The Mobile Future of Augmented Reality

Qualcomm Technologies, Inc.
December 2016

Agenda

1. Brief introduction to Augmented Reality
2. Evolution of AR from today to the future
3. New technologies for AR requirements

Augmented reality vs. virtual reality

Similar underlying technologies but distinct experiences

Virtual reality

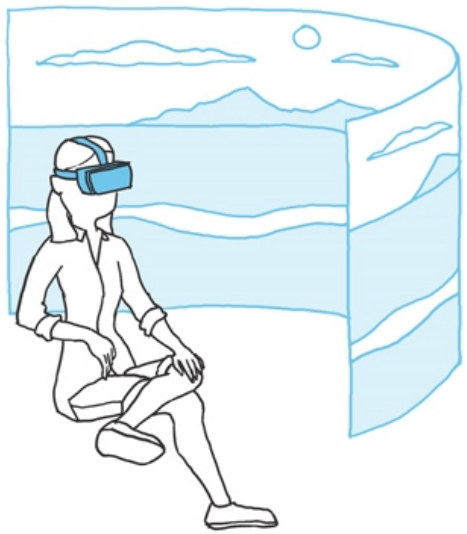
Simulates physical presence in real or imagined worlds, and enables the user to interact in that world

Augmented reality

Superimposes content over the real world such that the content appears to be part of the real-world scene

Evolution of user experience from VR to AR

Today



VR: Mostly 3-DOF, lower resolution videos & games

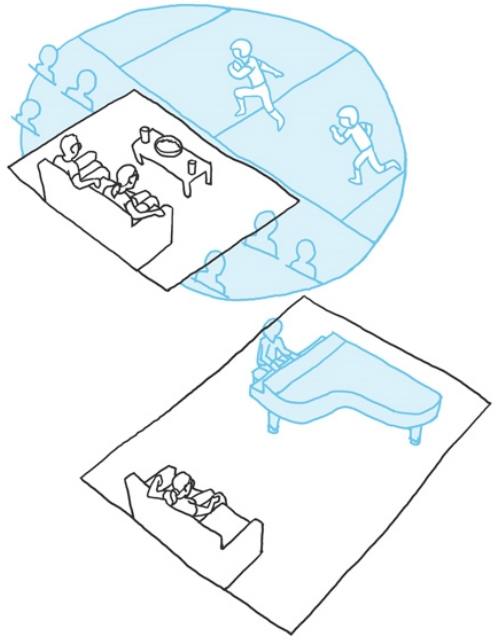
AR: Pokémon Go, Google Translate, Snapchat, and other rudimentary AR apps

Soon

VR: Ability to move around through live events, with better sense of “presence”

AR: Still rudimentary, yet more useful and immersive, streaming AR services, abled to be accessed on the go

The Future



AR: Entire scenes, like entertainment events, can be accessed with your mobile AR device that are so realistic and interactive that they’ll be nearly indistinguishable from reality. VR becomes an occasionally used “mode” within AR

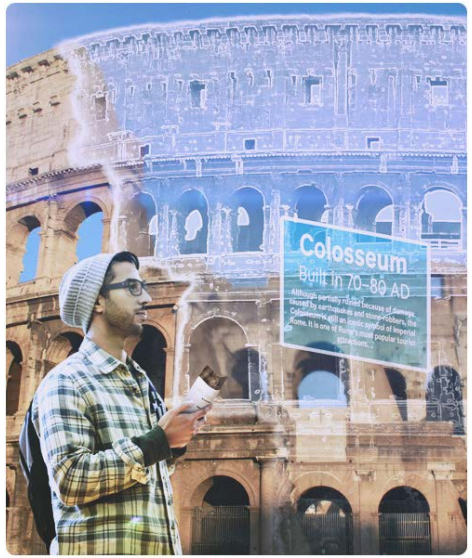
AR will serve a broad spectrum of roles in daily life

Applicable across ages, genders, and activities

Children Playing

Kids chasing virtual characters in more interactive & 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

AR will eventually revolutionize industries and enterprises

Increased productivity, efficiency, and safety

Industrial & manufacturing
- Guided training and remote support
- Improved safety
- Real-time factory diagnostics

Engineering
- 3D visualization and CAD
- Colleague collaboration and communication

Healthcare
- More efficient patient care
- Diagnosis and treatment assistance
- Surgical training and visualization

Retail
- Try before you buy: clothes, furniture, car, real estate shopping, etc.
- Navigation to products and personalized coupons

Education
- Immersive, self-guided, interactive visual learning
- Any subject, from history and physics to vocational

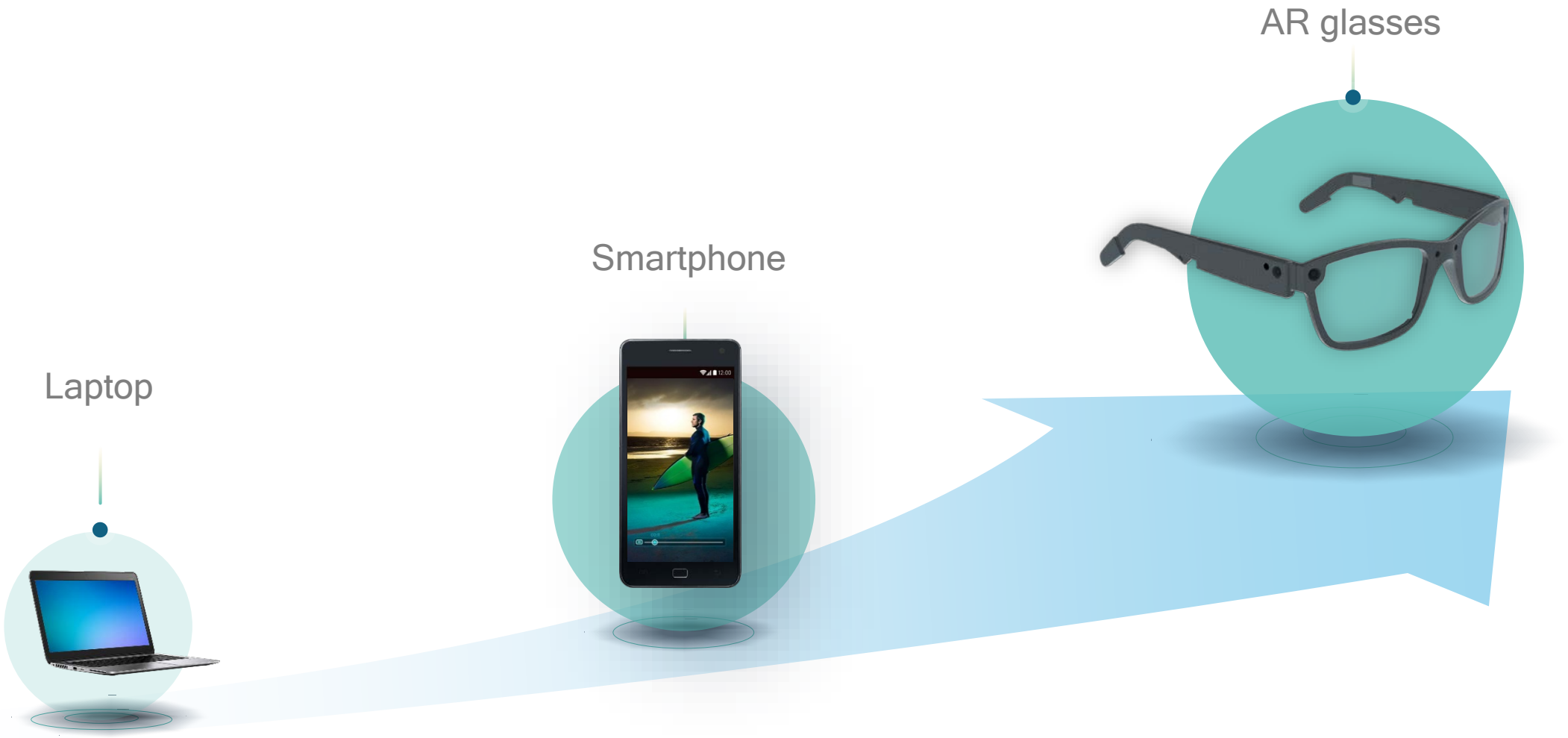
Marketing & advertising
- Personalized ads based on context
- Consumer data – what they like, what they look at, etc.

Military
- Instructional training
- In-the-field assistance

Emergency response
- Police, fire, security response
- Potential improvements in safety, response time, and saving lives.

AR is the next mobile computing platform

Nearly everything we've learned for smartphones will be used for AR



AR technologies & use cases evolve from mobile

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


Landline

PDA


Handheld gaming


Camera


Laptop


Smartphone


TV


Desktop PC


Gaming consoles


AR glasses


VR HMD

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

AR is here today, but it is still in its infancy

Like smartphones, the AR evolution will take years but has the potential to be huge

Technology Phase: Infancy
Market: Mostly early adopter “Prosumers”

Technology Phase: Rapid evolution
Market: Surging consumer adoption

Technology Phase: Maturity
Market: Worldwide, ubiquitous use

AR will follow a similar ~30 year cycle of sleeker designs, with tremendously increasing functionality

AR is here today, but it is still in its infancy

Currently shipping devices that use Qualcomm® Snapdragon™ processors

Today's Smartphones and Phablets

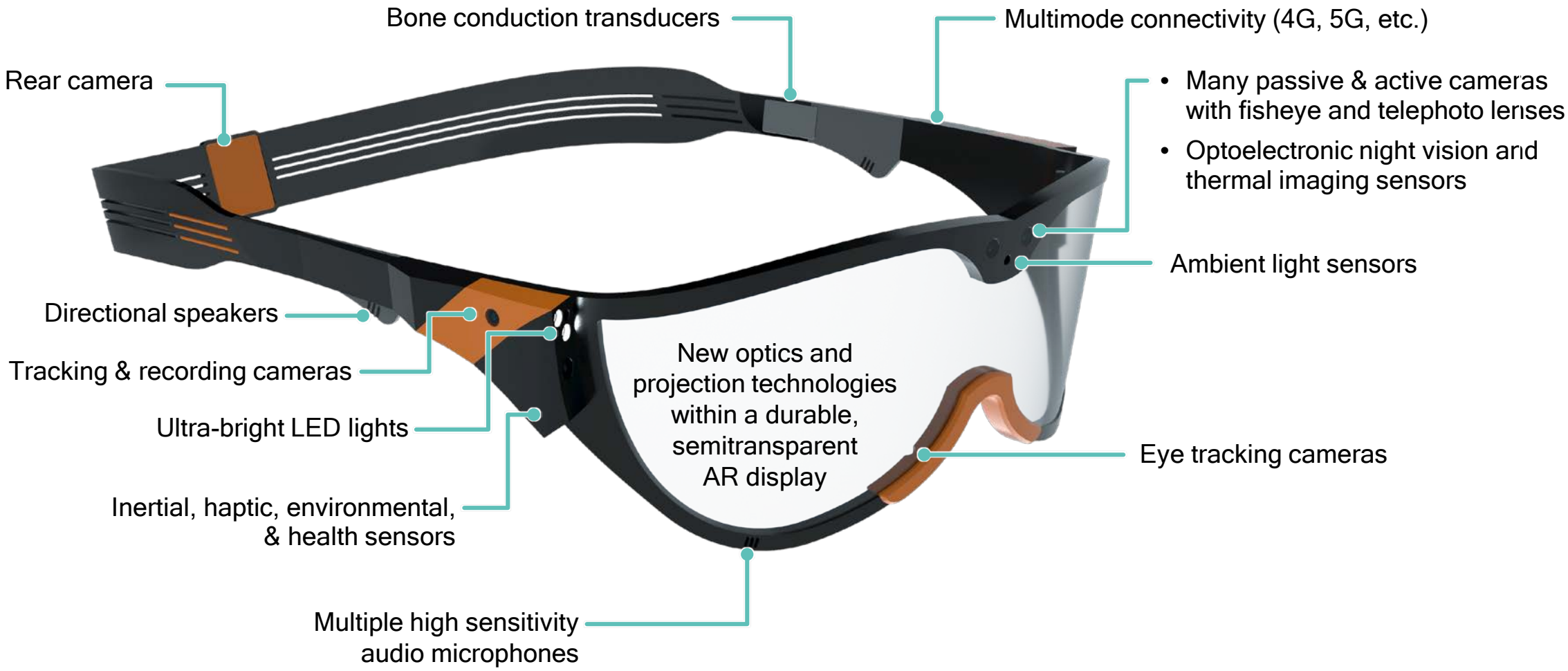
Tango

Glasses

ODG
OSTERHOUT DESIGN GROUP

A glimpse into the future

First responder AR glasses



New technologies for future AR requirements

Providing an always-on experience that intelligently enhances our lives

Immersive

The visuals, sounds, and interactions are so realistic that they are true to life

Cognitive

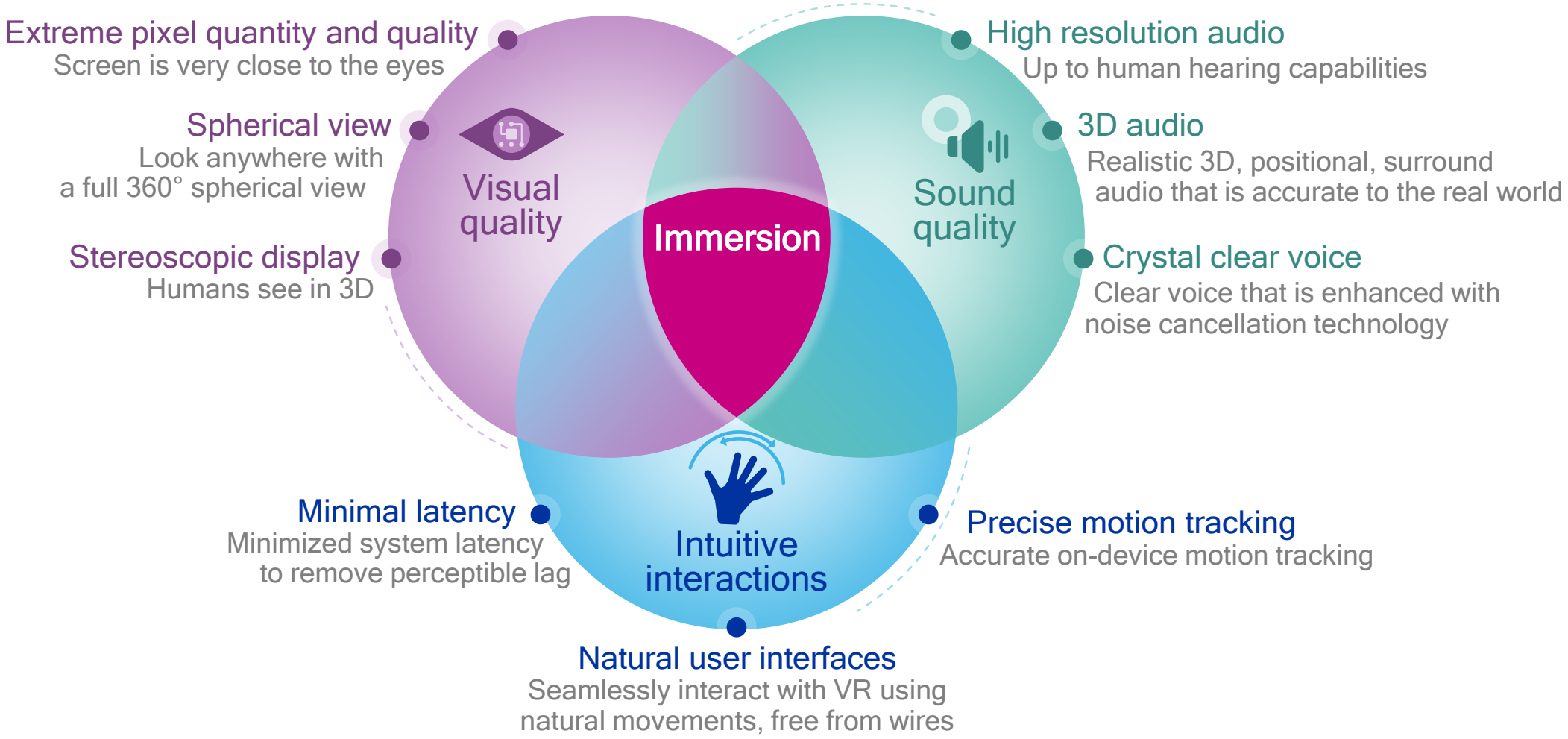
It understands the real world, learns personal preferences, and provides security & privacy

Connected

An always-on, low power wearable with fast wireless cloud connectivity anywhere

AR shares requirements similar to VR for immersion

Achieving realistic AR at low power to enable a comfortable, sleek form factor



Learn more about our vision for the future of VR: www.qualcomm.com/VR

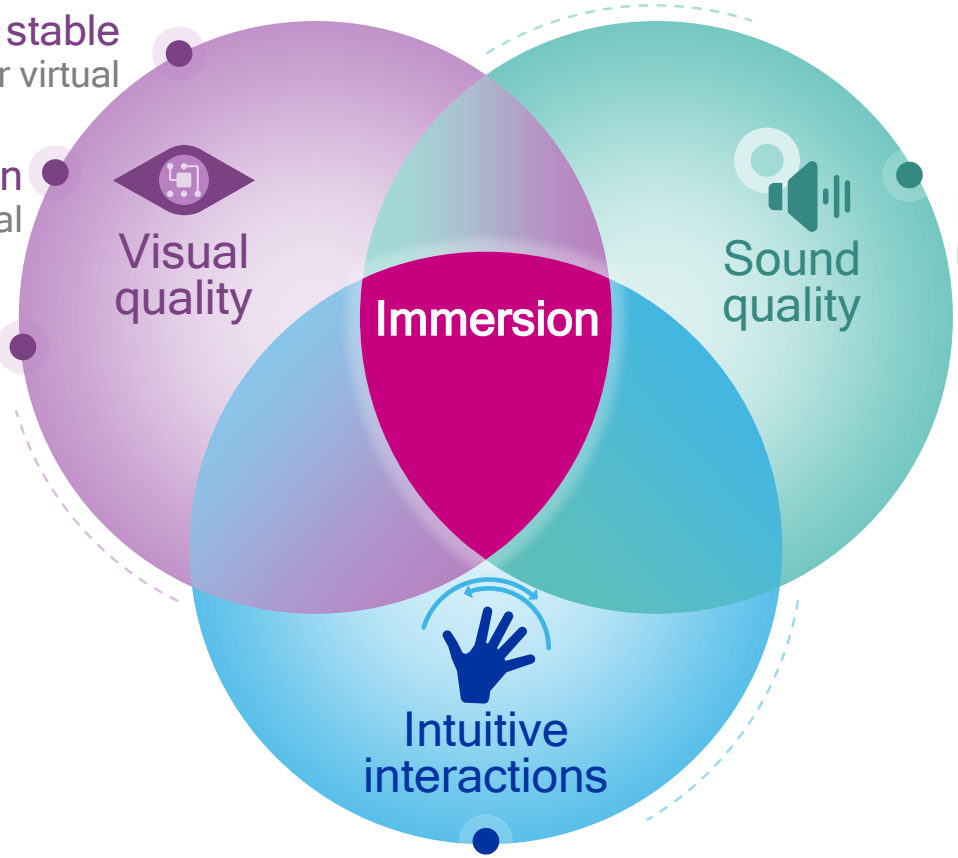
AR introduces additional requirements for immersion

Seamlessly integrating virtual objects with the real world

Keeping the world stable
Seamlessly anchor virtual objects to the real world

Occlusion
Showing and hiding virtual objects appropriately

Common illumination
Lighting virtual objects realistically and dynamically



Realistic virtual sounds
Modifying virtual sounds based on the real world environment

Natural user interfaces
Seamlessly interact with AR using natural movements, free from wires

Keeping the world stable

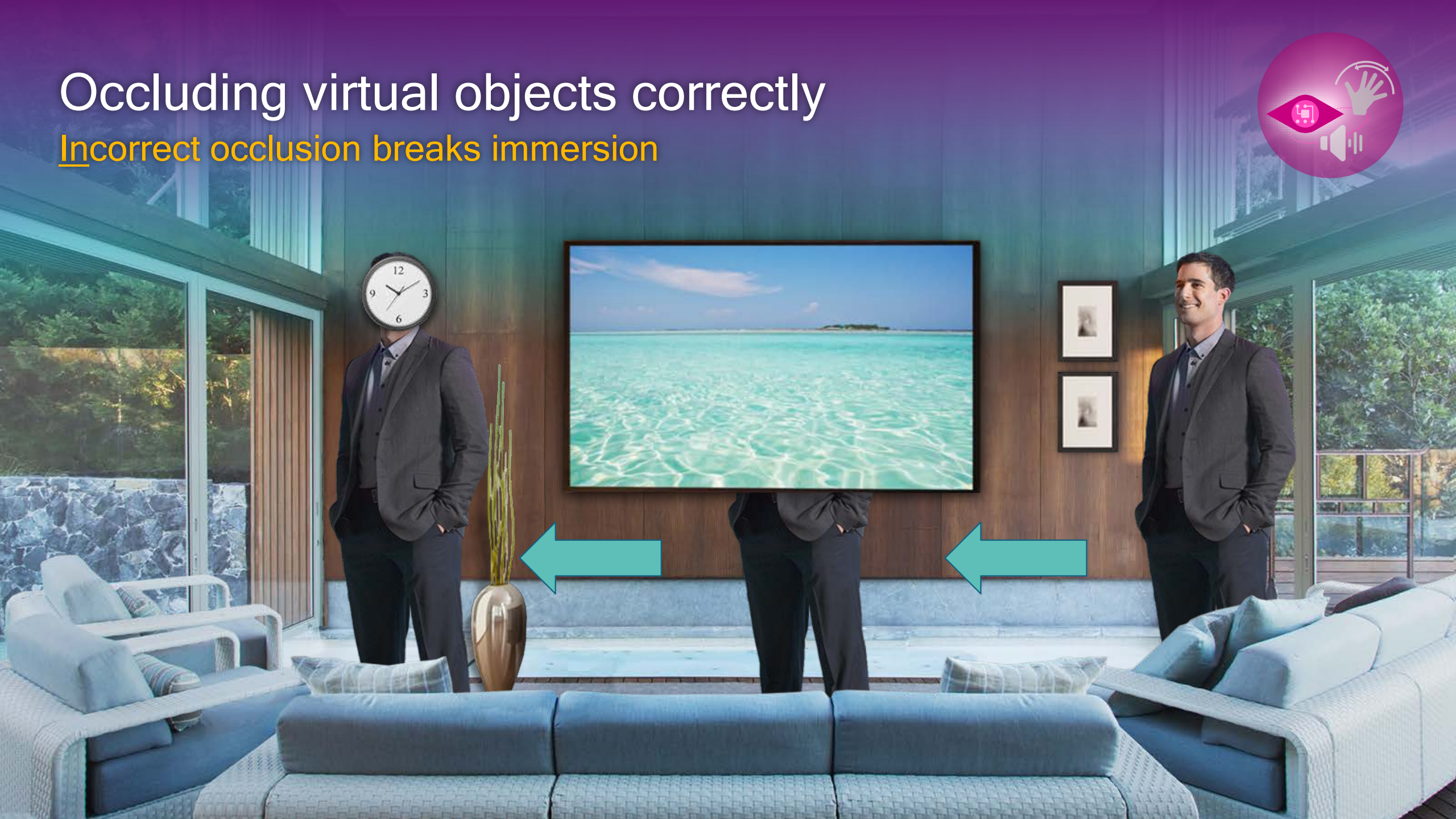
In an unstable environment, virtual objects are NOT seamlessly anchored to the real world

Keeping the world stable

In a stable environment, virtual objects are seamlessly anchored to the real world

Occluding virtual objects correctly

Incorrect occlusion breaks immersion



Occluding virtual objects correctly

Correct occlusion accounts for the depth of virtual and real objects

Occluding virtual objects correctly

Smart occlusion accounts for both object depth and user preferences

Lighting virtual objects realistically and dynamically

Incorrect lighting poorly represents the position, intensity, and orientation of all light sources

Poor environment processing

- Virtual objects look fake and out of place
- Static lighting; often incorrect for environment
- Solid objects do not look solid
- Materials look physically incorrect
- Interactivity is not smooth

Lighting virtual objects realistically and dynamically

Correct lighting considers the position, intensity, and orientation of all light sources

Proper AR environment processing

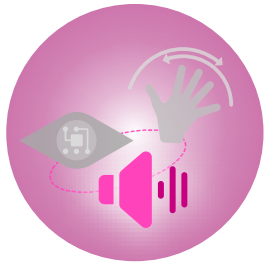
- Virtual objects look real and correctly placed
- Dynamic lighting; correct for the environment
- Solid objects look solid
- Materials look physically correct
- Interactivity is smooth

Making it possible

- Intelligent, fast interaction between many different sensors & rendering systems
- New computer vision and global illumination algorithms to dynamically render and overlay realistic AR objects

Creating virtual sounds based on the real world

Sound reflections spread and interact with the environment appropriately



Airport

- Limited sound reflections
- Significant ambient sound

Hotel room

- Significant sound dampening

Conference room

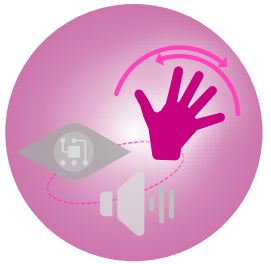
- Enclosed room with reflective surfaces
- Virtual people should sound like they are in the conference room

Required technologies

- Environment modeling
- Noise filtering
- Reverberation
- Positional audio

Interacting naturally with AR

Interactions will become more intuitive & adaptive to personal preferences



Motion & gesture recognition

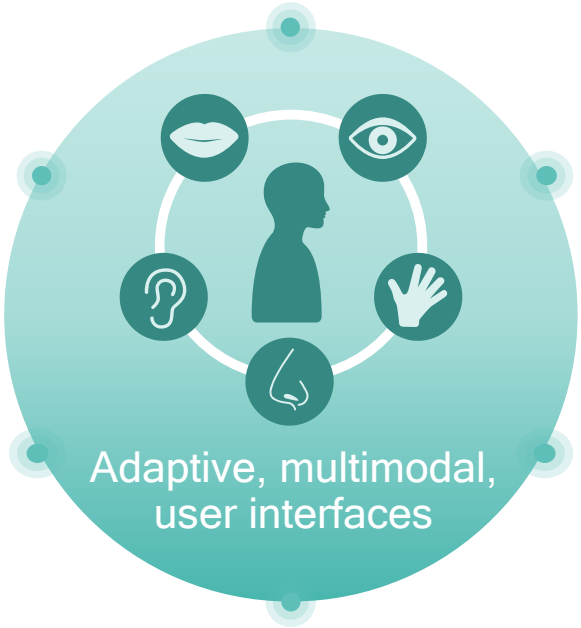
Use CV along with motion sensors, and new types of connected, haptic devices to help users interact within AR

Speech recognition and learning

Use of natural language processing, intelligently personalized to user's voice and lexicon

Face recognition

Use of advanced CV to authenticate and accurately recognize facial expressions



Personalized interfaces

Learn and know a myriad of user preferences based on machine learning

Eye tracking

Use CV to much more accurately authenticate, and also track & measure point of gaze

Bringing life to objects

Efficient user interfaces for controlling interaction with IoT devices and cloud services

Cognitive technologies are key for AR adoption

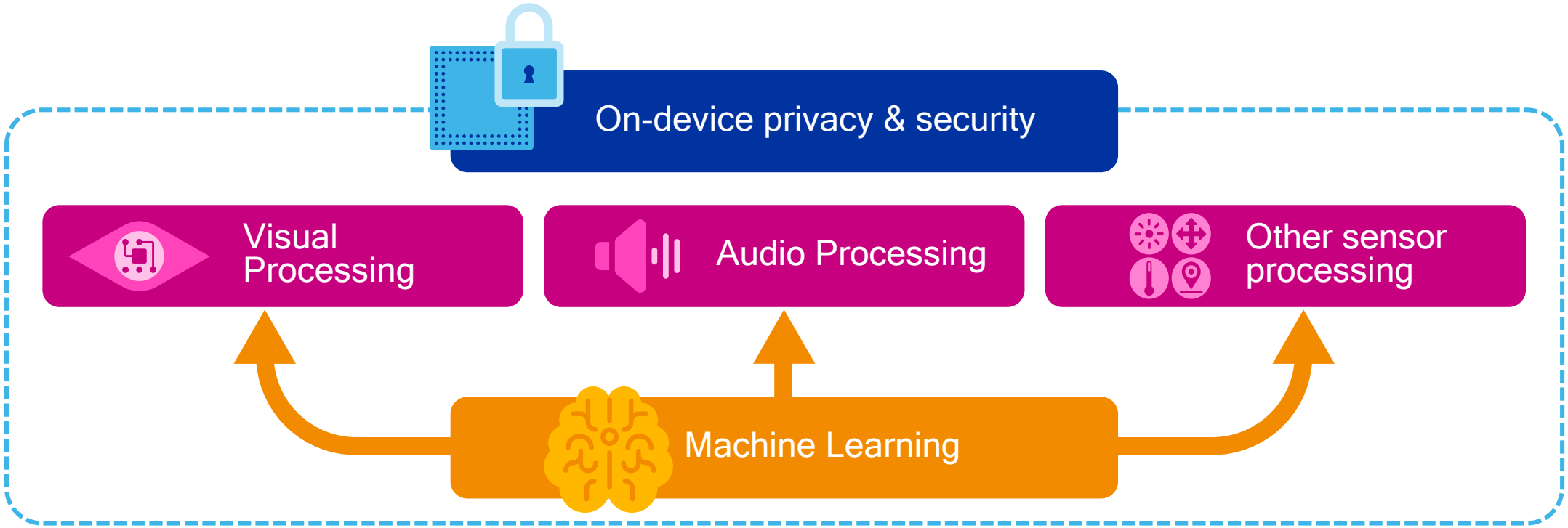
Making sense of the world while protecting our privacy and security

Machine learning

- Makes visual, audio, and other sensor processing more intelligent

Security & privacy are critical for AR

- Continuous authentication necessary for identity and access
- Utilize combined machine learning on biometrics and behavioral activity



Cognitive AR will greatly expand our human abilities

By understanding the environment and providing personalized assistance

Make travel easier

Describe the landmarks around you and translate street signs

Assist the visually impaired

Help the visually impaired map their environment and get around

Become a pro

Make a gourmet meal, fix your car, or perfect your jump shot

Contextual intelligence to “sense” the world

Many types of sensors and personal information are required

Sensor data

Environment
Iris scan
Ambient light
Compass
Camera
Microphone
Temperature
Humidity
Gyroscope
Pulse

On-device data

Calendar
Messaging
Apps

Cloud and IoT data

Cloud data
Connectivity

Low power sensing, processing, and connectivity

- Efficient, heterogeneous architectures
- Sensor fusion and machine learning
- Integrated, always-on data capturing
- Low-energy wireless technologies (e.g. BT-LE, LTE IoT, LTE Direct, 802.11ah)

Visual intelligence to “see” the world around you

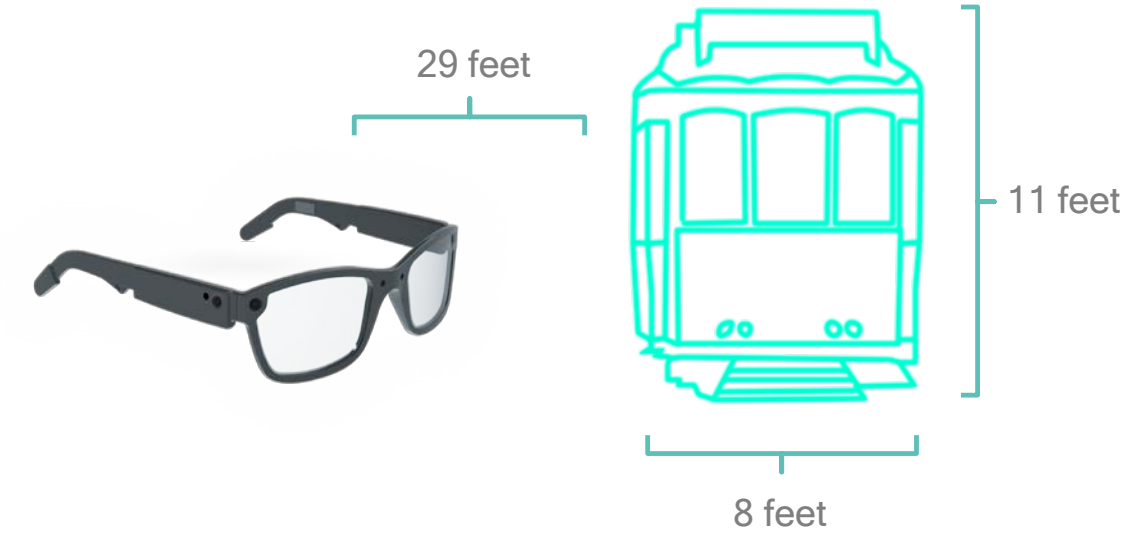
Continually monitoring the visual world to intelligently identify

3D depth capture, interpolation & reconstruction

Using passive + active cameras, along with advanced CV & machine learning algorithms

Object recognition, tracking & registration

Using CV and machine learning so that objects in the real and virtual worlds are properly aligned with respect to each other



Determine the size, direction, and distance of different objects, and (sometimes) store the whole 3D scene for various uses

Recognize, track, map & reconstruct surroundings

Underlying technologies

Object recognition, tracking and registration

Simultaneous localization and mapping (SLAM)

Visual inertial odometry (VIO)

3D reconstruction

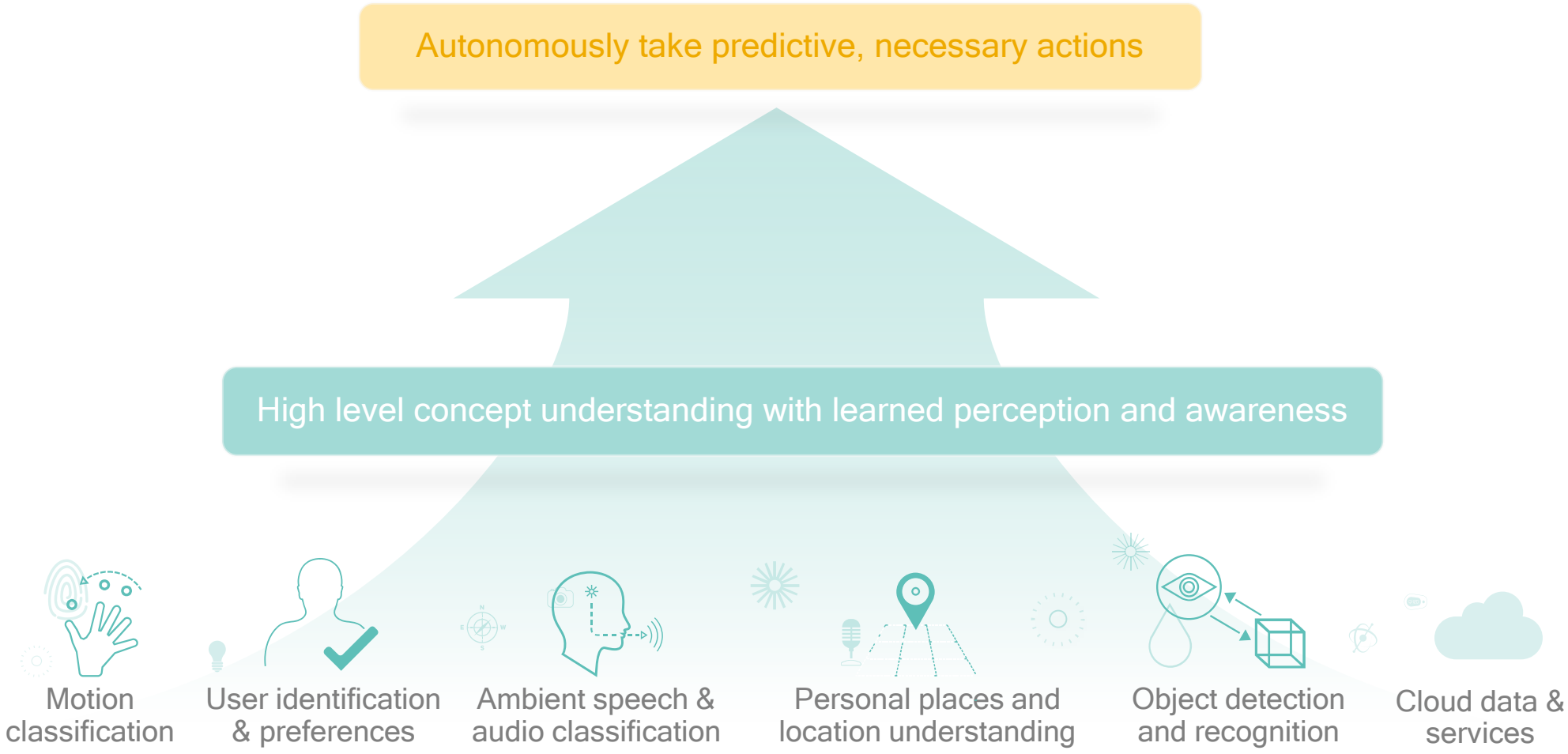

Understand and inform
Recognize the relationship between objects & provide relevant information
Lisbon, Portugal
Temp: 98° F
Cable Car
Cost: €3
Departing: 10 min
Destination time: 1 hr
Café
4.5 stars
Serves Caldo Verde
Taxi
Cost: €25
Departing: Now
Destination time: 15 min
18th Street
Sarah M.
Last talked: 2 months
Ask about her son, Joe
Passenger boarding
Perceptual tasks
Identify real objects
Understand text
Recognize people
Distinguish activities

Recommend actions

Personalized virtual tour guide

Machine learning to autonomously take actions

Infer context and anticipate needs

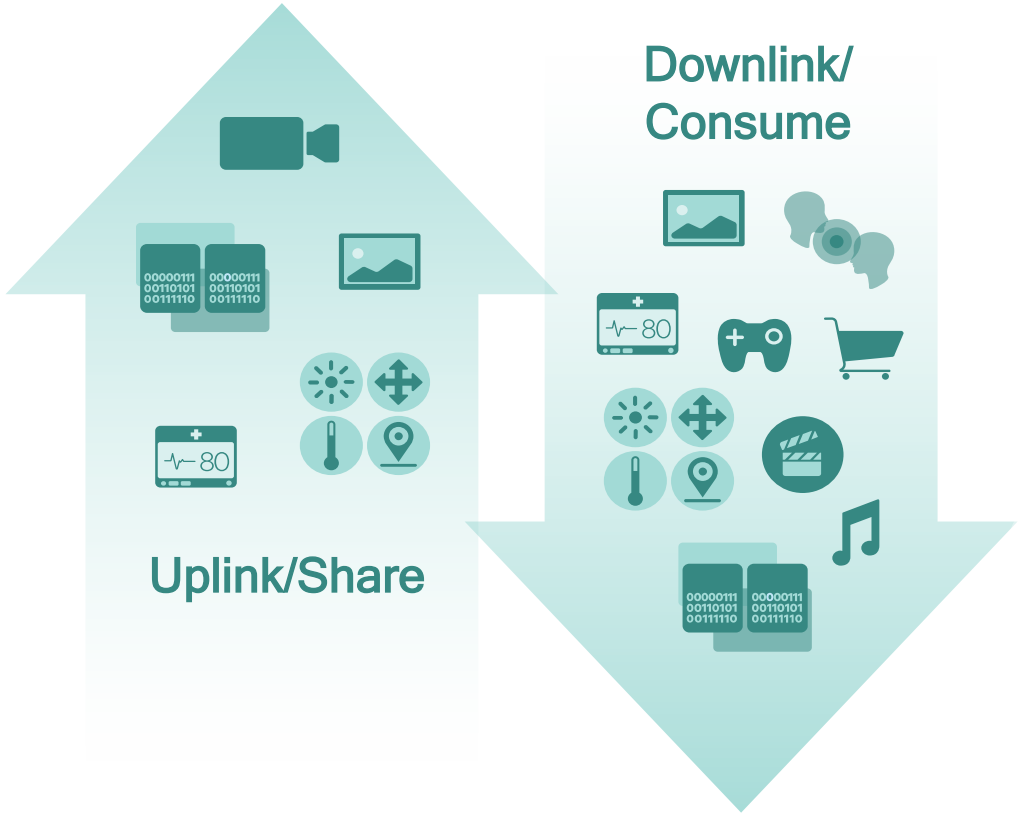


AR requires the next level of ubiquitous connectivity

Connecting everything and enabling cloud computing

Continuous AR use:

- Generates and demands more data
- Requires constant connectivity
- Must be very fast and affordable



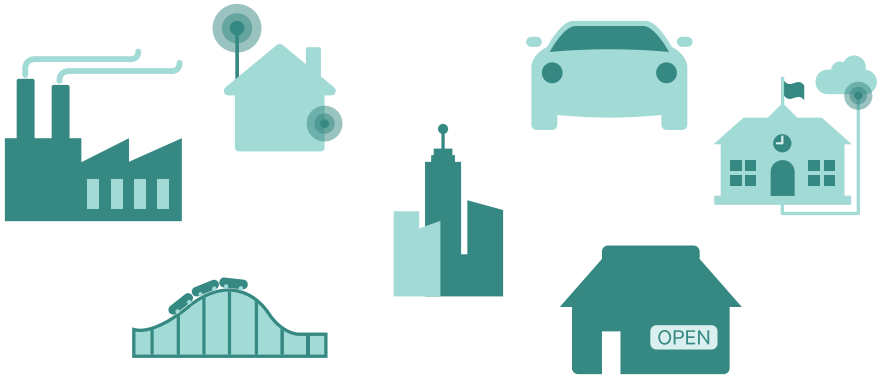
AR needs consistent, faster, higher-capacity uplink and downlink connectivity than today

Taking AR experiences to the next level with 5G

Ubiquitous LTE coverage with Gigabit LTE / 5G multi-mode devices

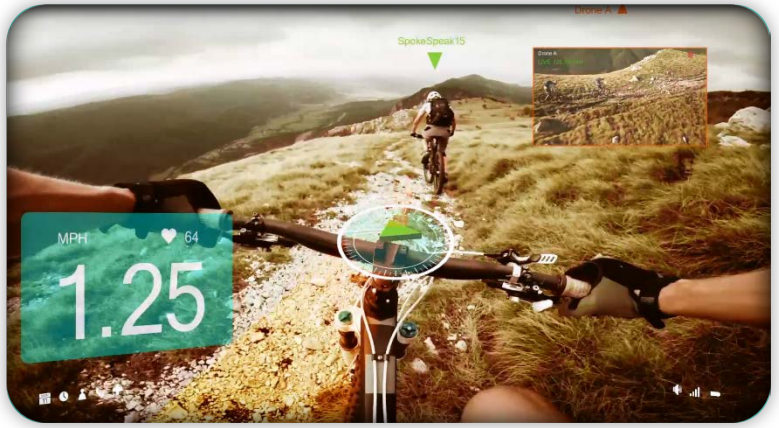
Enjoy AR experiences everywhere

At home, at work, at school, in the car, walking around, …



Share real-time/interactive experiences

Events, meetings, telepresence, …



Extreme throughput
multi-gigabits per second

Ultra-low latency
down to 1ms latency

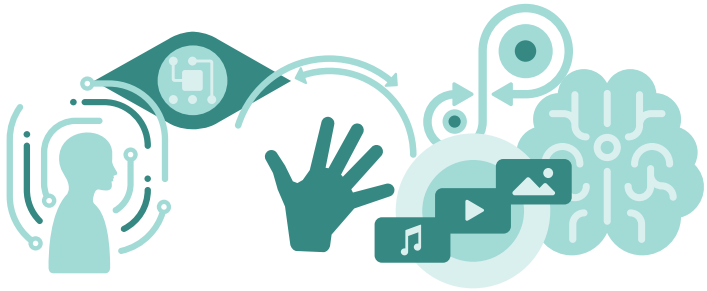
Uniform experience
with much more capacity

All while improving energy efficiency and lowering cost

Learn more about our vision for the future of mobile networks: www.qualcomm.com/5G

Power efficiency is also essential for AR

The AR headset needs to be comfortable to wear all day



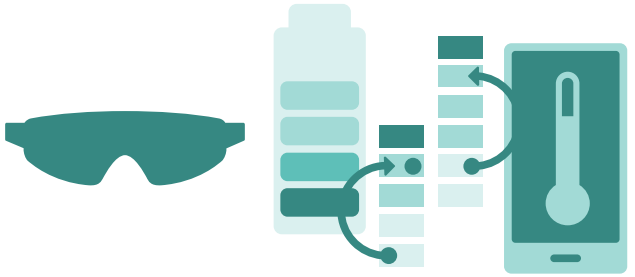
AR workloads

Compute intensive

Complex concurrencies

Always-on

Real-time



Constrained mobile wearable environment

Thermally efficient for sleek, ultra-light designs

Long battery life for all-day use

We’re developing foundational technology for AR

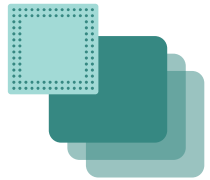
Qualcomm Technologies’ investments and the confluence of mobile technologies

Computer Vision

- 6-DOF VIO
- SLAM & 3DR
- Object detection & recognition

Cognitive & Security

- AI for advanced cognitive processing
- Local and cloud machine learning
- Security and privacy



Heterogeneous Computing

- Lower power, higher perf. AR visual processing
- Advancements in always-on sensor fusion
- Next-gen AR audio

Next-Gen Connectivity

- Gigabit LTE and Wi-Fi
- Pioneering 5G technologies
- Connectivity convergence

We are also investing in these innovative start-ups

Qualcomm Ventures portfolio

LYTRO

Professional “light field” cameras & software

matterport

Professional 3D reconstruction cameras & software

blippAR

Smartphone AR software for “visual marketing”

XIMMERSE

Software & hardware for AR/VR controllers

Owlchemy Labs

Virtual reality game studio

magic leap

Wearable mixed reality

AR is the next mobile computing platform

AR is here today, but still in infancy

Advancements are required to make AR optimally immersive, cognitive, and connected

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Qualcomm Technologies will continue to innovate AR technologies

Thank you

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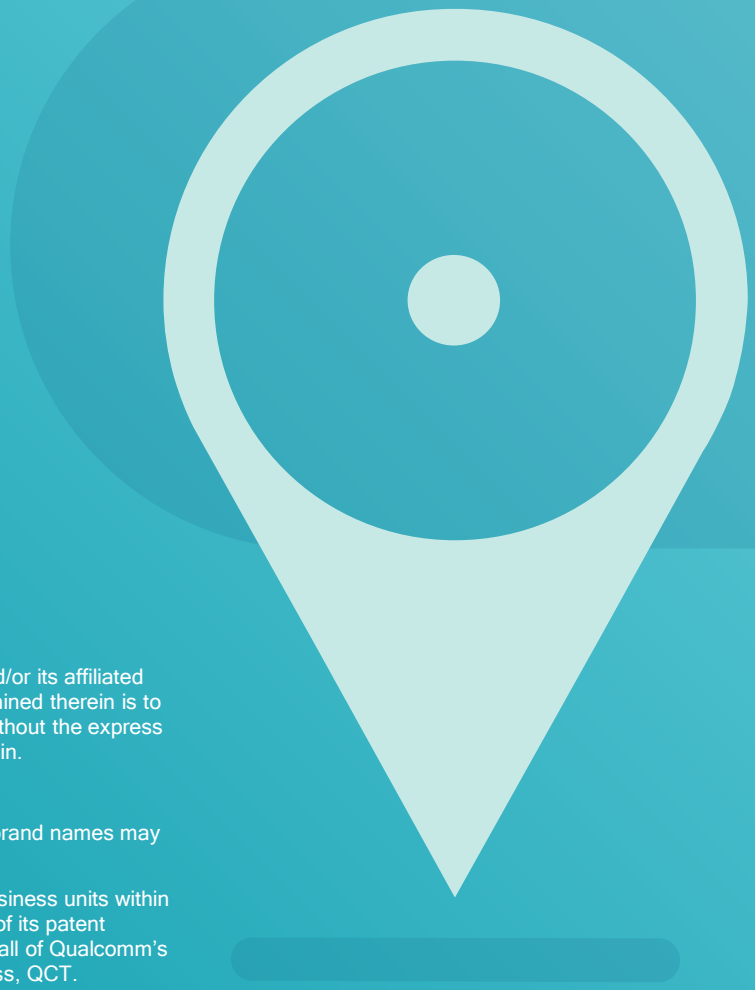

Resources

Websites

- Augmented reality: https://www.qualcomm.com/AR
- Virtual reality: https://www.qualcomm.com/VR
- Immersive experiences: https://www.qualcomm.com/Immersive
- Developers: https://developer.qualcomm.com
- Newsletter signup: http://www.qualcomm.com/mobile-computing-newsletter

Presentations

- Virtual reality: https://www.qualcomm.com/documents/making-immersive-virtual-reality-possible-mobile
- Immersive experiences: https://www.qualcomm.com/documents/immersive-experiences-presentation
- SlideShare: http://www.slideshare.net/qualcommwirelessevolution

Papers

- Virtual reality: https://www.qualcomm.com/documents/whitepaper-making-immersive-virtual-reality-possible-mobile
- Immersive experiences: https://www.qualcomm.com/documents/whitepaper-driving-new-era-immersive-experiences-qualcomm

Videos:

- Immersive experiences webinar: https://www.qualcomm.com/videos/webinar-new-era-immersive-experiences-whats-next
- Virtual reality webinar: https://www.qualcomm.com/videos/webinar-making-immersive-virtual-reality-possible-mobile