



3GPP and VRIF WORKSHOP ON VR ECOSYSTEM & STANDARDS VR Device/hardware Ecosystem

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Introduction

Objective

- What is the state of the art for VR capabilities?
- What are the device requirements for the optimal user experience?
- What is expected to hit the market over the next few years?
- What does the device architecture look like?
- Where do you see needs for standards?



Team's involvement in AR/VR

Working on AR/VR since 2012: Bringing on-chip latency down from 130 ms to 7 ms

2014: 1st Snapdragon AR Prototype



2015-2017: ODG R7/R8/R9



April 2016: BMW Augmented Vision



2016-2017: Snapdragon VR 820/835



A glimpse into the future – everyday AR glasses

Bone conduction transducers

Directional speakers

Tracking and recording cameras

Inertial, haptic,
and health sensors

Multiple high sensitivity
audio microphones

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

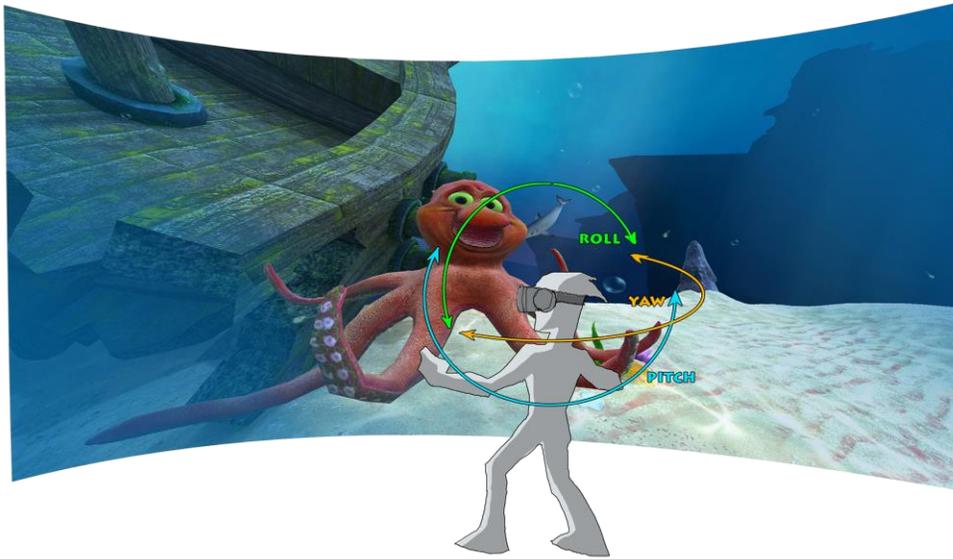
Eye tracking cameras

New optics and projection
technologies within a durable,
semitransparent display



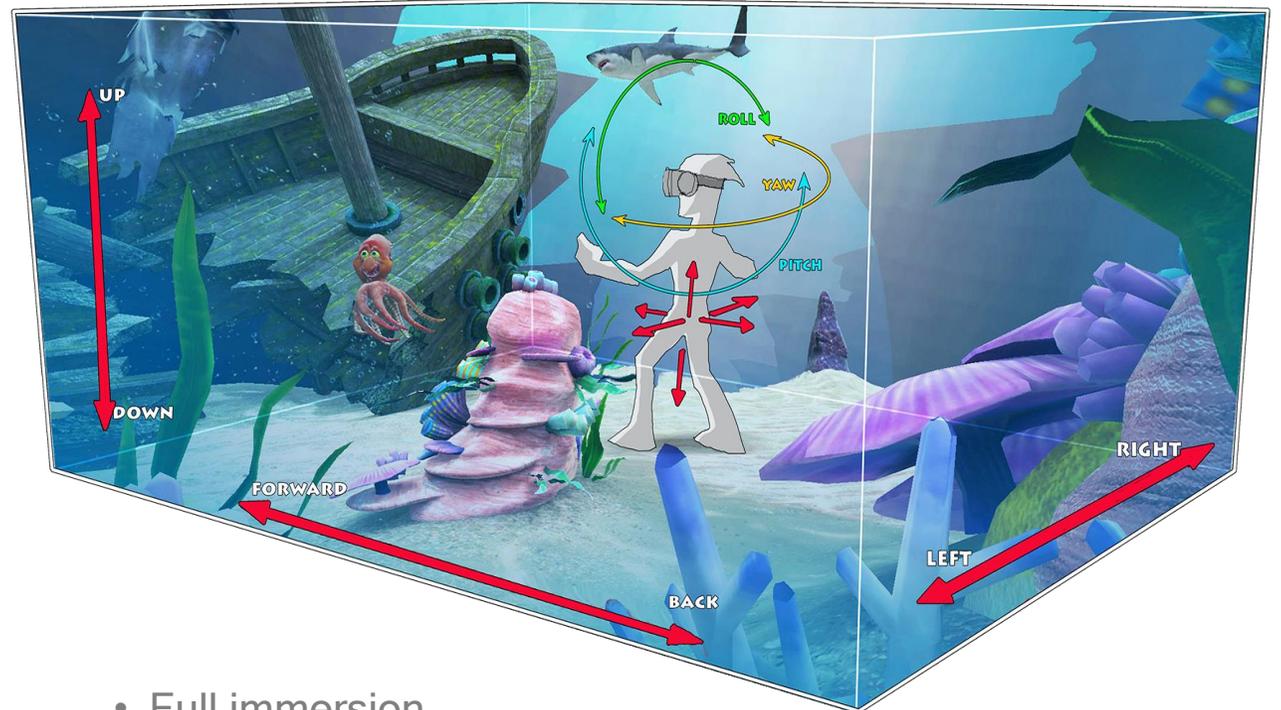
6-DoF allows developers to bring the user into their story

3 degrees of freedom (3-DoF)



- Can only watch

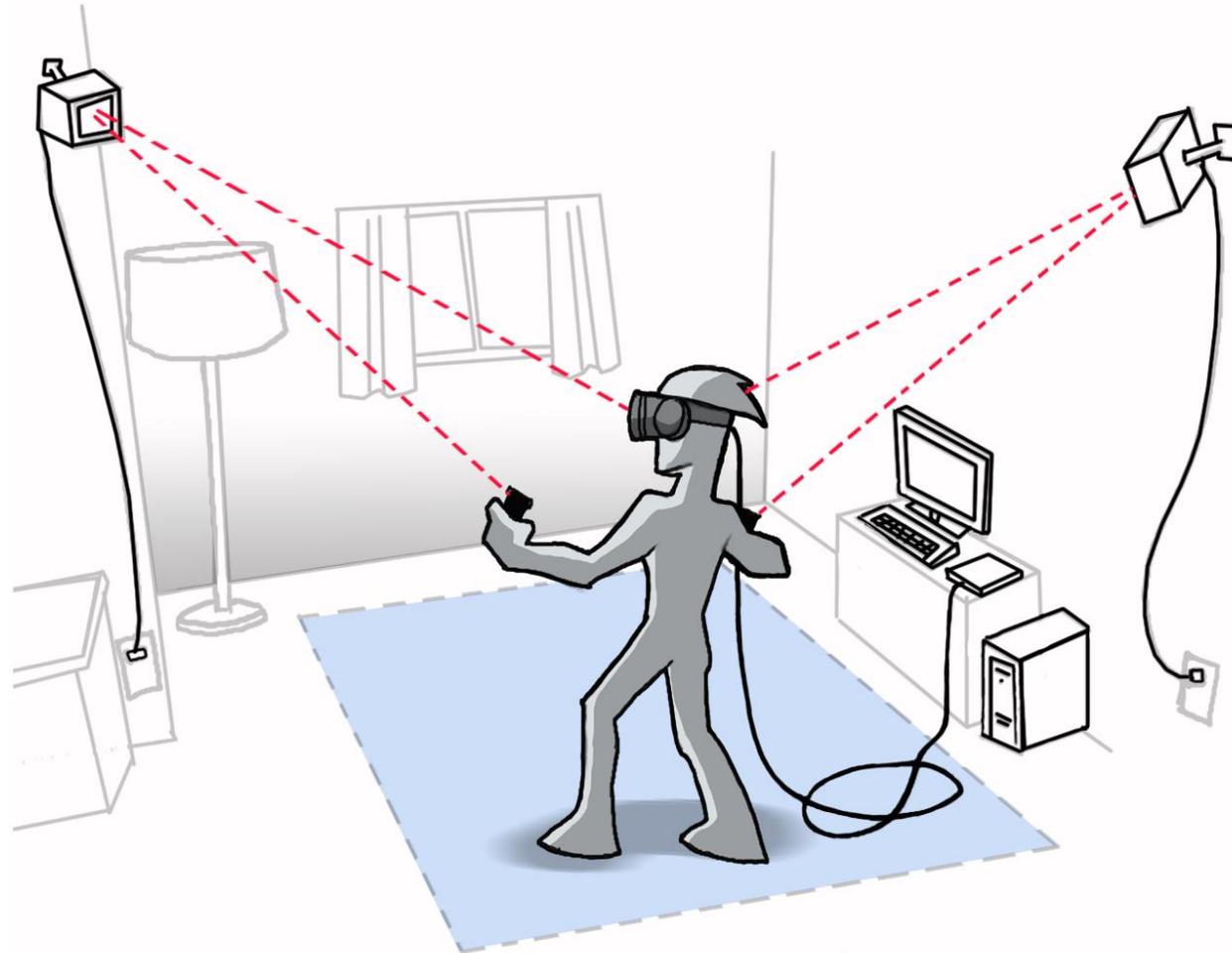
6 degrees of freedom (6-DoF)



- Full immersion
- Can become part of the story
- Can now interact and change the story

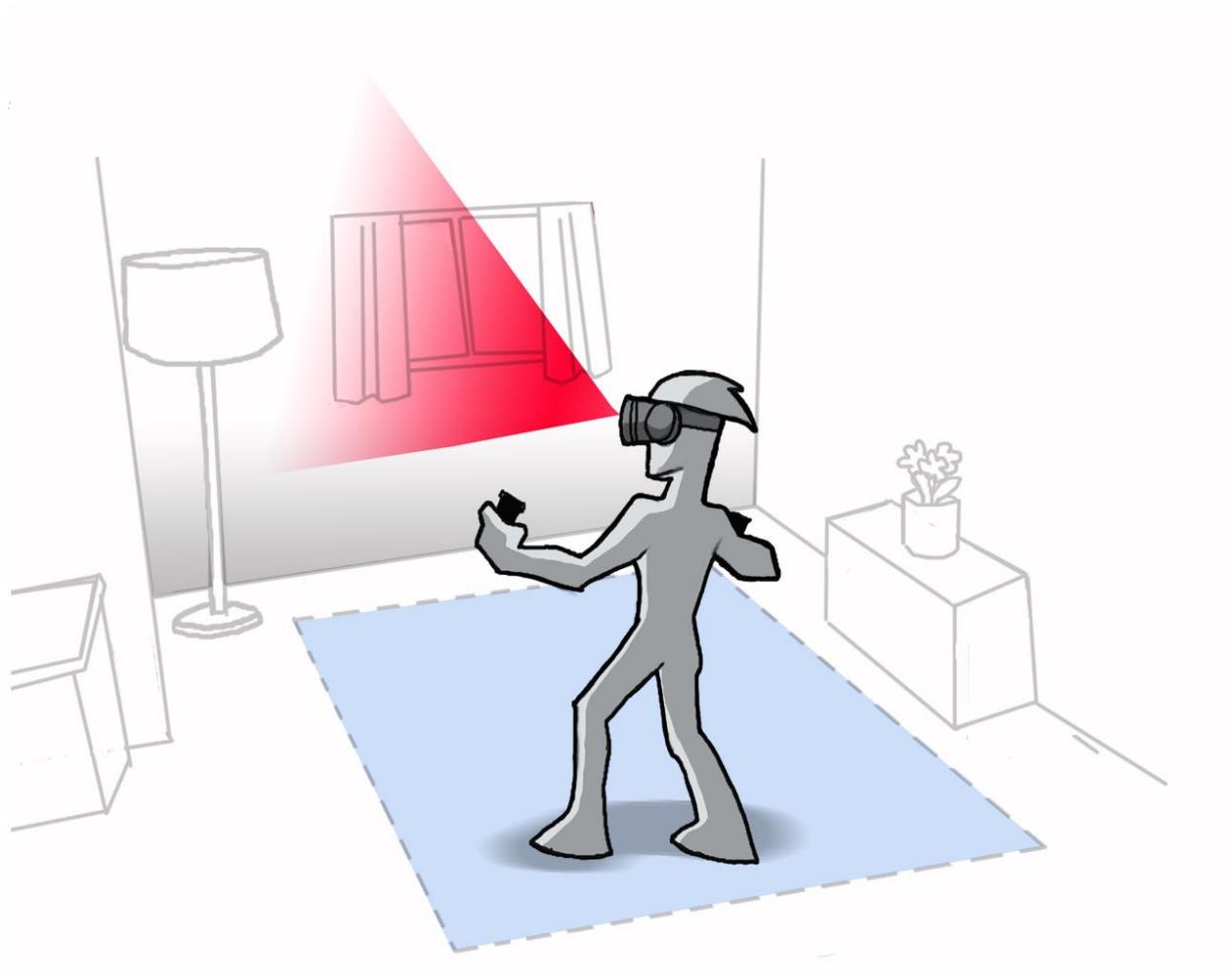
Conventional 6-DoF: “Outside-in” tracking

External sensors determine the user’s position and orientation



Mobile 6-DoF: “Inside-out” tracking

Visual inertial odometry (VIO) for rapid and accurate 6-DoF pose



Mobile 6-DoF: “Inside-out” tracking

Visual inertial odometry (VIO) for rapid and accurate 6-DoF pose



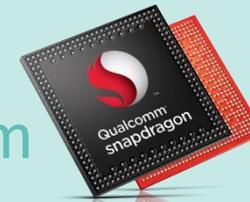
Mono or stereo camera data

Captured from tracking camera image sensor at ~30 fps

Accelerometer & gyroscope data

Sampled from external sensors at 800 / 1000 Hz

“VIO” subsystem on Qualcomm® Snapdragon™ Mobile Platform



Camera feature processing

Inertial data processing

Qualcomm® Hexagon™ DSP algorithms

- Camera and inertial sensor data fusion
- Continuous localization
- Accurate, high-rate “pose” generation & prediction

6-DoF position & orientation

(aka “6-DoF pose”)



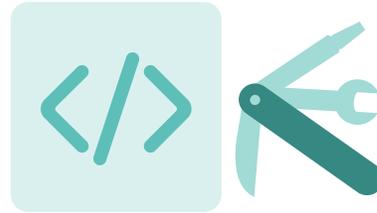
We are accelerating the adoption of VR and AR

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

Device Architecture / Technology Enablers for XR

Optimizations needed across the SoC and system SW

HW streaming interfaces

- Bypass DRAM with engine to engine communication
 - ISP to DSP
 - Sensors to DSP

Global time stamps

- Maintain synchronization across various processing engines

Accurate motion tracking

- Fast and accurate 6-DOF
- Accurate predictive 6-DOF for a small future window

Late latching

- Using the latest pose
- Asynchronous threads for consistent frame rate

Multiview stereoscopic rendering

- Single pass render of left and right eye

High frame rate

- 90 FPS for reduced frame latency

Foveated rendering

- Reduce pixel generation workload while maintaining high image quality

Direct access to VR features

- Bypass Android latency

Fast connectivity

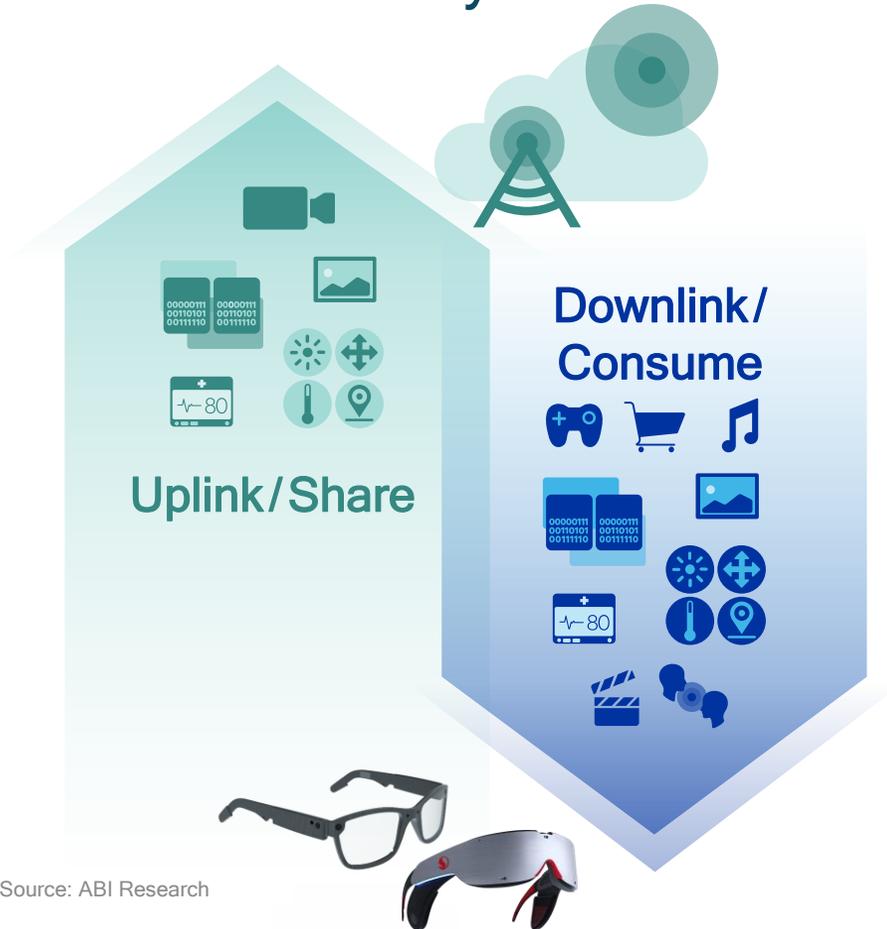
- Low latency connectivity
- High bandwidth

Single buffer

- Low latency connectivity
- High bandwidth

VR and AR require efficient increase in wireless capacity

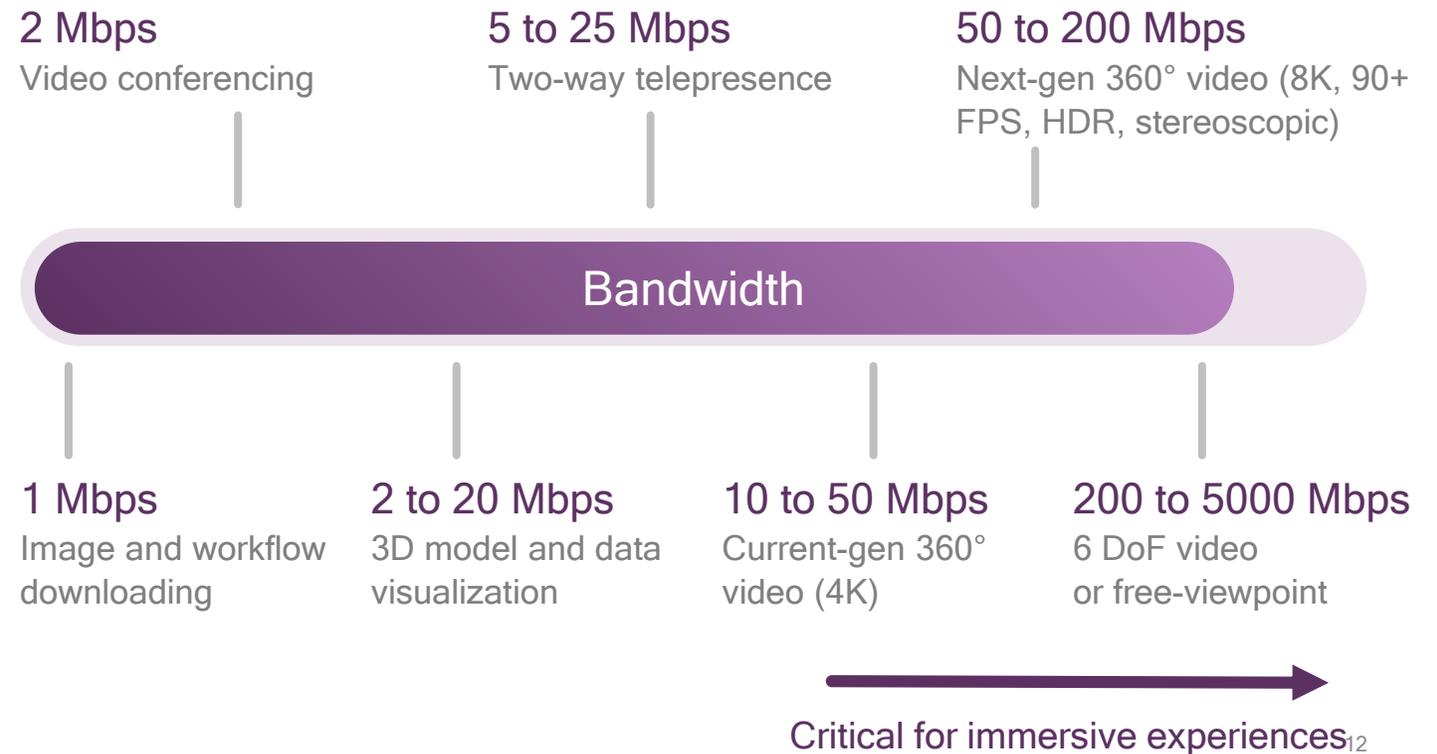
Constant up/download on an all-day wearable



Source: ABI Research

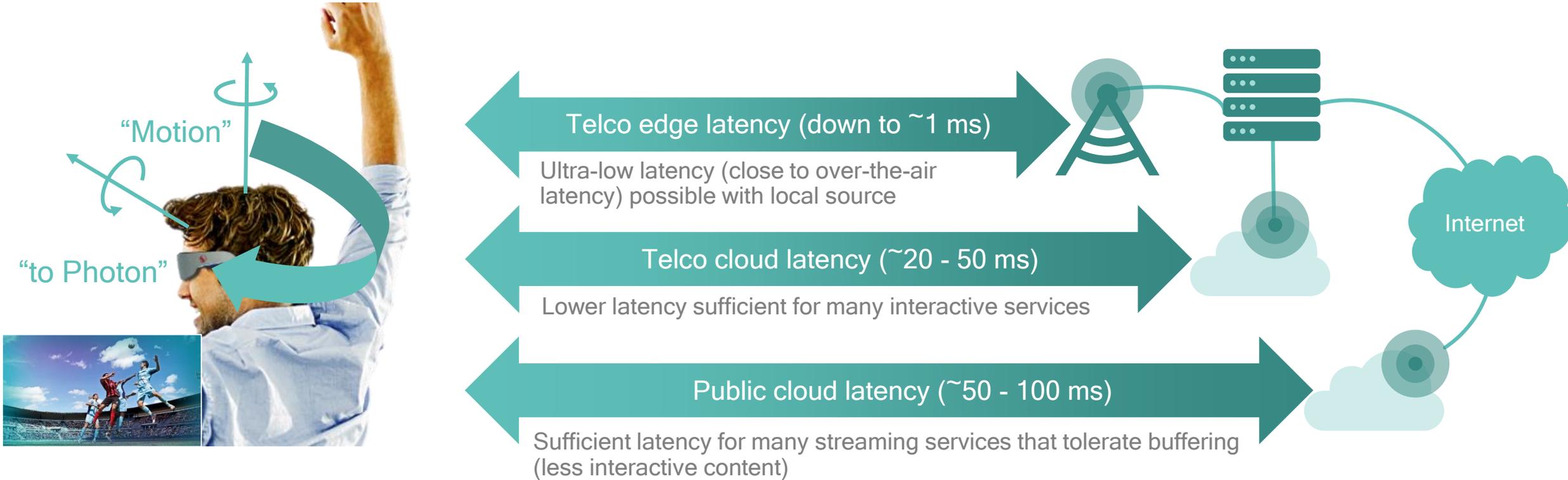
Richer visual content

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



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

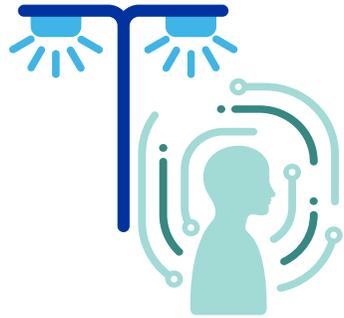
¹ Specific use cases, e.g. local edge content, may allow some processing to be intelligently split over the air-interface

Solving the key XR technology challenges ahead



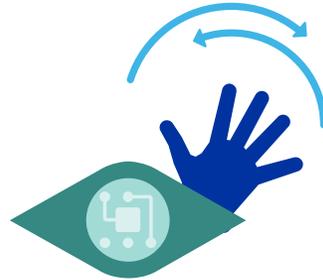
Display

Displaying richer visual content, and switching seamlessly between fully and partially virtual worlds



Common illumination

Making virtual objects in augmented worlds indistinguishable from real objects within the same view



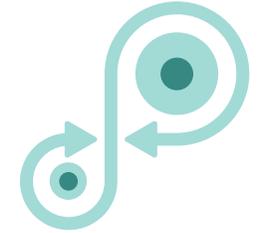
Motion tracking

Intelligent, completely on-device tracking for intuitive head, hands, and eye interactions



Power and thermal

All day battery life, years of recharging, and compatible with sleek, thin, light passively cooled devices with no fans



Connectivity

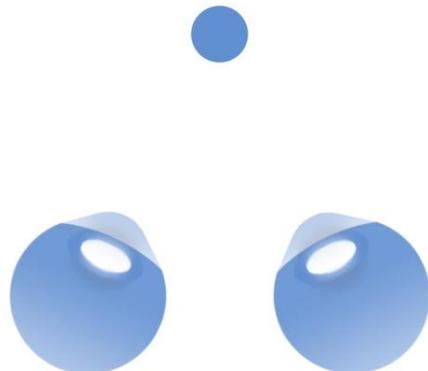
The next level of ubiquitous, wireless connectivity for anywhere usage at fiber-optic speeds

XR human factors challenges for displays

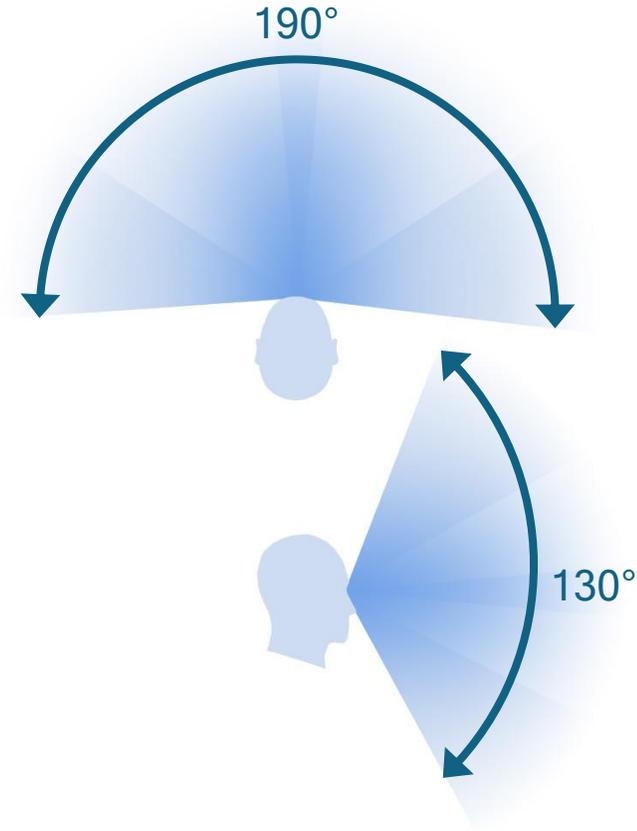
Vergence and accommodation conflict and human field of view (FoV)



Vergence & accommodation



Field of view (binocular) in XR glasses



Future XR needs a disruption in display technology

First step towards high volume converged XR form factor are new displays



- Solve the vergence accommodation conflict
- Deliver necessary FoV both for immersive VR and useful AR
- Be completely opaque for VR, yet at least $\sim 85\%$ transparent for AR
- Support an angular resolution of at least 0.5 - 1.0 arc minutes per pixel
- Drive HDR, at least Rec. 2020 gamut, with $\sim 5X$ improvement in nits
- Be capable of refreshing at a minimum of $\sim 120\text{Hz}$ (per eye)
- Be light, mechanically flexible, very durable, and eventually cost under $\sim \$100$ at very high volumes



Where we are today

Virtual objects look fake

- In part due to mostly static lighting that's often incorrect for the environment
- Even when dynamic, the graphics shader's lights don't consistently match real world light sources or intensity
- Consequently objects and materials look physically incorrect for the scene
- It is always immediately obvious which objects are real and which are virtual



Where we must eventually be

Virtual objects must look real

- With sampled light from cameras or ALS used to determine final color of every pixel in the virtual object
- Virtual lights should be very frequently updated with real world lights to be perceptually correct for real environment

Making it possible

- New, more intelligent, faster interaction between many different sensors and rendering systems
- New computer vision and global illumination algorithms that use real world lights to dynamically render and overlay more realistic virtual objects



Improvements needed in motion tracking

Taking immersive mobile XR experiences to the next level will require:

- Improved head/body tracking
 - User friendly, inside-out 6 DoF head tracking
 - Power efficient, sub-10ms motion to photon latency with sub-millimeter drift
 - Functional at world scale with capability to appropriately alert for collision avoidance
- Improved eye tracking
 - Automatic IPD calibration
 - Tracking accuracy for foveation/depth of field rendering and viewport aware video
 - Also for more natural intent-based interaction and interfaces



Other improvements needed in motion tracking

Intuitively interacting in virtual worlds

- Controllers, when required, must be 6 DoF, responsive and low cost
- However, for most use cases, the best controller is no controller

Making it possible

- New, better 3DR so that virtual hands in VR mode look just like your own
- CV, machine learning, and graphics convergence so they *work* just like them too



Recap

- What is the state of the art for VR capabilities? What are the device requirements for the optimal user experience?

Latency, Resolution, Frame Rate, Video Decode, Power, Connectivity

- What is expected to hit the market over the next few years?

New Displays, Neural Network Processors, VR Hardware Blocks, Connectivity, Immersive Streams

- What does the device architecture look like?

XR Optimized Hardware Blocks

- Where do you see needs for standards?

Application / Device APIs (Khronos OpenXR)
Immersive Streaming Content (MPEG / OMAF)
Low Latency Networks (3GPP)



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