Oct 2018

@qualcomm_tech

Qualcomm

The mobile future of augmented reality

Qualcomm Technologies, Inc.

Agenda

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

Augmented reality will impact every aspect of our lives

Offering unprecedented experiences and increased productivity

AR and VR offer distinct experiences

But share similar underlying technologies

Virtual reality

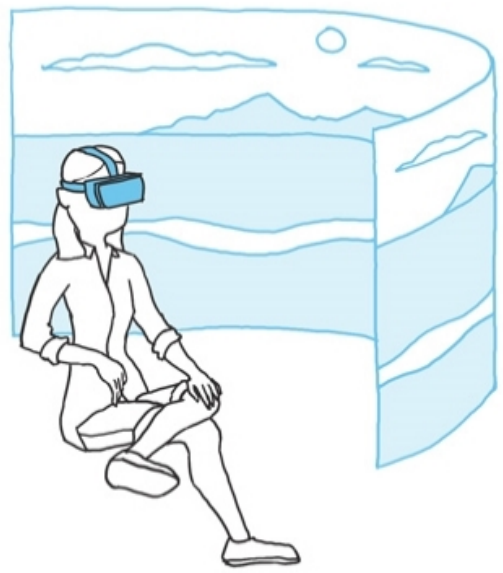
Simulates physical presence in real or imagined worlds, and enables the user to interact in that world

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 and games

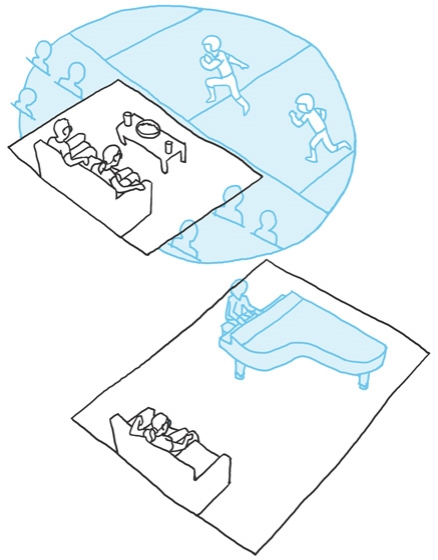
AR: Pokémon Go, Google Translate, Snapchat, and other rudimentary AR apps

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



XR: 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 transform the way we live and interact with the world

Offering unprecedented experiences and increased productivity

A plurality of experiences in AR

Play	Explore	Communicate	Work	Thrive
Interactive gaming in any environment	Immersive education and learning	Telepresence	Training and productivity	Health
Movies and shows on a big screen, anywhere	3D design and art	Shared visualizations and personal moments	Virtual office, anywhere	Fitness and sports
Augmented live concerts, sports, and other events	Travel and navigation	Personalized advertising	Collaboration through a shared view	Personalized recommendations
	Shopping and retail			

Helping us navigate our daily lives

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

AR will revolutionize industries and enterprises

Increased productivity, efficiency, and safety

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

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

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

Military
- Instructional training
- In-the-field assistance

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

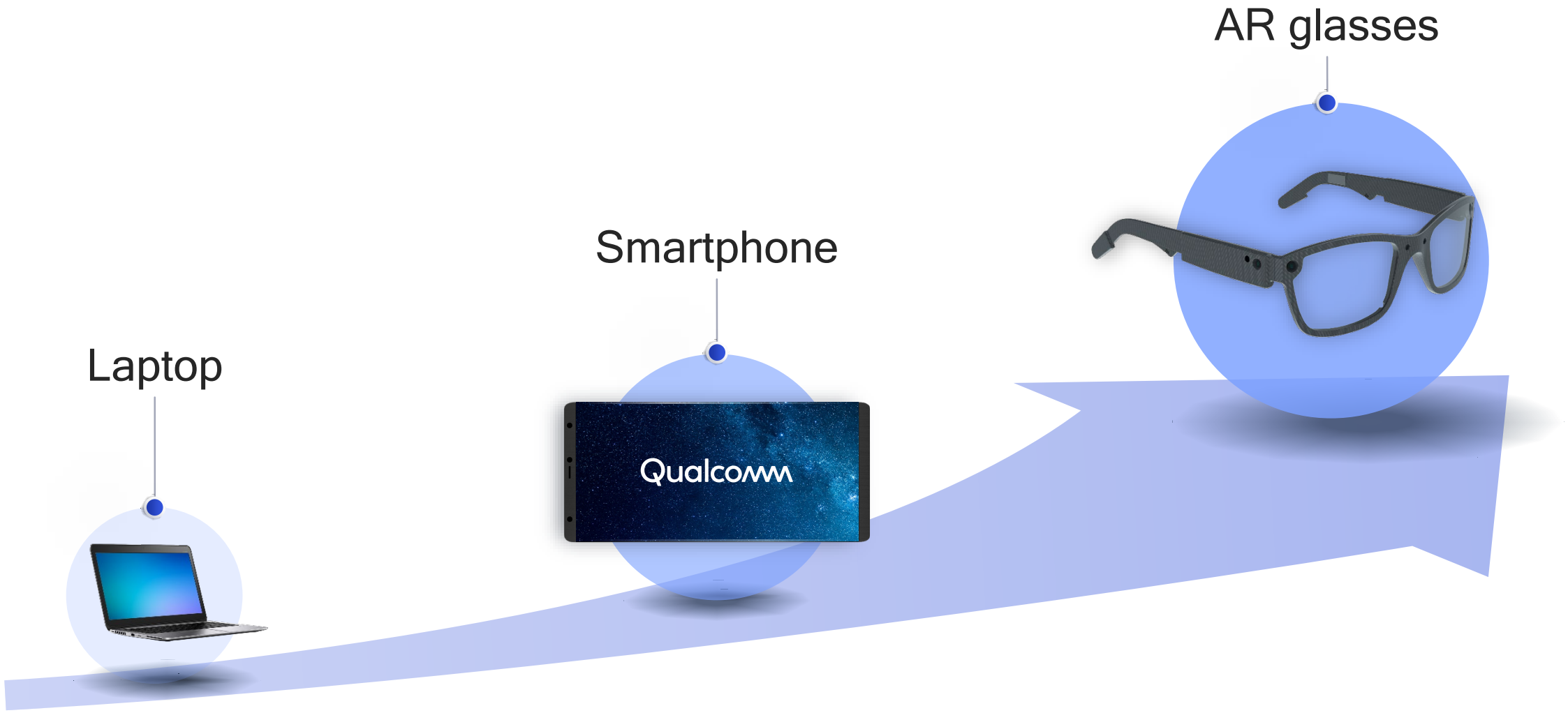
Retail
- Try before you buy: clothes, furniture, car, real estate shopping, etc.
- Navigation to products and personalized coupons

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

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

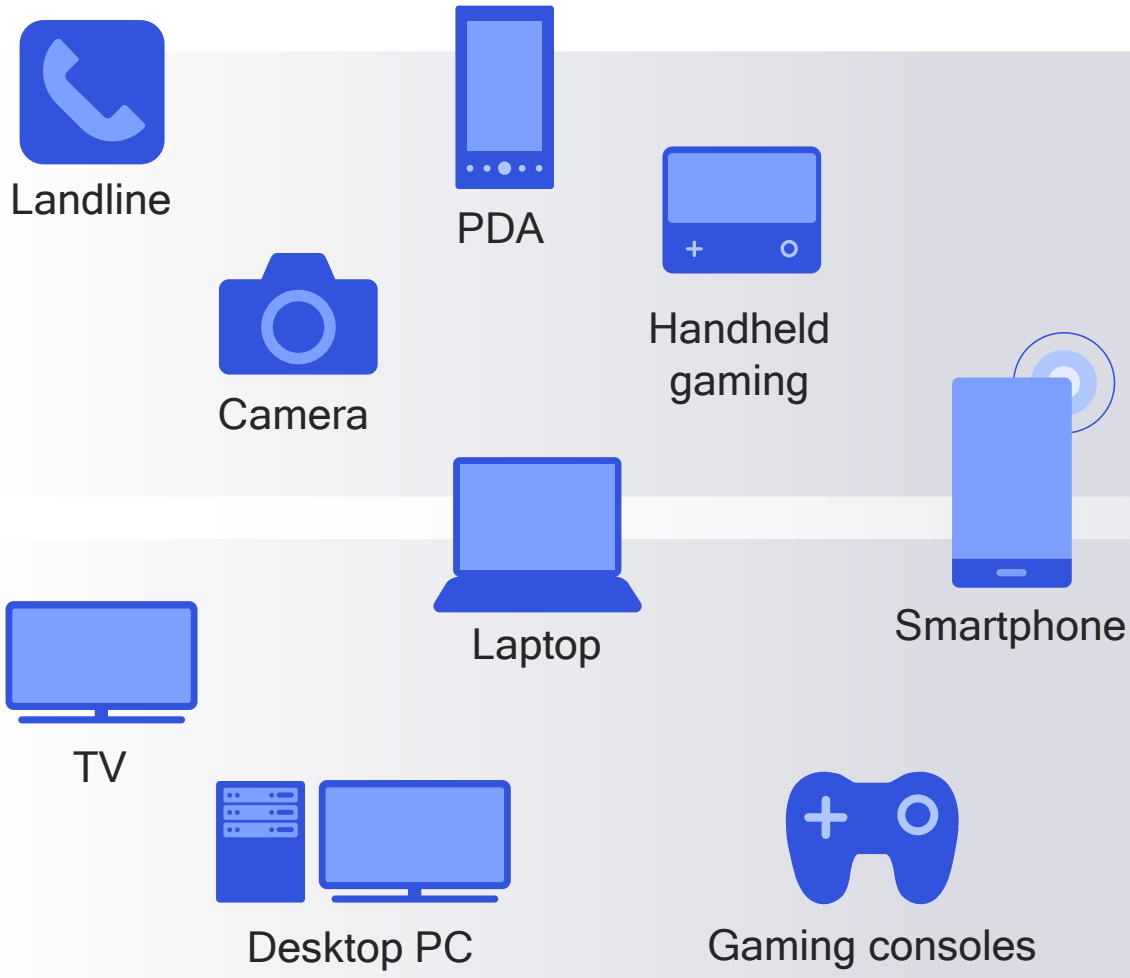
AR is the next mobile computing platform

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



AR technologies and use cases evolve from mobile

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



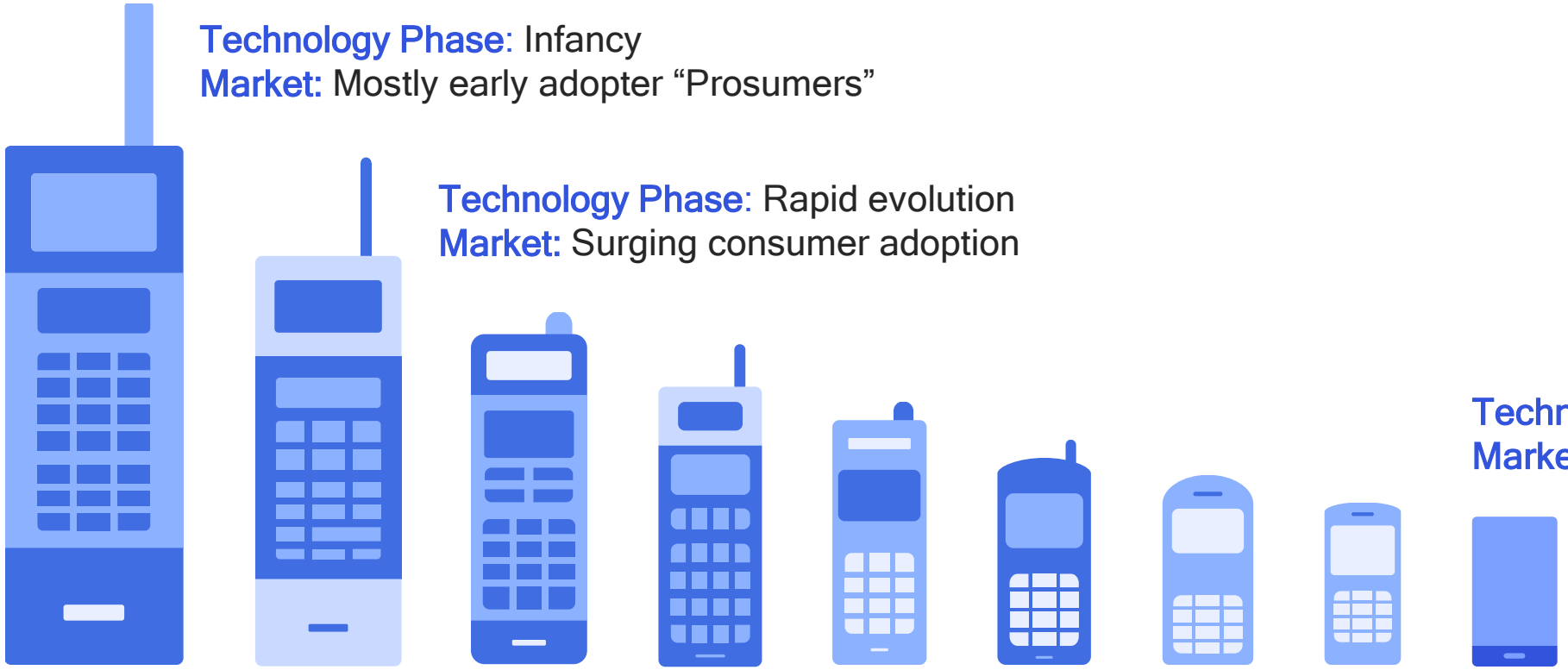
AR glasses

VR HMD

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

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”

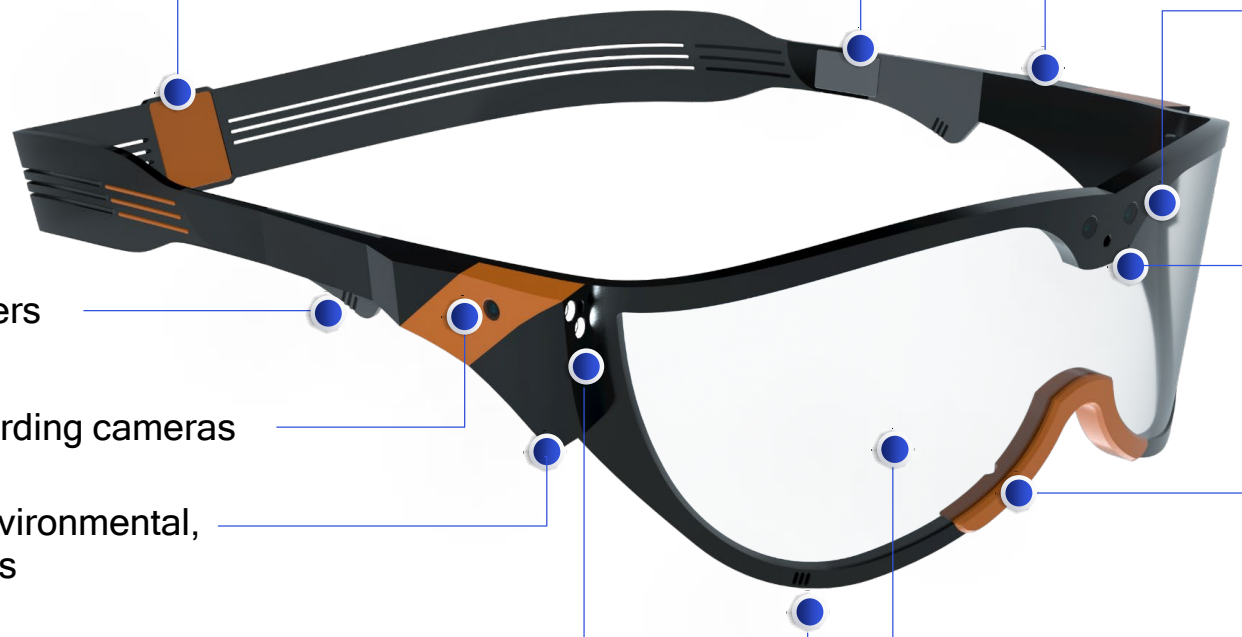
Technology Phase: Rapid evolution
Market: Surging consumer adoption

Technology Phase: Maturity
Market: Worldwide, ubiquitous use

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

A glimpse into the future

First responder AR glasses



Bone conduction transducers

Rear camera

Directional speakers

Tracking and recording cameras

Inertial, haptic, environmental, and health sensors

Ultra-bright LED lights

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

AR will seamlessly merge the real world with virtual objects

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

Intelligent

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

Connected

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

Immersive

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

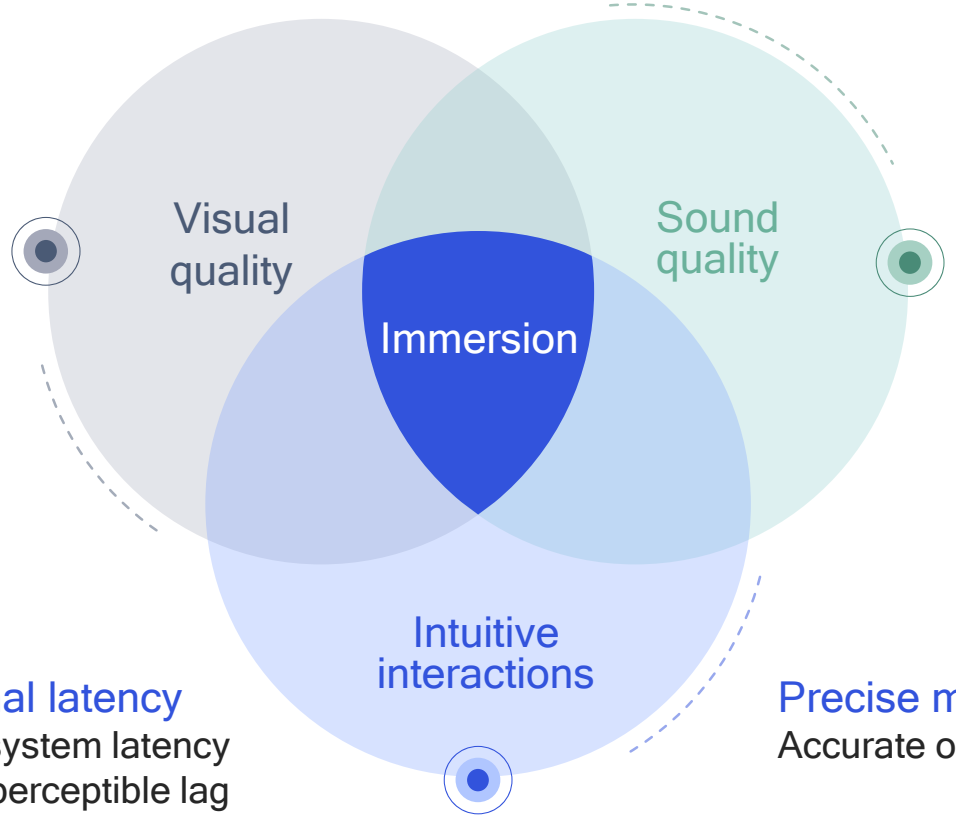
AR shares requirements similar to VR for immersion

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

Extreme pixel quantity and quality
Screen is very close to the eyes

Spherical view
Look anywhere with a full 360° spherical view

Stereoscopic display
Humans see in 3D



High resolution audio
Up to human hearing capabilities

3D audio
Realistic 3D, positional, surround audio that is accurate to the real world

Crystal clear voice
Clear voice that is enhanced with noise cancellation technology

Minimal latency
Minimized system latency to remove perceptible lag

Precise motion tracking
Accurate on-device motion tracking

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

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

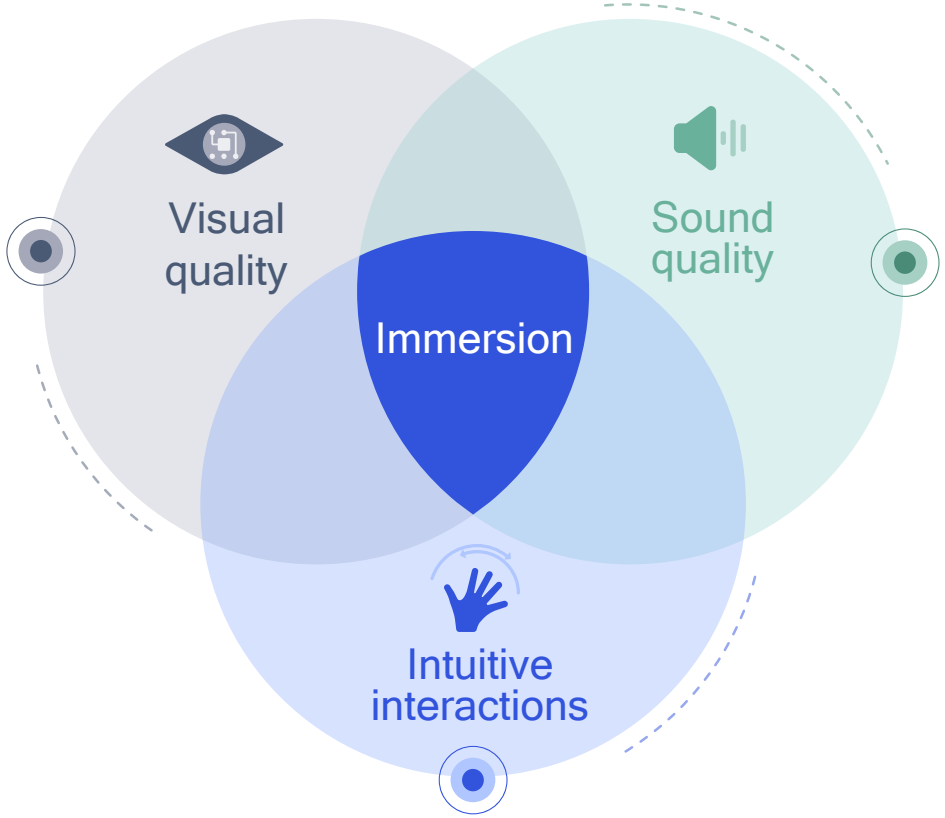
AR introduces additional requirements for immersion

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 VR 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

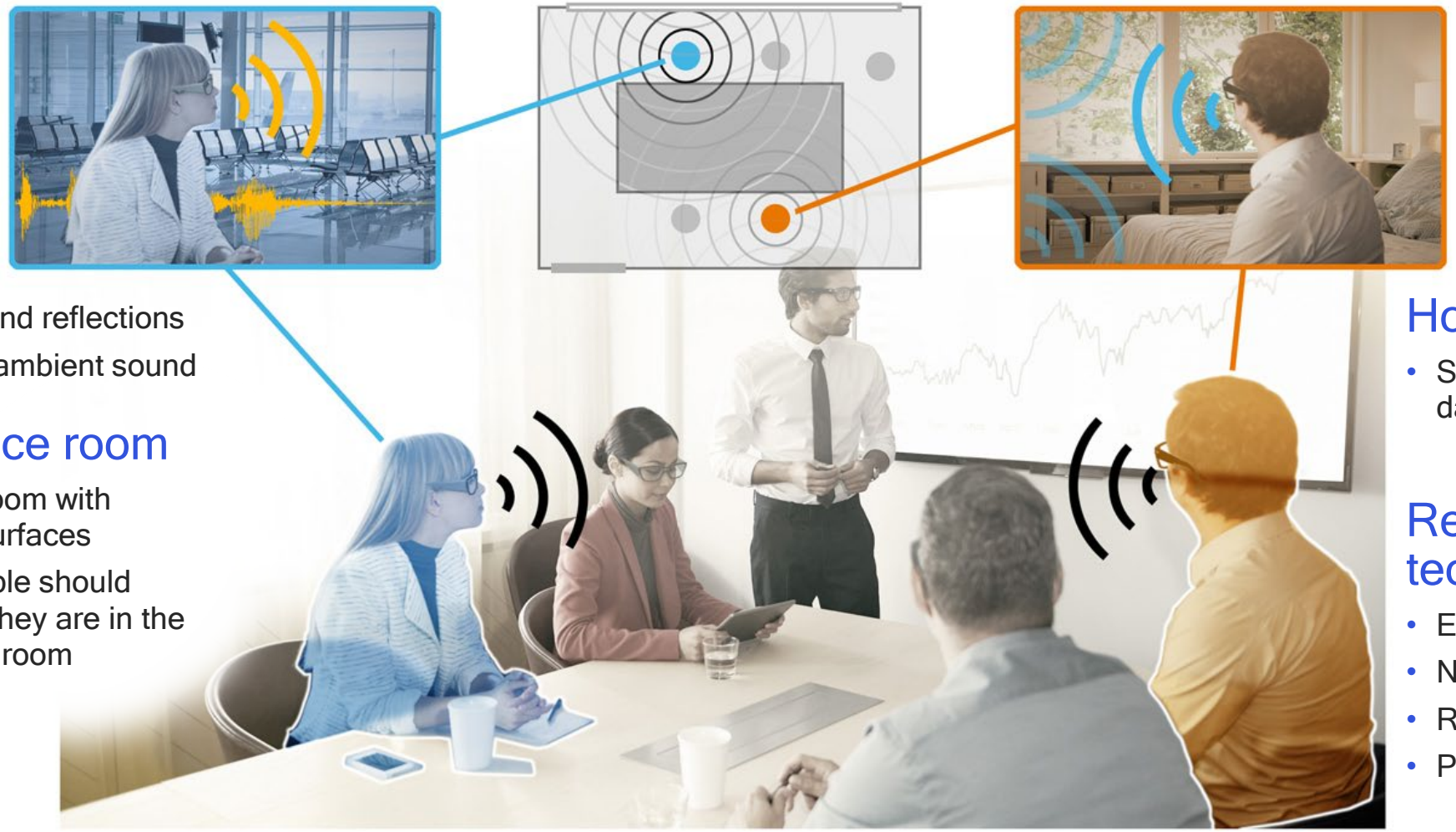
- Virtual objects look real and correctly placed
- Dynamic lighting; correct for the environment
- Solid objects look solid
- Materials look physically correct
- Interactivity is smooth

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

Conference room

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

Hotel room

- Significant sound dampening

Required technologies

- Environment modeling
- Noise filtering
- Reverberation
- Positional audio

Interacting naturally with AR

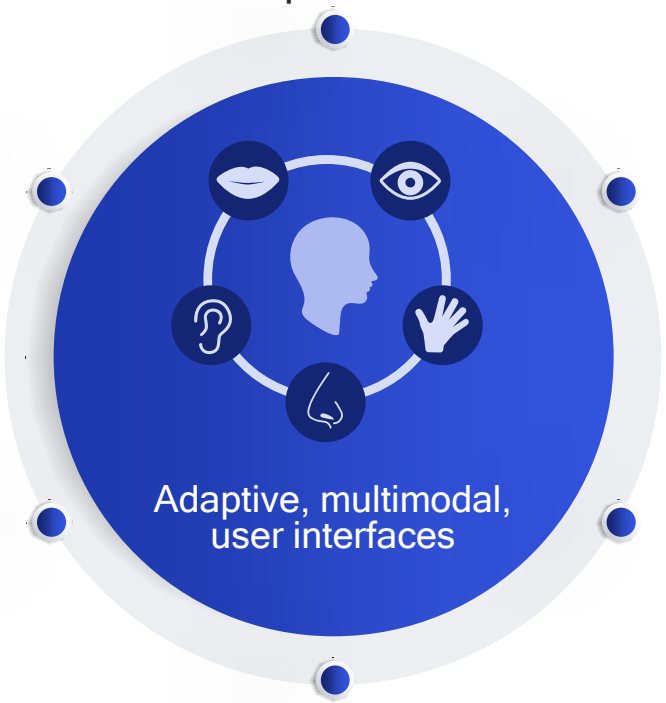
Interactions will become more intuitive and adaptive to personal preferences

Motion and 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

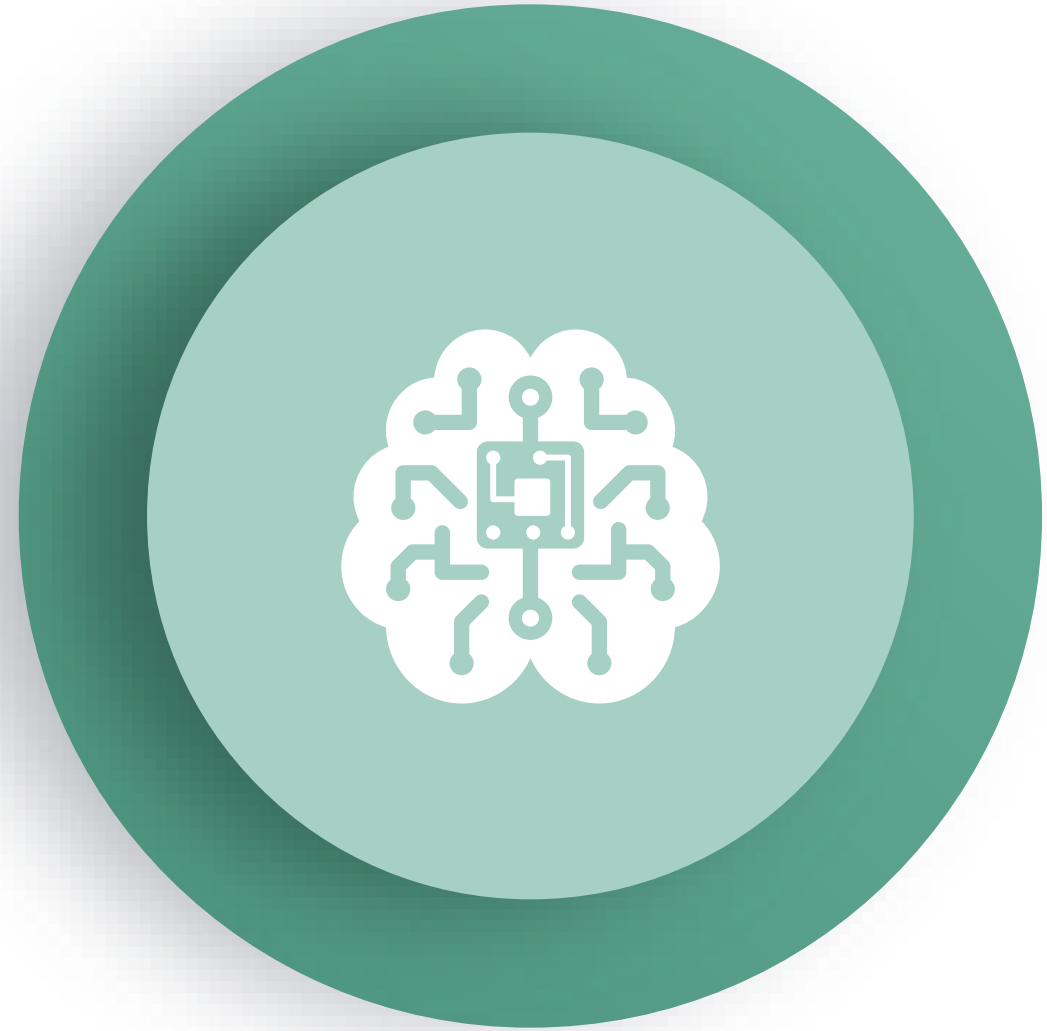
Use CV to much more accurately authenticate, and also track and measure point of gaze

Bringing life to objects

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

Intelligence

Understanding the real world and learning personal preferences



AI technologies are key for AR adoption

Making sense of the world while protecting our privacy and security

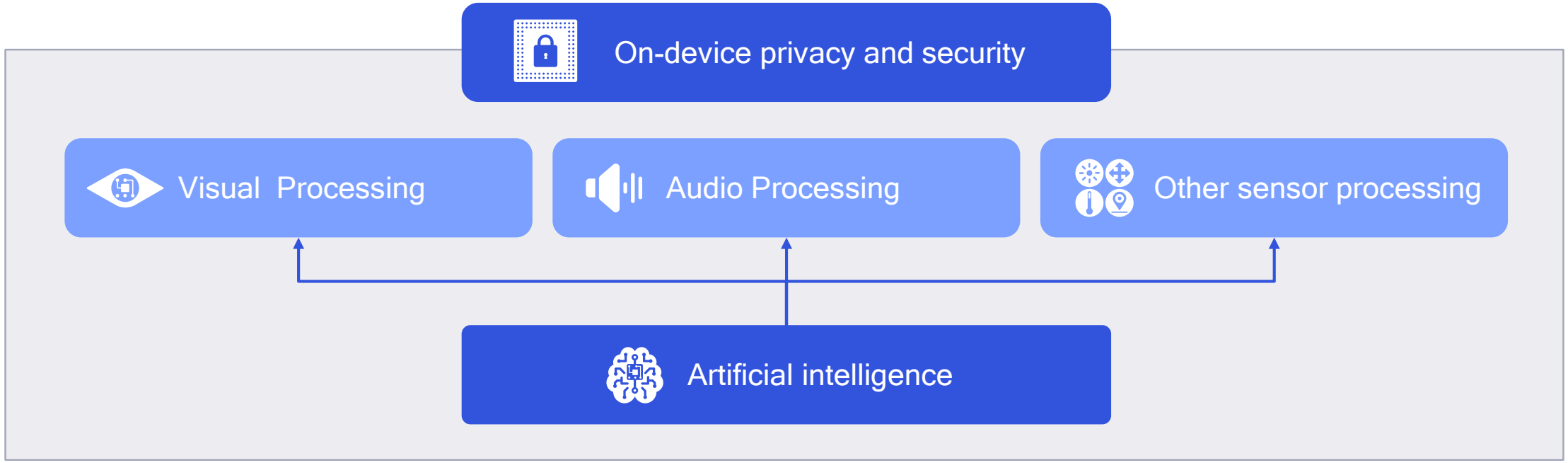
Machine learning

Makes visual, audio, and other sensor processing more intelligent

Security and privacy are critical for AR

Continuous authentication necessary for identity and access

Utilize combined machine learning on biometrics and behavioral activity



Intelligent 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

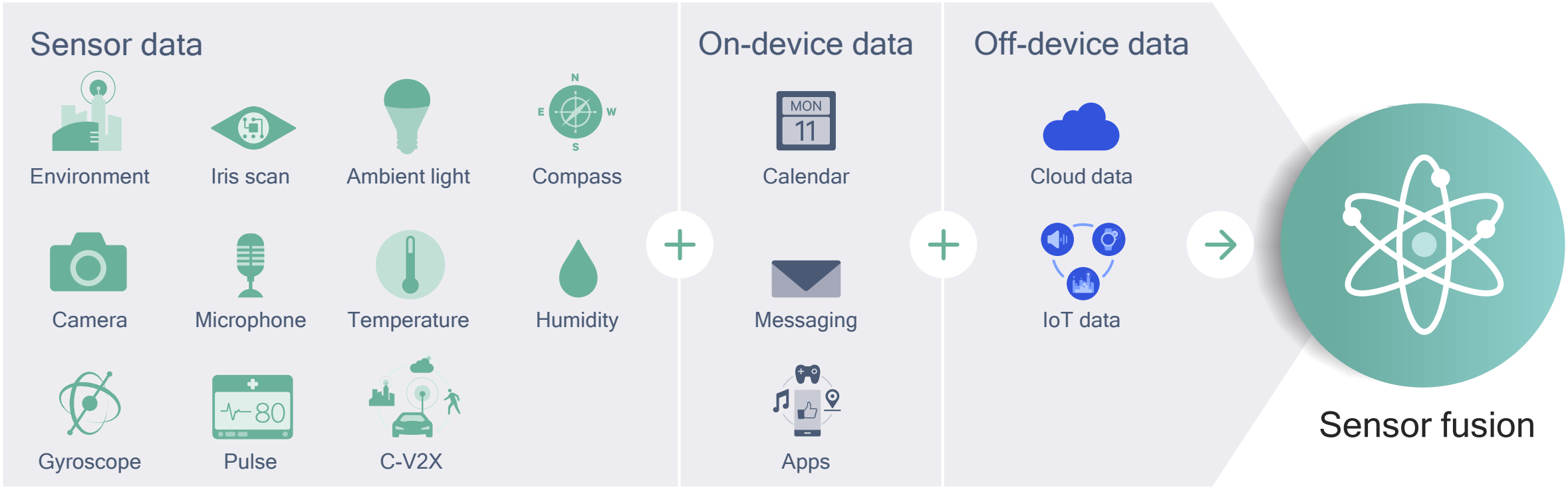
Help the visually impaired map their environment and get around

Become a pro

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

Contextual intelligence to “sense” the world

The fusion of many types of sensors and personal information is required



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, 5G NR IoT)

Visual intelligence to “see” the world around you

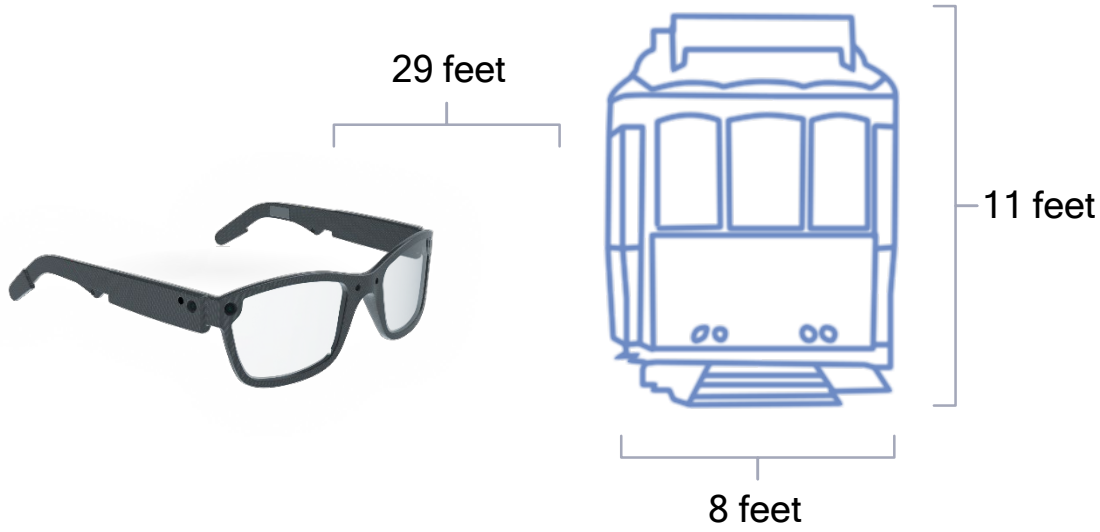
Continually monitoring the visual world to intelligently identify

3D depth capture, interpolation, and reconstruction

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

Object recognition, tracking, and 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 amd reconstruct surroundings

Underlying technologies

Object recognition, tracking and registration

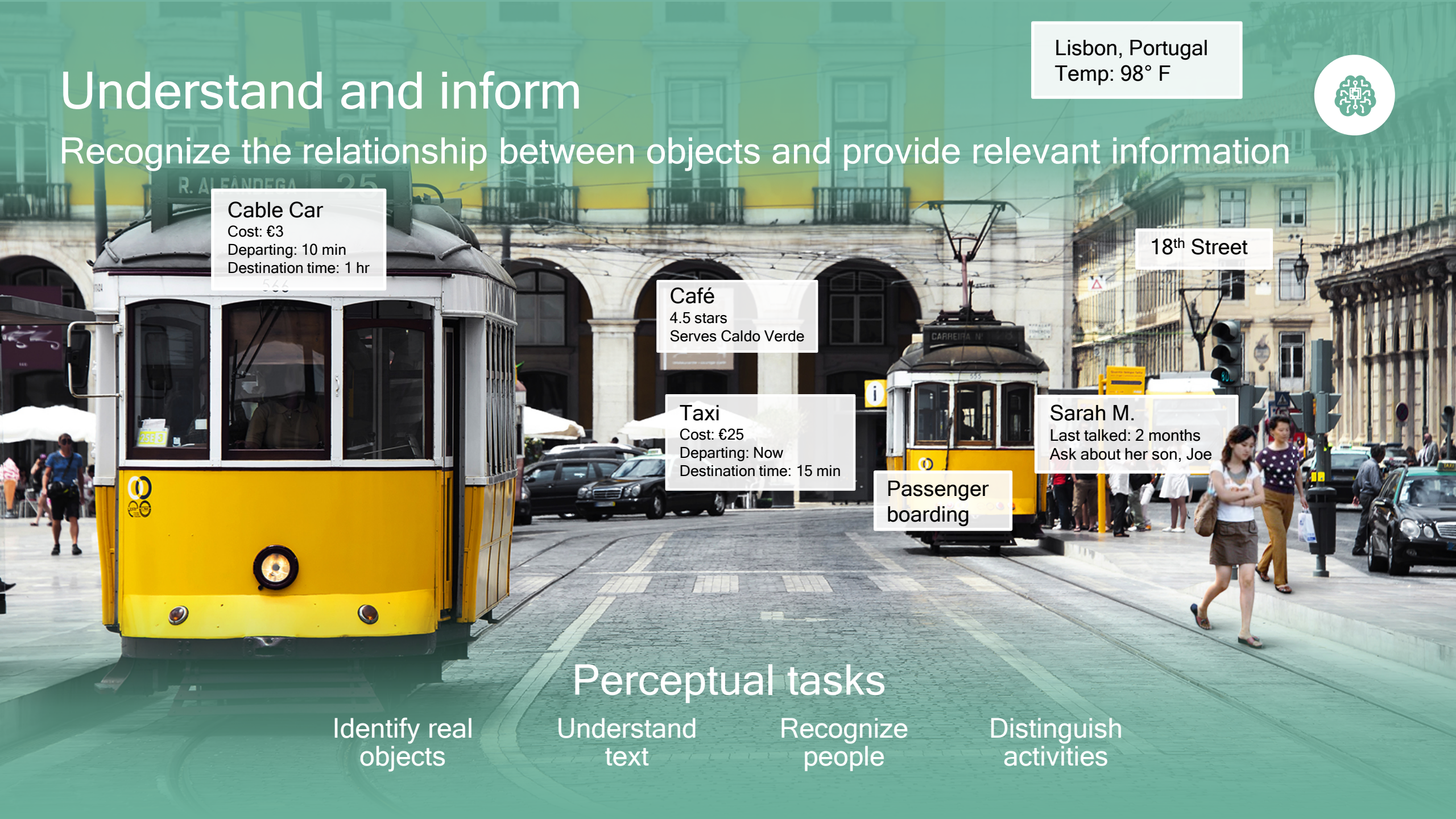
Simultaneous localization and mapping (SLAM)

Visual inertial odometry (VIO)

3D reconstruction

Understand and inform

Recognize the relationship between objects and provide relevant information



Perceptual tasks

- Identify real objects
- Understand text
- Recognize people
- Distinguish activities

Recommend actions

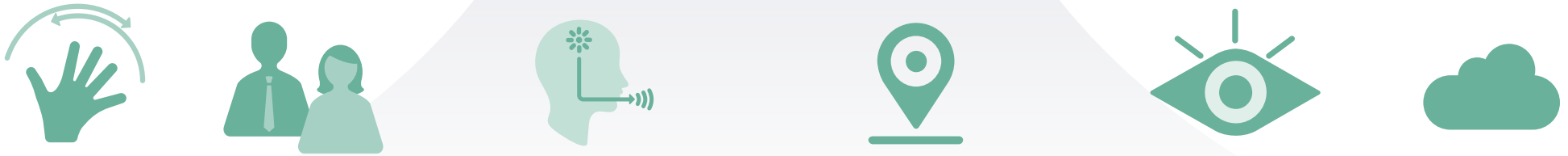
Personalized virtual tour guide

AI to autonomously take actions

Infer context and anticipate needs

Autonomously take predictive, necessary actions

High level concept understanding with learned perception and awareness



Motion classification

User identification and preferences

Ambient speech and audio classification

Personal places and location understanding

Object detection and recognition

Cloud data and services

Connected

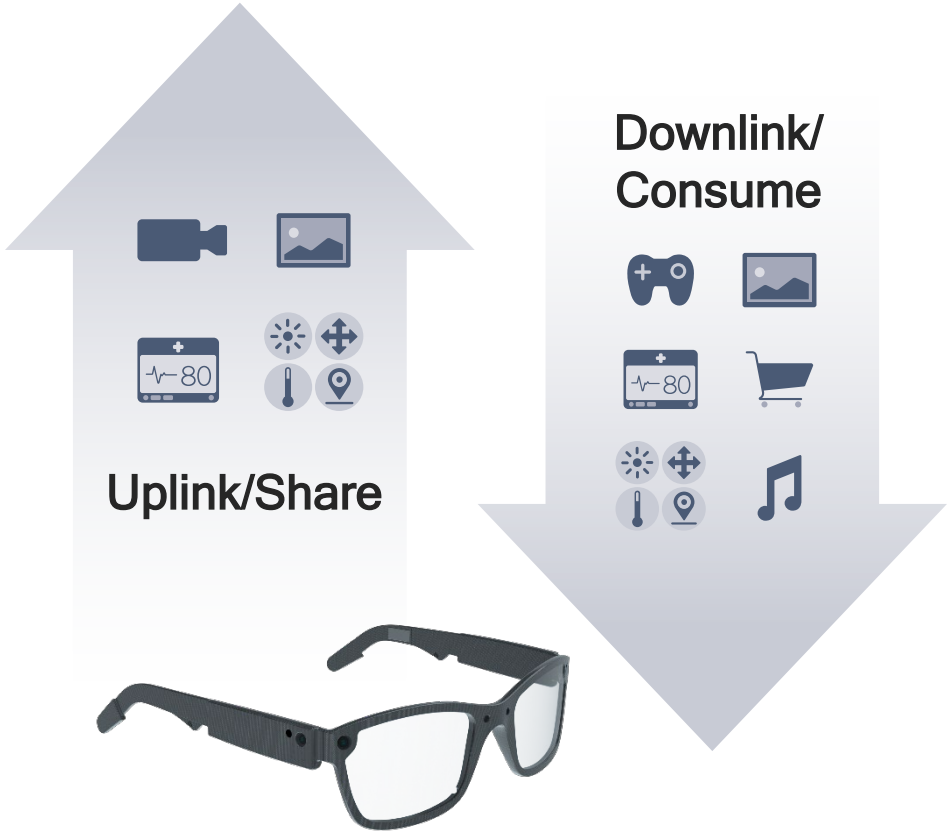
An always-on device with fast wireless cloud connectivity anywhere

AR requires the next level of ubiquitous connectivity

The mass adoption of a highly mobile, intelligent, always-on wearable device

AR drives the need to efficiently grow wireless capacity

High-capacity connectivity to share and consume content 24/7



Demanding and generating more data

Visual content, such as videos,images, or graphics

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

Contextual data from sensors and the cloud

Constant upload and download on an all-day wearable

Mass adoption–the next mobile computing platform

Gigabit Class LTE is the foundation for AR wireless capacity

Technology enablers for achieving Gigabit Class LTE

More bandwidth

Better spectral efficiency

Best use of all spectrum assets

Carrier Aggregation

Combines multiples LTE carriers for wider bandwidth, e.g. fatter pipe

Aggregation across diverse spectrum types

Makes the best use of spectrum, e.g. FDD/TDD, licensed/unlicensed spectrum

Advanced MIMO (4x4)

Leverages more antennas to increase spectral efficiency

Higher-order modulation (256-QAM)

Transmits more bits per symbol to increase spectral efficiency

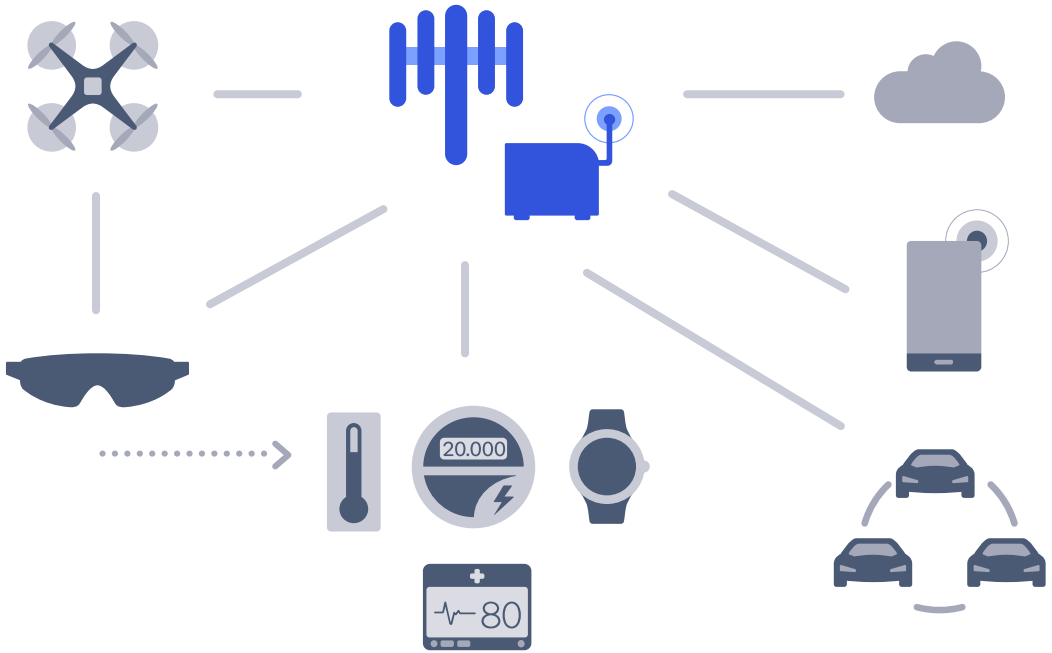
QAM = quadrature amplitude modulation, MIMO = multiple-input and multiple-output

Contextual intelligence requires connecting everything

UI augmentation is limited without hyper-connectivity

Creating a connectivity fabric for everything

Securely gathering contextual data for increased intelligence



Connecting:

- Device to device
- Device to cloud
- AR glasses to devices
- AR glasses to cloud

Heterogeneous connectivity for IoT

LTE | Wi-Fi | Bluetooth | GNSS/Location | NFC | Powerline

Cloud computing complements on-device processing

Leveraging ubiquitous connectivity for the best of both worlds

On-device processing

- Security and user privacy
- Low latency for instant processing
- Availability in and out of coverage
- Efficient use of network bandwidth and processing

Both are needed

Personal information and limited context

Public information and in-depth context

Cloud computing

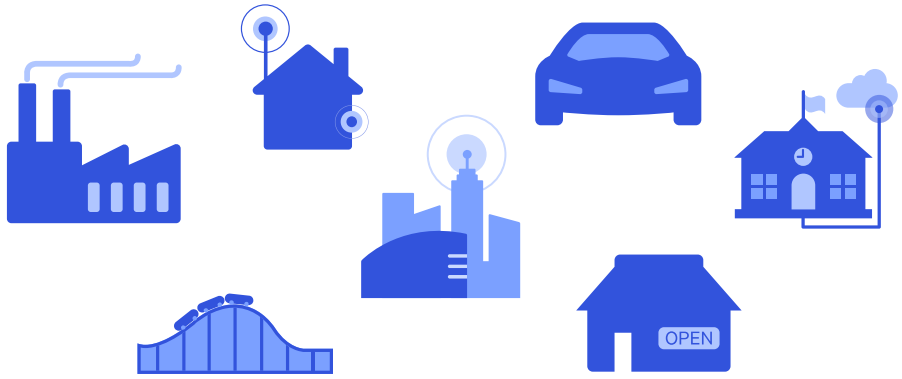
- Boundless cloud data and storage
- Crowd-sourcing and data aggregation
- Big data processing without power constraints
- Reliable, low-latency, and global cloud connectivity

Taking AR experiences to the next level with 5G

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

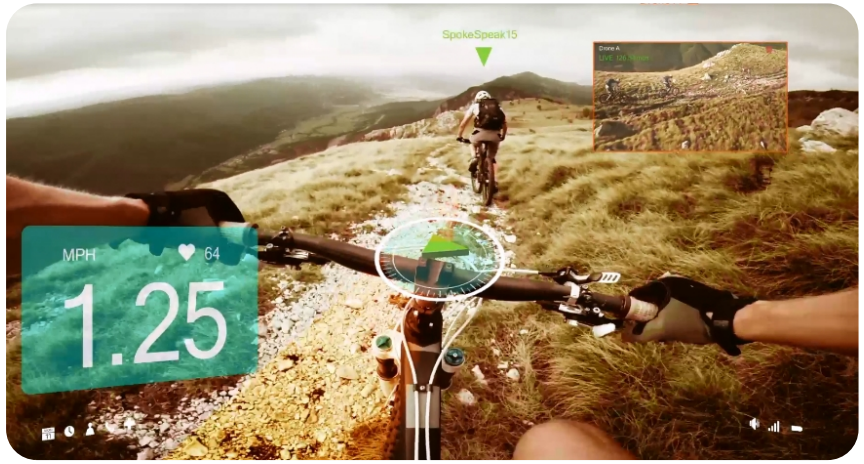
Enjoy AR experiences everywhere

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

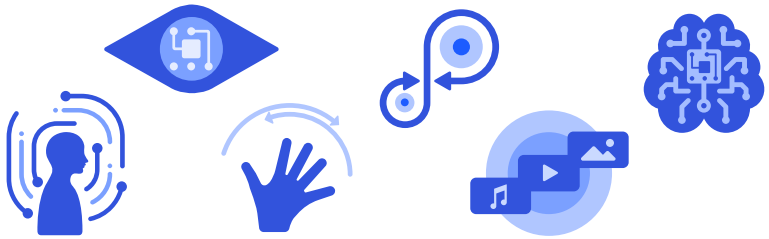
Uniform experience
with much more capacity

All while improving energy efficiency and lowering cost

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

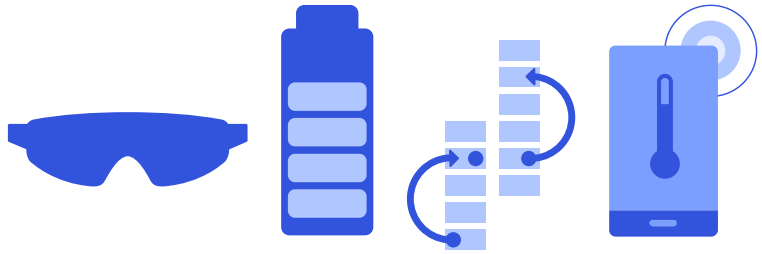
Power efficiency is essential for AR

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

QTI is uniquely positioned to support superior AR experiences

Custom designed SoCs and investments in the core AR technologies

We’re developing foundational technology for AR

Qualcomm Technologies’ investments and the confluence of mobile technologies

Computer vision

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

AI and security

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

Heterogenous computing

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

Next-gen connectivity

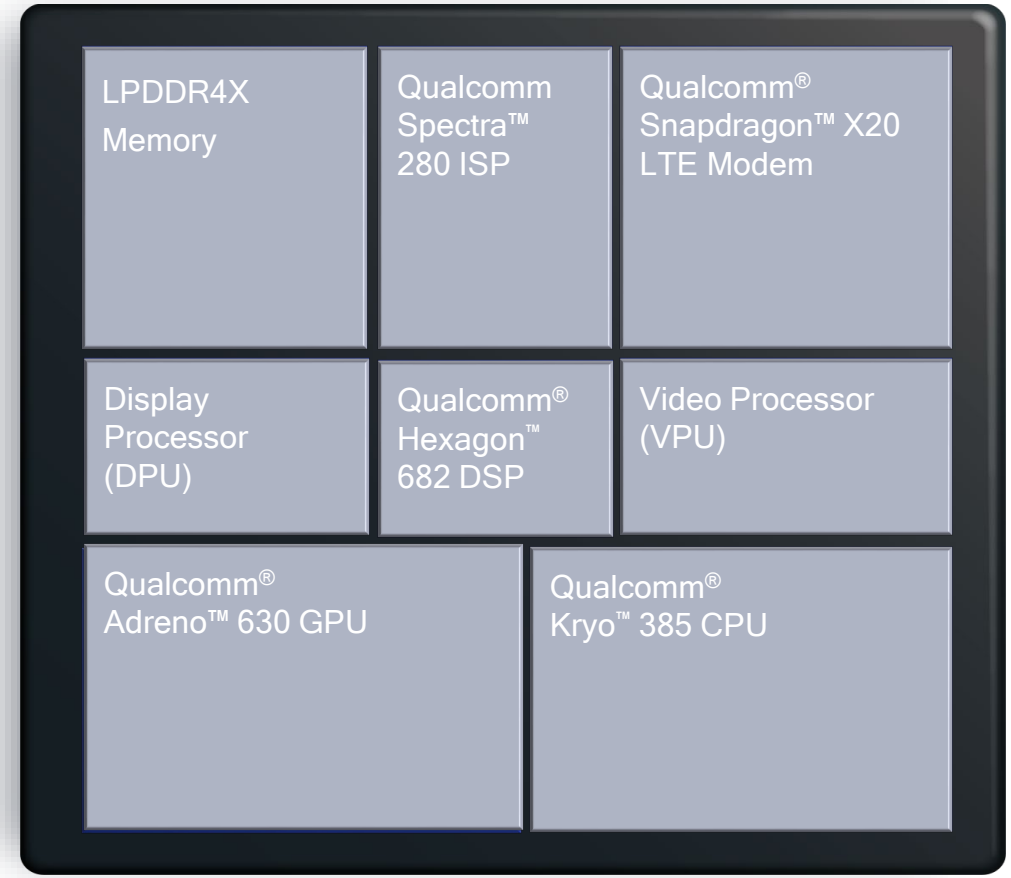
- Gigabit LTE and Wi-Fi
- Pioneering 5G technologies
- Connectivity convergence

Snapdragon 845 is designed to meet AR requirements

Utilizing specialized engines across the SoC for efficient processing

Augmented reality requires heterogeneous computing

Computer vision, machine learning, image processing, sensor processing, graphics, video processing, and cloud connectivity



Entire SoC is used!

■ High-utilization

* Not to scale

We are also investing in these innovative start-ups

Qualcomm Ventures portfolio

LYTRO

Professional “light field” cameras and software

matterport®

Professional 3D reconstruction cameras and 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, intelligent, and connected

Qualcomm Technologies will continue to innovate AR technologies

Qualcomm

Thank you

Follow us on:

For more information, visit us at:

www.qualcomm.com & www.qualcomm.com/blog

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