

October 2018

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Qualcomm

VR and AR pushing connectivity limits

Qualcomm Technologies, Inc.



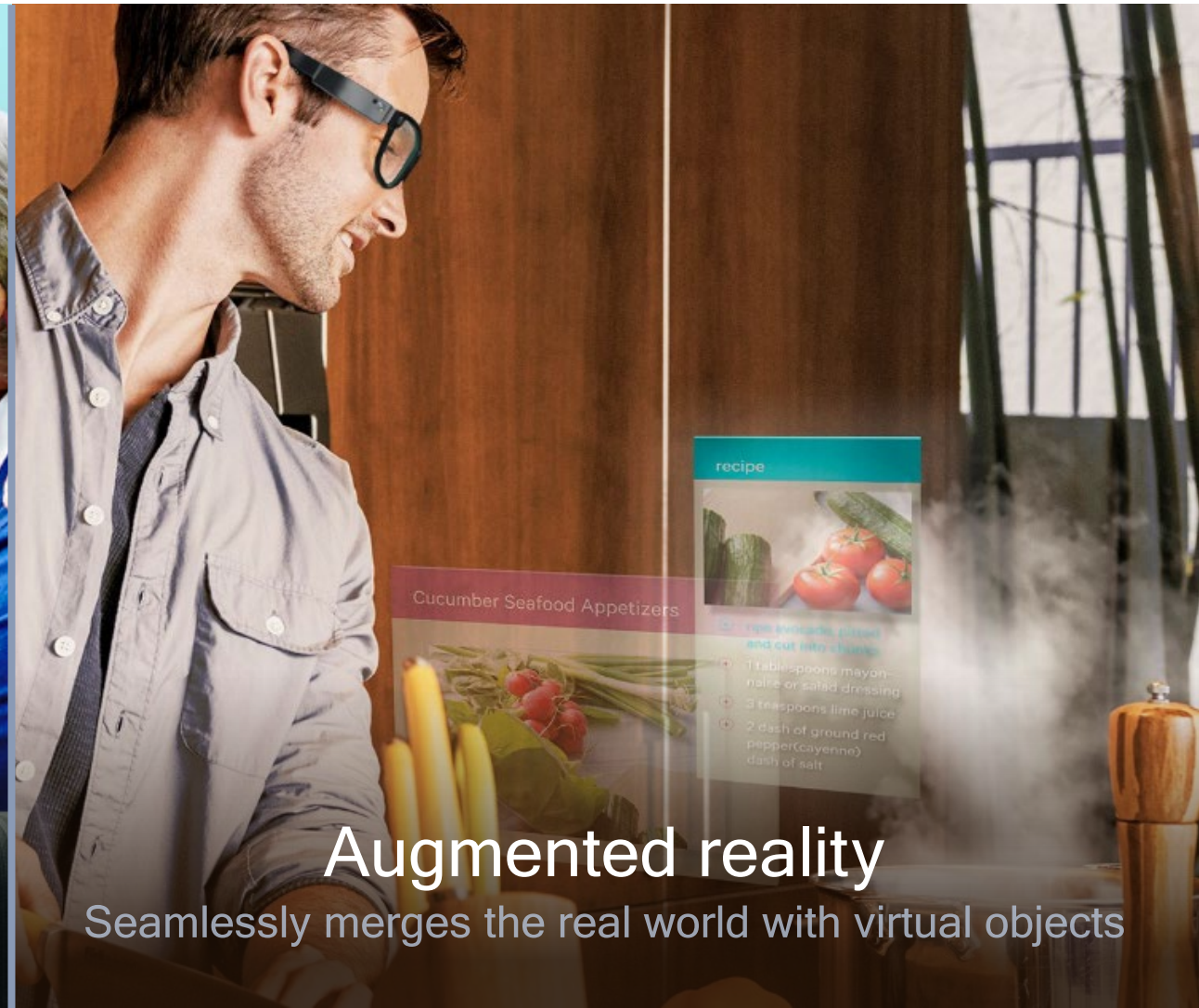
AR and VR are revolutionary interfaces

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



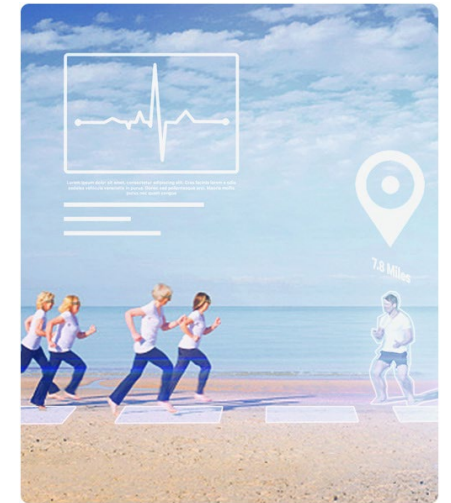
Families virtually brought together with life-like communication

Professionals Working



Architects collaborating on a shared design to improve efficiency

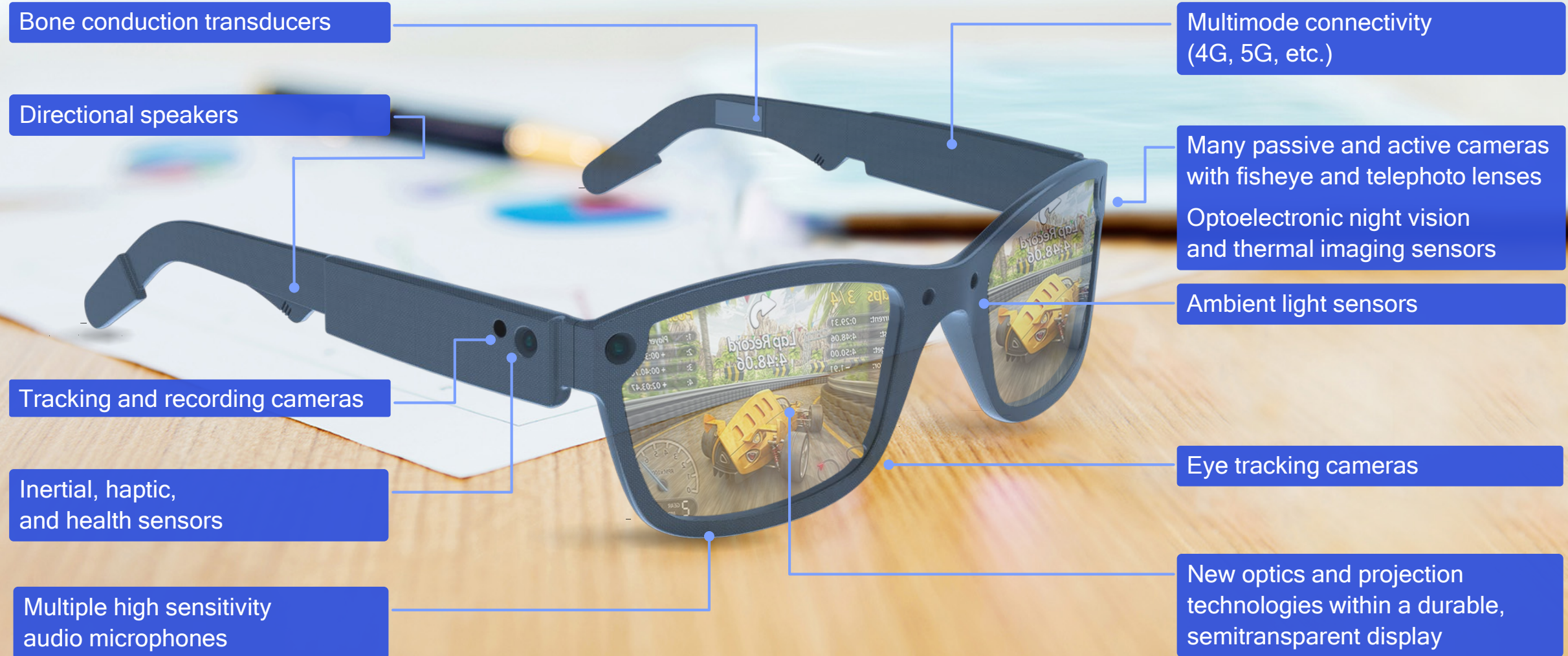
Fitness Enthusiasts Thriving



Group running with a virtual trainer to motivate them

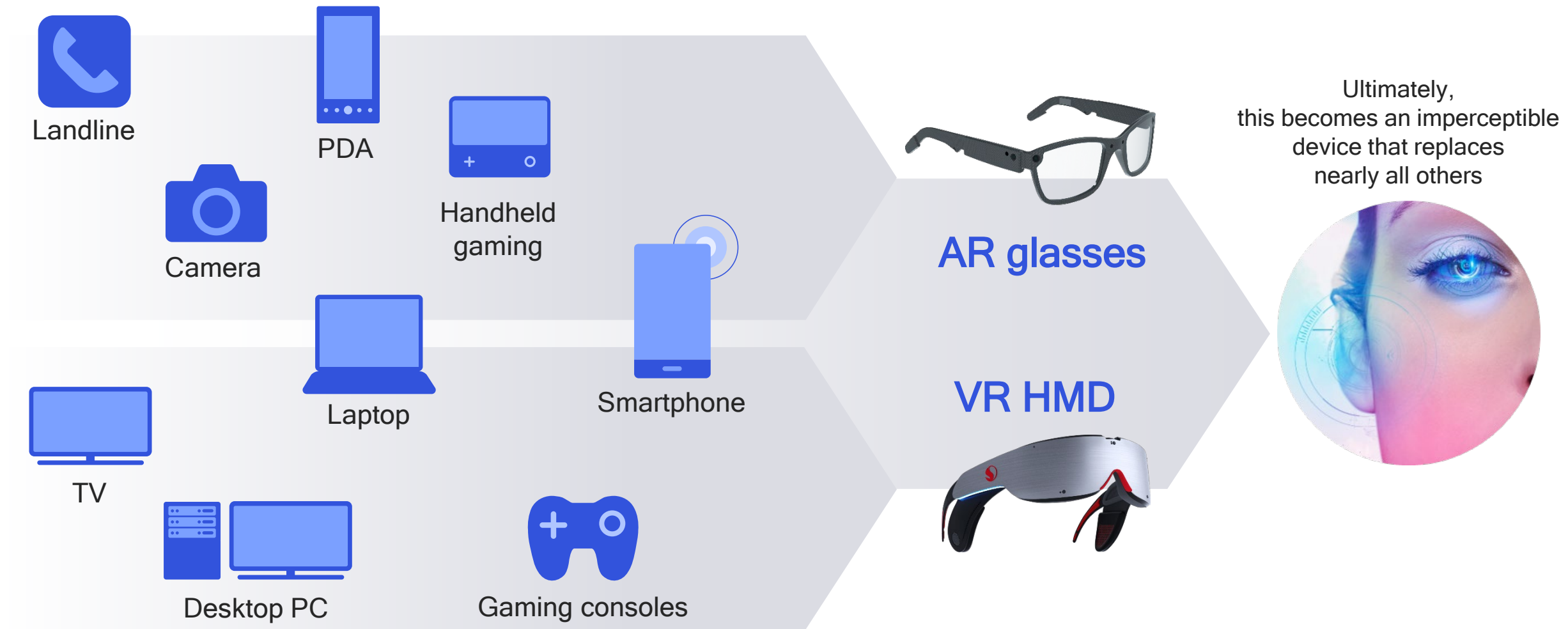
A glimpse into the future – sleek and stylish XR glasses

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



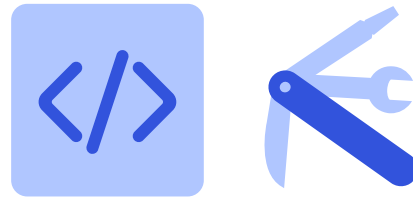
We are accelerating the adoption of VR and AR

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

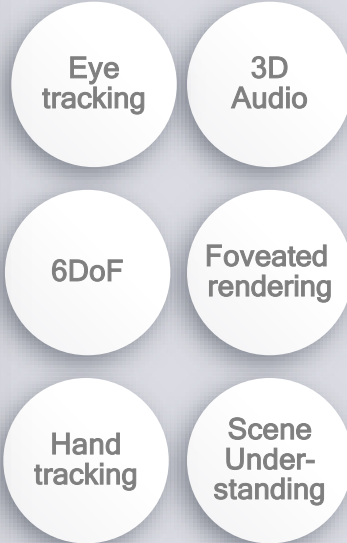
Platform



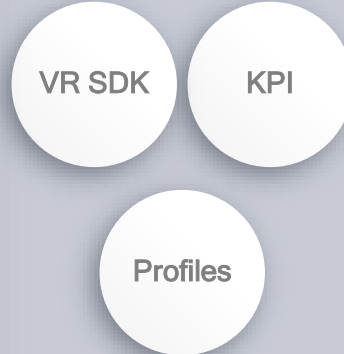
Software



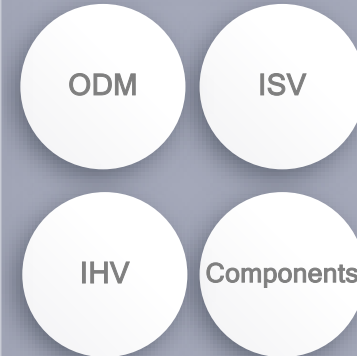
Advanced Algorithms



Ref Design, SDKs & Tools



HMD Accelerator Program (HAP)



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*



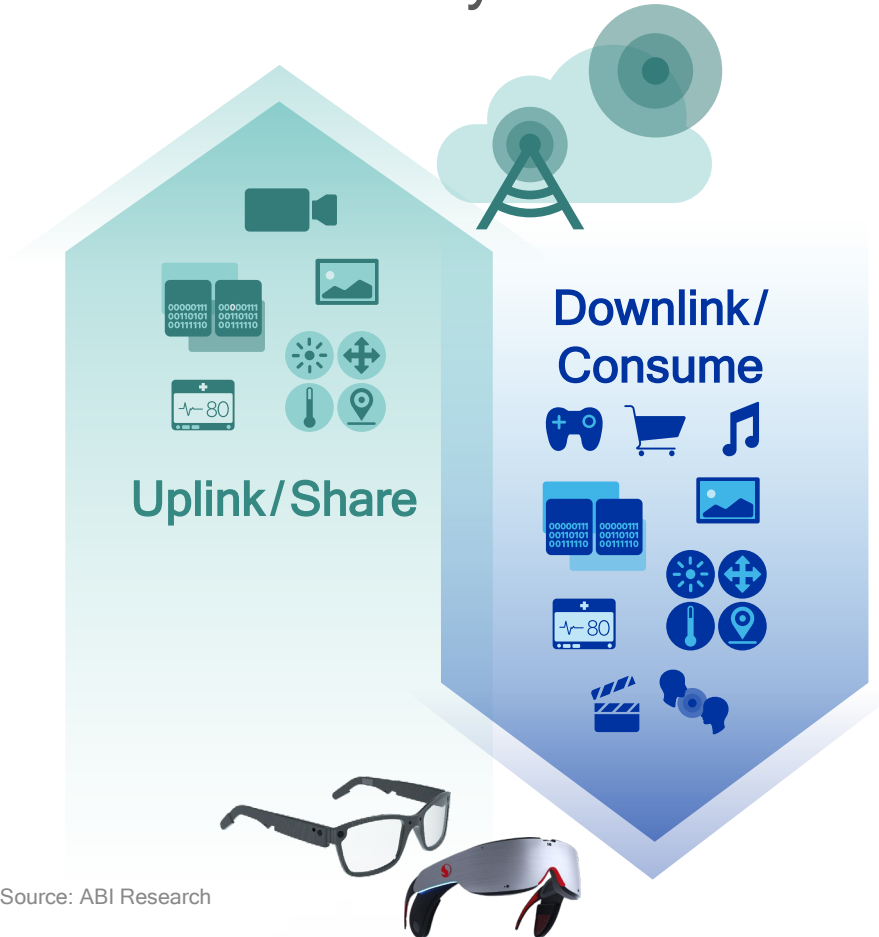
Uniform experience

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)

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

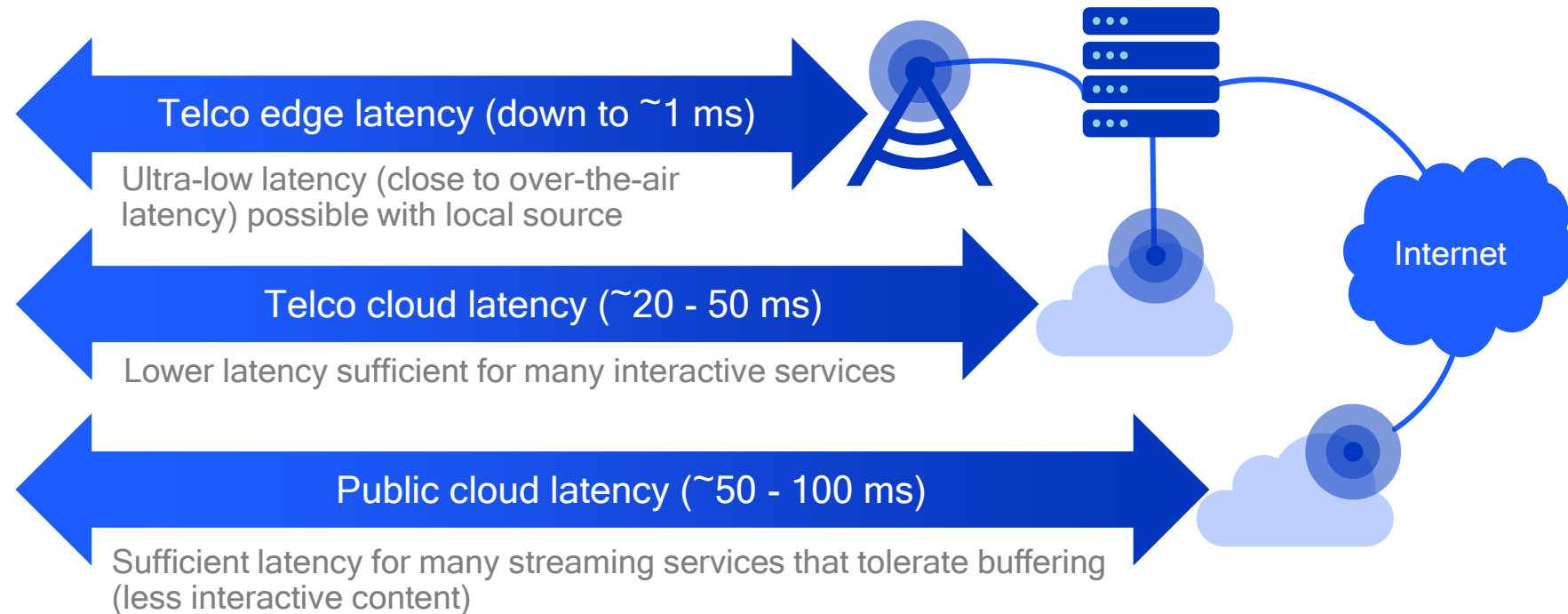
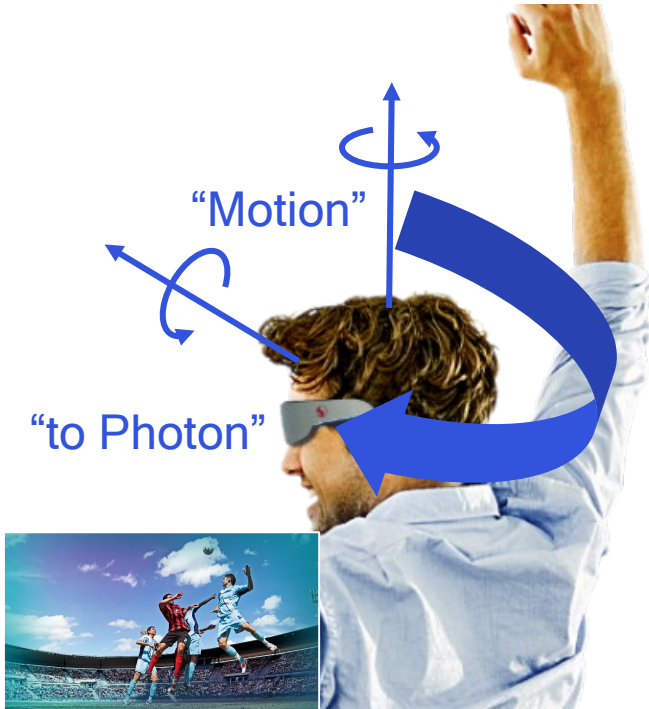
6 DoF video or free-viewpoint

Bandwidth

Critical for immersive experiences¹⁰

Low wireless latency is critical for immersion

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

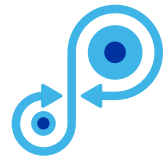


Motion to Photon (MTP) latency below 15 ms generally avoids discomfort – processed on the device¹

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

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 / 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

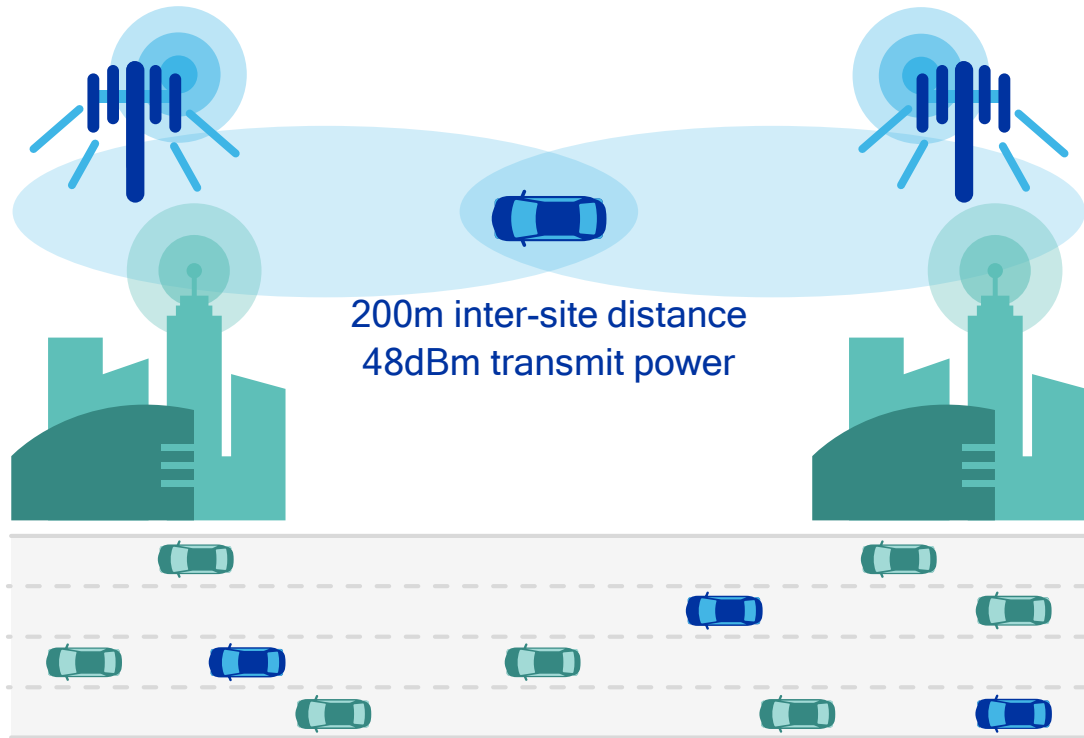
- Interactive remote experiences often ranging from 40 ms to 300 ms (includes transport latency)
- Feedback below 5 ms will enable novel uses of multi-sensory remote tactile control



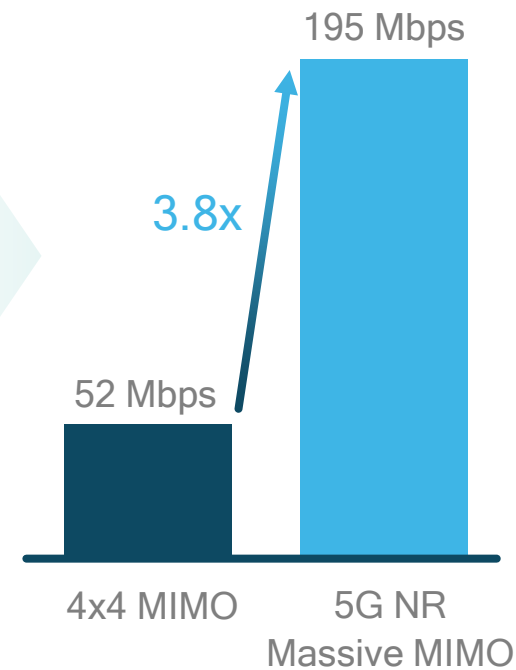
5G NR massive MIMO brings a more uniform experience

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

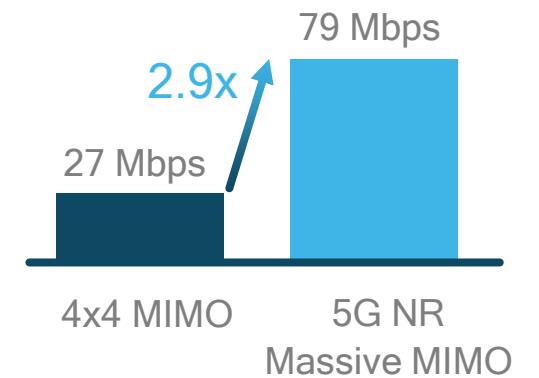
Exploit 3D beamforming with up to 256 antenna elements



Median user perceived throughput

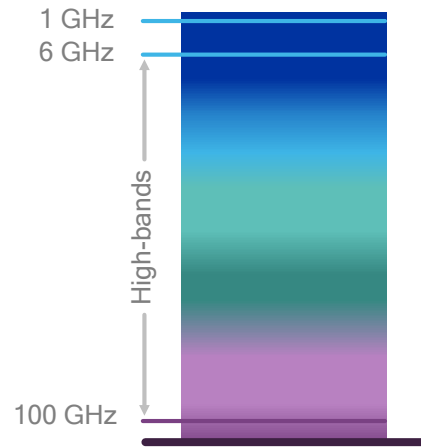


Cell edge user perceived throughput



5G NR mmWave is capable of delivering massive capacity

Exploiting higher bands and more flexible use of available bandwidth



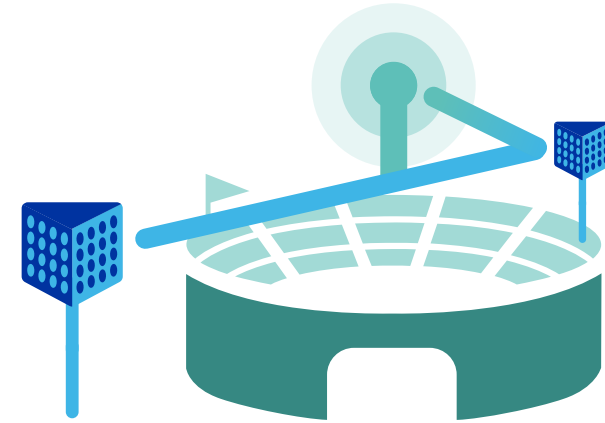
Large bandwidth

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



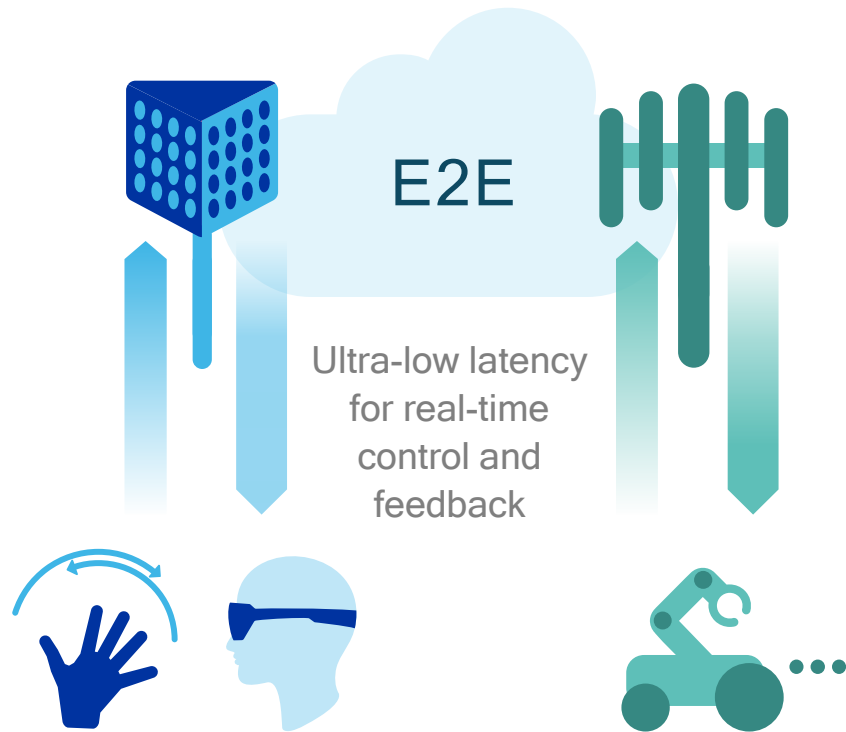
Small cell densification

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

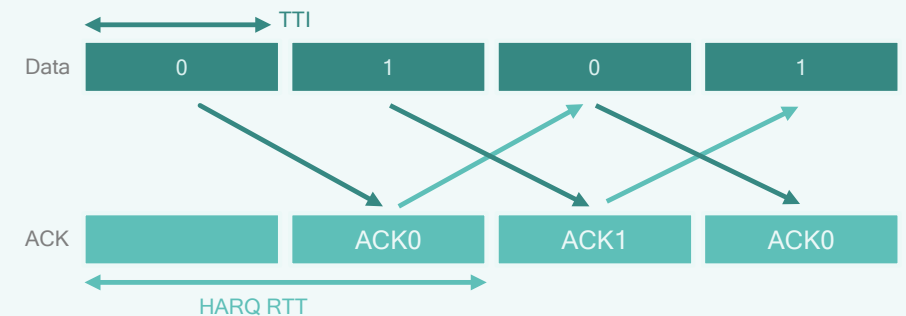
Shorter transmission time interval (TTI)



Reduced round-trip time (RTT)

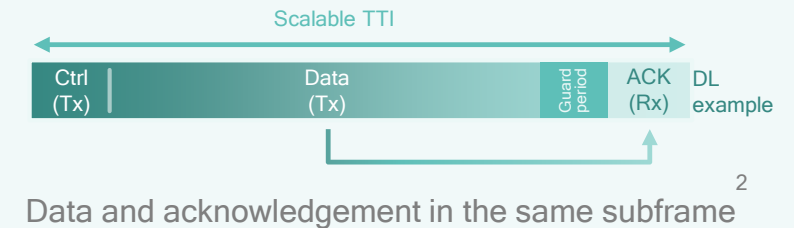
FDD

Fewer HARQ¹ interlaces



TDD

Self-contained subframe design



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



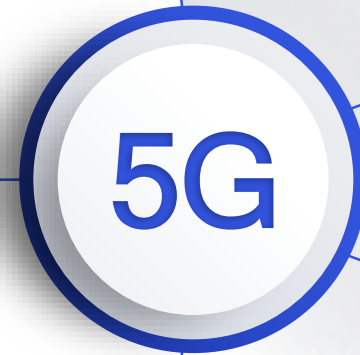
End-to end
system
prototypes
and test beds



Commercial
chipsets:
Qualcomm®
Snapdragon™
X50 5G modem



Commercial
networks
and products





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