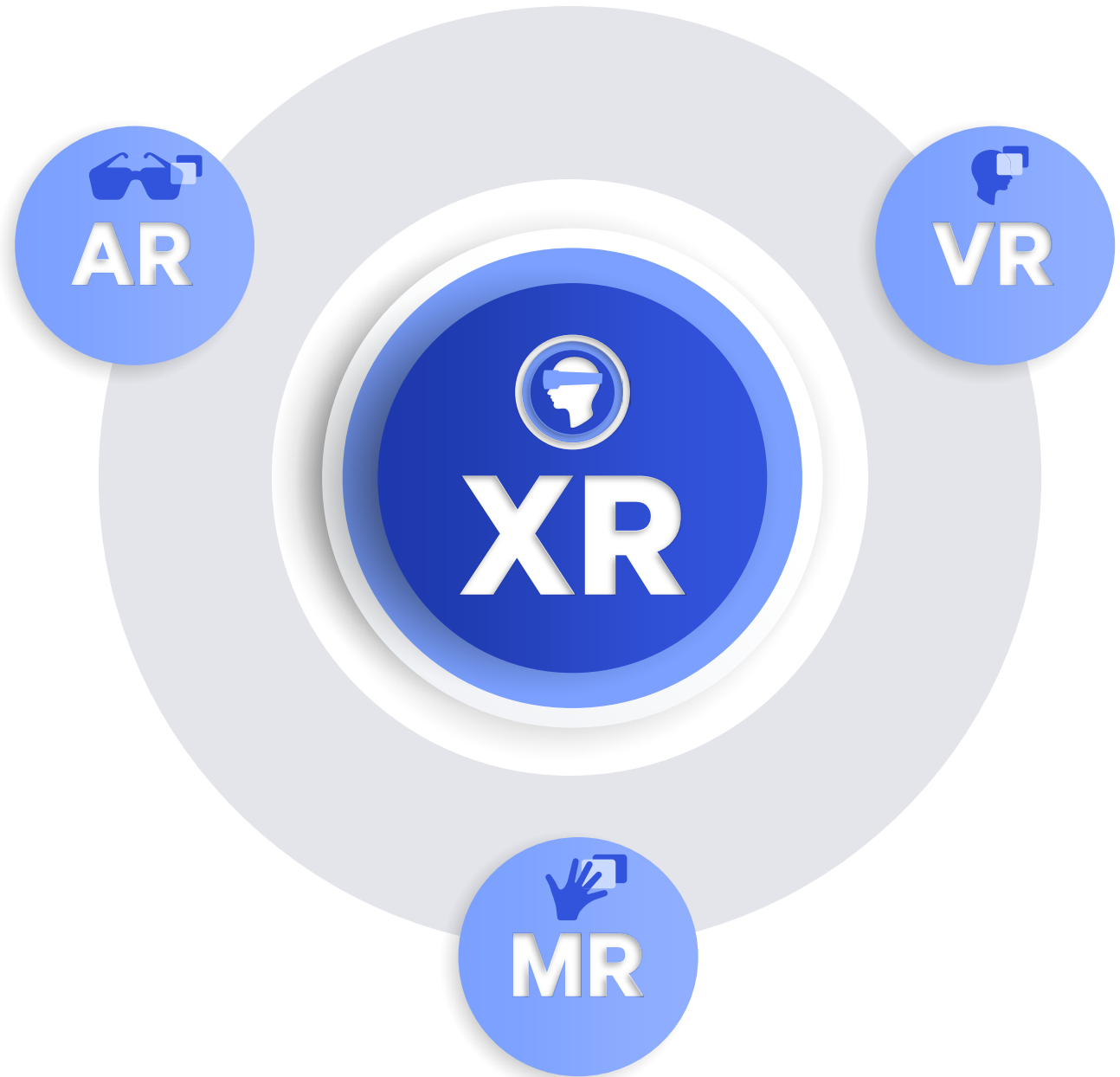# Boundless photorealistic mobile XR over 5G

Qualcomm Technologies, Inc.

XR is meant to be mobile

XR is meant to be mobile

Industrial & manufacturing

Engineering

Healthcare

Retail

Education

XR

Marketing & advertising

Military

Emergency response

Entertainment

A glimpse into the future – sleek and stylish XR glasses
How do we get there?

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
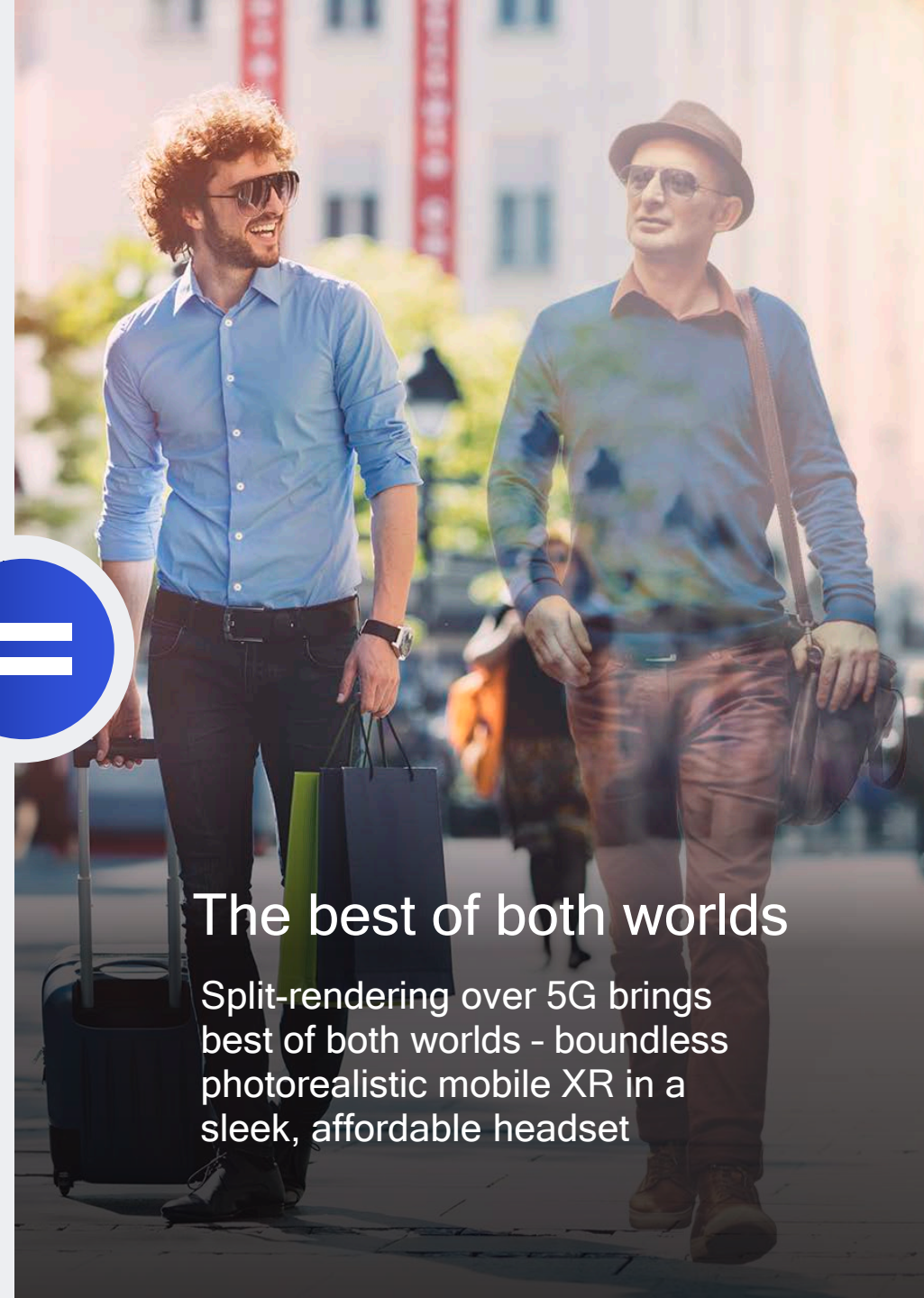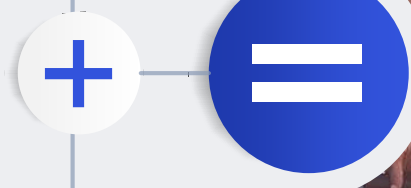
Mobile XR

- Reliable, anywhere anytime usage
- Ease of use with no setup
- Battery powered sleek, ultra-light design
- Leverages mobile ecosystem scale

PC-tethered XR

- Not limited by power and thermal constraints
- Expensive and niche for high-end experiences
- Wires limit intuitive actions and immersion
- Usage limited to a fixed location

+ **=**

The best of both worlds

Split-rendering over 5G brings best of both worlds - boundless photorealistic mobile XR in a sleek, affordable headset

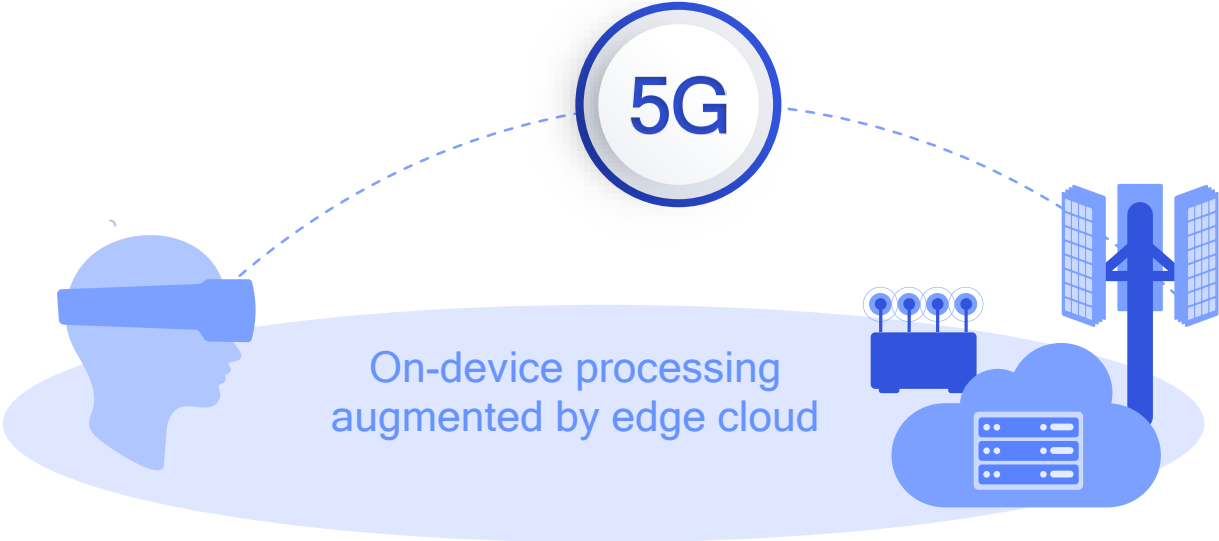# Boundless mobile XR – the best possible XR anywhere

On-device processing, access to rich content

5G

On-device processing augmented by edge cloud

Premium XR anywhere

Efficient on-device processing to deliver immersive XR

Utilize connectivity for less time-sensitive content and downloads
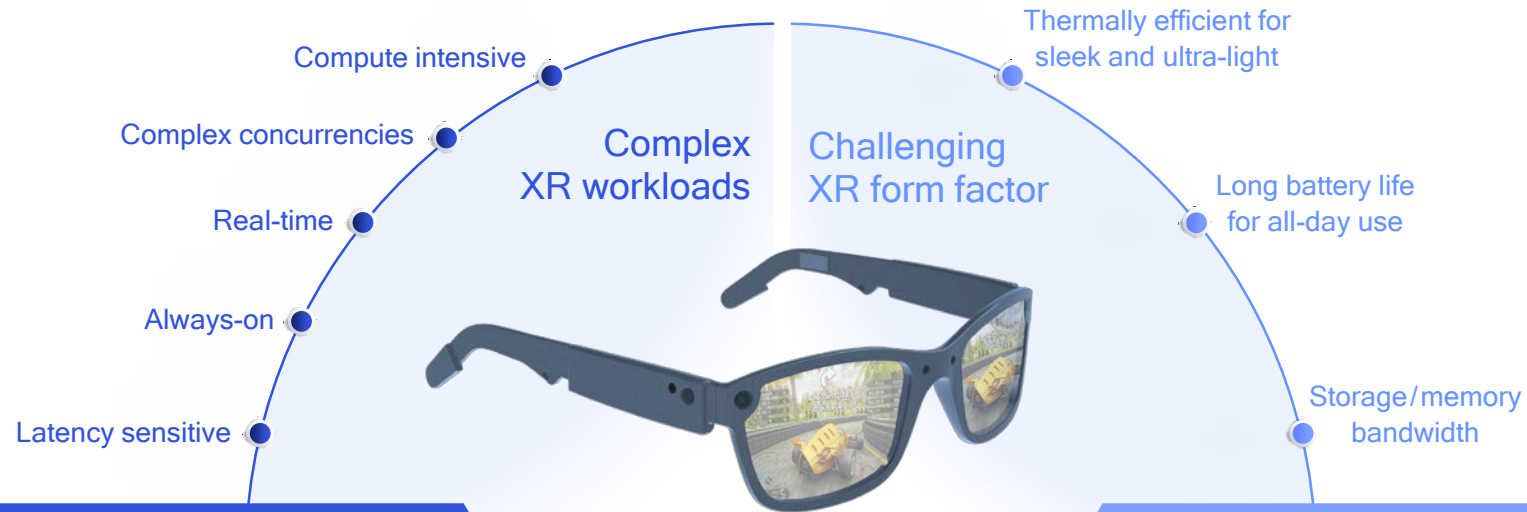
We are doing this today

Photorealistic graphics and visuals

Enhanced experience where possible with new split-rendering architecture

On-device processing augmented by compute located at cloud edge over 5G connectivity

A new era in distributed processing

Compute intensive

Complex concurrencies

Real-time

Always-on

Latency sensitive

Complex XR workloads

Challenging XR form factor

Thermally efficient for sleek and ultra-light

Long battery life for all-day use

Storage/memory bandwidth

Essential on-device processing ▶ Split rendering ◀ **Augment by edge cloud processing**

Optimized under strict power, thermal, size constraints
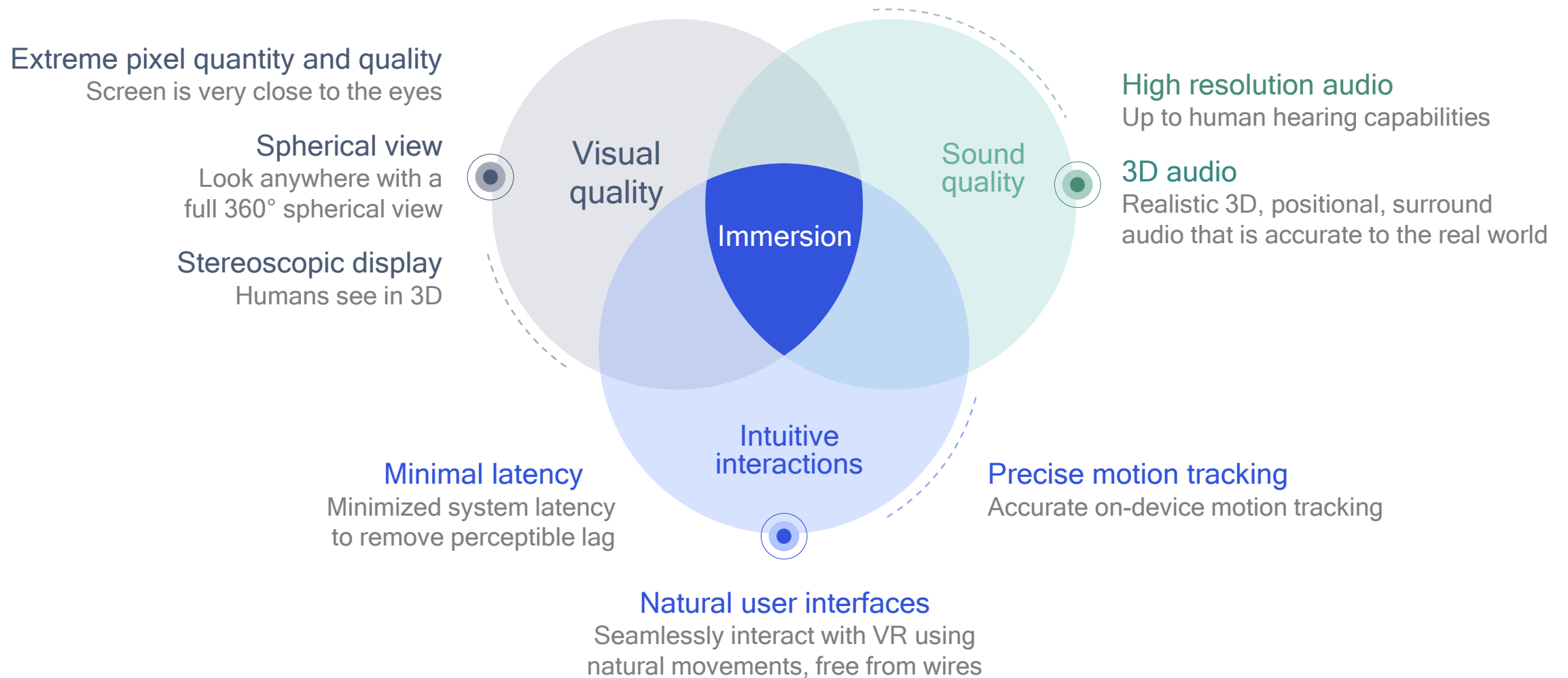
Premium experiences today that continuously improve

5G

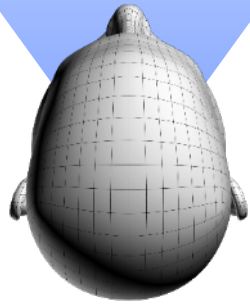Low latency

High capacity

Reliable link

Significantly higher power envelope—beyond PC class

Augment on-device rendering with edge cloud rendering

7

Achieving immersive mobile XR is challenging
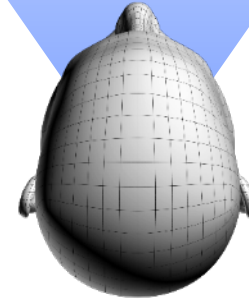
Extreme pixel quantity and quality
Screen is very close to the eyes

Spherical view
Look anywhere with a
full 360° spherical view

Stereoscopic display
Humans see in 3D

Visual quality

Sound quality

Immersion

Intuitive interactions

High resolution audio
Up to human hearing capabilities

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

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

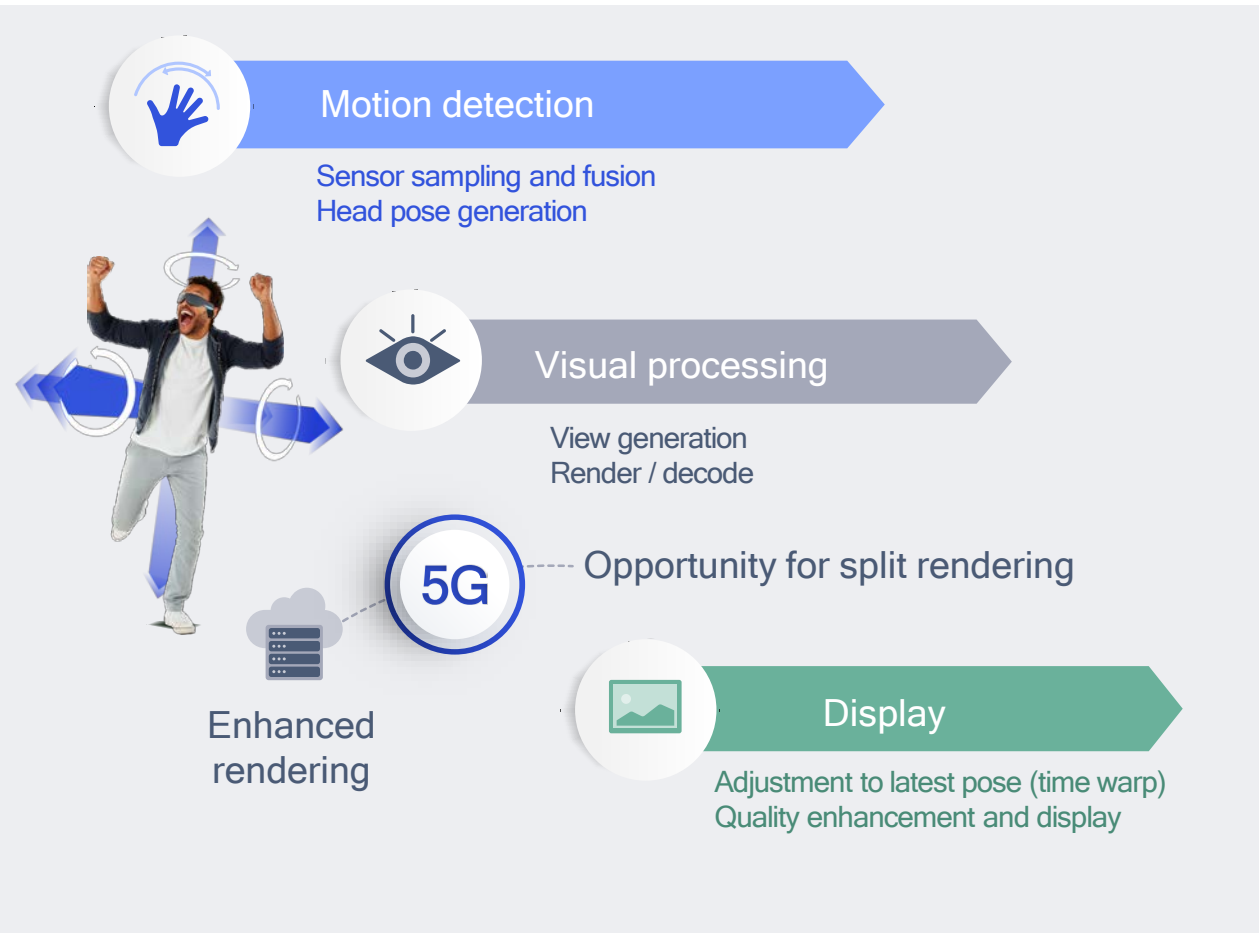# Minimizing motion to photon latency is crucial for immersion

Low latency

Noticeable latency

Lag prevents immersion and can cause discomfort

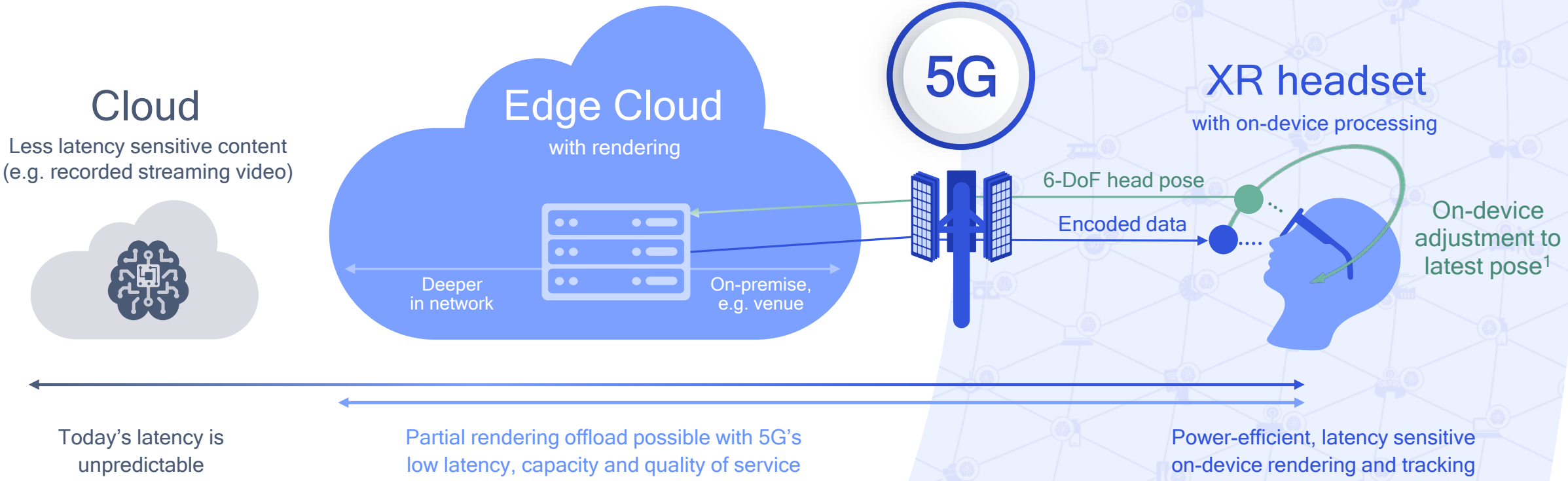# Workloads must run efficiently on-device at low latency

Motion detection

Sensor sampling and fusion
Head pose generation

Visual processing

View generation
Render / decode

5G ----- Opportunity for split rendering

Enhanced rendering

Display

Adjustment to latest pose (time warp)
Quality enhancement and display

"Motion" — Total time (motion to photon latency) for steps must be less than 20 milliseconds
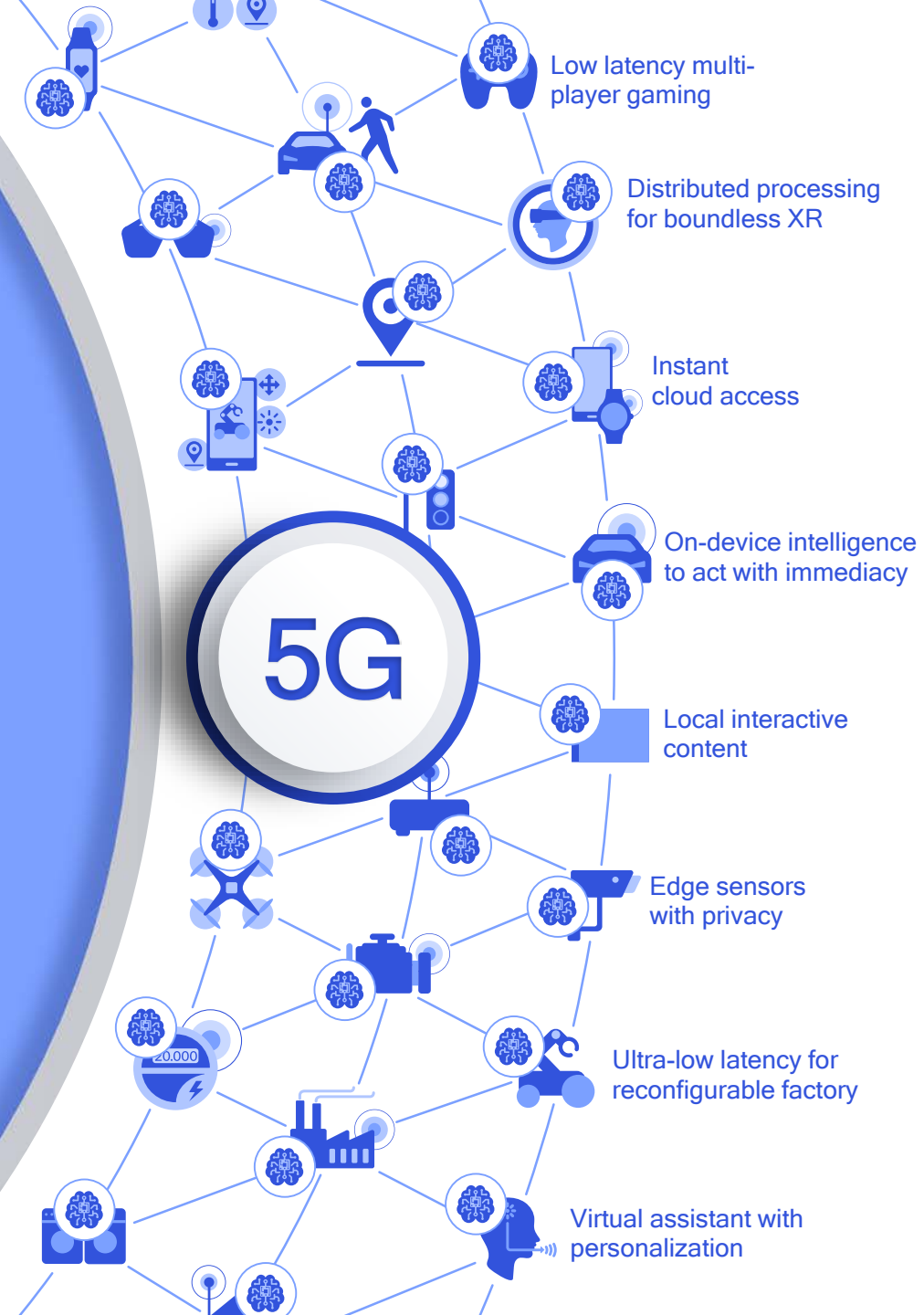
"Photon" (new pixels' light emitted from the screen)

Augment on-device processing for boundless photorealistic mobile XR

Cloud
Less latency sensitive content
(e.g. recorded streaming video)

Edge Cloud
with rendering

Deeper
in network

On-premise,
e.g. venue

5G

XR headset
with on-device processing

6-DoF head pose

Encoded data

On-device
adjustment to
latest pose[1]

Today's latency is
unpredictable

Partial rendering offload possible with 5G's
low latency, capacity and quality of service

Power-efficient, latency sensitive
on-device rendering and tracking

1. Asynchronous time warp reduces Motion to Photon (MTP) latency by using on-device processing based on the latest available pose. MTP below 20 ms generally avoids discomfort – has to be processed on the device

The wireless edge transformation realizes the full potential of 5G

○ New experiences with new levels of immersion, immediacy, personalization and privacy

○ Creating new industries and transforming existing industries in the new era of distributed autonomy

○ Essential on-device capabilities augmented with processing/compute, content, control,… at edge cloud

5G

Low latency multi-player gaming

Distributed processing for boundless XR

Instant cloud access

On-device intelligence to act with immediacy

Local interactive content

Edge sensors with privacy

Ultra-low latency for reconfigurable factory

Virtual assistant with personalization

12

Our technologies are transforming the wireless edge today

Inventing technology at scale to realize the promise of massive on-device AI

Providing the connectivity fabric with LTE, Wi-Fi, Bluetooth today
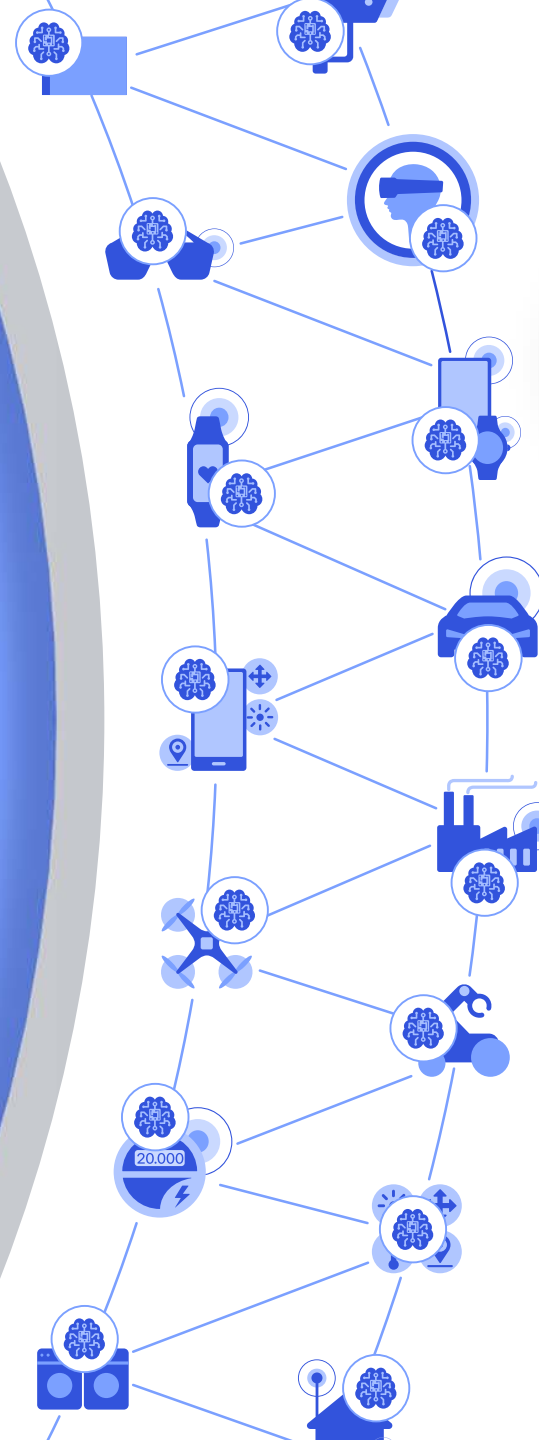
Security

Sensing
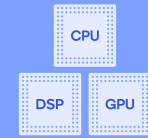
Processing
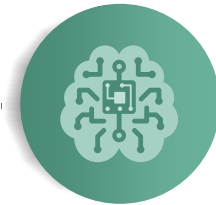
Connectivity

Edge services

On-device AI

Perceive
Hear, see, monitor, and observe
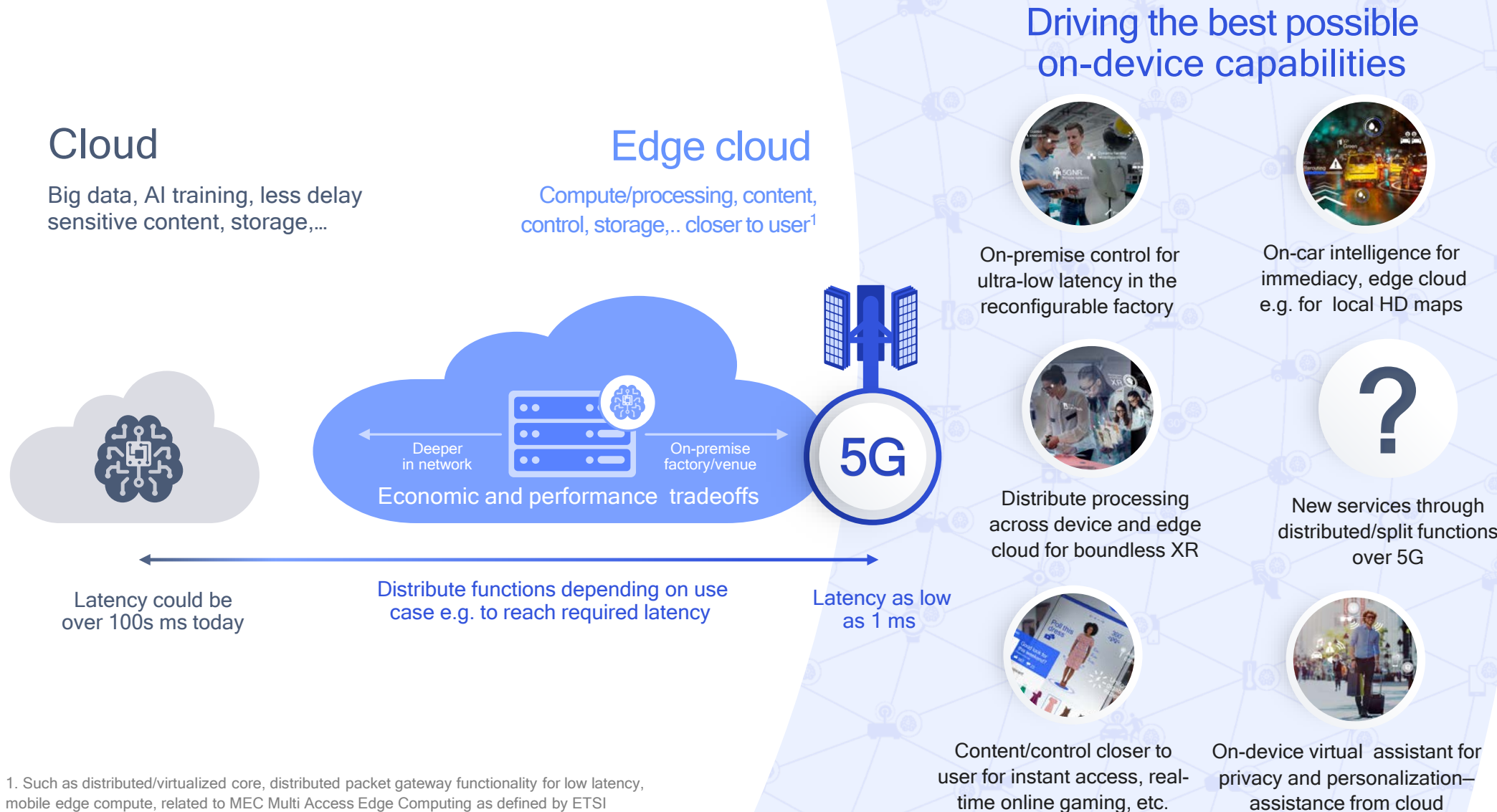
Reason
Learn, infer context, and anticipate

Act
Act intuitively, interact naturally, and protect privacy

Distribute functions based on economic and performance tradeoffs for use case

Cloud

Big data, AI training, less delay sensitive content, storage,…

Edge cloud

Compute/processing, content, control, storage,.. closer to user[1]

Economic and performance tradeoffs

Deeper in network ← → On-premise factory/venue

5G

Latency could be over 100s ms today

Distribute functions depending on use case e.g. to reach required latency

Latency as low as 1 ms

Driving the best possible on-device capabilities

On-premise control for ultra-low latency in the reconfigurable factory

On-car intelligence for immediacy, edge cloud e.g. for local HD maps

Distribute processing across device and edge cloud for boundless XR

New services through distributed/split functions over 5G

Content/control closer to user for instant access, real-time online gaming, etc.

On-device virtual assistant for privacy and personalization– assistance from cloud

1. Such as distributed/virtualized core, distributed packet gateway functionality for low latency, mobile edge compute, related to MEC Multi Access Edge Computing as defined by ETSI

Opportunity for operators to take advantage of the wireless edge transformation for XR

Enhanced mobile broadband with 5G

Enhanced XR experiences through increased capacity, lower latency, and uniform experience

Rich visual content

Interactive content

Frequent upload and download of XR content, virtually anywhere
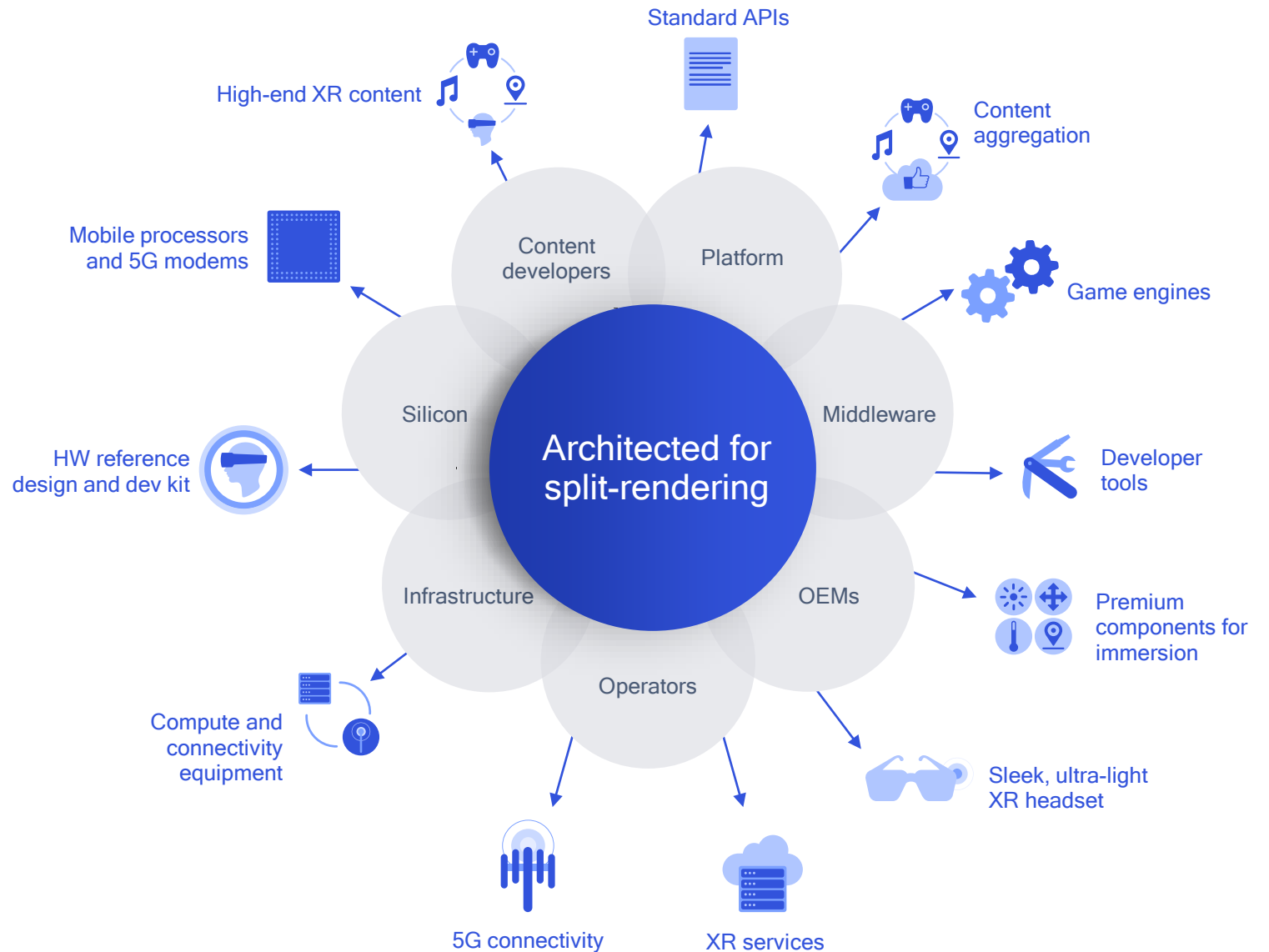
Services platform at edge cloud

Content processing, storage, and distribution as a service

Even lower latency with content closer to devices

Business and consumer applications for boundless XR

Synergy from the XR ecosystem working together

XR Industry benefits from increased consumer adoption

High-end XR content

Standard APIs

Content aggregation

Mobile processors and 5G modems

Content developers

Platform

Game engines

Silicon

Architected for split-rendering

Middleware

HW reference design and dev kit

Developer tools

Infrastructure

OEMs

Premium components for immersion

Compute and connectivity equipment

Operators

Sleek, ultra-light XR headset

5G connectivity

XR services

Real-time interactive collaboration

Bust
33-34½

Waist
24½-26½

Hip
33½-35½

Real-time insights

Days to market

Production estimate

37

2.3M

Distribution (K)

Color swatches

Orders (K)

360°

Six degrees
of freedom
XR

Bathilde
São Paulo

Aylin
Istanbul

Edge cloud
for low latency,
processing, content,...

Augmenting
on-device processing
and intelligence

Multi-player gaming
with photorealistic graphics

Next-gen 6-DoF video

*6 DoF: Six degrees of freedom

Our mobile office or living room,
virtually anywhere

Shopping like never before

Almost out of stock!
PLEATED A-LINE SKIRT

LONG SLEEVE ROMPER

Available in 3 more colors

25% OFF
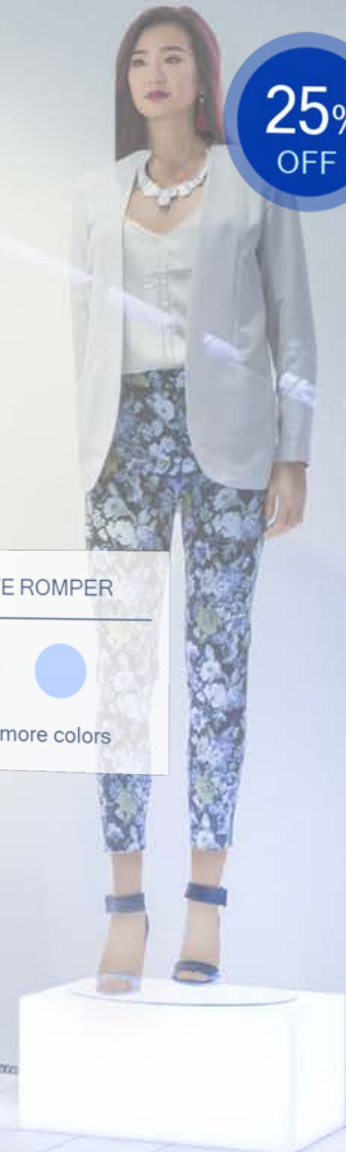
Supporting boundless mobile XR experiences

Split-rendering with 5G as the connectivity fabric

5G

Edge cloud
XR content partially rendered on powerful compute resources in the network

5G
Compressed content delivered via high-bandwidth, low-latency air interface

On-device processing
Power-efficient, high-performance, latency-sensitive on-device rendering and tracking

XR is meant to be mobile, and our superior on-device processing powers immersive experiences today

Boundless XR with photorealistic visuals is possible by augmenting on-device processing with edge cloud rendering over 5G

Our leadership in on-device processing and 5G at the wireless edge is helping drive the industry to boundless XR

The wireless edge transformation realizes full potential of 5G for a plethora of other applications

Thoth
played many vital roles in Egyptian mythology, such as maintaining the universe, and being one of the two deities who stood on either side of Ra's boat.

Qualcomm

Thank you

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