



# VR and AR pushing connectivity limits

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Qualcomm Technologies, Inc.  
May 2017



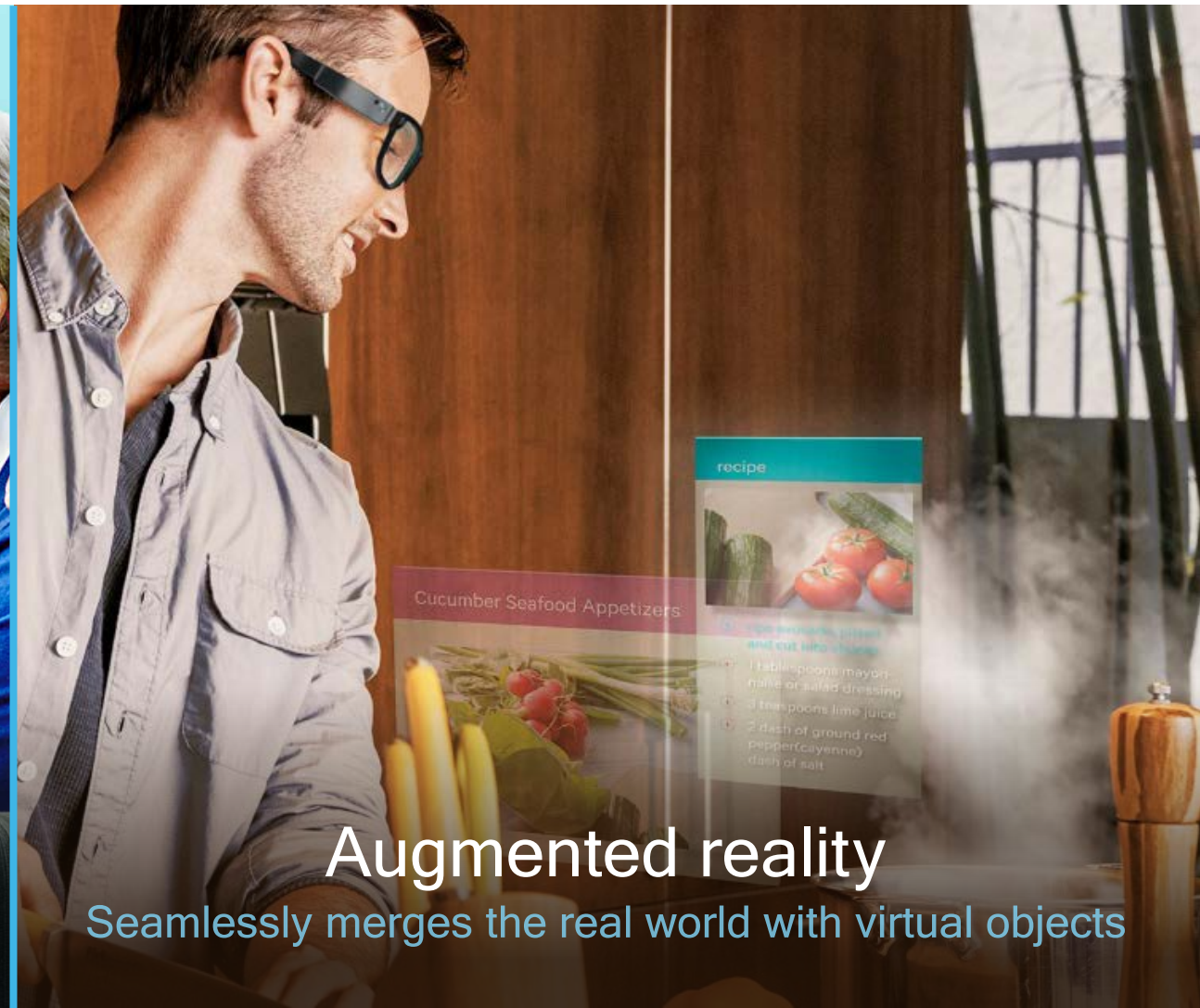
# AR and VR are revolutionary interfaces

Sharing many of the same underlying technologies



## Virtual reality

Creates physical presence in virtual worlds



## Augmented reality

Seamlessly merges the real world with virtual objects



# VR will offer unprecedented experiences and possibilities



## Play

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Immersive movies and shows

Live concerts, sports, and other events

Interactive gaming and entertainment



## Learn

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Immersive education

Training and demos

3D design and art



## Communicate

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Social interactions

Shared personal moments

Empathetic storytelling





# AR will serve a broad spectrum of roles in daily life

Applicable across ages, genders, activities

## Children playing



Kids chasing virtual characters in interactive and immersive games

## Young adults exploring



A young man exploring Rome and seeing the originally built Colosseum

## Families communicating



Families virtually brought together with life-like communication

## Professionals working



Architects collaborating on a shared design to improve efficiency

## Fitness enthusiasts and thriving



Group running with a virtual trainer to motivate them

# A glimpse into the future – everyday AR glasses

Bone conduction transducers

Directional speakers

Multimode connectivity  
(4G, 5G, etc.)

Many passive and active cameras  
with fisheye and telephoto lenses  
Optoelectronic night vision  
and thermal imaging sensors

Ambient light sensors

Tracking and recording cameras

Inertial, haptic,  
and health sensors

Multiple high sensitivity  
audio microphones

Eye tracking cameras

New optics and projection  
technologies within a durable,  
semitransparent display





# AR technologies and use cases evolve from mobile

VR usage primarily comes from console/TV/PC, but it's also moving towards AR



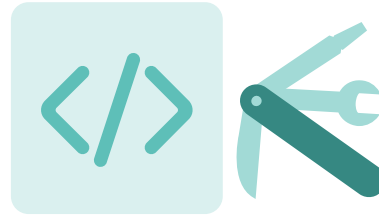
# We are accelerating the adoption of VR and AR

Designed to make it easy to develop premium mobile VR and AR experiences



## Qualcomm® Snapdragon™ 835 SoC

Purpose built silicon  
for superior mobile  
VR & AR



## Snapdragon VR SDK

Access to advanced VR features  
to optimize applications and  
simplify development



## Snapdragon 835 VR HMD

Accelerating the development  
of standalone head-mounted  
displays

# Actively working with ecosystem innovators

## Design wins based on Snapdragon Platforms



Google Pixel  
Daydream



Google Pixel XL  
Daydream



ZTE Axon 7  
Daydream



Lenovo Phab Pro 2  
Tango



Asus Zenfone AR  
Tango and Daydream



Moto Z  
Daydream



## VR HMDs

Baofeng Matrix

Coocaa Wondergate G1

IQiYi Adventure

Pico Neo

Whaley VR



## More to come with Snapdragon 835

### Google Daydream support

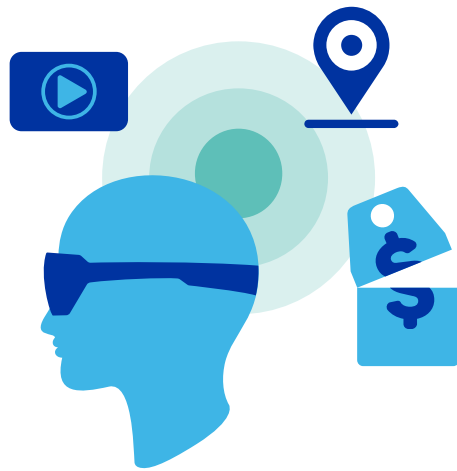
Snapdragon 835  
hardware and software  
is “Daydream-ready”

### Tencent collaboration

Working with Qualcomm  
China to develop  
mobile AR/VR games



# VR and AR will push connectivity requirements



## More capacity, lower cost

Increased throughput per user as quality of immersion improves, and more simultaneous usage



## Low latency

Reduces throughput requirements, buffering requirements, and lag for interactive content like tactile Internet and 6 DoF\*



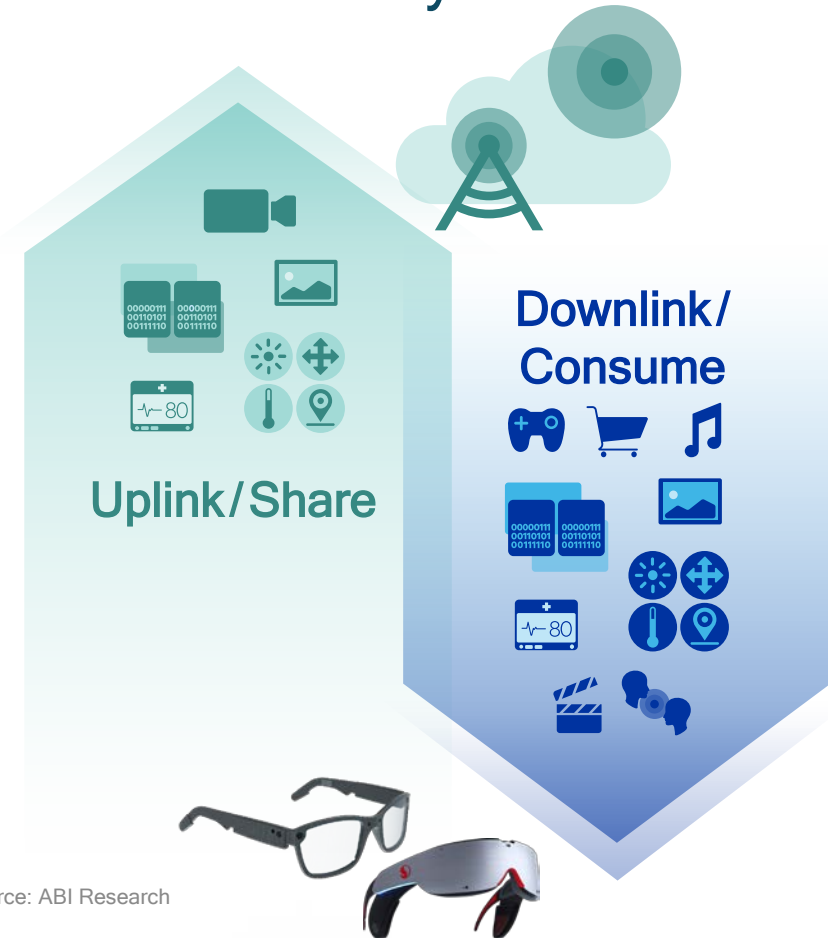
## Uniform experience

Full immersion everywhere requires consistent throughput, even at the cell edge

\*6 DoF: Six degrees of freedom

# VR and AR require efficient increase in wireless capacity

## Constant up/download on an all-day wearable



Source: ABI Research

## Richer visual content

- Higher resolution, higher frame rate
- Stereoscopic, High Dynamic Range (HDR), 360° spherical content, 6 DoF

2 Mbps

Video conferencing

5 to 25 Mbps

Two-way telepresence

50 to 200 Mbps

Next-gen 360° video (8K, 90+ FPS, HDR, stereoscopic)

1 Mbps

Image and workflow downloading

2 to 20 Mbps

3D model and data visualization

10 to 50 Mbps

Current-gen 360° video (4K)

200 to 5000 Mbps

6 DoF video or free-viewpoint

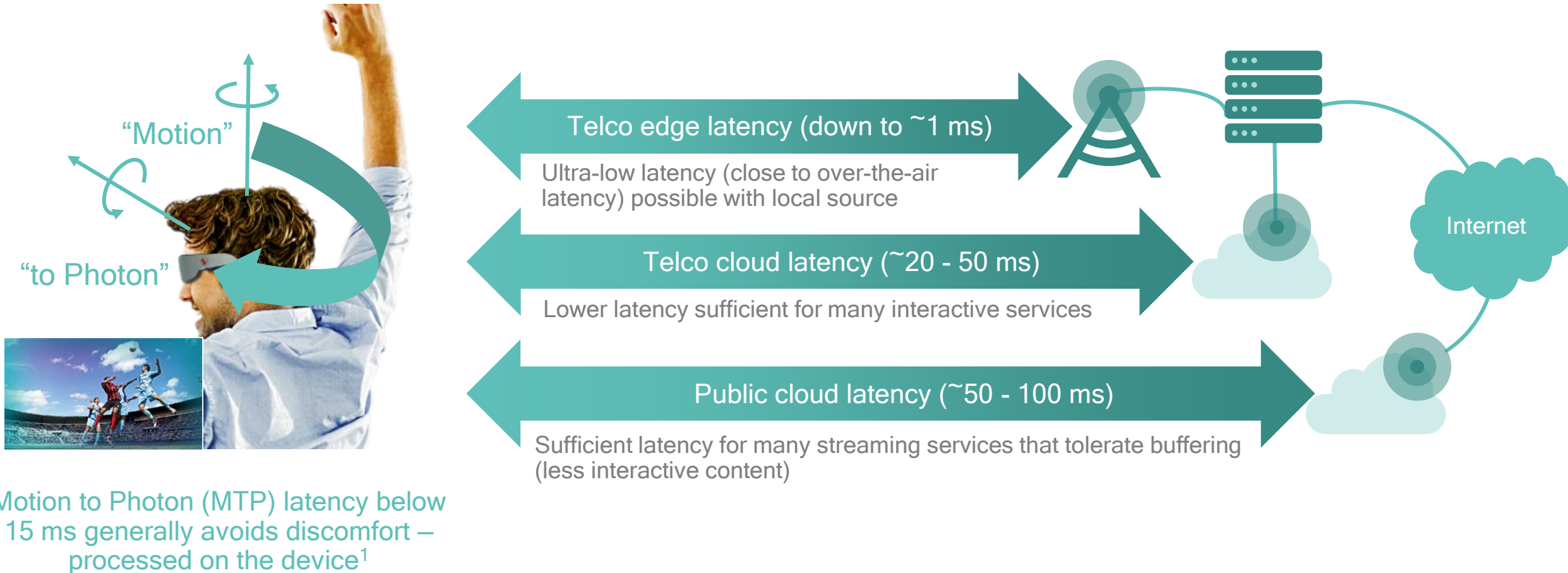
Bandwidth

Critical for immersive experiences<sub>10</sub>



# Low wireless latency is critical for immersion

The air interface is one component of the overall end-to-end latency



<sup>1</sup> Specific use cases, e.g. local edge content, may allow some processing to be intelligently split over the air-interface

# A uniform experience is paramount for AR and VR

Lag, stutter, and stalls are unacceptable for user experience and comfort



## Consistent quality, e.g. latency

- No disruptions from buffering
- No reduction in quality from fluctuating bitrates



## Anywhere usage

- From cities to rural area
- Reliable service even in challenging environments or the cell edge



## High mobility

- Fast moving situations, like cars
- Constant head movement



Immersion must be maintained at all times



# Our vision for 5G is a unifying connectivity fabric

Delivering always-available, secure cloud access



Enhanced mobile  
broadband



Mission-critical  
services



Massive Internet  
of Things

Unifying connectivity platform for future innovation

Convergence of spectrum types / bands, diverse services, and deployments,  
with new technologies to enable a robust, future-proof 5G platform

# 5G enhanced mobile broadband is required to take VR/AR experiences to the next level

Extreme throughput – with Multi-Gbps  
Ultra-low latency – down to 1 ms  
Uniform experience – even at cell edge

Gigabit  
LTE

Ubiquitous coverage with Wi-Fi and Gigabit LTE, the anchor of the 5G broadband experience





Automotive video streaming  
High uniformity

Crowded event sharing  
Extreme capacity

# 5G

Essential for  
next-gen AR/VR  
experiences

6 DoF immersive content  
High throughput, low latency

Remote control/ Tactile Internet  
Low latency

\*6 DoF: Six degrees of freedom



# Automotive video streaming

100

Mbps

User cell edge rate  
with mobility

Uniform experience

Cars are becoming increasingly  
autonomous and efficiently shared

Coverage: Excellent user experience  
anywhere, even at cell edge while moving

Capacity: ~700 Mbps per cell with 1%  
penetration (for 8-lane freeway example)

Assumptions: 1. ~667 cars per cell tower and 500 meter ISD. 2. 0.01 (1%) AR/VR users per car 3. Each AR/VR app uses 100 Mbps. Minimum 100 Mbps downlink is one of the IMT-2020 requirements.



# Social sharing at crowded venues

Massive simultaneous content upload through social media

**12.5**  
Tbps / km<sup>2</sup>  
upload capacity



Assumptions: 1: 50,000 fans are simultaneously streaming in a 0.1 km<sup>2</sup> stadium, 2: Each video is 4K 360° video @ 25 Mbps. Minimum 50 Mbps uplink is one of the IMT-2020 requirements, along with 10 Tbps/km<sup>2</sup> downlink area density (example for uplink)



# 6 DoF\* content

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Next-gen video for more immersive experiences (move freely around)

## Requirements

- Tradeoff between throughput and latency
- 5-20 ms latency requires 400-600 Mbps, while 1-5 ms latency requires 100-200 Mbps

\*6 DoF: Six degrees of freedom





# Remote control and tactile Internet

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Reduced latency for better interactivity and expanded use cases

## End-to-end latency requirements

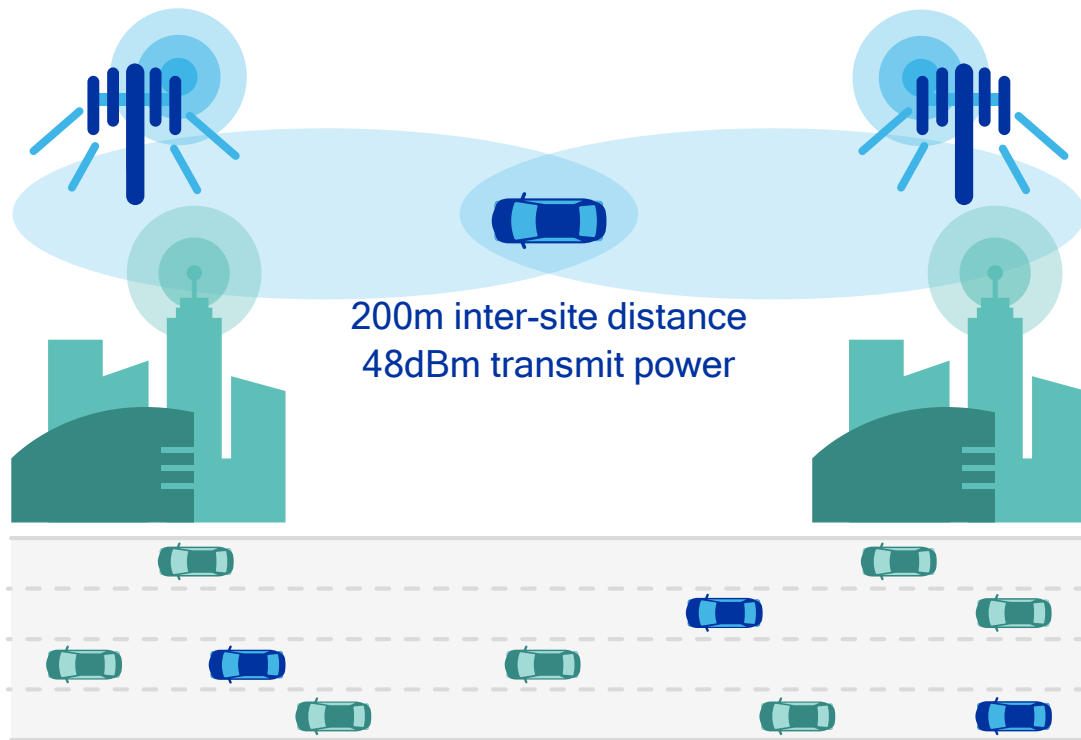
- Interactive remote experiences often ranging from 40 ms to 300 ms (includes transport latency)
- Feedback below 5 ms will enable novel uses of multi-sensory remote tactile control



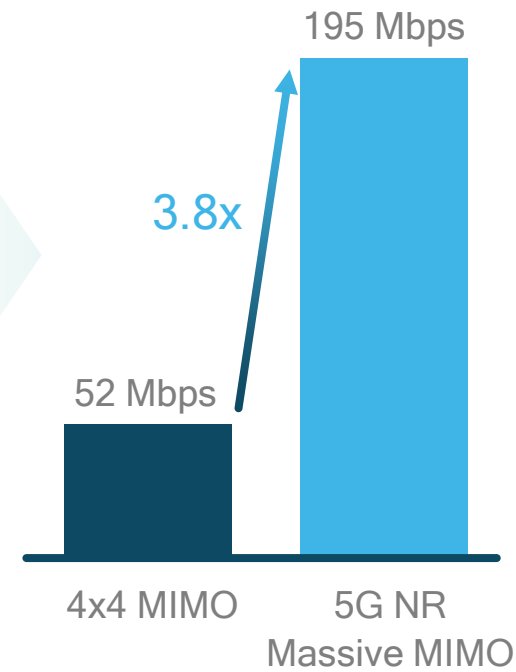
# 5G NR massive MIMO brings a more uniform experience

With higher capacity and better coverage; also enables higher bands, e.g., 4 GHz

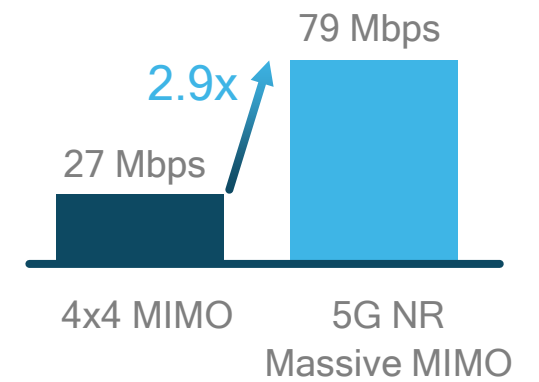
Exploit 3D beamforming with up to 256 antenna elements



Median user perceived throughput



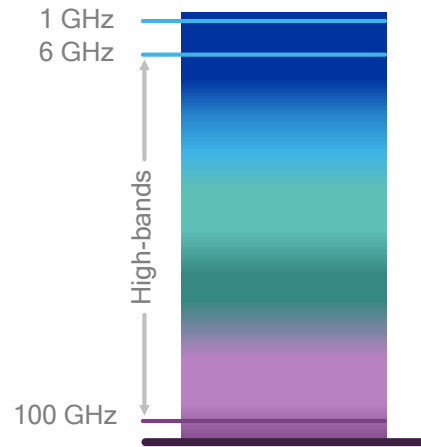
Cell edge user perceived throughput





# 5G NR mmWave is capable of delivering massive capacity

Exploiting higher bands and more flexible use of available bandwidth



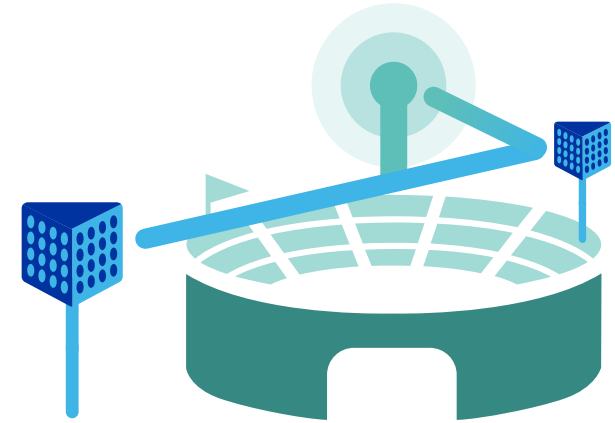
## Large bandwidth

Leveraging higher spectrum bands (e.g., at 28 GHz) previously not available to LTE



## Flexible capacity

Adapting to network traffic needs with dynamic UL / DL switching, enabled by new self-contained TDD design



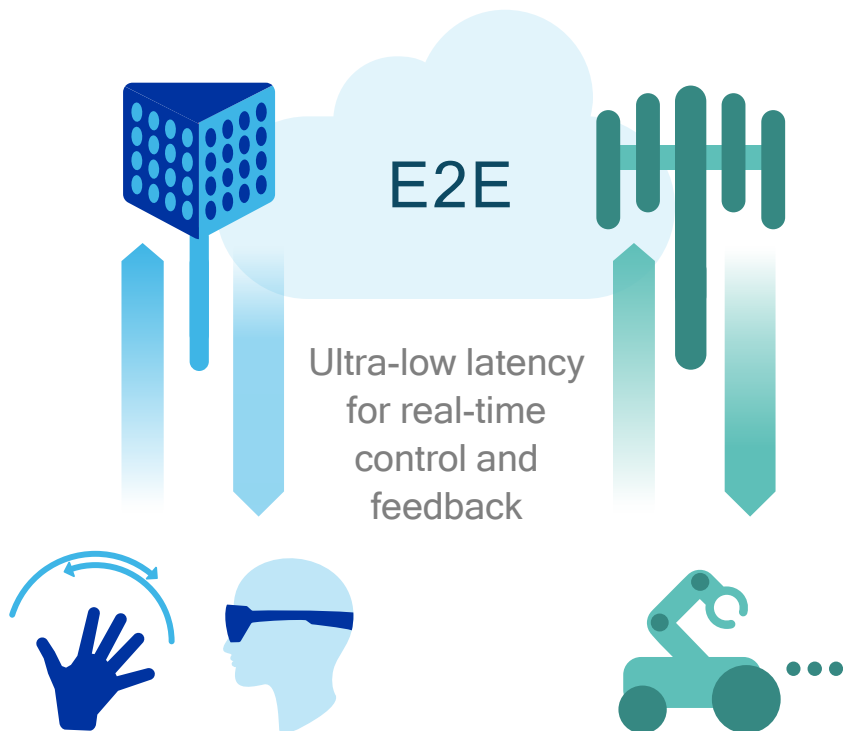
## Small cell densification

Enabling easy / low-cost deployment of small cells with integrated access and backhaul

Simultaneous connectivity with spectrum bands below 6GHz (Gigabit LTE or 5G NR) ensures a seamless, ubiquitous user experience

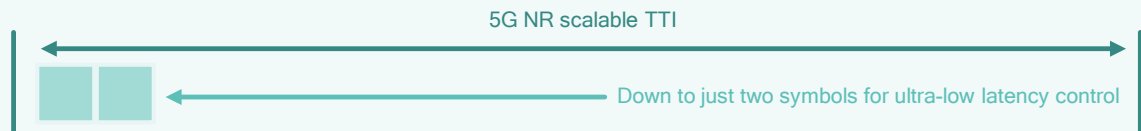
# 5G NR scalable over-the-air latency down to 1 ms

Enhancing VR/AR user experience and enabling new use cases



Low latency beneficial for 6 DoF to reduce amount of data

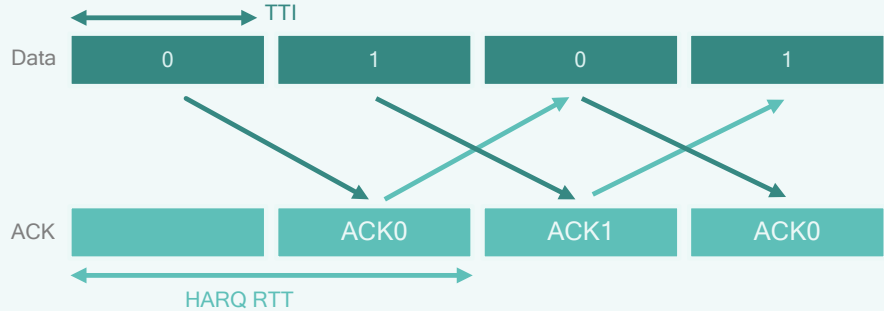
## Shorter transmission time interval (TTI)



## Reduced round-trip time (RTT)

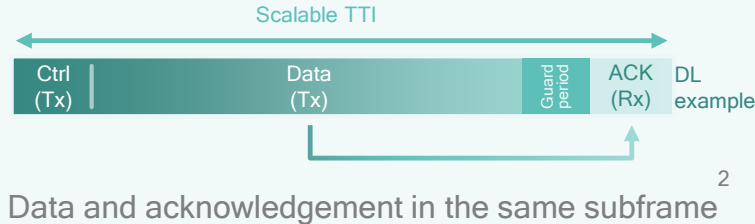
### FDD

Fewer HARQ<sup>1</sup> interlaces



### TDD

Self-contained subframe design



1. Compared to LTE's eight HARQ interlaces; 2. Retransmission may occur immediately in the next TDD subframe

# We are accelerating the path to 5G NR

Best-in-class 5G  
prototype systems  
and testbeds



Test, demonstrate and verify  
our innovative 5G designs to  
contribute to and drive  
standardization

5G standards,  
technology and  
research leadership



Such as advanced channel  
coding, self-contained  
subframe, mobilizing  
mmWave, ...

Impactful trials and  
early deployments with  
network operators



Over-the-air interoperability  
testing leveraging prototype  
systems and our leading  
global network experience

Modem and RFFE  
leadership to solve  
5G complexity



Roadmap to 5G significantly  
more complex and faster  
moving—builds upon our rich  
history of industry firsts



# Thank you

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