7

Total number of IAB nodes:

28

Total number of devices:

300

[Link to full demonstration video](#)



### Map Legend



gNodeB site

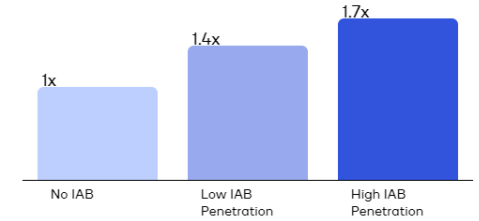


IAB site

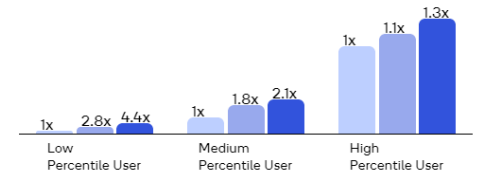


# mmWave devices

### Average downlink signal improvement



### Network throughput improvement



### mmWave coverage simulation results



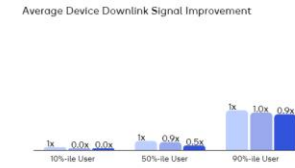
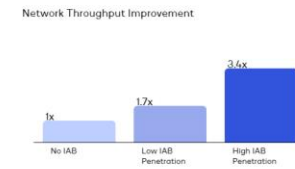
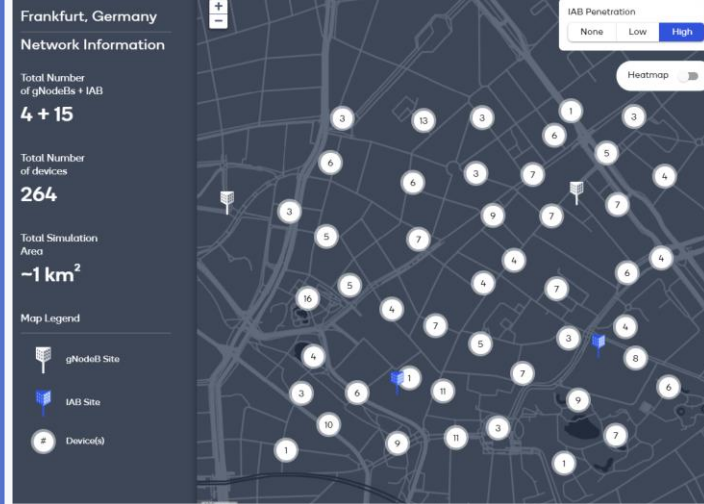
No IAB



With IAB



# Breaking the technology boundary with 5G mobile mmWave evolution



37%

Average Power Saving Enhancement



## Advanced 5G mmWave OTA test network

- 3GPP-compliant 5G mmWave network operating at 28 GHz capable of 800 MHz bandwidth
- Robustness with crowd blocking and high-speed mobility (i.e., device travelling on a drone)
- Boundless virtual reality (VR) experiences using 5G, edge cloud and on-device processing

## 5G mobile mmWave technology evolution

- System simulations of new features in Rel-16+
  - Integrated access and backhaul
  - Multiple transmission and reception point
  - Advanced device power saving features



# 5G NR enhancements for mmWave

## Completed Release 16 Projects



### Integrated access and backhaul (IAB)

Enabling flexible deployment of small cells reusing spectrum and equipment for access and backhaul



### Enhanced beam management

Improving latency, robustness and performance with full beam refinement and multi-antenna-panel beam support



### Power saving features

Maximizing device sleep duration to improve power consumption as well as allowing faster link feedback



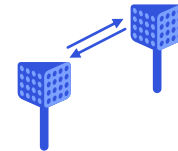
### Dual connectivity optimization

Reducing device initial access latency and improving coverage when connected to multiple nodes



### Positioning

Meeting initial accuracy requirements of 3m (indoor) to 10m (outdoors) for 80% of time



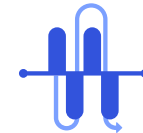
### Improved IAB for distributed deployment

Introducing full duplex operations and mobile relays for improved capability, coverage, and QoS



### Optimized coverage & beam management

Reducing overhead, enhancing performance (e.g., beam selection), improving coverage



### Expanded spectrum support

Supporting licensed and unlicensed spectrum in frequencies ranging from 52.6 GHz to 71 GHz



### New use cases beyond eMBB

Expanding mmWave support for sidelink, URLLC, and industrial IoT use cases (e.g., NR-Light)







### Enhanced positioning

Enhancing capability for a wide range of use cases – cm-level accuracy, lower latency, higher capacity





# Thank you

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