November 27th, 2018 @qualcomm_tech RCR Wireless Webinar

Qualcomm

How do we plan for 5G NR network deployments coming in 2019?

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Qualcomm Technologies, Inc.

Agenda

1. **Making 5G NR a commercial reality**
   Networks and devices in 2019

2. **Deploying 5G NR for outdoor networks**
   Sub-6 GHz and mmWave

3. **Supporting new mobile experiences with mmWave**
   Venues and enterprises

4. **Questions?**


A unifying connectivity fabric
for future innovations
Like electricity, you will
just expect it everywhere
5G
Scalable to
extreme simplicity
Multi-gigabit
speed
Ultra-low
latency
Virtually
unlimited
capacity
Extreme
reliability
On-device
intelligence

Global ecosystem is accelerating 5G NR deployments

A comparison with the global 4G transition

December 2008
3GPP completed LTE Release 8

December 2009
First live commercial LTE network[1] for dongles

Sep-Dec 2010
First commercial LTE networks in US[2] / Germany[3]

February 2011
First Android smartphone launched in US[4]

November 2012
First LTE networks launched in the UK[5]

April 2013
First commercial LTE deployment in China

1.5+ years

2+ years

4+ years

1 By TeliaSonera in Sweden and Norway; 2 September 2010 by MetroPCS in two markets, December 2010 by Verizon in 38 markets; 3 Vodafone Germany in 2 markets; 4 Samsung Galaxy Indulge; 5 EE in 5 cities

5G NR NSA spec. completed in Dec'17 → 5G NR NSA launches (US) expected in Dec'18
5G NR smartphones supporting sub-6/mmWave expected in 1H'19

5G NR SA spec. completed in Jun'18 → 5G NR SA launches (China) expected to start in 2H'19

~1 year from standards to commercialization

Making 5G NR mmWave a commercial reality in 2019

- Industry-leading R&D
- Interoperable global standards
- End-to-end system prototypes
- Network and system simulations
- Interoperability testing and field trials
- Qualcomm® Snapdragon™ X50 5G modem & QTM052 RFFE
- Commercial 5G NR mmWave networks and products

Qualcomm Snapdragon and QTM052 are products of Qualcomm Technologies, Inc. and/or its subsidiaries.

World’s first 5G NR milestones led by Qualcomm

November 2017

ZTE中兴

World’s first interoperable 5G NR sub-6 GHz data connection

December 2017

ERICSSON

World’s first interoperable 5G NR mmWave data connection

February 2018

NOKIA

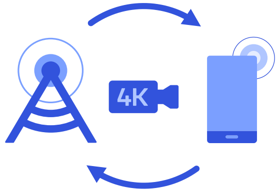
Successful multi-band 5G NR interoperability testing

MWC 2018

GSMA MOBILE WORLD CONGRESS

Interoperable 5G NR sub-6 GHz & mmWave connections with 5 vendors

SAMSUNG HUAWEI



June 2018

大唐移动 DTmobile

5G NR interoperability testing preparing for the Chinese mass market

2H-2018

Rel-15 5G NR trials based on Snapdragon X50 modem chipset and QTM052 antenna modules

Qualcomm snapdragon X50 5G modem

Driving the 5G ecosystem towards 2019 launches in collaboration with 18+ global mobile network operators and 20+ device manufacturers

Multi-Gigabit over **mmWave** on working **Snapdragon X50 silicon**

October, 2017

February, 2018

5G NR Interoperability and **field trials** using form factor mobile test device

2H 2018

First 5G NR *mmWave* over-the-air data call, with Ericsson

Sept 2018

First 5G NR *Sub 6 GHz* over-the-air data call, with Ericsson

Oct 2018

Providing **Qualcomm Reference Design** to accelerate commercial devices

Qualcomm snapdragon X50 5G modem

1H 2019

X50
5G Modem family

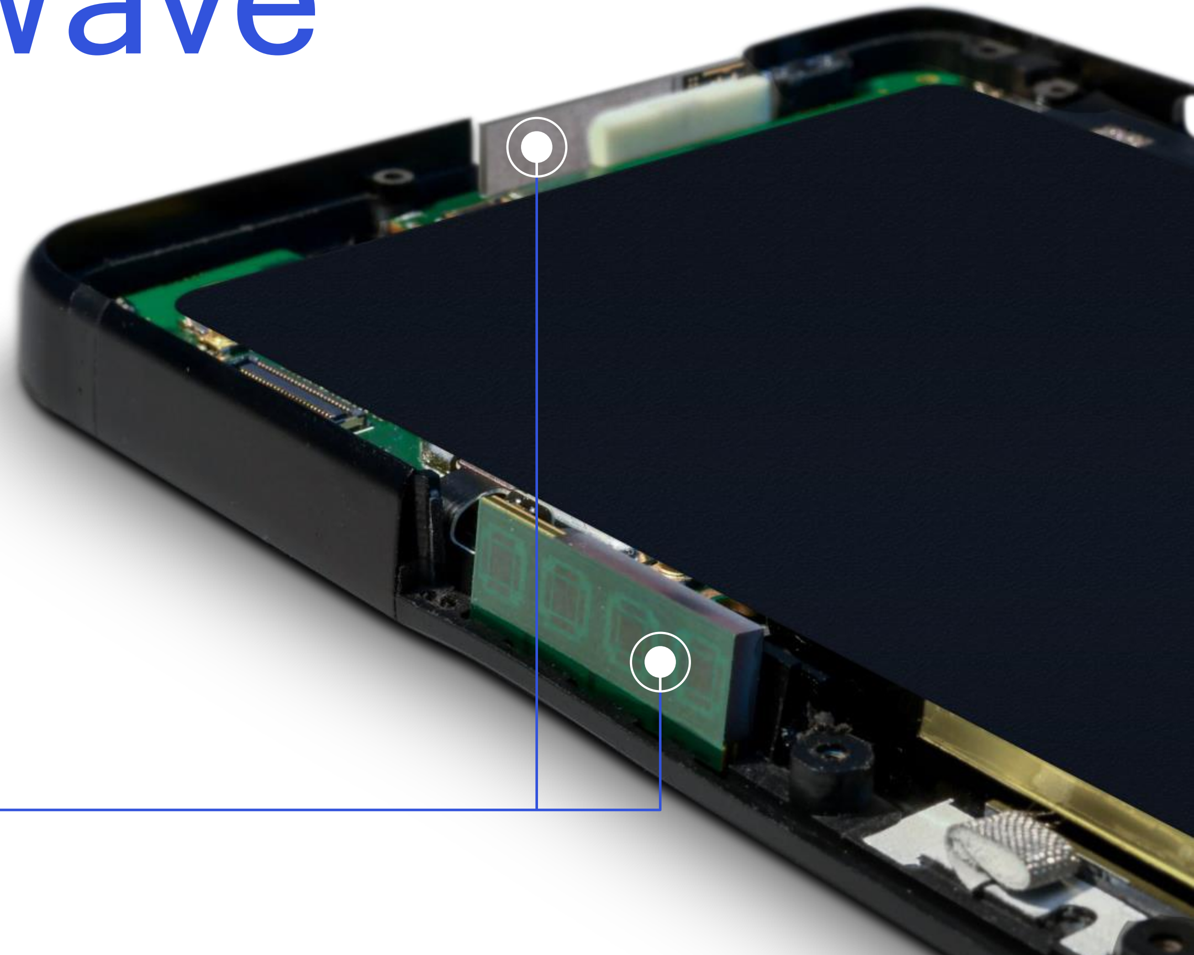
World's first 5G NR modems

- 5G NR standards compliant
- Sub-6 + mmWave
- Premium-tier smartphones in 2019

QTM052 5G mmWave antenna module

Rapid miniaturization of mmWave modules to bring 5G smartphones to the World in 2019

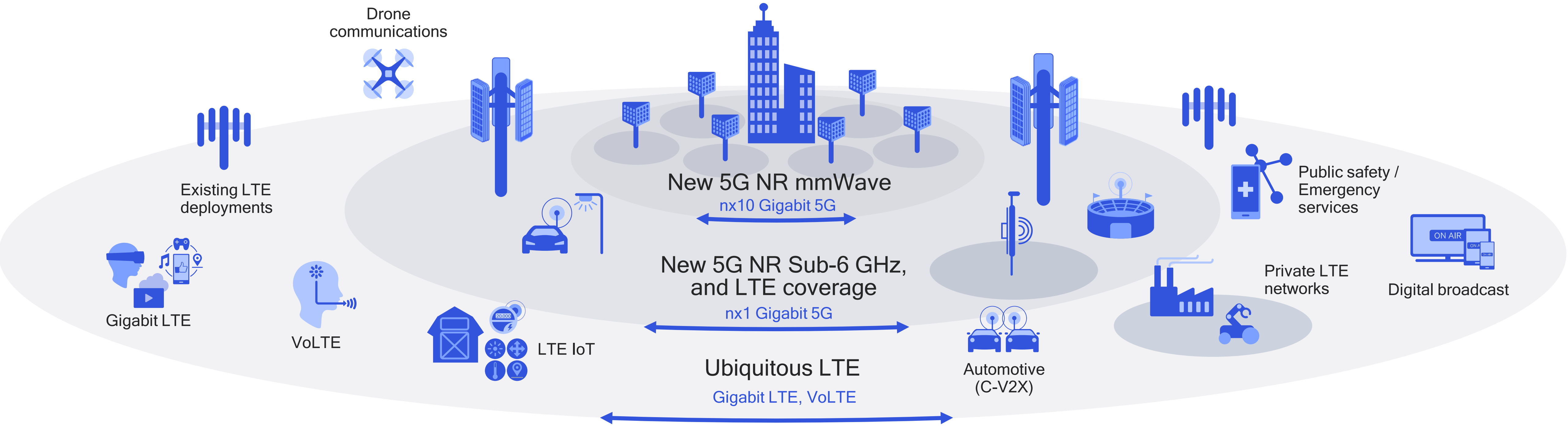
Previous New



Qualcomm 5G NR reference design (partially assembled state)

Deploying 5G NR for outdoor networks

Defining 5G NR coverage by co-siting with existing LTE

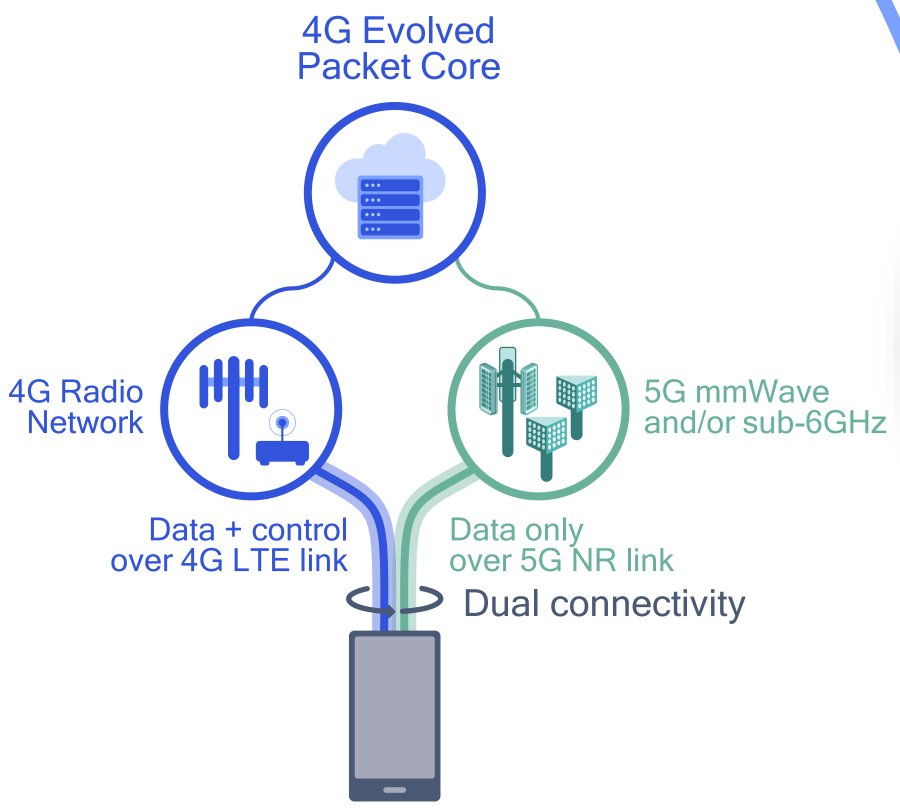


LTE provides ubiquitous coverage and essential services like VoLTE

Gigabit LTE is here now and delivers a virtually seamless 5G mobile experience

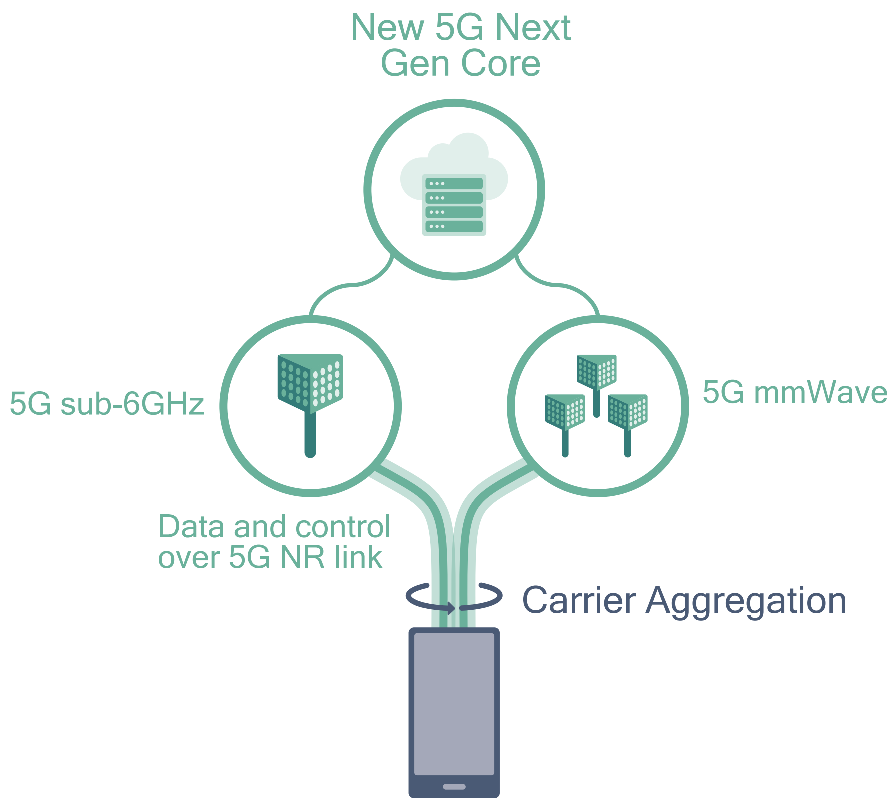
LTE IoT, private LTE, C-V2X are expanding to new industries today

Non-Standalone (NSA) stepping stone to new core



Fast-to-launch | VoLTE & CS voice

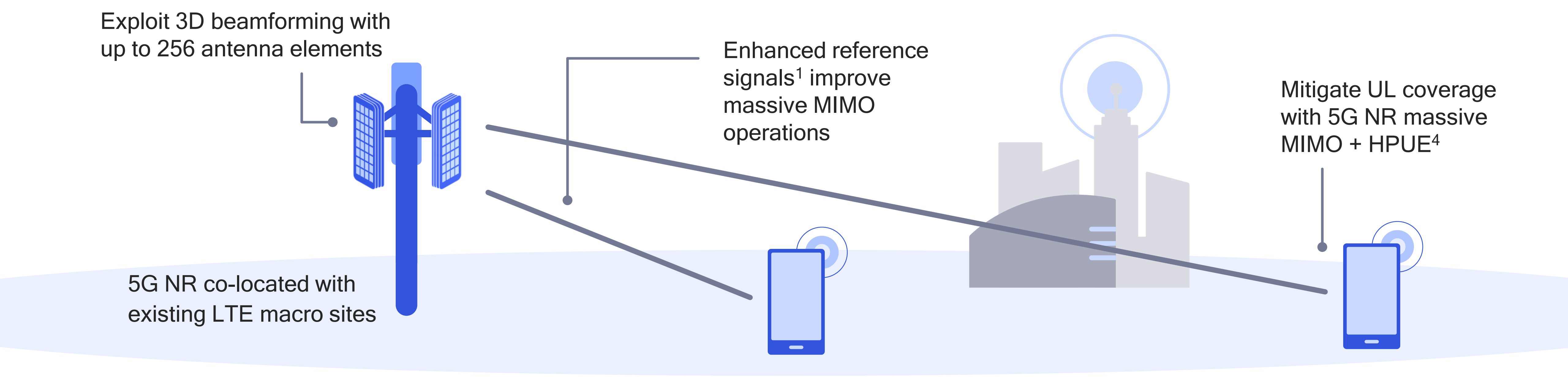
Standalone (SA) for new core benefits



NFV and SDN | VoNR & fallback to VoLTE

5G NR massive MIMO enables the use of higher mid-band

E.g., Co-siting 3.5 GHz with existing lower-band LTE infrastructure



Enabled through an advanced 5G NR end-to-end massive MIMO design (network and device)

- Optimized design for TDD reciprocity procedures utilizing UL SRS[2]
- Enhanced CSI-RS[3] design and reporting mechanism
- Advanced, high-spatial resolution codebook supporting up to 256 antennas
- New features, such as CoMP[5]

1. SRS and CSI-RS 2. Sounding Reference Signal. 3. Channel State Information Reference Signal; 4. High-Power User Equipment (HPUE) Tx power gains; 5. Coordinated Multi-Point

Deployment of active antenna systems for 3.5 GHz

Active antenna system performance depends on:

# of supported sync. & reference signals[1]	Users distribution	Infrastructure implementation

Key considerations include:

of elements: more elements enable better beamforming but tradeoff with cost/weight

Square-shape: supporting horizontal & vertical traffic distribution

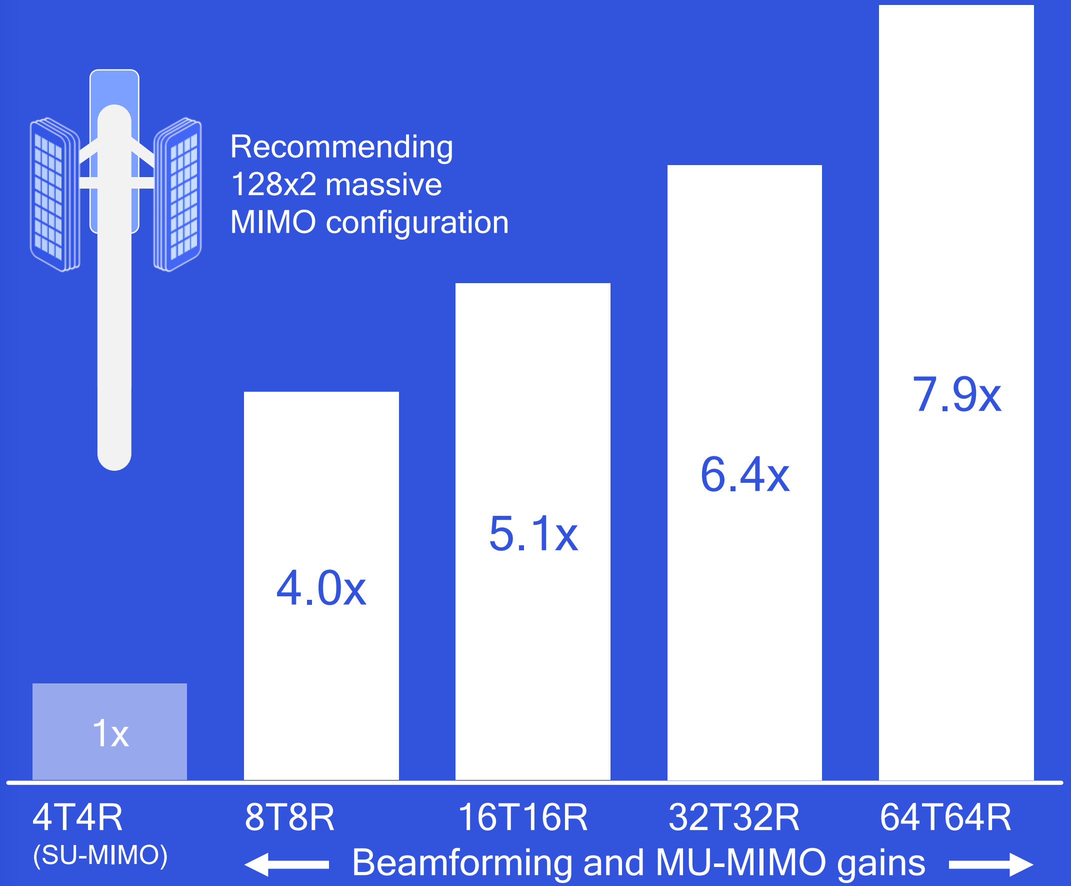
Inter-beam overlap impacts MU-MIMO

Recommendations:

Massive MIMO with 128x2 elements with configuration of 8(h) x 16(v) x 2(x-pol.) for urban, dense urban deployments

1. SSB: Synchronization Signal Blocks and CSI-RS: Channel State Information Reference Signal

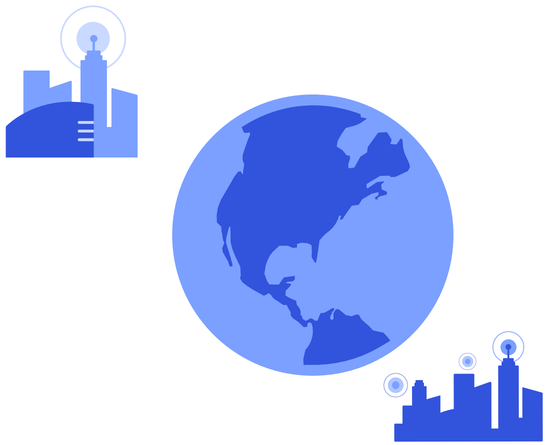
Massive MIMO delivers significant capacity gains



Note: Chart shows benefits of beamforming gains by adding more analog RF ports, not array gains (antenna used is an array of 128x2 elements for all scenarios)

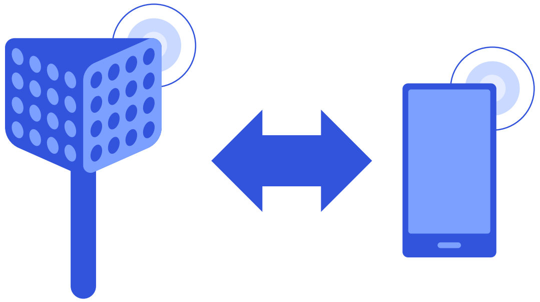
Collaborating with global operators to predict coverage

For 5G NR sub-6 GHz and mmWave



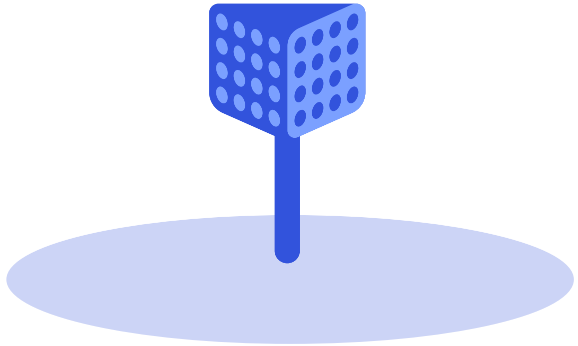
Defining geographic maps and site locations

Selecting dense urban areas of global cities that experience high mobile traffic



Establishing link budget and RF propagation model

Developing link budget for a target cell edge spectral efficiency

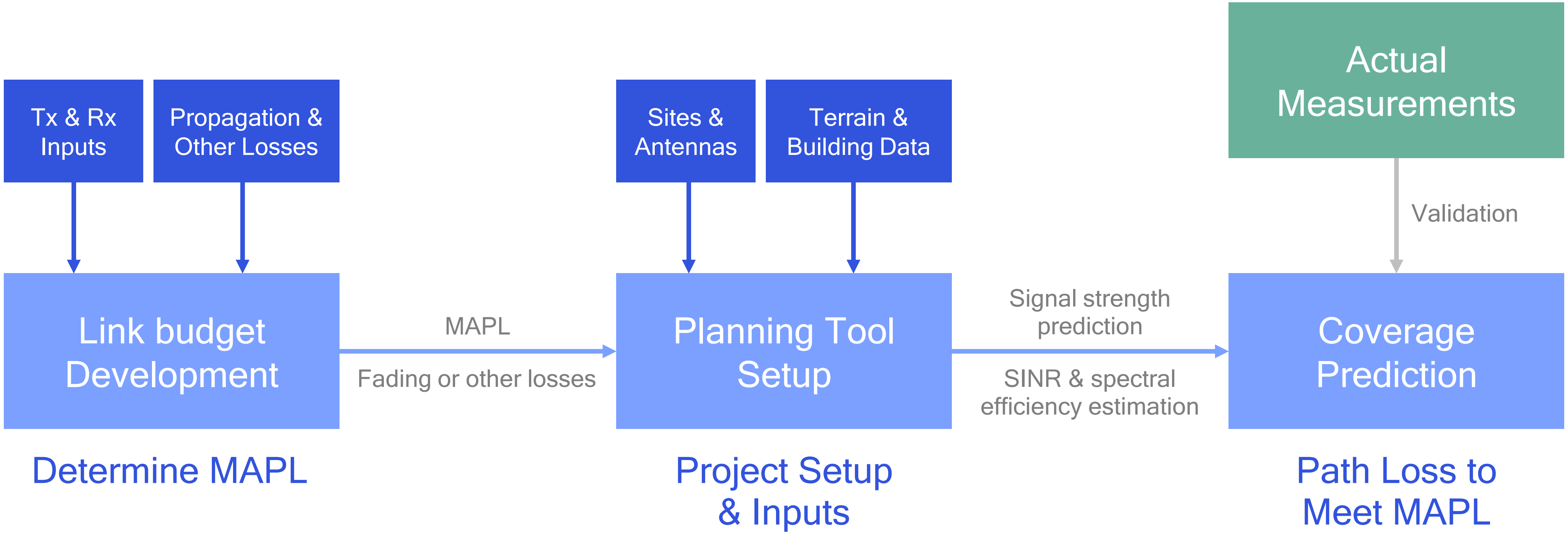


Predicting 5G NR coverage

Using a commercial planning tool to model 5G NR coverage and performance

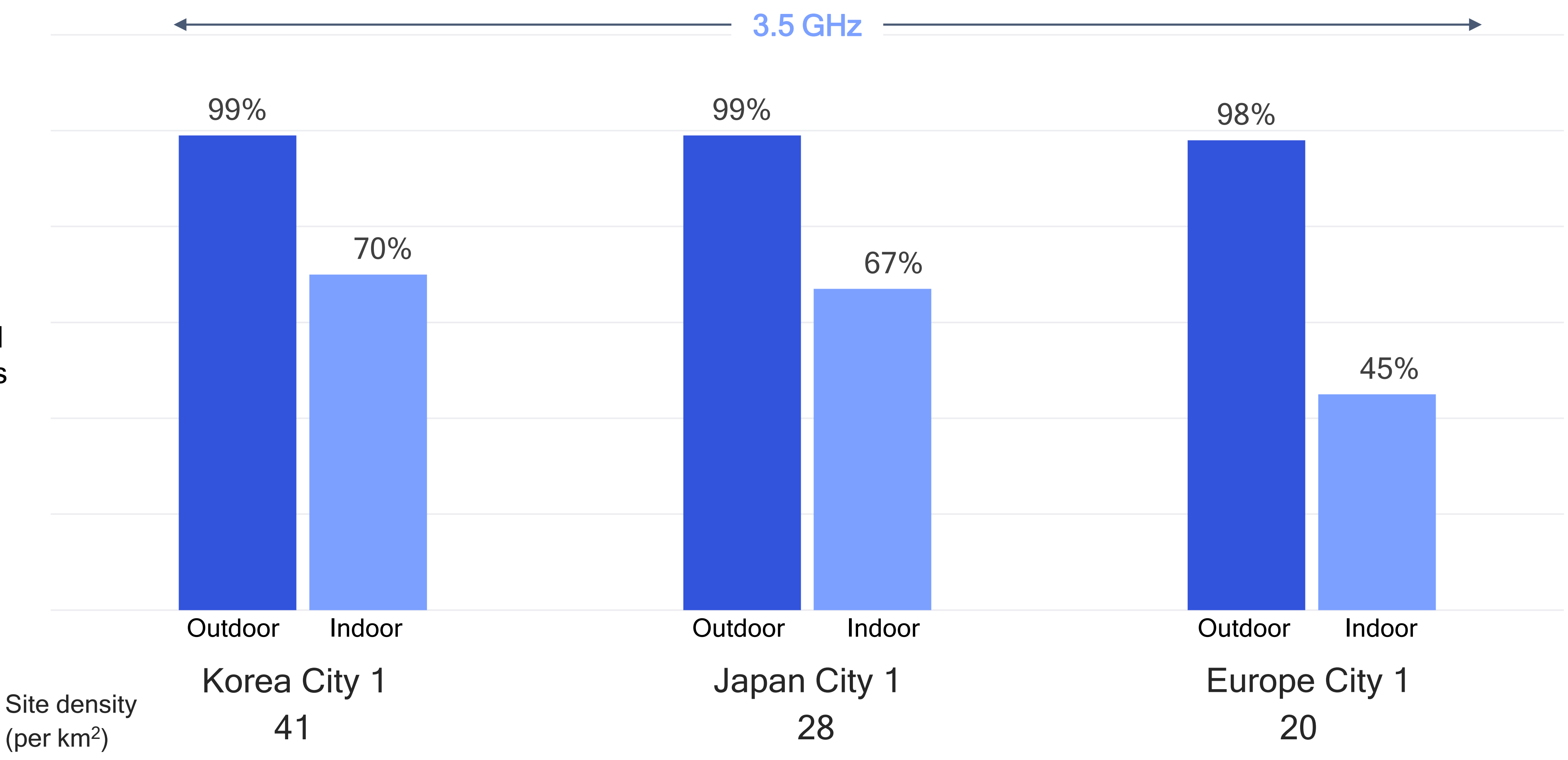
5G NR coverage prediction methodology

Use of link budget & RF planning tool



Downlink Coverage %

Simulations based on over-the-air testing and channel measurements



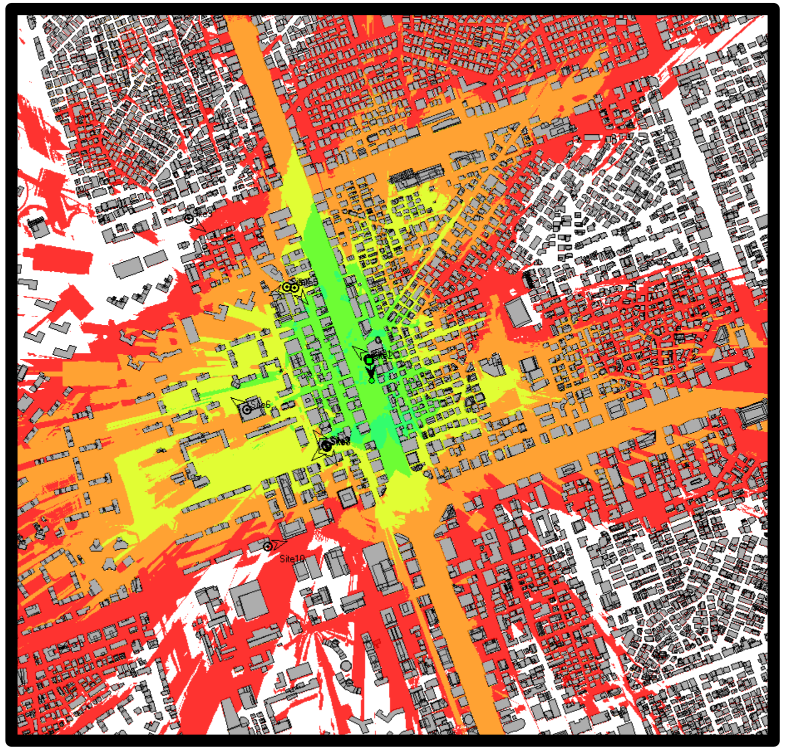
Assuming minimum spectral efficiency of 0.3 bps/Hz over 100 MHz = ~30 Mbps at cell edge; With LTE, outdoor/indoor coverage for Korea city :100%/96%, Japan city 100%/87%, Europe city 100%/80%

Significant 5G NR 3.5 GHz outdoor & indoor coverage

Co-siting 5G NR with existing outdoor LTE cell sites – opportunity to density indoors

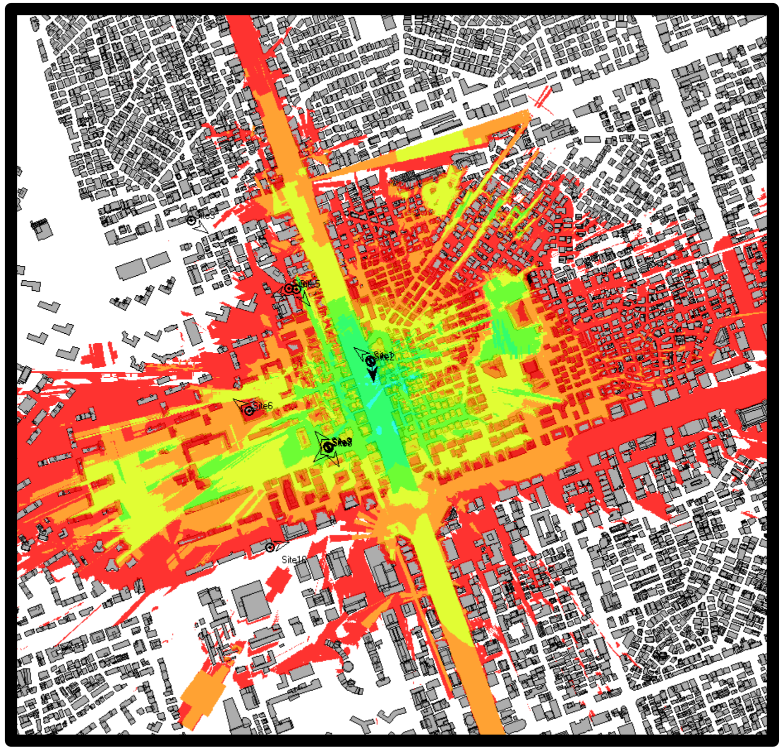
Model tuning needed to accurately predict coverage / SINR

Allows accurate beamforming and MU-MIMO estimations at 3.5 GHz



Legend (dB)

- -50
- -60
- -70
- -80
- -90
- -100
- -110
- -120



Default model without tuning

Mean error: -1.15 dB

Error sigma: 5.73 dB

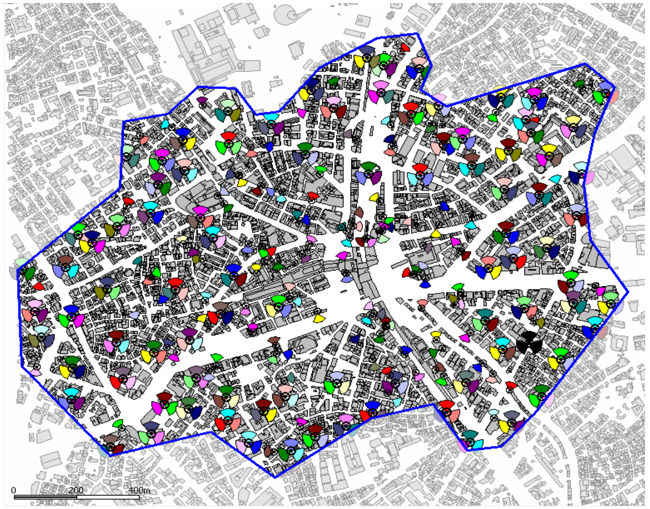
Tuned model for 3.5 GHz

Mean error: 0 dB

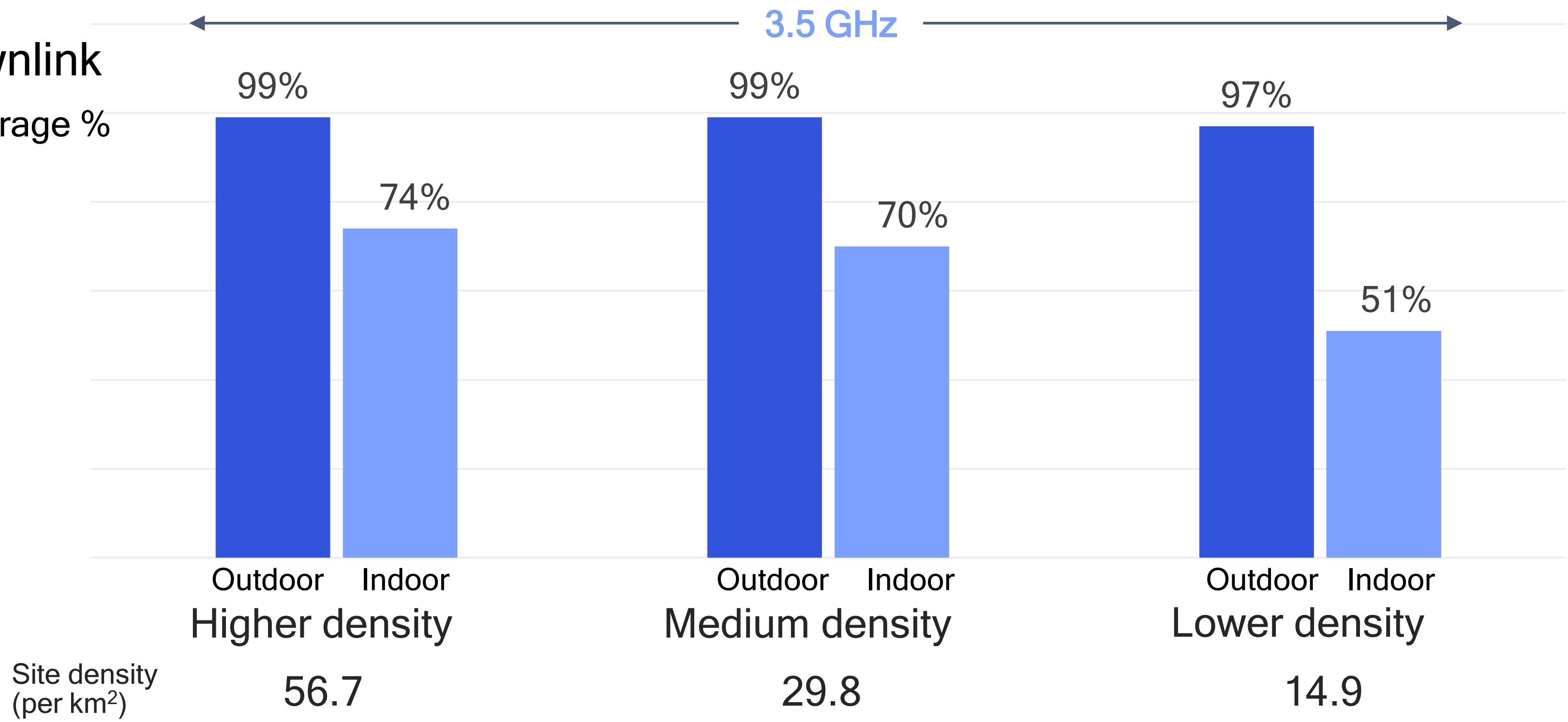
Error sigma: 3.34 dB

Impact of deploying sparse 5G NR in the 3.5 GHz band

Non-co-located LTE/NR may cause near-far effect requiring additional optimization



Analyzing a dense urban cluster with optimization of site azimuths as site density is reduced

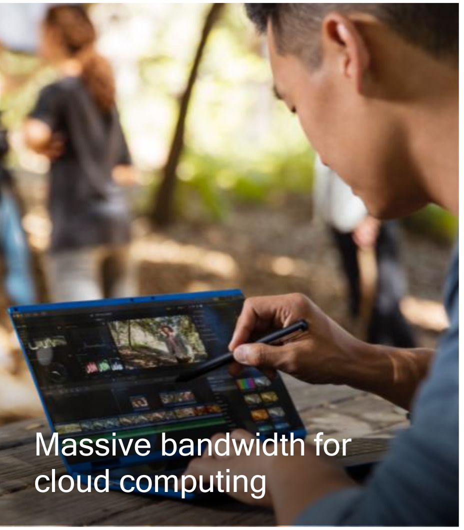


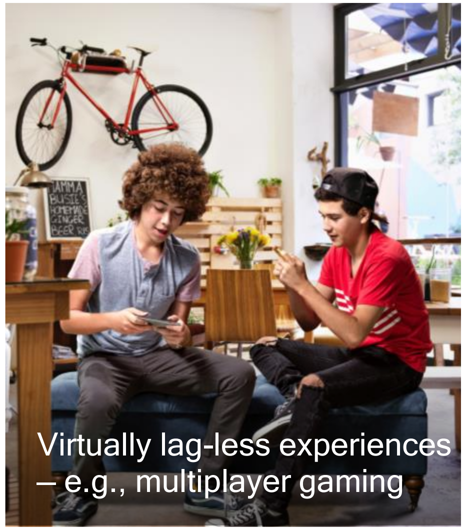
Out-to-out coverage is minorly impacted with reduction in sites

Out-to-in coverage is more impacted – opportunity to densify indoors


Rich media and entertainment for outdoor – augmenting lower bands


More indoor capacity as outdoor mmWave offloads outdoor lower bands


Massive bandwidth for cloud computing


Virtually lag-less experiences – e.g., multiplayer gaming


Dense indoor & outdoor connectivity for venues


New indoor opportunities – e.g., connected enterprises

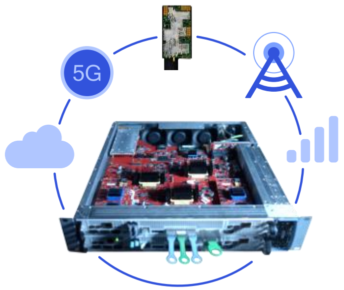

Fiber-like broadband to the home – fixed mmWave

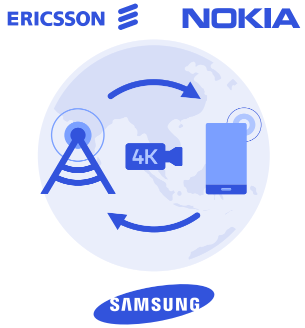

Beyond smartphones – e.g., smart manufacturing

5G NR mmWave will support new and enhanced mobile experiences

- Fiber-like data speeds
- Low latency for real-time interactivity
- Massive capacity for unlimited data
- Lower cost per bit

A system approach to the mobile mmWave challenge





1 Cutting-edge R&D

Overcoming numerous challenges to make mmWave viable for mobile use cases

2 Prototyping while driving standards

Validating mobile 5G NR mmWave technologies, feedback loop to standards

3 Advanced network and system simulations

Accurately predicting mmWave coverage, capacity, performance using real network models

4 Broad interoperability testing and trials

Fully leveraging prototype systems and our leading global network experience

5 Leading modem and RFFE solutions

Announced the Qualcomm® Snapdragon™ X50 5G modem family & QTM052 antenna module

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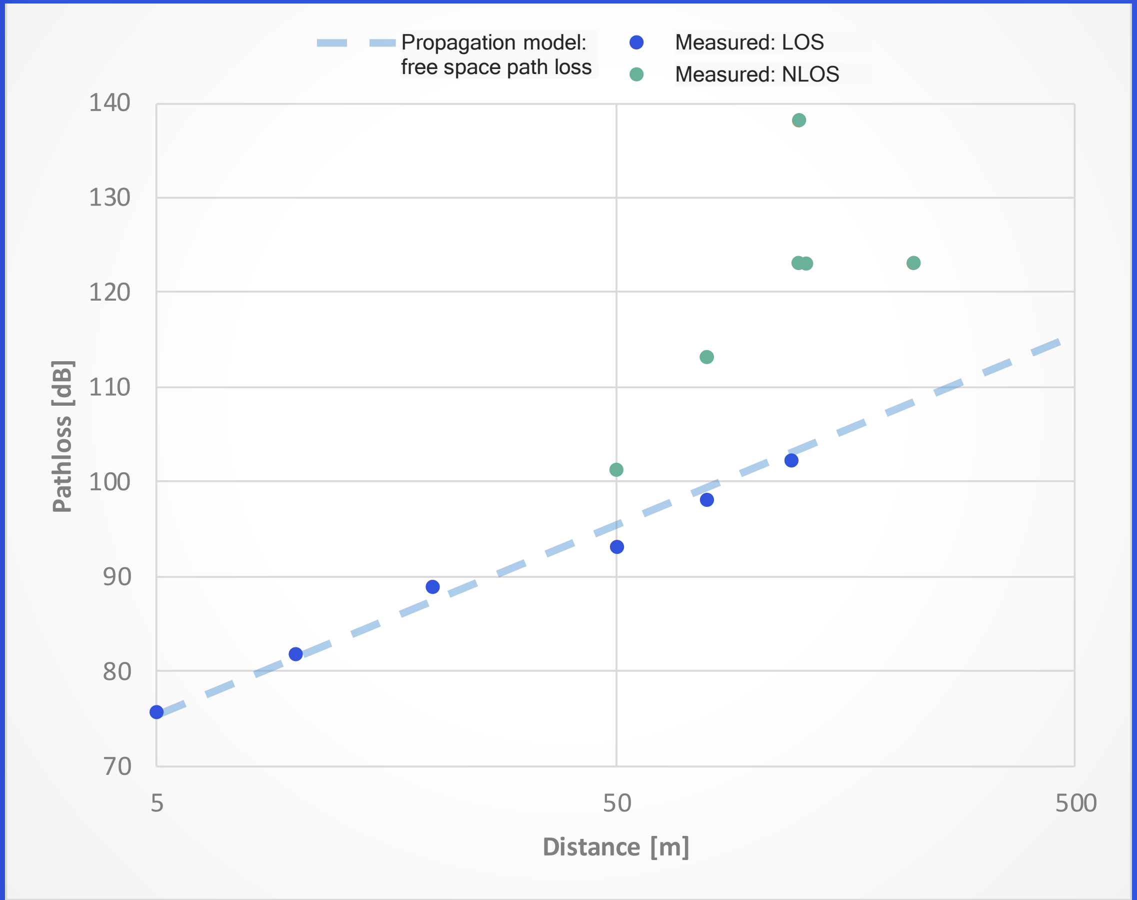
Measuring 5G NR mmWave propagation characteristics

At Qualcomm San Diego campus



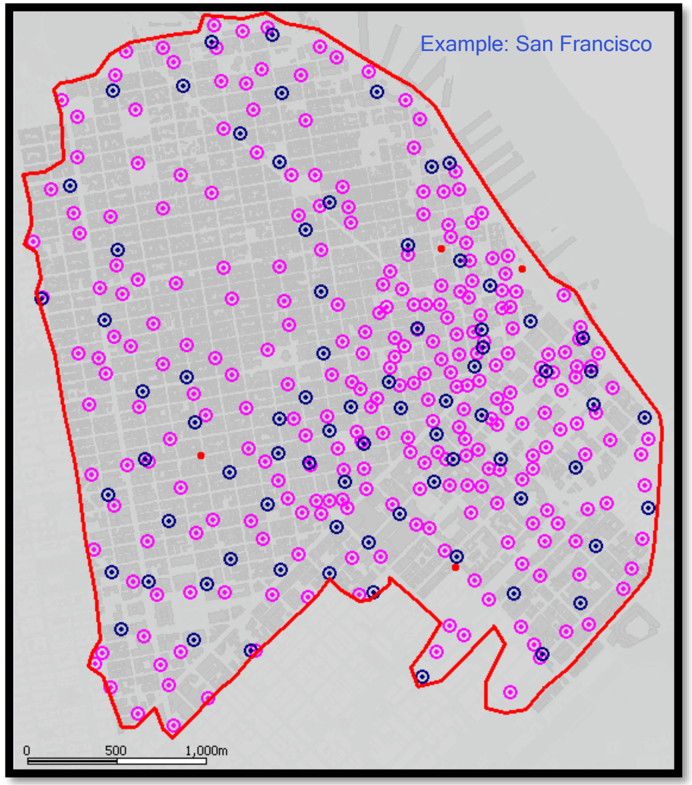
For line-of-sight (LOS), measured pathloss closely follow propagation model

For non-line-of-sight (NLOS[1]), measured pathloss shows variations → requiring accurate 3D maps

1. NLOS measurements are at locations experiencing varying obstructions (foliage, body) and reflection losses

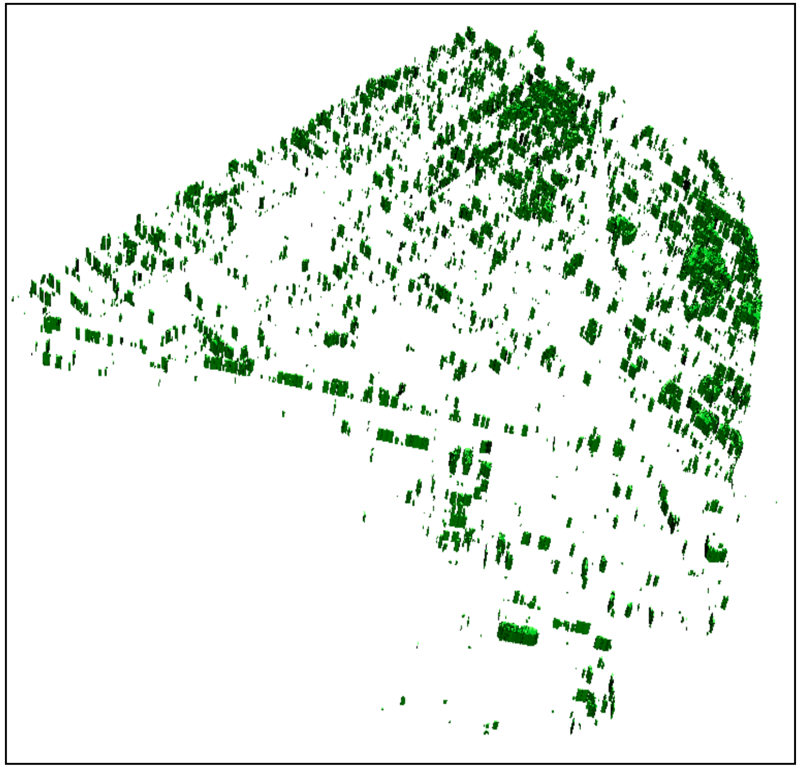
Accurately predicting 5G NR mmWave coverage

Map of existing LTE sites



3D model of buildings

3D model of foliage



Utilizing geographically accurate 3D models
2m x 2m resolution with accurate and up-to-date information on buildings/foliage

Co-siting with 4G LTE sites in service today
Macro/small cell sites are used, including exact antenna height/orientation

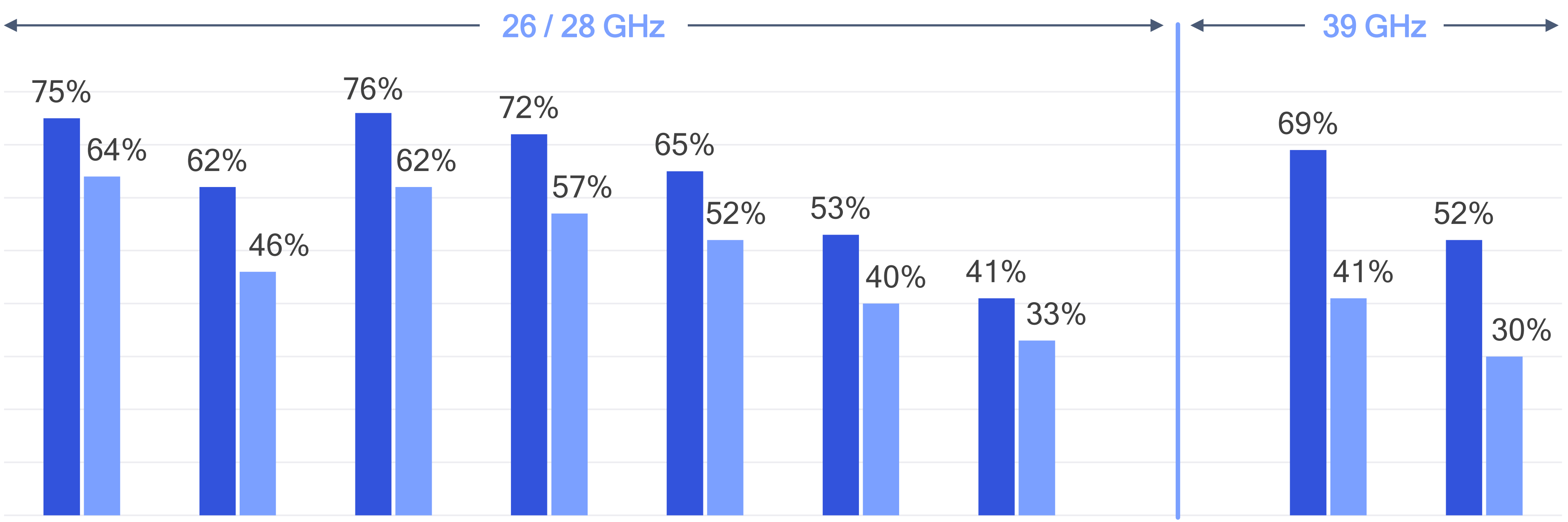
Establishing baseline with potential to improve
No additional sites used in simulations (e.g., outdoor Wi-Fi) that can further improve coverage

Downlink

Uplink

Coverage %

Co-siting with LTE



		US City 1	US City 2	Korean City 1	Hong Kong	Japan City 1	Russia City 1	Europe City 1	US City 1	US City 2
Median Downlink Burst Rate (Gbps)		2.2 Gbps	1.5 Gbps	2.7 Gbps	2.4 Gbps	2.7 Gbps	2.0 Gbps	2.2 Gbps	1.5 Gbps	1.2 Gbps
Site density (per km^2)	Total	48	36	41	39	28	26	28	48	36
	Macro	0	8	33	39	28	26	7	0	8
	Small	48	28	8	0	0	0	21	48	28

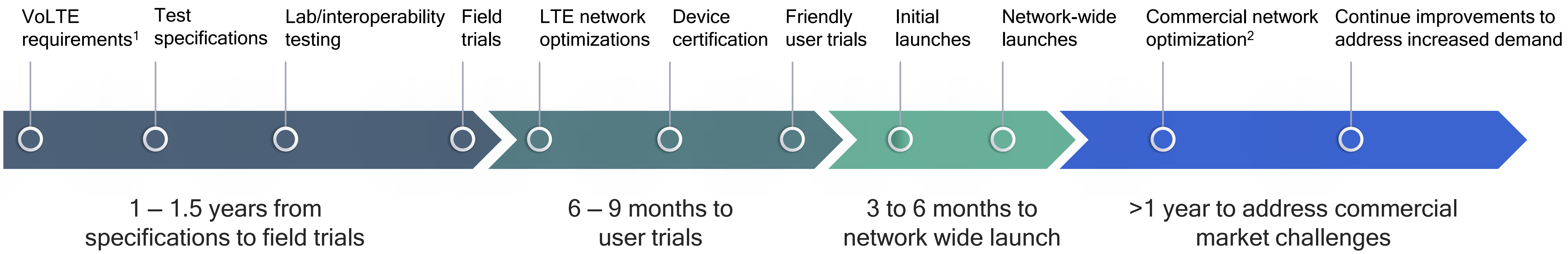
Simulations assumptions: Based on MAPL (maximum allowable path loss) analysis with ray tracer propagation model and city/area specific models; minimum 0.4 bps/Hz and 0.2 bps/Hz for downlink data and control, out-to-out coverage only; Using 800 MHz DL bandwidth and 100 MHz uplink bandwidth with 7:1 DL:UL TDD

Significant 5G NR mmWave outdoor coverage via co-siting

Simulations based on over-the-air testing and channel measurements

VoLTE remains to be the 5G voice solution for many years

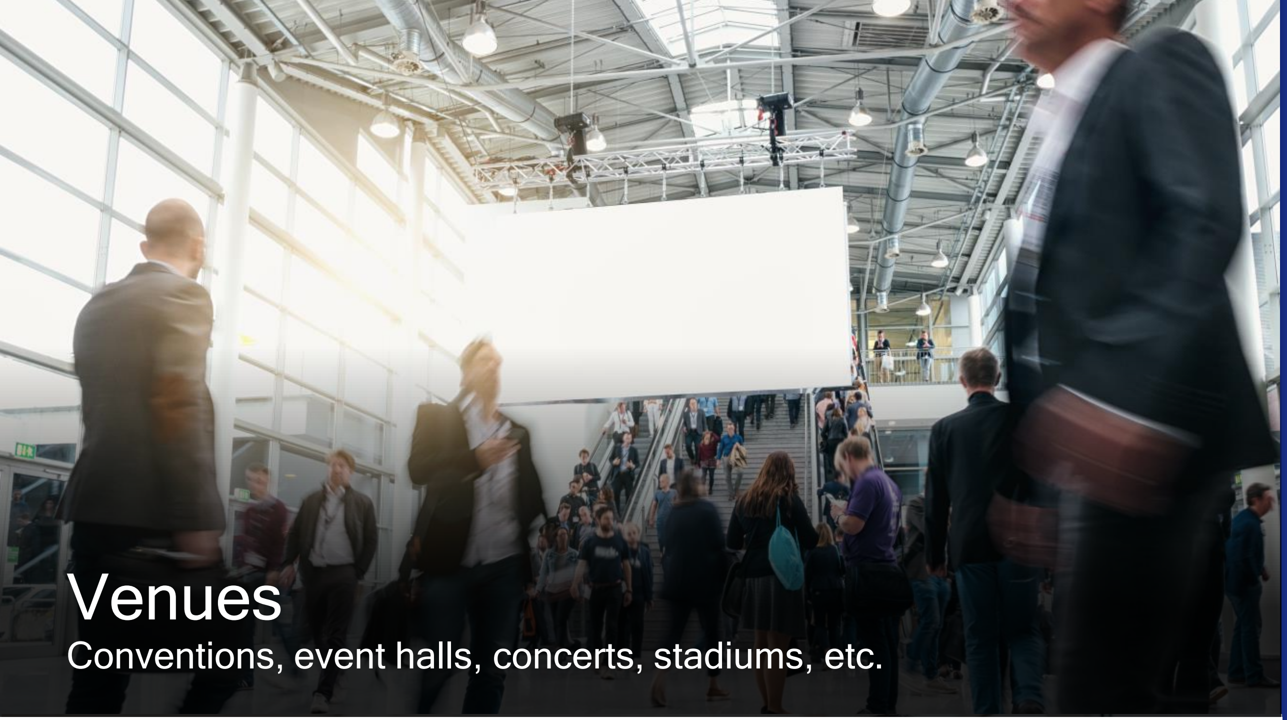
Example VoLTE adoption timeline in the US



1 Including device, RAN, and IMS; 2 Improving accessibility, retainability, voice quality;

Voice over 5G NR is expected to follow similar standardization to commercialization timeline as VoLTE

Supporting new mobile experiences with mmWave



Venues
Conventions, event halls, concerts, stadiums, etc.

Enterprises
Offices, shop floors, meeting rooms, auditoriums, etc.

Extending 5G NR mmWave to indoors for new and enhanced experiences

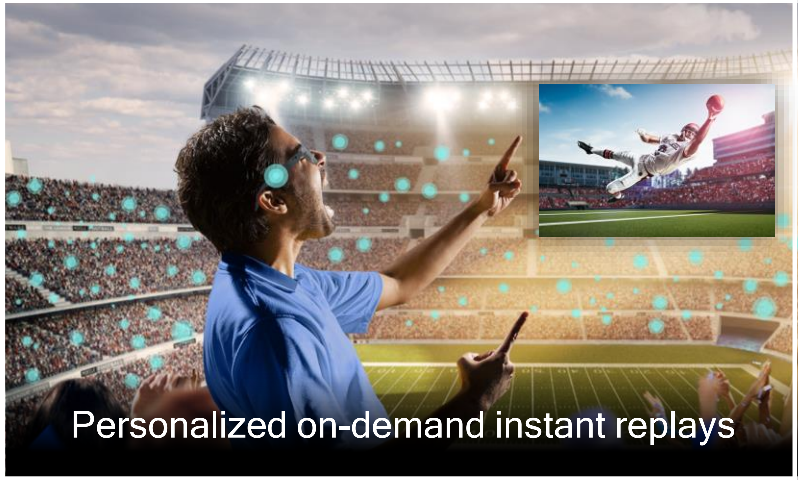
Complementing Wi-Fi deployments

- Bringing multi-Gigabit, low-latency, and virtually unlimited capacity
- Supporting devices beyond smartphones – tablets, always-connected laptops, XR
- Leveraging existing infrastructure – Wi-Fi or cellular – by co-siting small cells

Rich media and interactive entertainment

New levels of social sharing

Following your favorite player on the field



Personalized on-demand instant replays

Wireless screens virtually everywhere

Watching the event from virtually any seat

5G NR mmWave for dense venue deployments

- Multi-Gigabit speeds with virtually unlimited capacity
- Personalized experiences exclusively at the venue
- New monetization opportunities during and after the event
- Easy and secure access over carrier networks

5G NR mmWave is suitable for venue deployments

For example: using the 28 GHz band

- Better antenna directivity
- Higher spectral efficiency
- Superior beamforming

Excellent capacity solution

- No in-building penetration losses
- Rain & foliage attenuation is not a factor
- Signal decay likely not significant for short ranges

Typical mmWave coverage challenges not of major concern

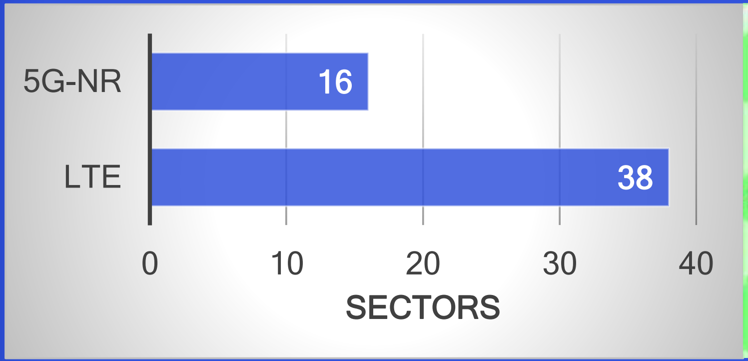
* Comparing to typical LTE deployments

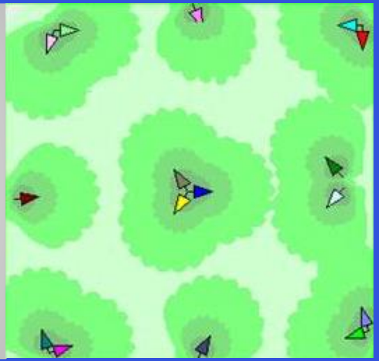
Predicting 5G NR mmWave coverage for

Music Concert Venue

based on actual venue layout and network model

Deploying 5G NR mmWave for dense outdoor venues





95% Outdoor coverage[1]

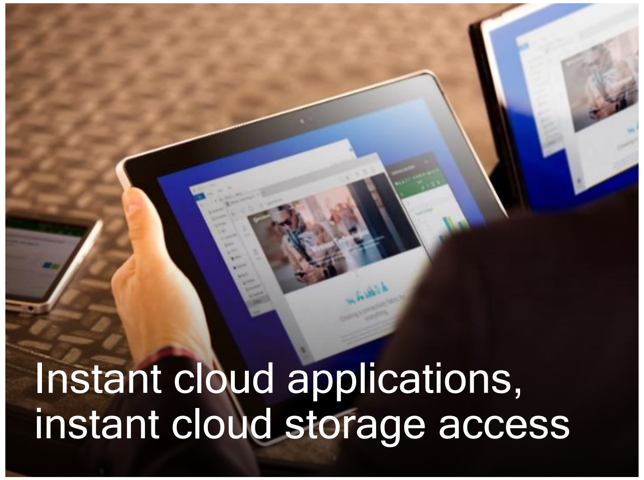
10x Increase in capacity[2]

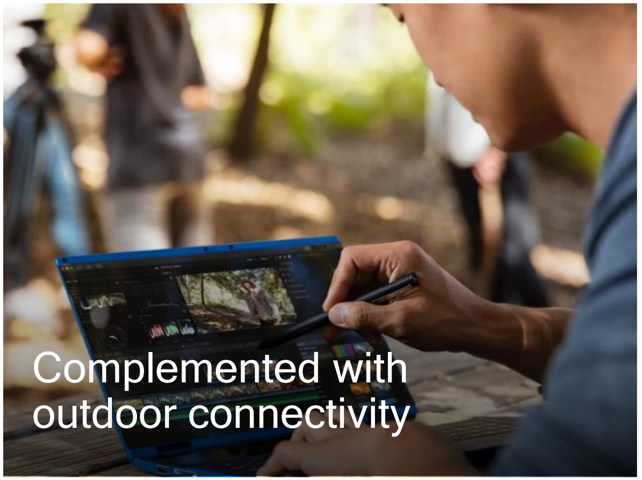
233Mbps Median burst rate[2]

100x Improvement in throughput[2]

- Leveraging existing LTE infrastructure that includes LAA small cells for Gigabit LTE
- Initial deployments can deliver significantly higher capacity even with fewer sectors (i.e., mmWave at a subset of LTE sites)
- Enabling new mobile experiences powered by multi-Gbps throughput and ultra-low latency

1 Cell edge defined as 0.4 bps/Hz
2 Comparing Gigabit LTE using 50 MHz spectrum with an initial 5G-NR mmWave deployment using 800 MHz spectrum and 7:1 DL-UL configuration and 10% 5G-NR capable device penetration





Enterprise networks: 5G NR mmWave + Wi-Fi

Always connected laptops and tablets[1]

- Multi-Gigabit speeds with virtually unlimited capacity
- Reuse licensed spectrum– in-/outside mmWave isolation
- Private 5G NR indoor network with cellular grade security

1) Requires network connectivity; 2) Expected coverage in typical office environments, actual coverage and performance depends on propagation and deployment.

5G NR mmWave boosts performance in Enterprise networks

Downlink/uplink coverage comparable to Wi-Fi with 1:1 or partial co-site

Realize multi-Gigabit burst rate with wider bandwidths (e.g., 800 MHz)

Complement indoor Wi-Fi deployments

Existing Wi-Fi access point locations – co-sited with 5G NR mmWave antenna locations

Complete coverage at 28 GHz[1] at Qualcomm headquarters

- ~98% Downlink coverage with 1:1 co-siting
- ~99% Uplink coverage with 1:1 co-siting
- 5 Gbps downlink median burst rate[3]

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; 2 Maximum Allowable Path Loss; DL: 115 dB, UL 117 dB 3 Using 800 MHz DL bandwidth and 100 MHz uplink bandwidth with 7:1 DL:UL TDD

Questions?

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