

Boundless XR and cloud gaming over 5G

Qualcomm Technologies, Inc.



Agenda

1



How 5G enables low-latency applications at scale

2



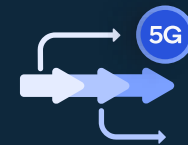
Optimizing 5G to meet boundless XR requirements

3



Optimizing 5G to meet cloud gaming requirements

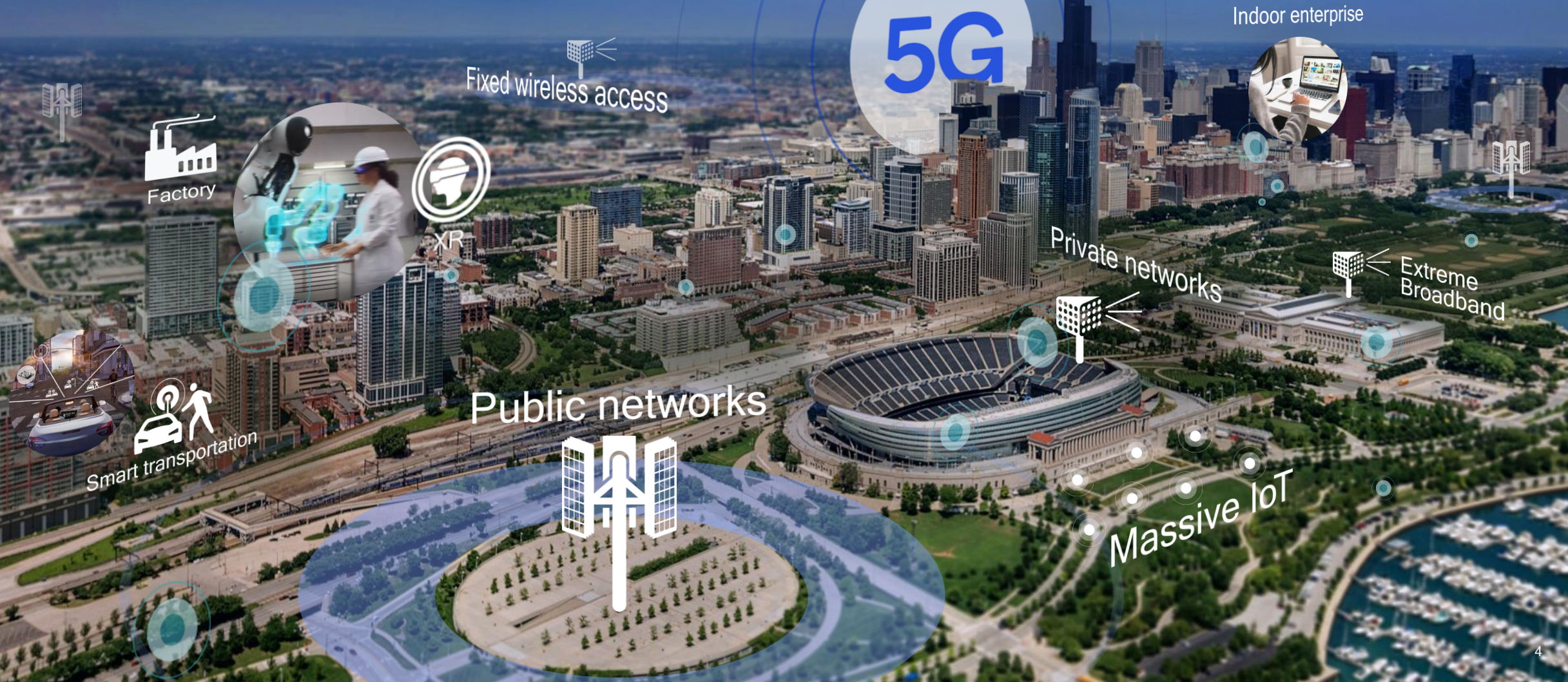
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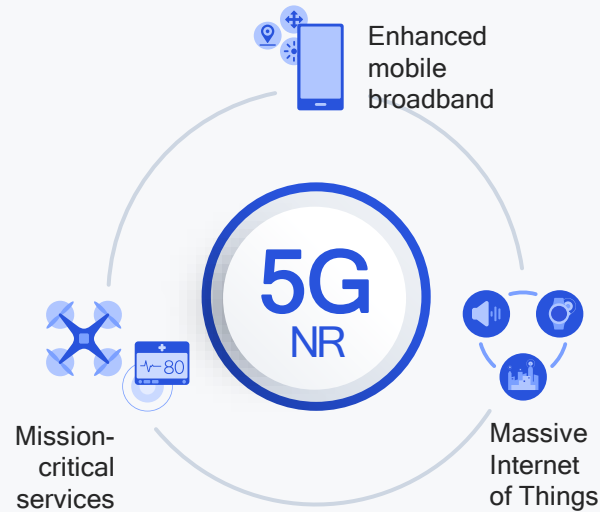
Upcoming features in future 5G releases to further improve low latency applications

Delivering on the 5G vision

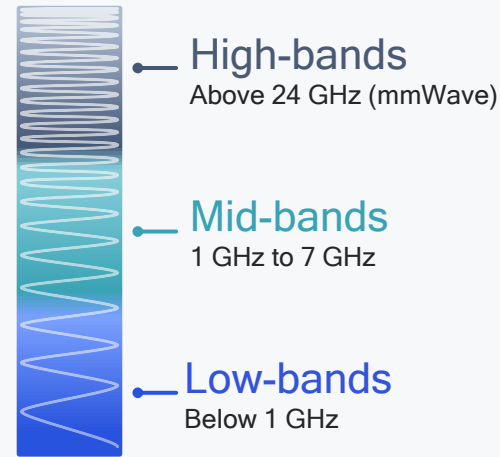
Where virtually everyone and everything is intelligently connected



5G unified air interface enables diverse use-cases



Diverse services



Licensed/shared/unlicensed

Diverse spectrum



Diverse deployments

10x
Decrease in
end-to-end latency

10x
Experienced
throughput

3x
Spectrum
efficiency

100x
Traffic
capacity

100x
Network
efficiency

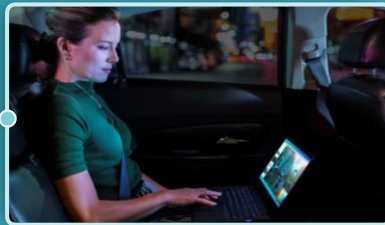
10x
Connection
density



Expand 5G coverage and performance



Expand fixed wireless access, integrated with Wi-Fi



Expand device classes to always connected PC/Laptop



Expand mobile gaming including cloud gaming



Expand experiences, like XR



Expand eMBB to vehicles – initially with R14 C-V2X



Expand reach with our small cell solutions



Expand 5G eMBB modules to more verticals

Expanding 5G beyond the smartphone

Cloud gaming



Boundless VR



Boundless AR



Enabling a new class of low-latency experiences

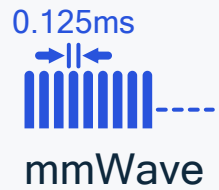
Shorter slot times



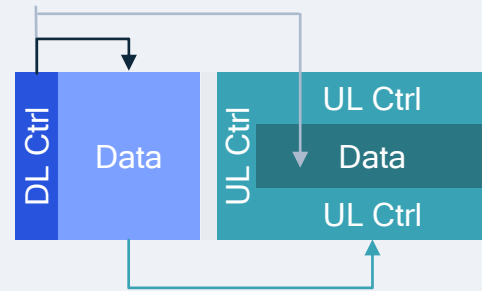
Low-band



Mid-band

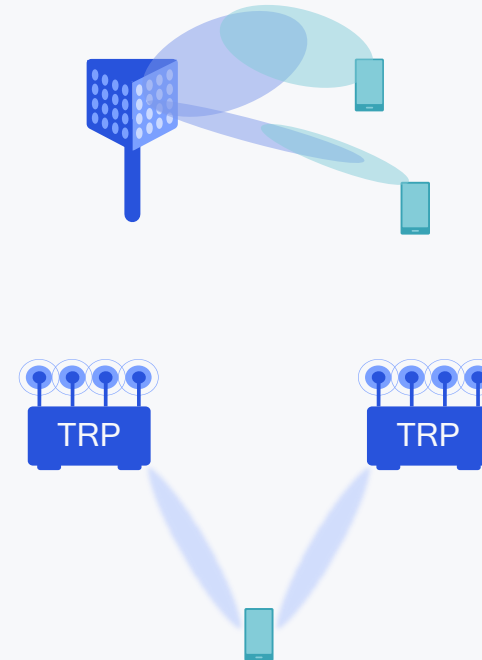


Fast processing timelines

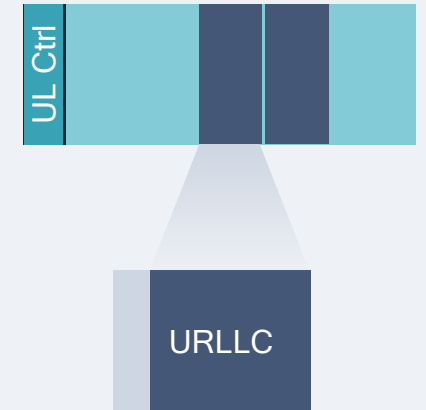


Example

Reliable beam forming



Mini slots



5G is built for low-latency and high reliability

Our fundamental research has been contributed to 3GPP

Mobile XR

- Reliable, anywhere anytime usage
- Ease of use with no setup
- Battery powered sleek, ultra-light design
- Leverages mobile ecosystem scale



+

5G

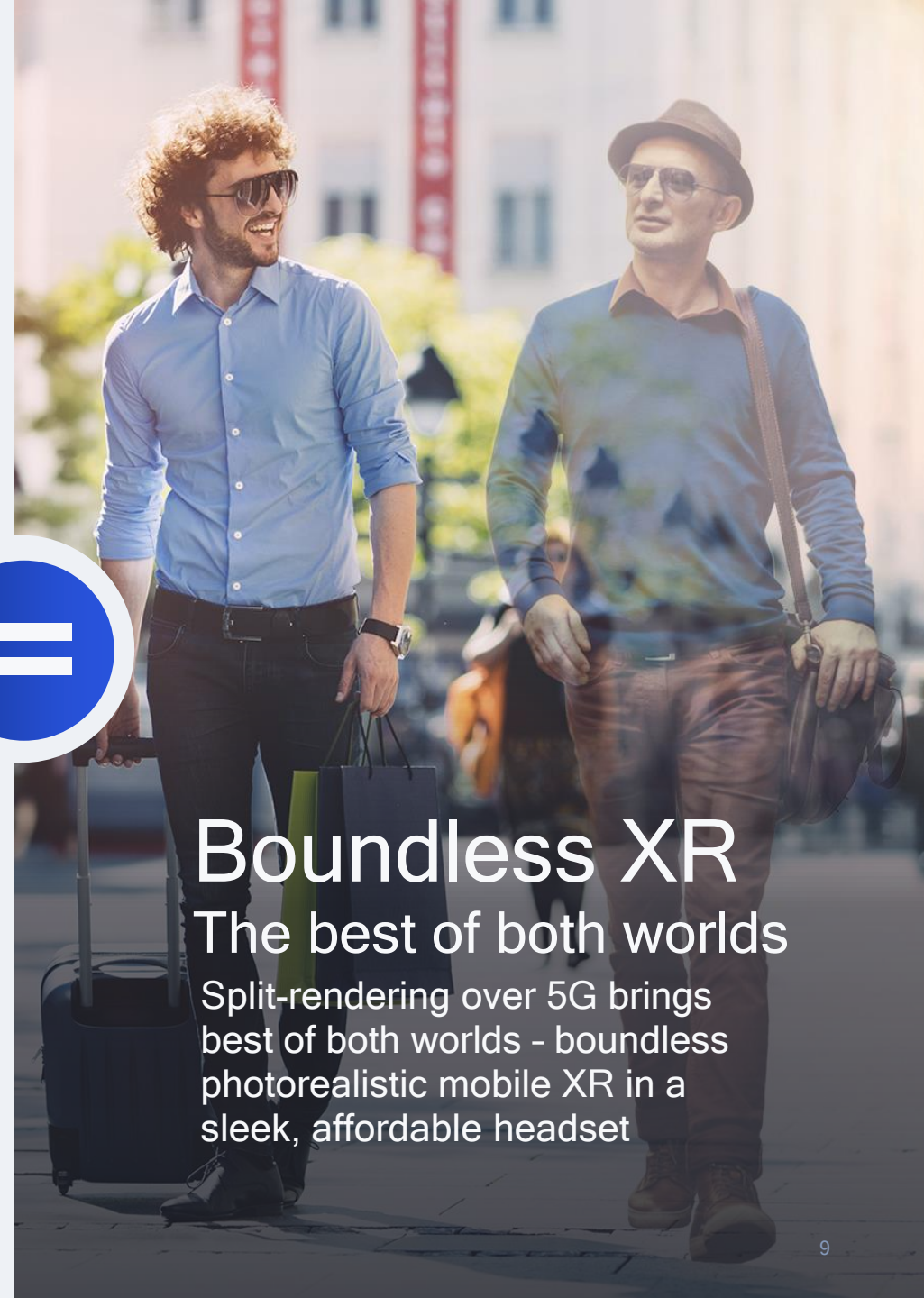
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PC-tethered XR

- Not limited by power and thermal constraints
- Expensive and niche for high-end experiences
- Wires limit intuitive actions and immersion
- Usage limited to a fixed location



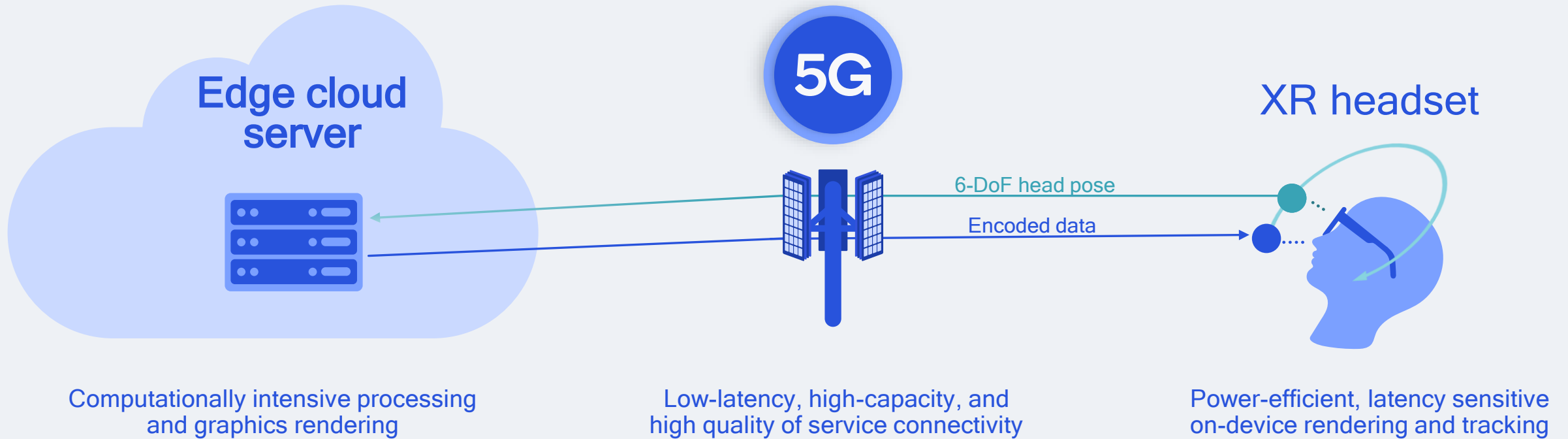
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Boundless XR

The best of both worlds

Split-rendering over 5G brings best of both worlds - boundless photorealistic mobile XR in a sleek, affordable headset



Boundless XR uses split rendering over 5G

Distribute computation between the edge cloud server and device to deliver truly immersive XR over 5G



Boundless XR over 5G

Motion-to-render-to-photon (M2R2P) animation video



Edge cloud server

Graphics rendering

5G mmWave antenna

mmWave NSA (n261, B48)
Ericsson 5G network

5G XR headset

Snapdragon® XR2 Platform
Snapdragon X55 5G Modem-RF System

Boundless XR is ready for deployment

Our multi-user 5G boundless VR system uses commercial products and platforms

Targets private indoor deployments | Delivers end-to-end optimizations



Latency¹

M2R2P latency < 70ms
5G RTT < 20ms



Frame rate

2kx2k per eye
at 90 frames per second

Throughput¹

Reliable average downlink throughput of ~50 Mbps
Reliable uplink throughput of ~1 Mbps, 500 Hz pose



Immersive VR

Photorealistic visuals
6-DoF mobility
Robust and reliable

Achieves initial KPIs for at-scale 5G boundless VR deployments



XR Experience



Demo Intro



5G Dashboard

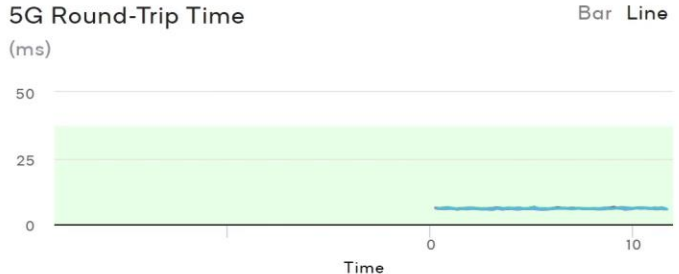
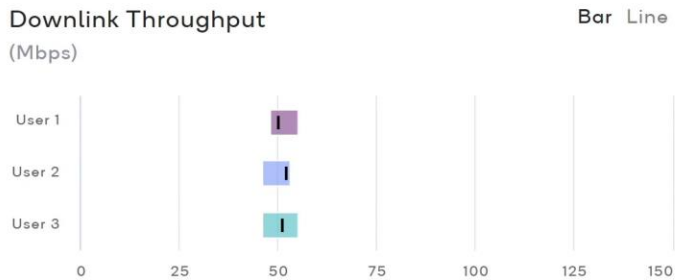
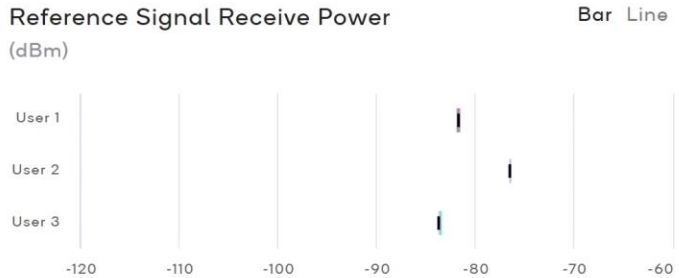


Multi-user boundless XR

Demo video – meeting KPIs

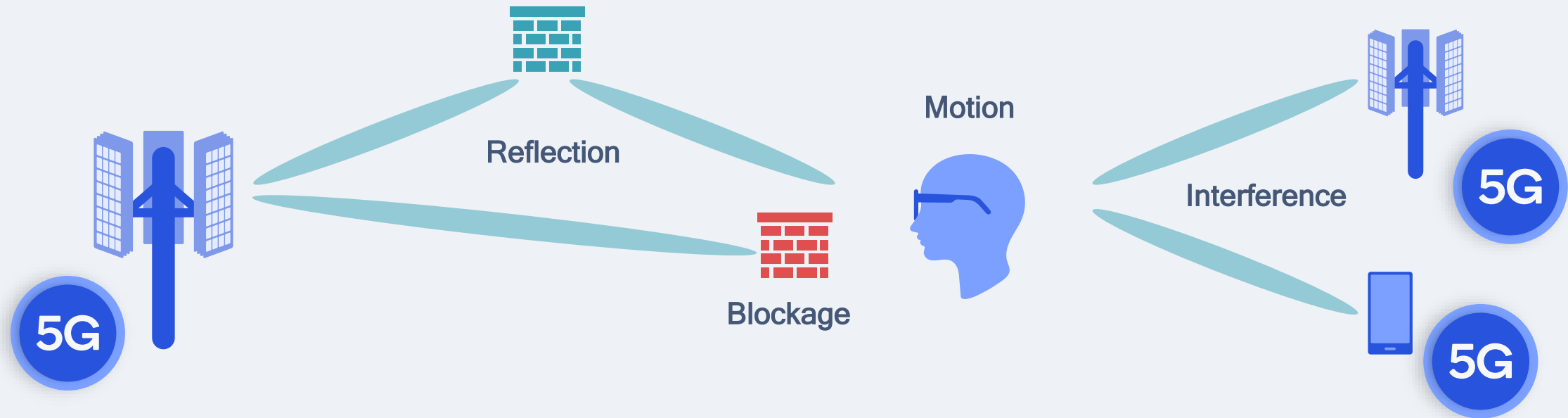
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Frame Rate VR Headset 90 FPS	Display Resolution Per Eye 2160 x 2160
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Real life deployments have latency challenges

Dynamic RF environments¹ with fading, motion, blockage and interference lead to latency spikes



Large latencies lead to poor XR user experience

At 90 fps, 1% of frames with large latencies leads to poor experience every ~1 s

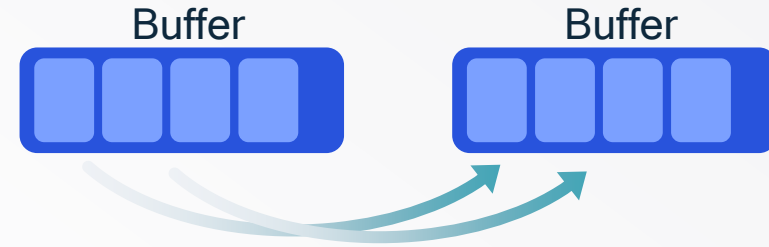
¹: Deployments in unlicensed spectrum can experience interference from co-channel systems.

5G device optimizations are key for good UX

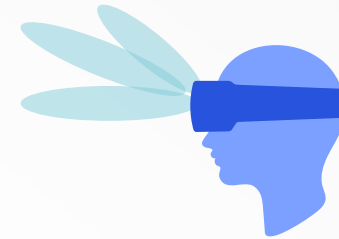
>25%

Reduction in tail latencies due to our device optimizations

Low-latency packet processing



Better beam management for improved reliability



Dynamic packet processing to meet application latency requirements



Decode relevant packets in N ms



XR Experience



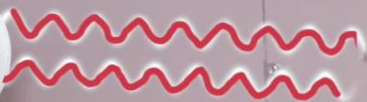
Demo Intro



5G Dashboard

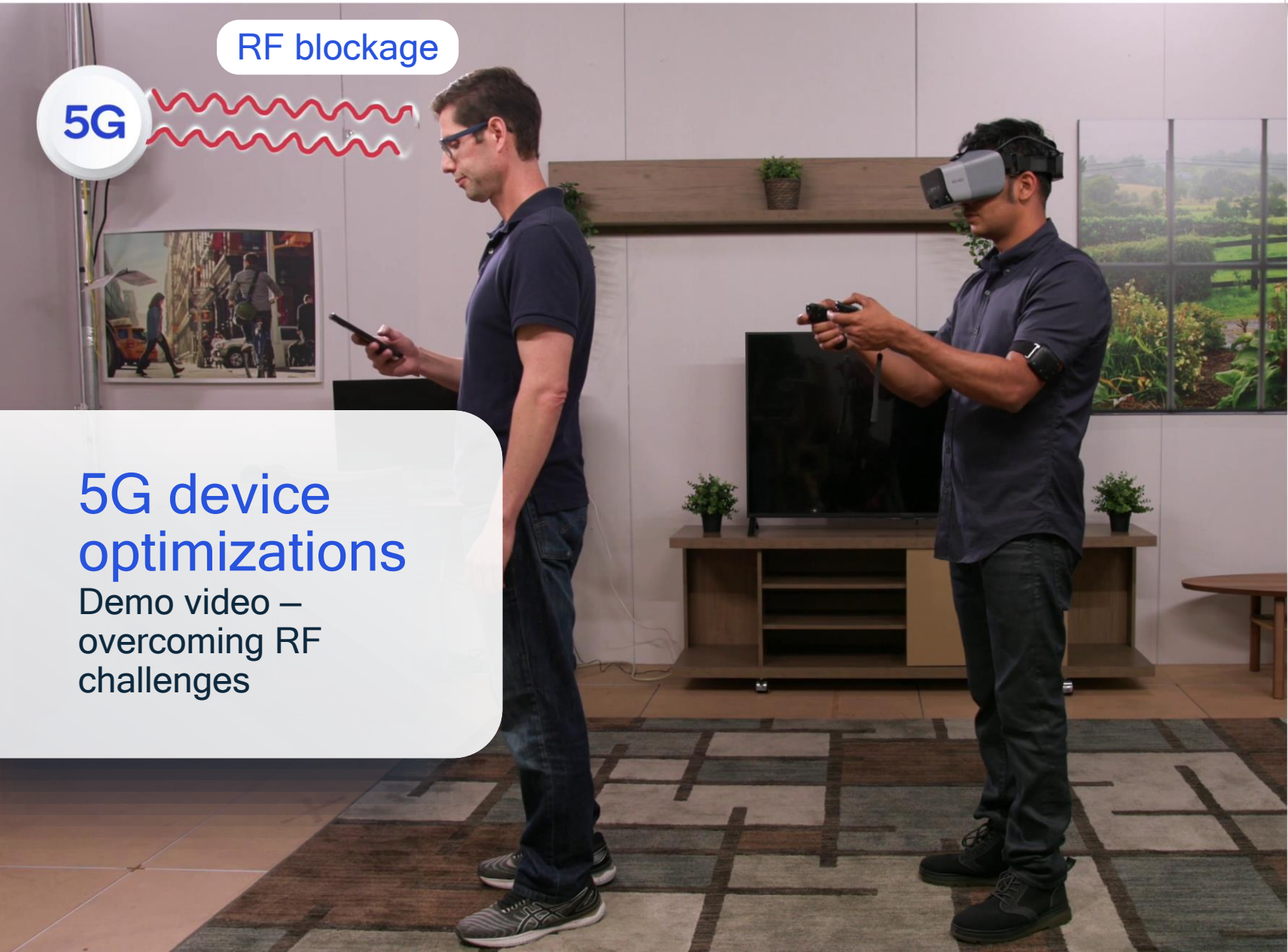
RF blockage

5G

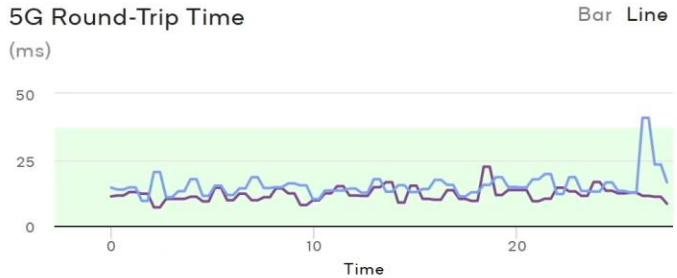


5G device optimizations

Demo video – overcoming RF challenges

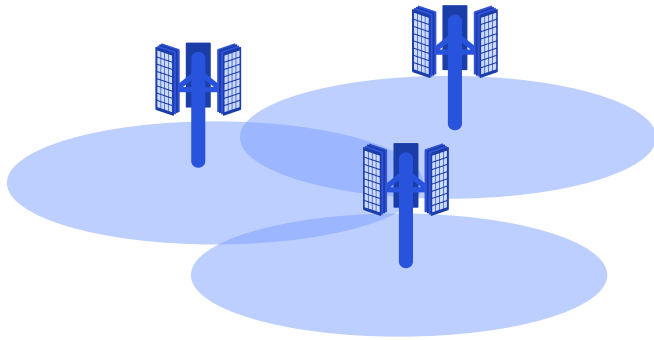


User 3 - Optimized User 3 - Baseline



gNodeB deployment

Select proper location, height, and transmit power for better coverage, capacity and interference mitigation



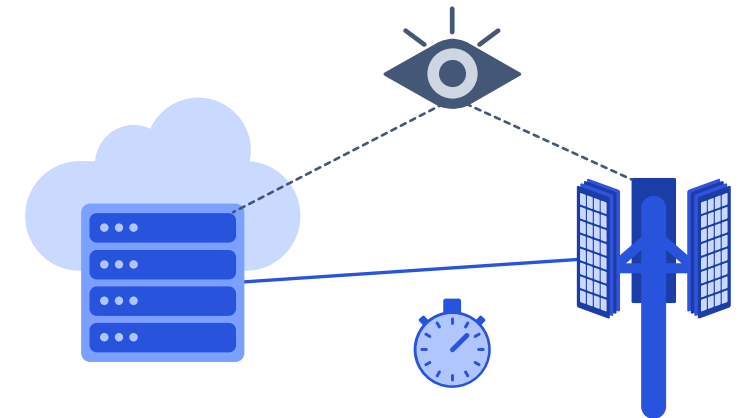
Network parameters

Optimize for low latency and low power



QOS and delay-aware scheduler

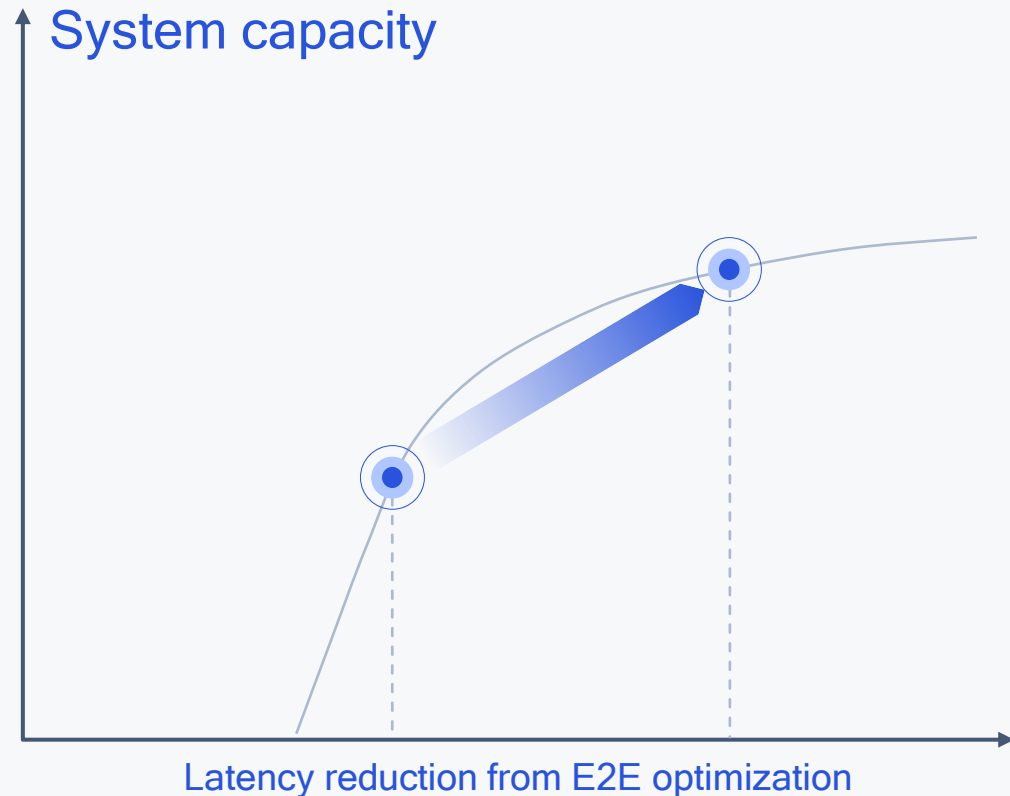
Optimize for further network performance improvement



5G network optimizations are important for good UX

E2E optimizations translate to capacity improvements

Latency reduction can be traded off for relaxed packet delay bounds, leading to higher system capacity

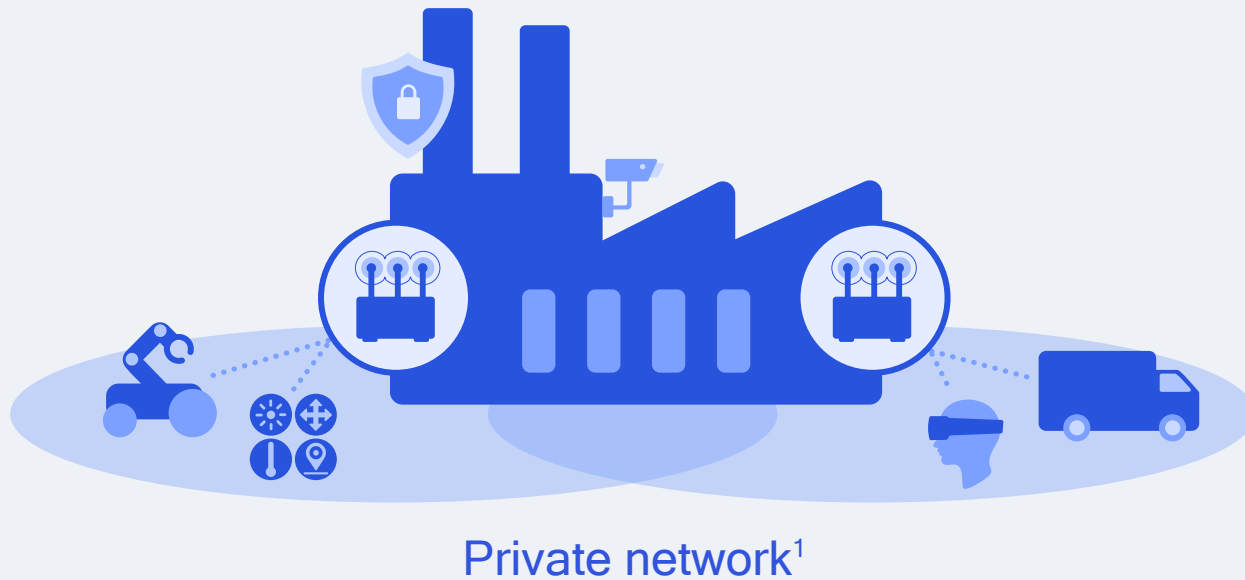


OTA system can support 6 boundless VR users per gNodeB on 100 MHz of system bandwidth due to E2E optimization¹

With advanced uplink efficiency features in mmWave, the system can support more than 12 boundless VR users per gNodeB

1. Assumptions: Each user supports 50Mbps; System bandwidth = 100MHz; mmWave NSA (n261, B48)

Boundless XR is ready for deployment in private networks



1. Also referred to as non-public network (NPN)

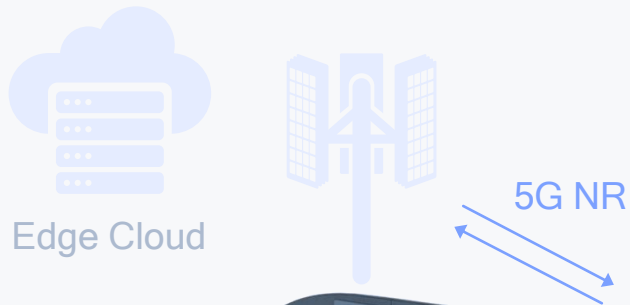


The future – Boundless AR glasses at scale

What will it take?



Enabling 5G technologies for boundless AR



Optimized edge processing

Interfaces for XR split processing over 5G NR



Improved traffic awareness

Optimizing scheduling¹ in the network to improve user experience and network efficiency



Low-power device features

3GPP based features and on-device optimizations



Cross-layer APIs

Bidirectional modem to application

Bidirectional modem to sensor to compute processing

¹ For example, using Application Data Unit (ADU) Error Rate and Delay Budget vs. Packet Error Rate (PER) and Packet Delay Budget (PDB)



Rel-15: Bandwidth Part (BWP)

Narrow BWP for low/no traffic arrival

Rel-17: Discontinuous PDCCH monitoring

Faster transition to sleep after XR burst

Rel-16: Cross-slot scheduling

Gap between control and data to increase sleep

Rel-17/18: Enhanced CDRX

Align short CDRX cycles to video frame rate

Rel-16: Scell dormancy indication

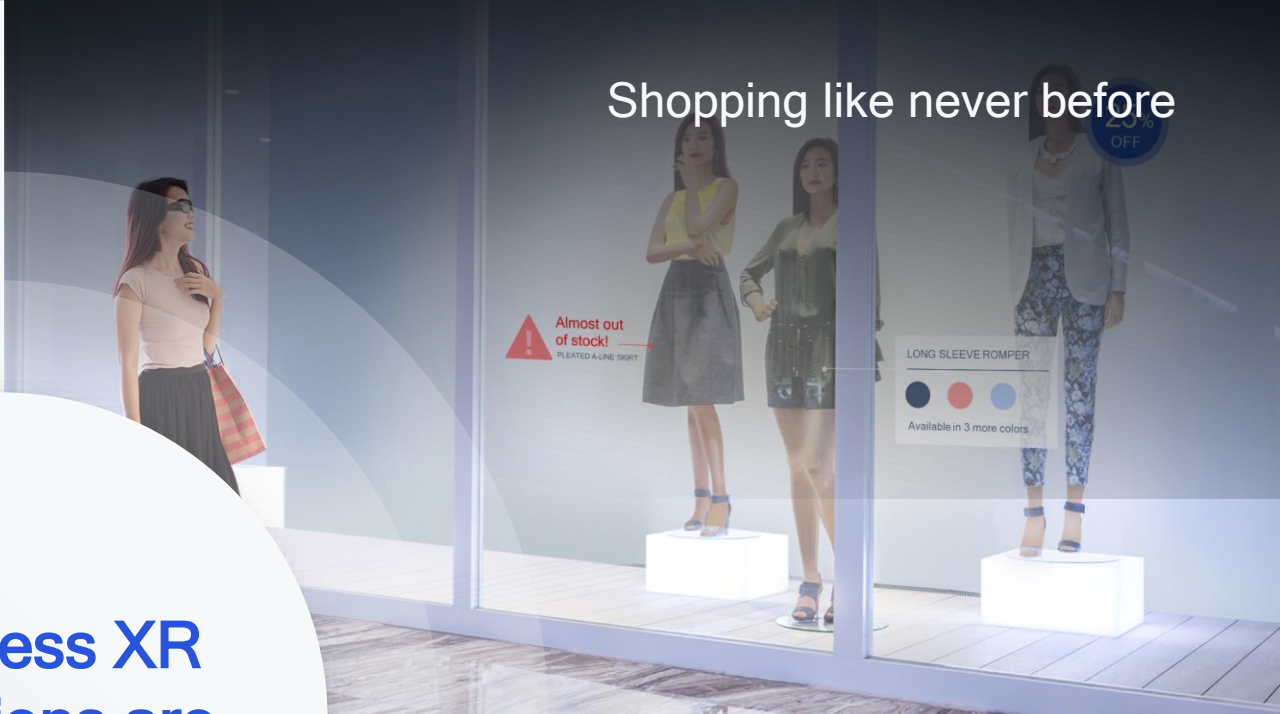
Fast transition of Scell to low-power mode in bursty traffic

5G NR is further enhancing device power efficiency

Real-time interactive collaboration



Shopping like never before



Multi-player gaming with photorealistic graphics



Our mobile office or living room, virtually anywhere



Boundless XR applications are virtually unlimited



Brings AAA
blockbuster titles
to palm of your hand

Enables
cross-platform
games



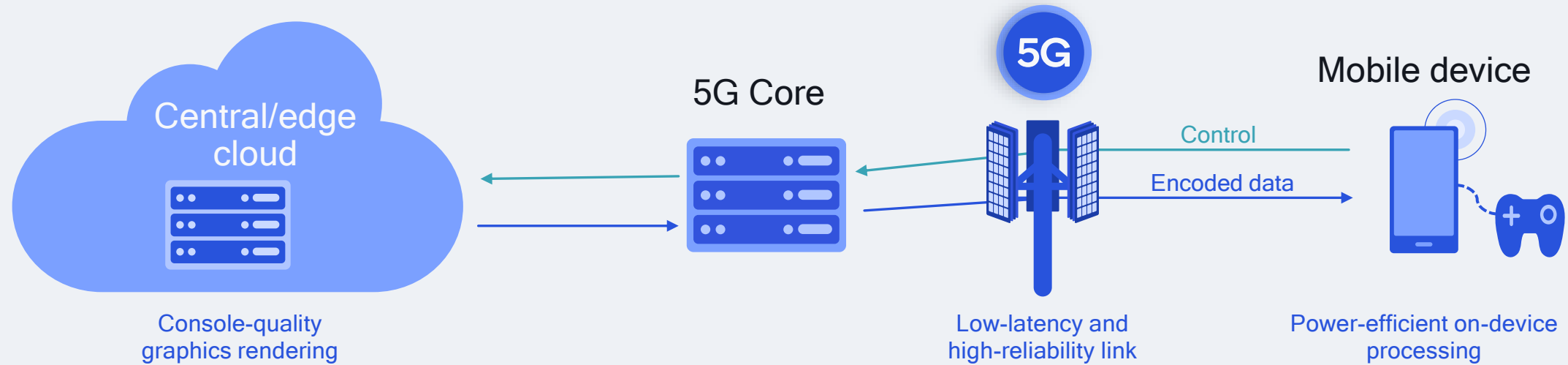
Faster input reaction
times from the device
back to the cloud

Increase in simultaneous
connected game play
from anywhere

5G cloud gaming is creating new experiences

Enabled by reliable, low-latency 5G connectivity | Console-based cloud gaming

Cloud gaming leverages the same building blocks as XR



$$\text{Controller to render to photon (C2R2P)} = \text{Cloud/edge processing} + \text{5G RTT} + \text{On-device processing}$$

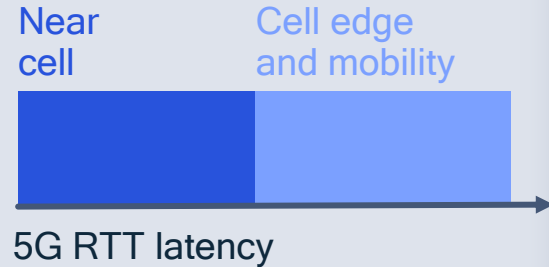
Requirements
C2R2P < 133ms¹
5G RTT < 50ms
Edge cloud latencies currently ~15-30ms

Distribute computation between edge cloud server and device to deliver console-quality gaming over 5G

5G device optimizations improve the gaming experience

Optimizations for XR also apply to cloud gaming

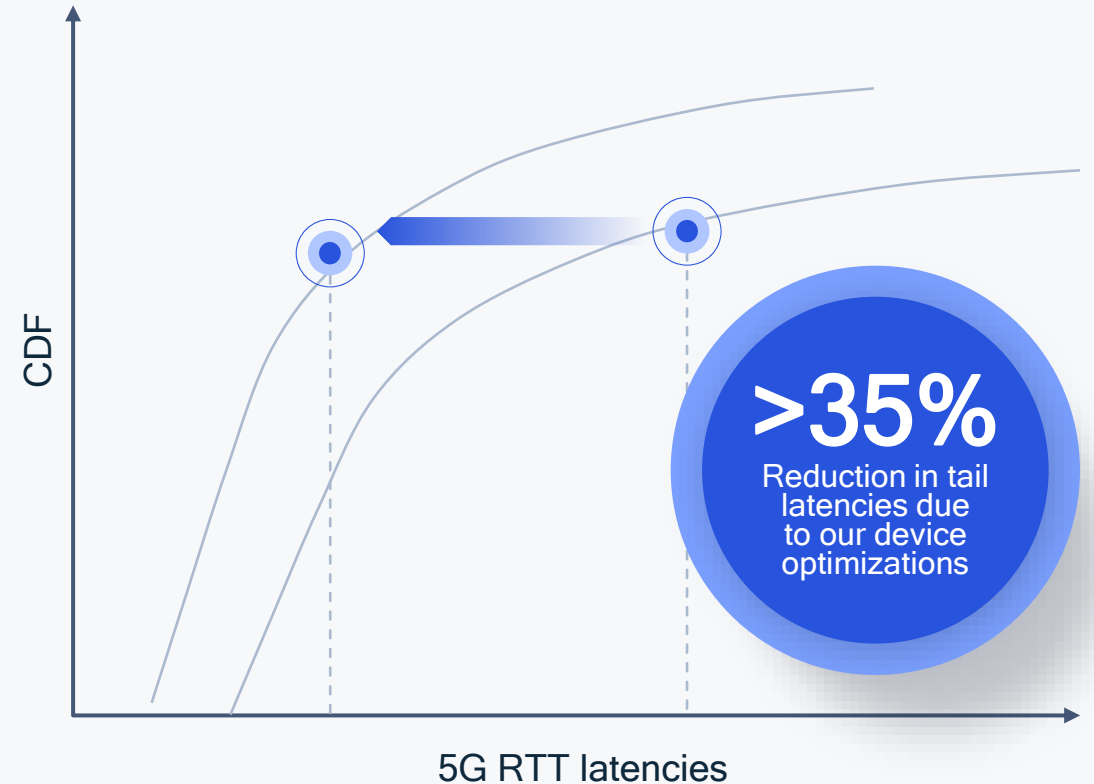
How much does latency matter?



Low latency is critical for user experiences

Cell edge and mobility scenarios can cause large latencies due to dynamic RF environment

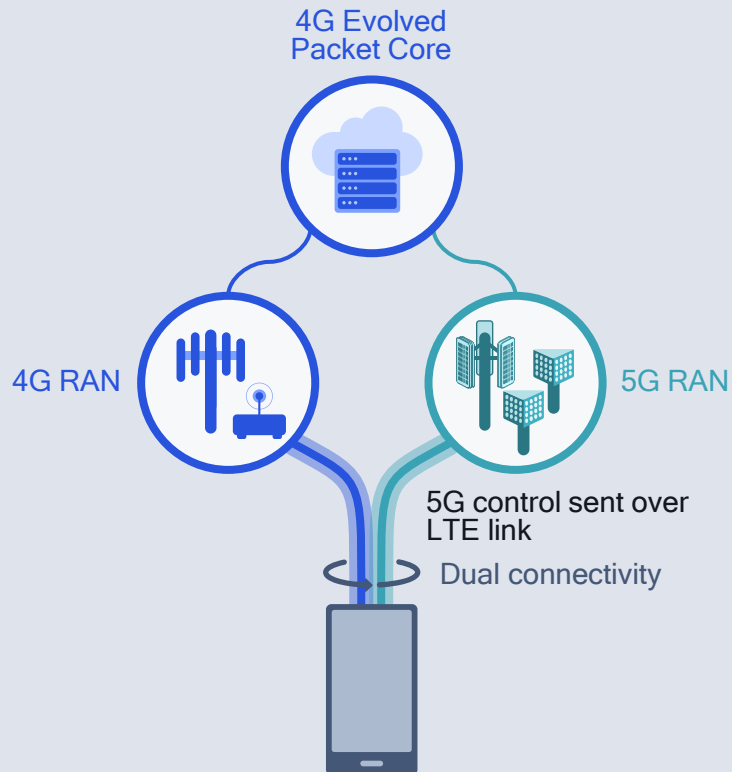
Latency reduction



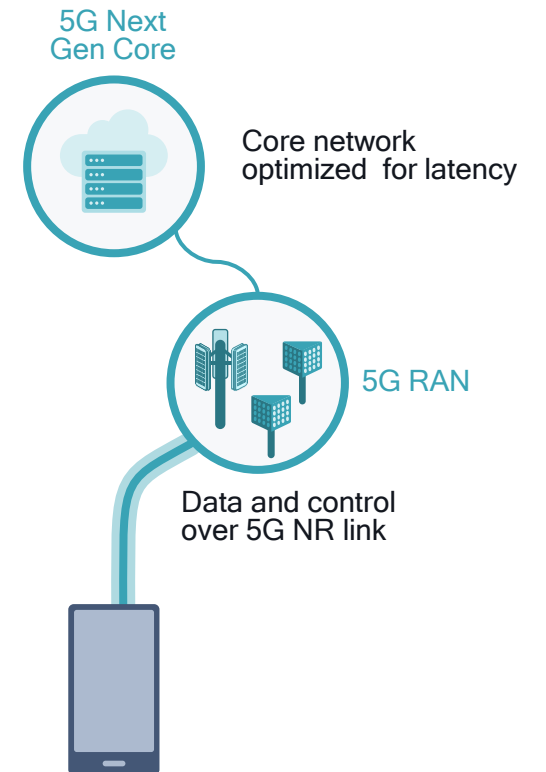
Migration to 5G SA mode will help improve latency



Non-Standalone (NSA) option

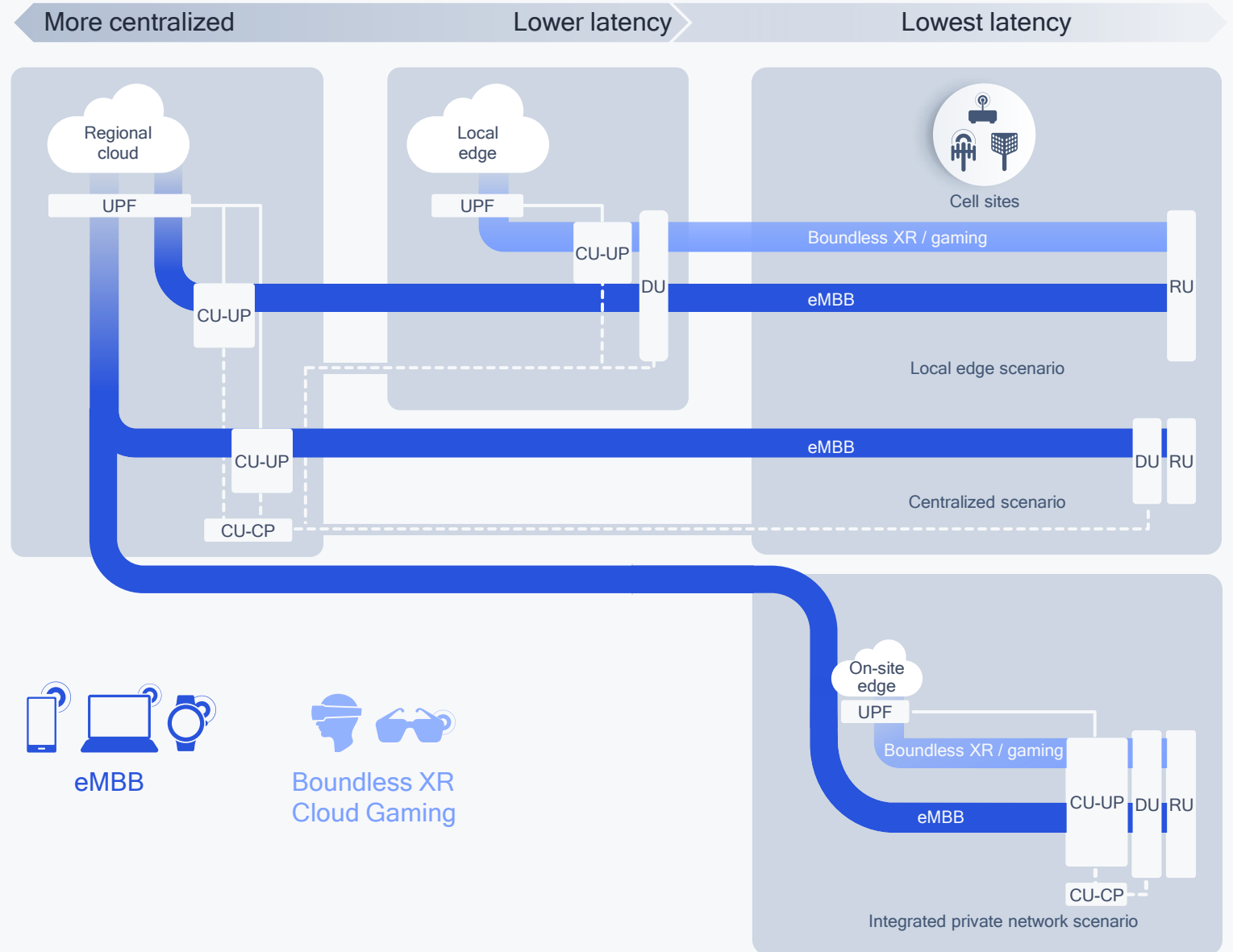


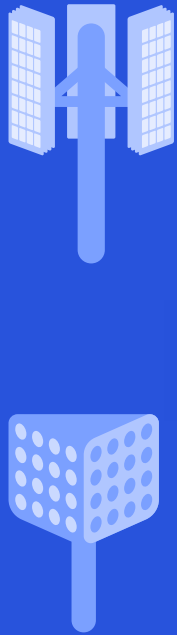
Standalone (SA) option



Migration from central cloud to local edge will improve latency

A scalable and flexible wireless edge





eMBB
enhancements
apply to XR and
cloud gaming

Release 16



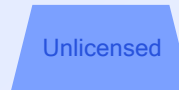
Enhanced DL/UL MIMO and
multiple transmission points



eURLLC with uplink power
boosting and uplink cancellation



More robust mobility with minimal
interruption during handover



Unlicensed spectrum including
standalone and license assisted



Enhanced low/mid-band
and mmWave CA and async DC

Release 17



Further improved MIMO
for e.g., higher mobility



Others such as, >4 Rx,
1024-QAM, multi-SIM



Further enhanced mobility
for mixed topologies

Advanced 5G features will further improve UX

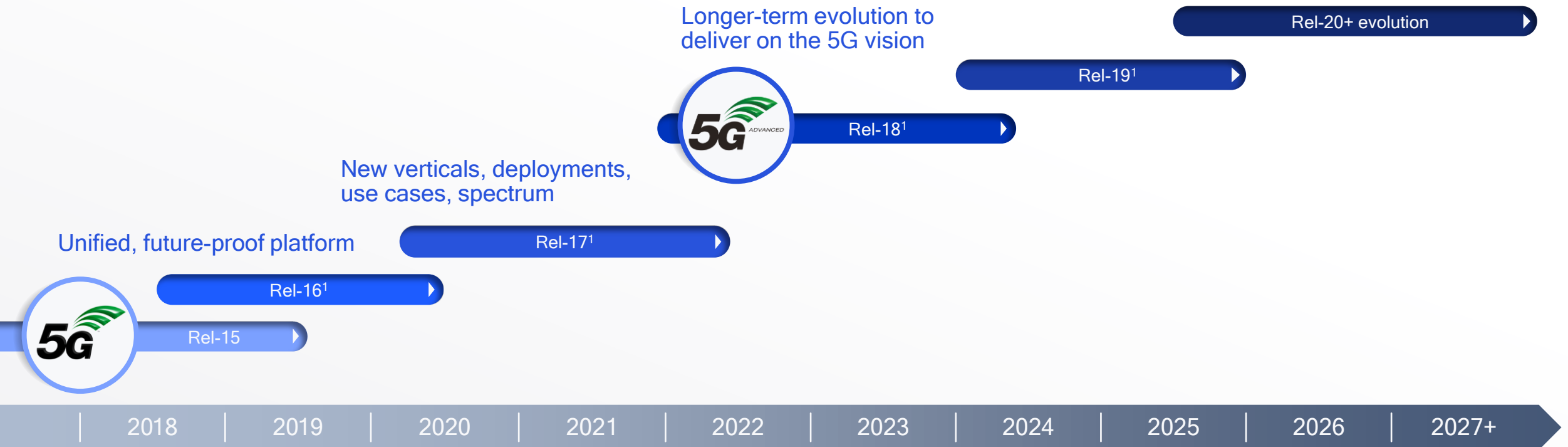
Foundational areas

Coverage, capacity, latency,
mobility, ...

Expanded deployments

New spectrum,
topologies, ...

Driving the 5G technology evolution in the new decade



Rel-15 eMBB focus

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

Rel-16 industry expansion

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

Rel-17 continued expansion

- Lower complexity NR-Light
- Higher precision positioning
- Improved IIoT, V2X, IAB, and more...

Rel-18+ 5G-Advanced

- Next set of 5G releases (i.e., 18, 19, 20, ...)
- Potential projects in discussions
- Rel-18 expected to start in 2022

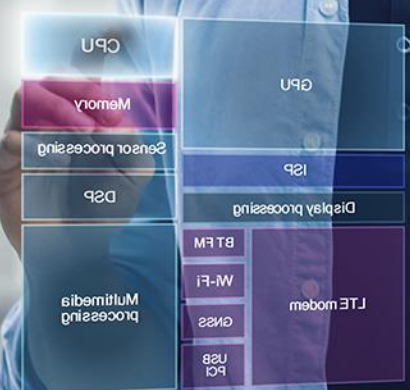
1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1



5G enables boundless XR and cloud gaming at scale and is ready for commercialization

The 5G evolution has a strong roadmap for enhanced low-latency experiences and deployments

We are making boundless XR and cloud gaming possible with end-to-end 5G algorithm development and optimization



Questions?

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