October 2018 @qualcomm_tech

Qualcomm

VR and AR pushing connectivity limits

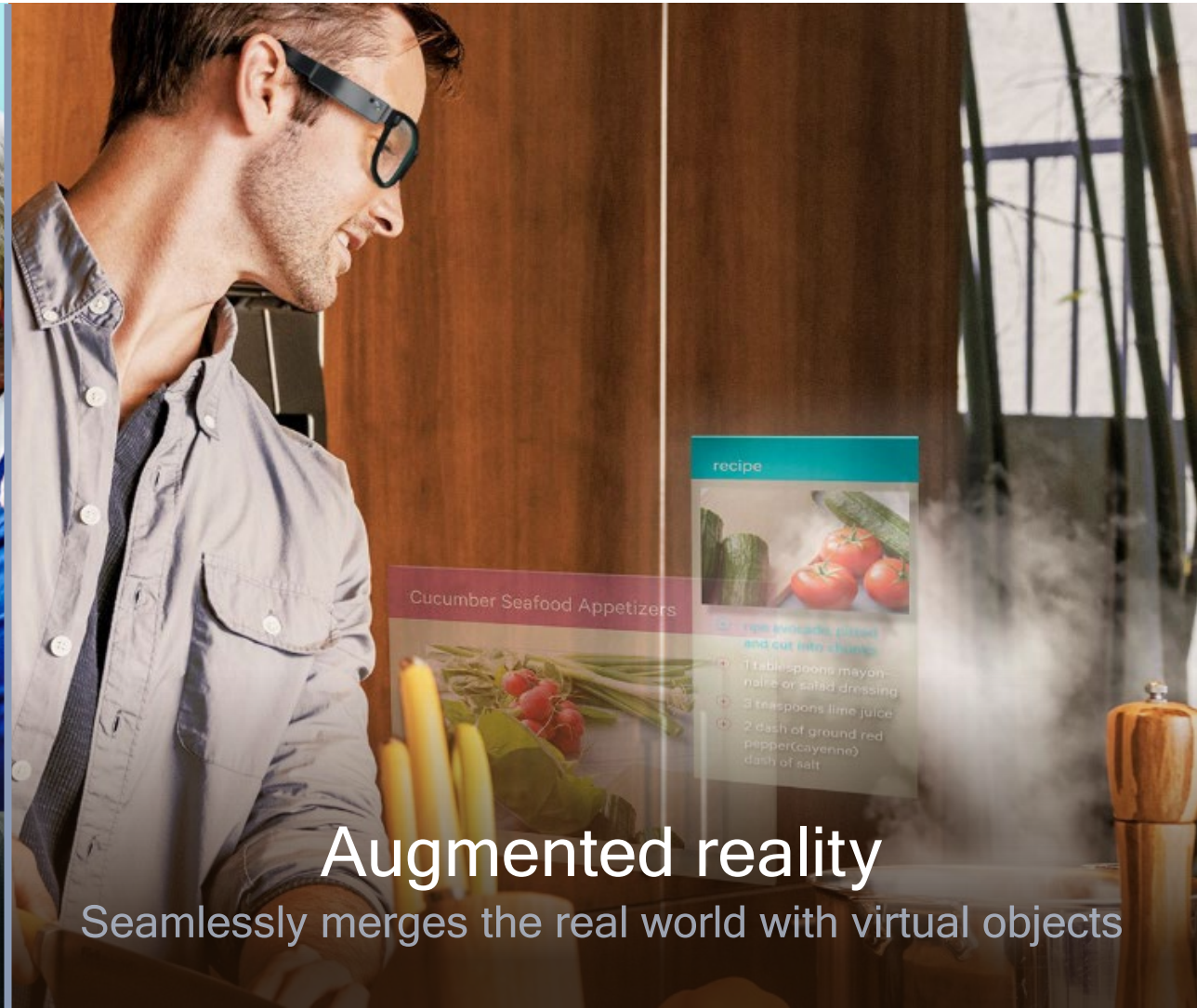
Qualcomm Technologies, Inc.

AR and VR are revolutionary interfaces

Sharing many of the same underlying technologies

Virtual reality

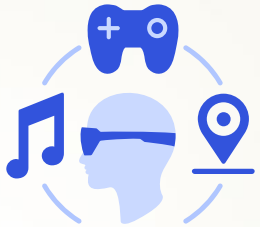
Creates physical presence in virtual worlds



Augmented reality

Seamlessly merges the real world with virtual objects

VR will offer unprecedented experiences and possibilities



Play

Immersive movies and shows

Live concerts, sports, and other events

Interactive gaming and entertainment

Learn

Immersive education

Training and demos

3D design and art

Communicate

Social interactions

Shared personal moments

Empathetic storytelling

AR will serve a broad spectrum of roles in daily life

Applicable across ages, genders, and activities

Children Playing

Kids chasing virtual characters in more interactive and immersive games

Young Adults Exploring

A young man exploring Rome and seeing the Colosseum as originally built

Families Communicating

Families virtually brought together with life-like communication

Professionals Working

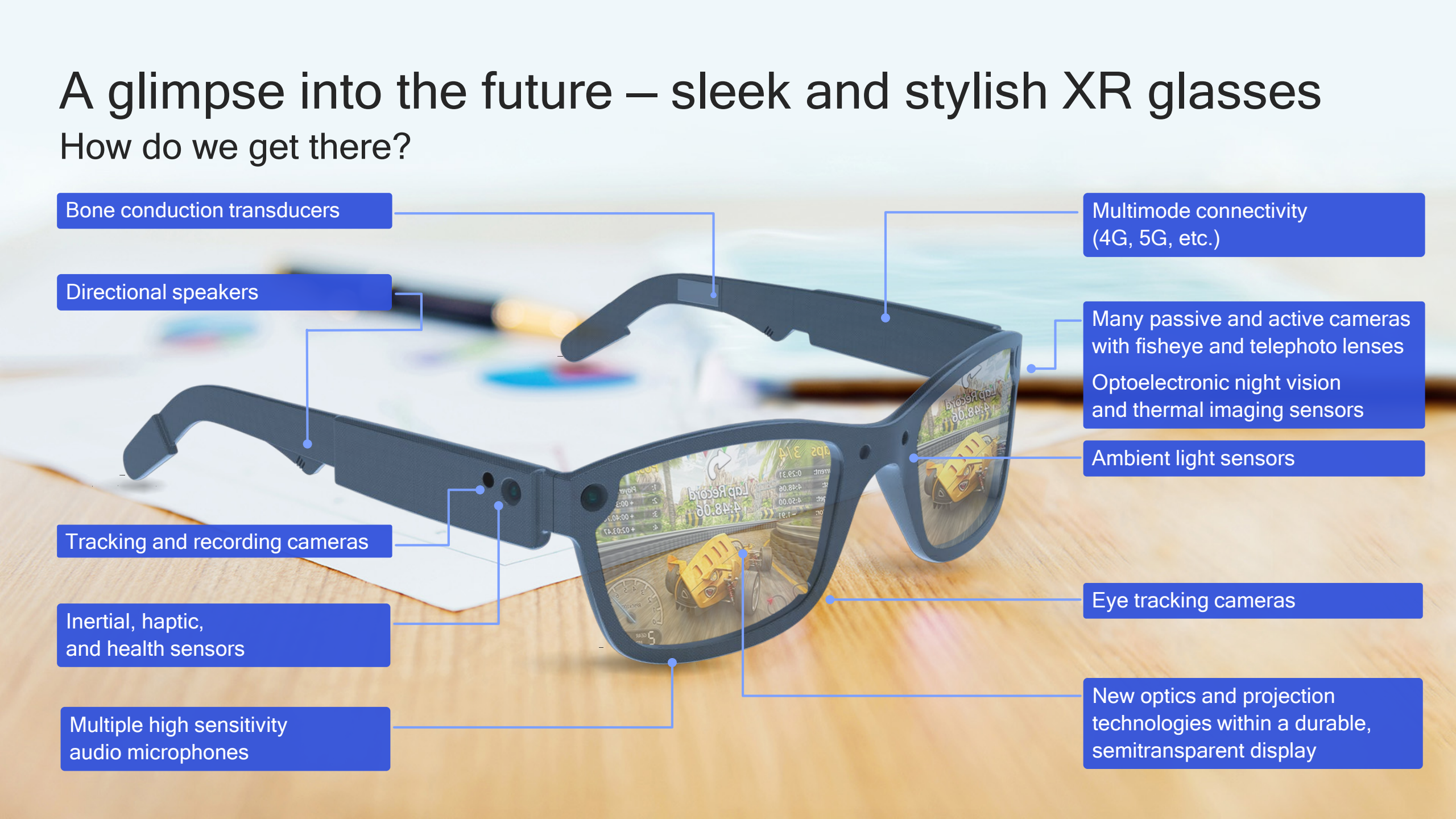
Architects collaborating on a shared design to improve efficiency

Fitness Enthusiasts Thriving

Group running with a virtual trainer to motivate them

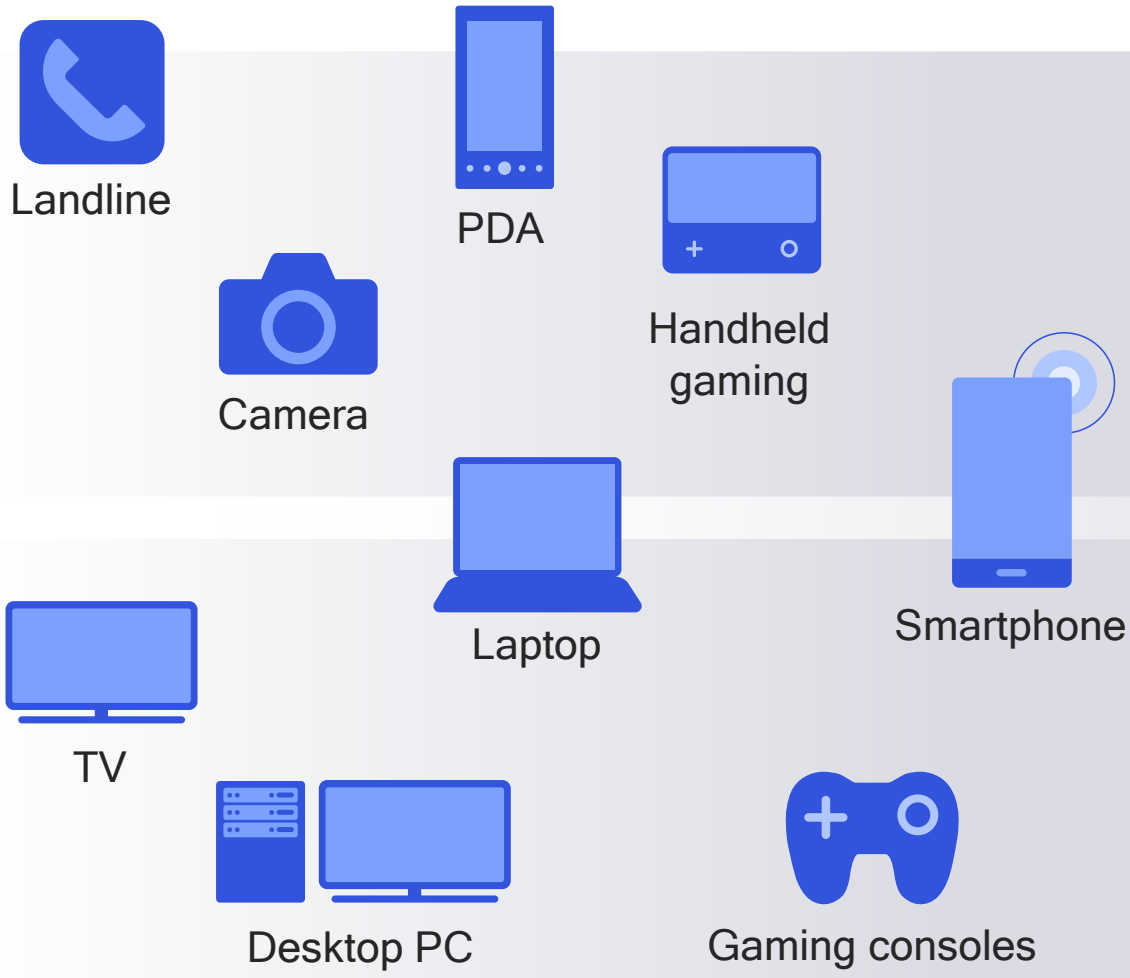
A glimpse into the future – sleek and stylish XR glasses

How do we get there?



AR technologies and use cases evolve from mobile

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



AR glasses

VR HMD

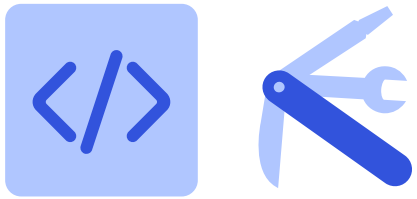
Ultimately,
this becomes an imperceptible device that replaces nearly all others

We are accelerating the adoption of VR and AR

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

Qualcomm® Snapdragon™ 845 SoC

Purpose built silicon for superior mobile VR & AR



Snapdragon VR SDK

Access to advanced VR features to optimize applications and simplify development

Snapdragon 845 VR HMD

Accelerating the development of standalone head-mounted displays

Platform

Qualcomm snapdragon

Software

Advanced Algorithms

- Eye tracking
- 3D Audio
- 6DoF
- Foveated rendering
- Hand tracking
- Scene Under-standing

Ref Design, SDKs &Tools

- VR SDK
- KPI
- Profiles

HMD Accelerator Program (HAP)

Qualcomm advantage network
HMD accelerator program

- ODM
- ISV
- IHV
- Components

advantage.qualcomm.com/hap

Devices

Actively working with ecosystem innovators

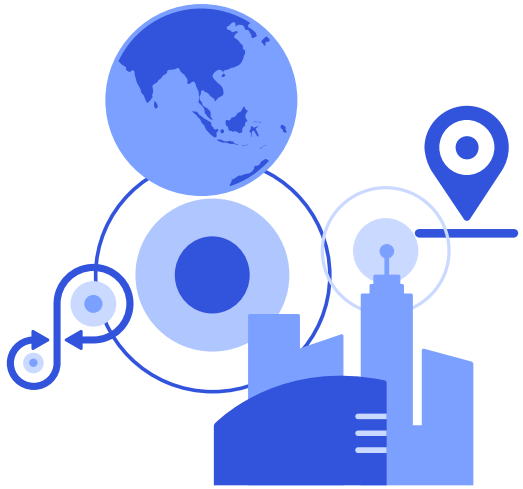
VR and AR will push connectivity requirements

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*



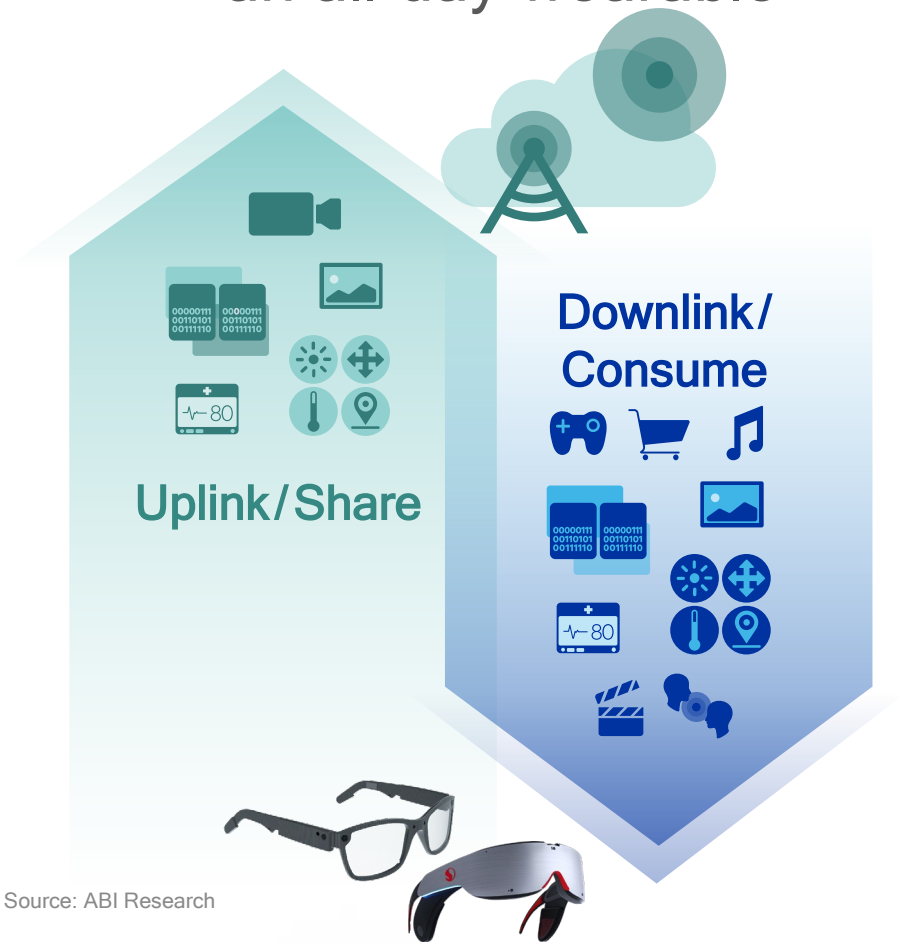
Uniform experience

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)

Bandwidth

1 Mbps
Image and workflow downloading

2 to 20 Mbps
3D model and data visualization

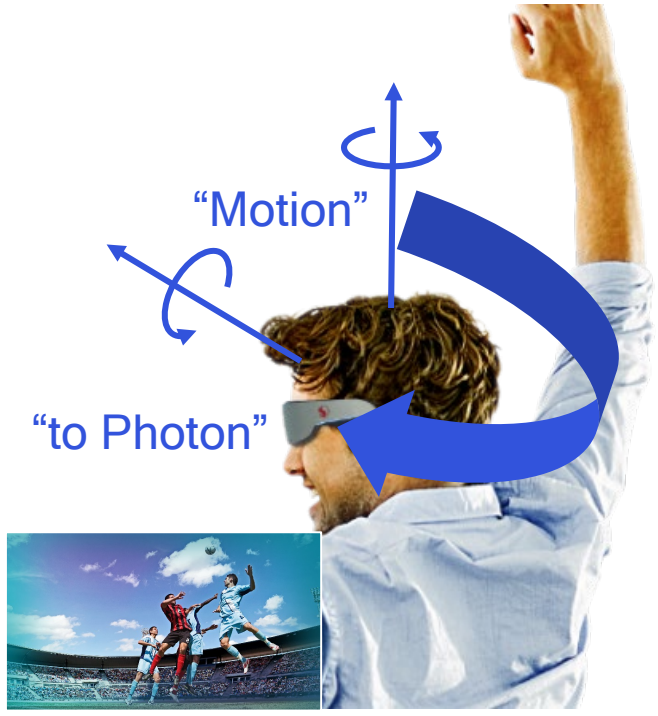
10 to 50 Mbps
Current-gen 360° video (4K)

200 to 5000 Mbps
6 DoF video or free-viewpoint

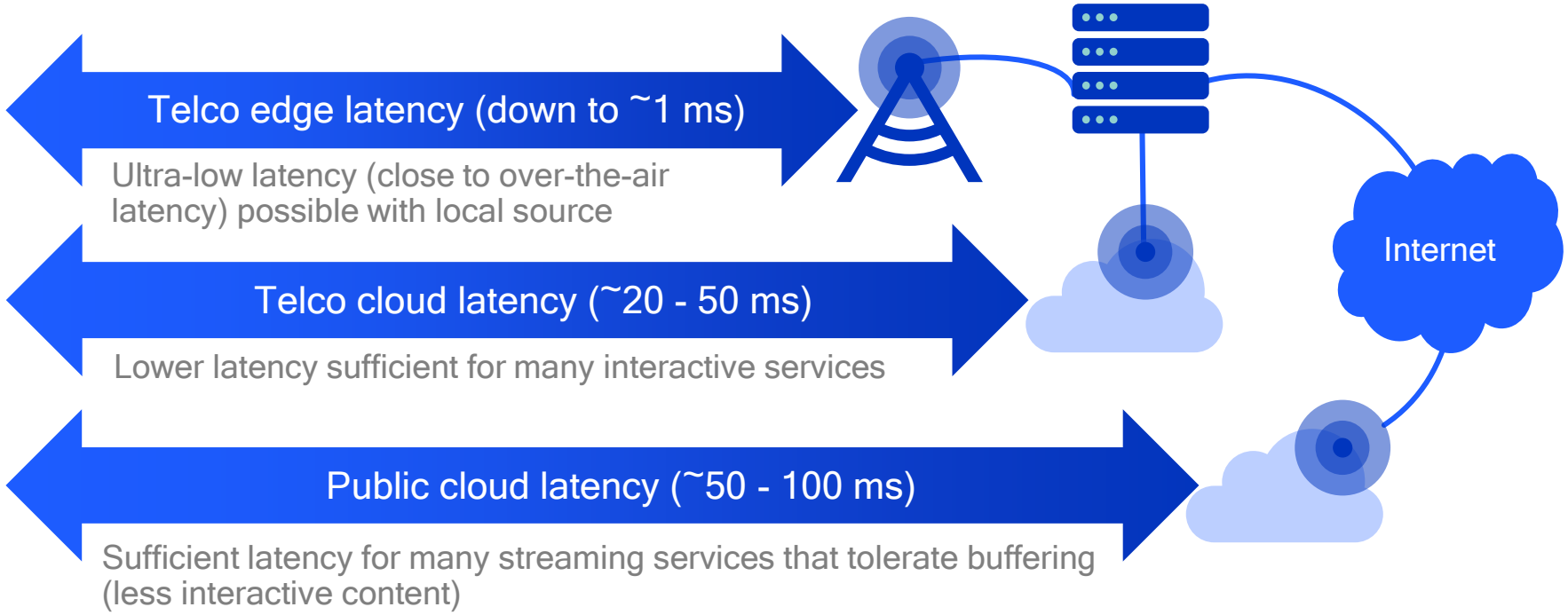
Critical for immersive experiences

Low wireless latency is critical for immersion

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



Motion to Photon (MTP) latency below 15 ms generally avoids discomfort – processed on the device[1]



1 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
*6 DoF: Six degrees of freedom
Remote control / Tactile Internet
Low latency

Automotive video streaming

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 / km²
upload capacity

Assumptions: 1: 50,000 fans are simultaneously streaming in a 0.1 km² 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/km² downlink area density (example for uplink)

6 DoF* content

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

Reduced latency for better interactivity and expanded use cases

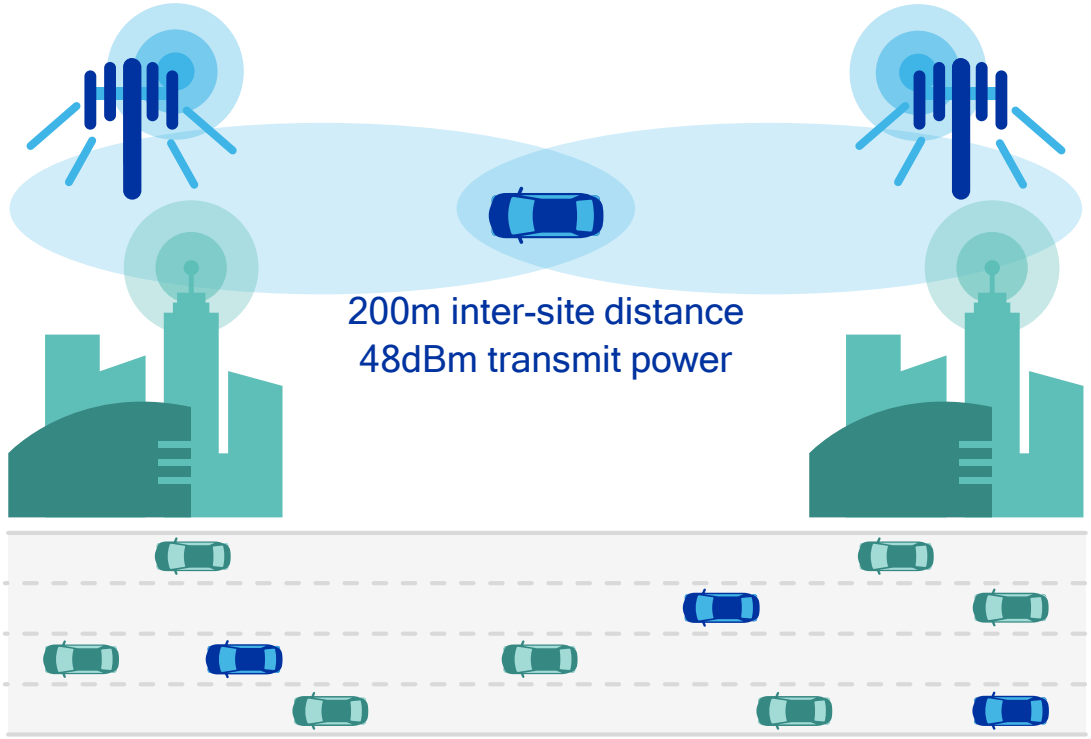
End-to-end latency requirements

- 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

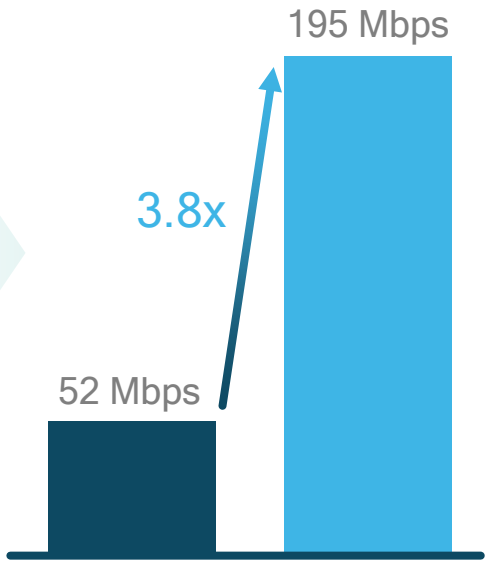
5G NR massive MIMO brings a more uniform experience

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

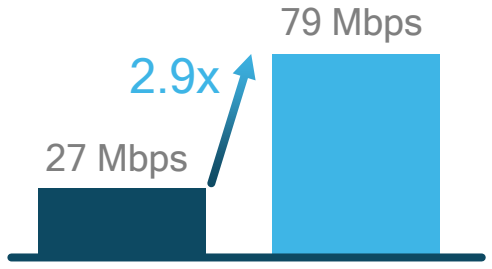
Exploit 3D beamforming with
up to 256 antenna elements



Median user
perceived throughput



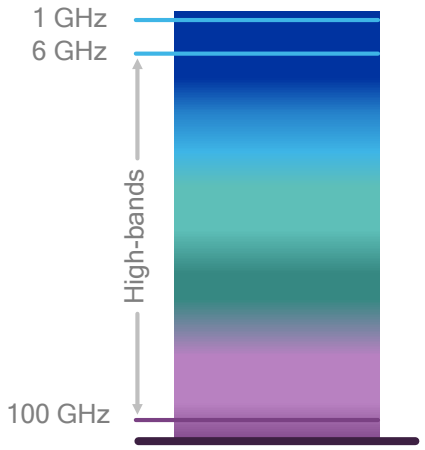
Cell edge user
perceived throughput



Assumptions: carrier frequency 4GHz; total bandwidth: 200MHz; base station: 256 antenna elements (x-pol), 48dBm Tx power over 200MHz; UE: 4 Tx/Rx antenna elements, 23dBm max. Tx power; full buffer traffic model, 80% indoor and 20% outdoor UEs

5G NR mmWave is capable of delivering massive capacity

Exploiting higher bands and more flexible use of available bandwidth

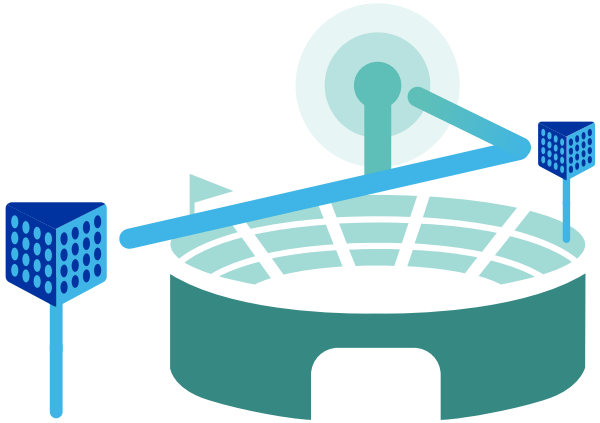


Large bandwidth

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



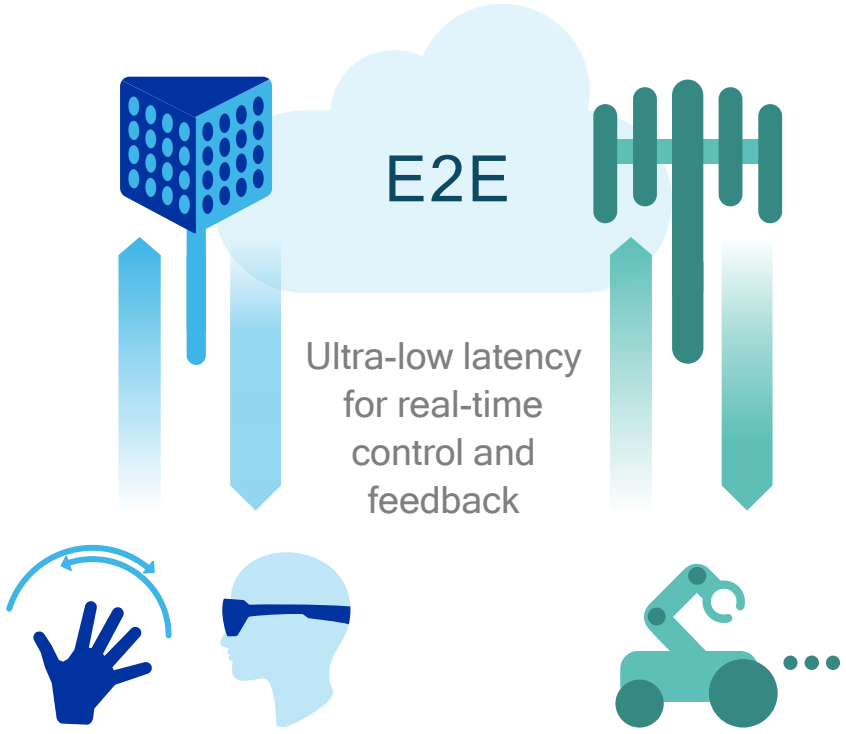
Small cell densification

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

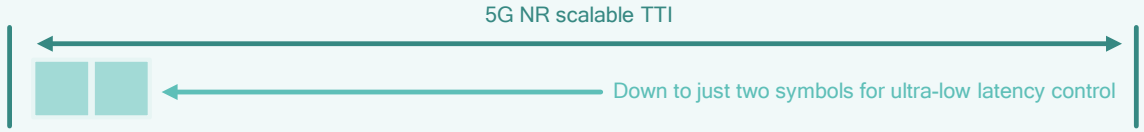
5G NR scalable over-the-air latency down to 1 ms

Enhancing VR / AR user experience and enabling new use cases



Low latency beneficial for 6 DoF to reduce amount of data

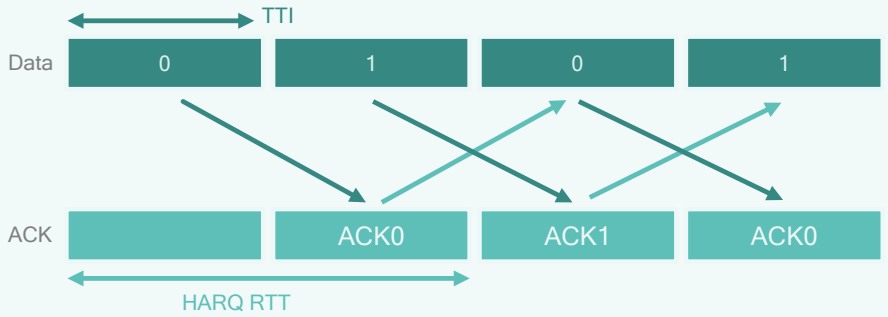
Shorter transmission time interval (TTI)



Reduced round-trip time (RTT)

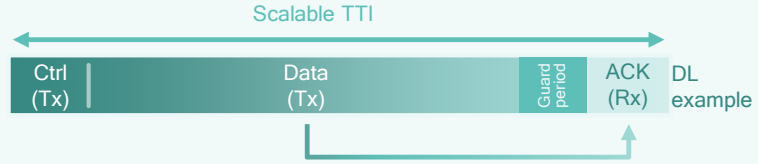
FDD

Fewer HARQ[1] interlaces



TDD

Self-contained subframe design



Data and acknowledgement in the same subframe[2]

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

Making 5G a reality in 2019

Industry-leading R&D

5G interoperable global standards

End-to end system prototypes and test beds

Commercial chipsets: Qualcomm® Snapdragon™ X50 5G modem

Commercial networks and products

Qualcomm

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