August 2018

@qualcomm_tech

Qualcomm

The wireless edge transformation has begun and will realize 5G's full potential

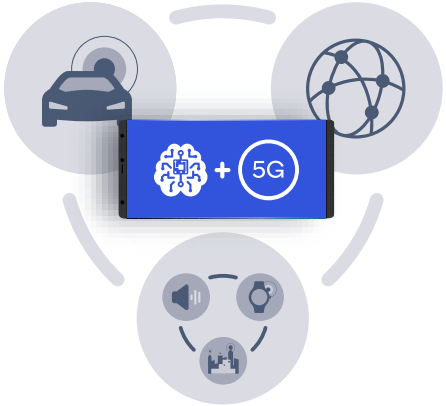
Leading mobile innovation for over 30 years

Digitized mobile communications

Analog
to digital

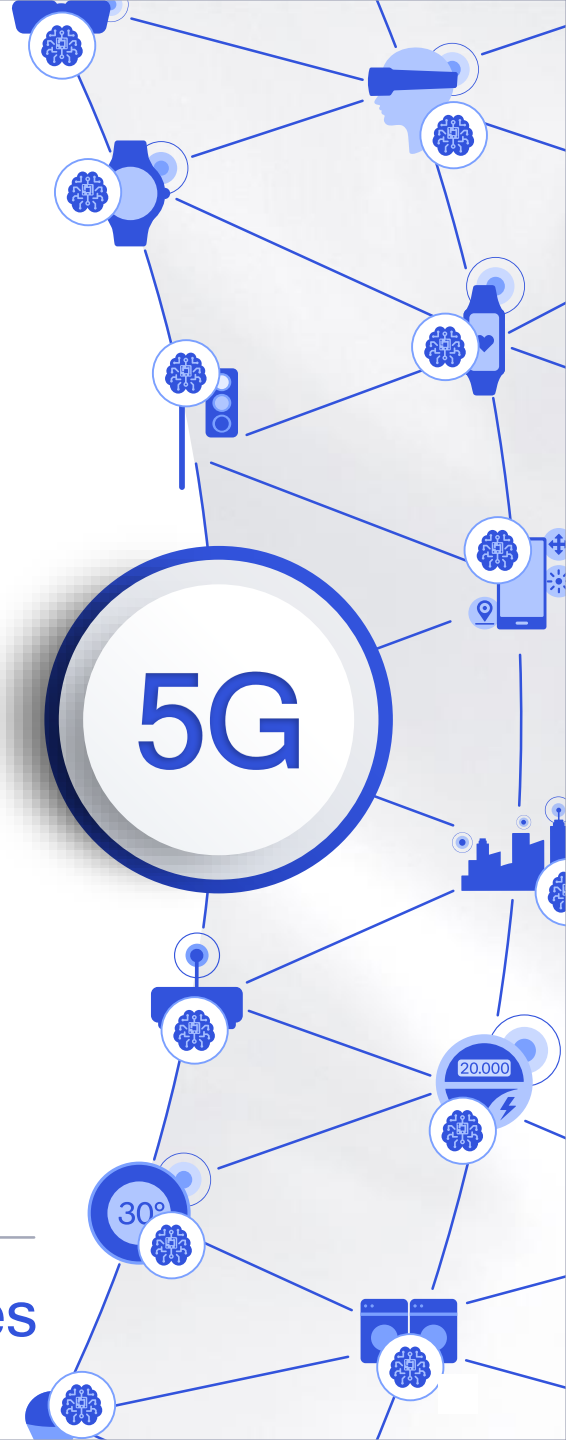
Redefined computing

Desktop to
smartphones



Transforming industries

Connecting virtually everything
at the wireless edge



Transforming how the world connects, computes and communicates

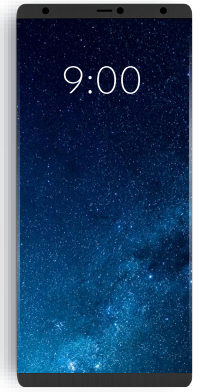
Making 5G a reality in 2019

Industry-leading R&D

5G interoperable global standards

End-to end system prototypes and test beds

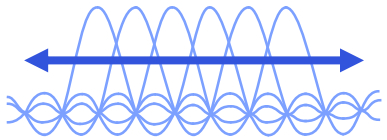
Commercial chipsets: Qualcomm® Snapdragon™ X50 5G modem



Commercial networks and products

Our technology inventions drove Rel-15 specifications

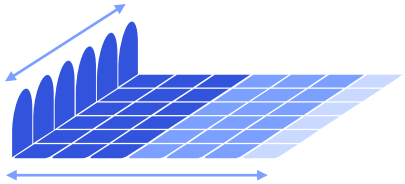
Scalable OFDM-based air interface



Scalable OFDM numerology

Address diverse spectrum, deployments/services

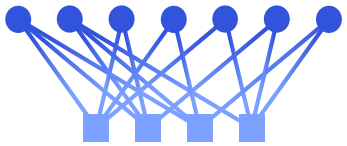
Flexible slot-based framework



Self-contained slot structure

Low latency, URLLC, forward compatibility

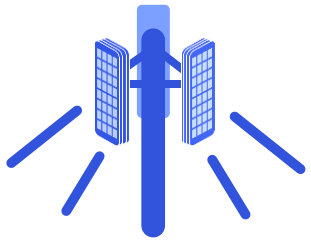
Advanced channel coding



Multi-Edge LDPC and CRC-Aided Polar

Support large data blocks, reliable control channel

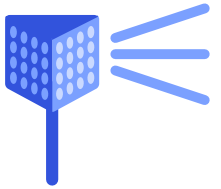
Massive MIMO



Reciprocity-based MU-MIMO

Large # of antennas to increase coverage/capacity

Mobile mmWave



Beamforming and beam-tracking

For extreme capacity and throughput

Early R&D investments | Best-in-class prototypes | Fundamental contributions to 3GPP

World’s first 5G NR milestones led by Qualcomm

ZTE中兴

World’s first interoperable 5G NR sub-6 GHz data connection

November 2017

ERICSSON

World’s first interoperable 5G NR mmWave data connection

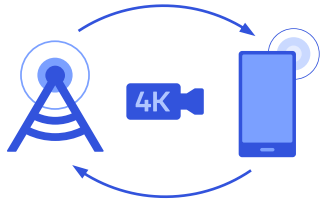
December 2017

NOKIA

Successful multi-band 5G NR interoperability testing

February 2018

SAMSUNG HUAWEI



GSMA MOBILE WORLD CONGRESS

Interoperable 5G NR sub-6 GHz & mmWave connections with 5 vendors

MWC 2018

大唐移动 DTmobile

5G NR interoperability testing preparing for the Chinese mass market

June 2018

Qualcomm snapdragon X50 5G modem

Rel-15 5G NR trials based on Snapdragon X50 modem chipset

2H-2018

Driving the 5G ecosystem towards 2019 launches in collaboration with 18+ global mobile network operators and 20+ device manufacturers

Operators select Snapdragon X50 5G modem for 5G NR trials in 2018

OEMs select X50 5G NR modem for global device launches in 2019

X50

5G Modem family

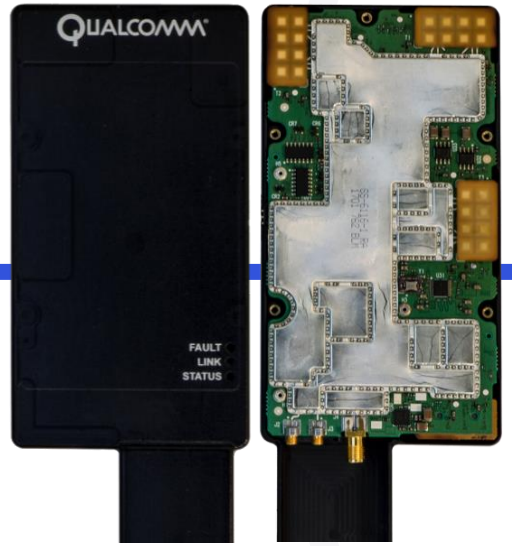
World’s first 5G NR multimode modems

- 2G/3G/4G/5G in a single chip
- Sub-6 + mmWave
- Premium-tier smartphones in 2019

Commercializing mmWave in a smartphone form factor

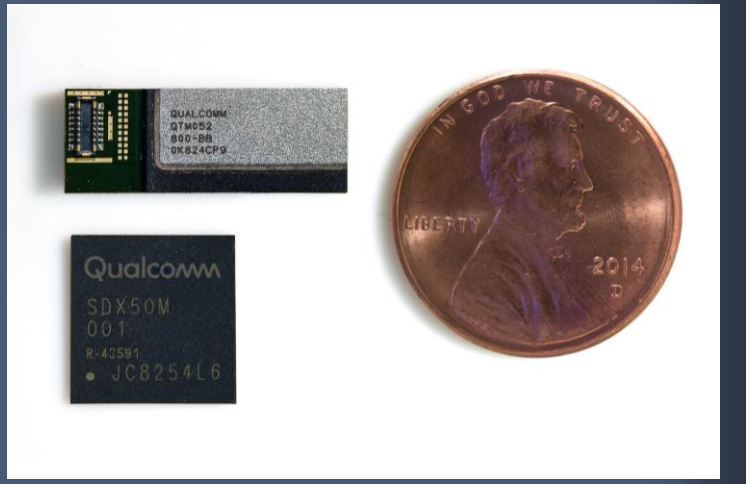
mmWave (60 GHz) viability in handset form factor

11ad in Asus
Zenfone 4 Pro



Qualcomm® 5G NR mmWave prototype

5G NR mmWave Qualcomm® Reference Design



Qualcomm®

QTM052 mmWave antenna modules

Making mobile mmWave viable and ready for commercialization

Smartphone form factor

Suitable for compact smartphone industrial designs with four mmWave modules

Fully-integrated mmWave RF

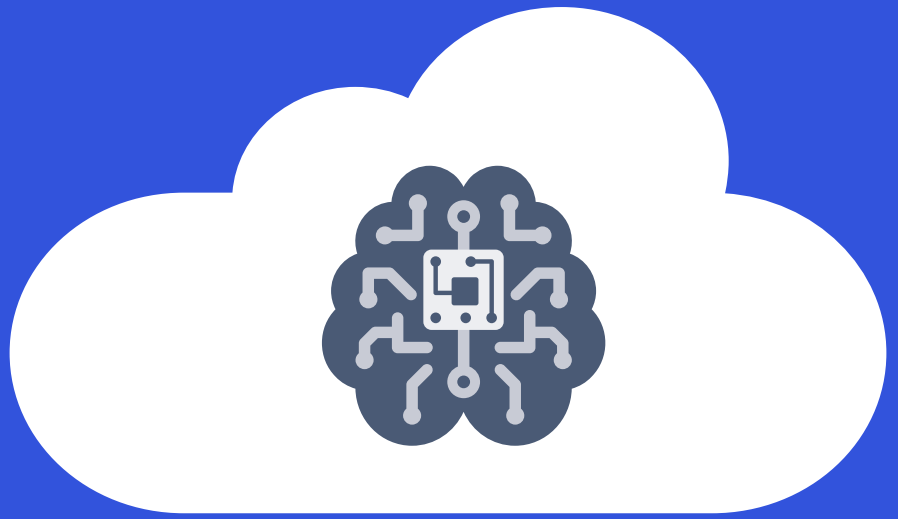
Including transceiver, PMIC, RF front-end components, and a phased antenna array

Newly supported mmWave bands

Supporting for up to 800 MHz of bandwidth in n257, n260, and n261 5G NR mmWave bands

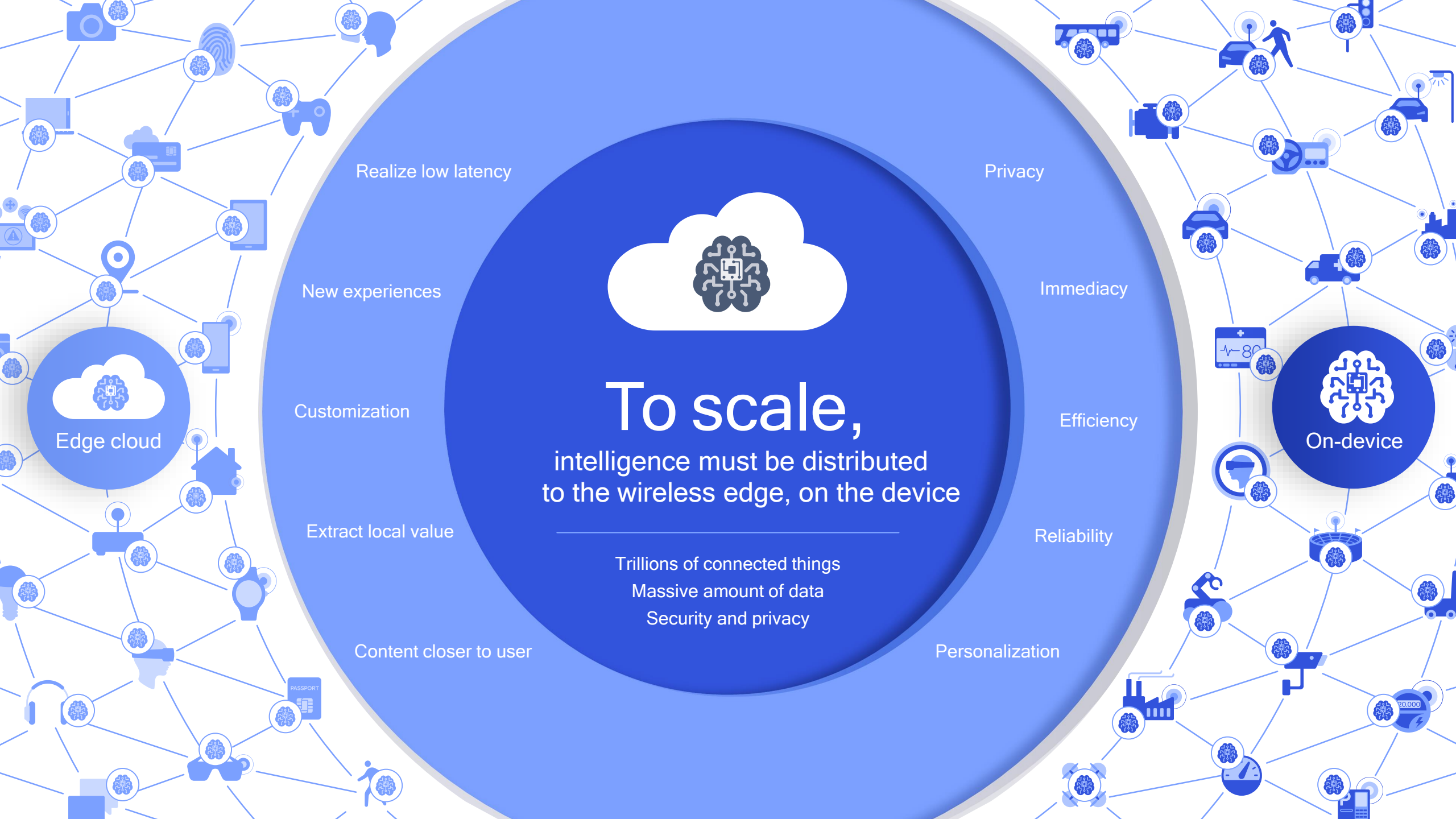
Advanced mobility features

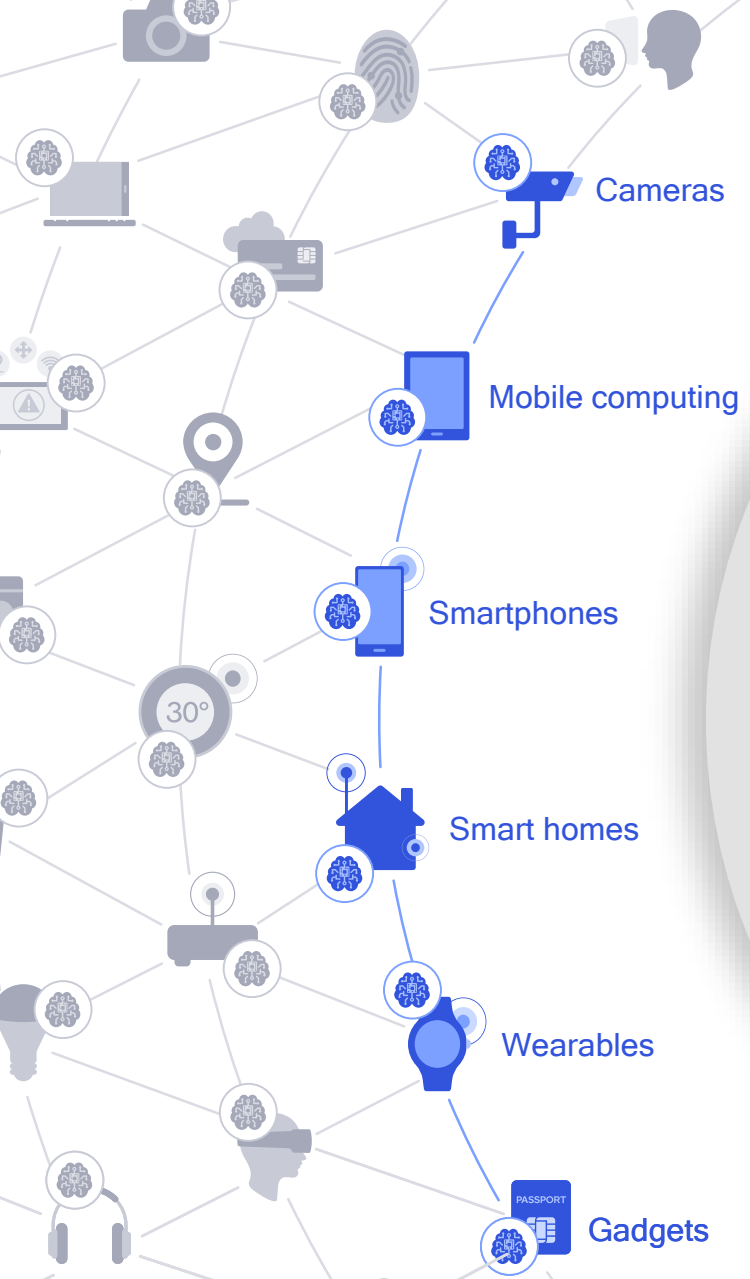
Supporting beamforming, beam steering, and beam tracking for bi-directional mmWave communications



Today,

intelligence is primarily associated with the cloud


Realize low latency
New experiences
Customization
Extract local value
Content closer to user
Privacy
Immediacy
Efficiency
Reliability
Personalization
Edge cloud
On-device
To scale,
intelligence must be distributed
to the wireless edge, on the device
Trillions of connected things
Massive amount of data
Security and privacy



Mobile is becoming the pervasive AI platform bringing broader

Societal benefits

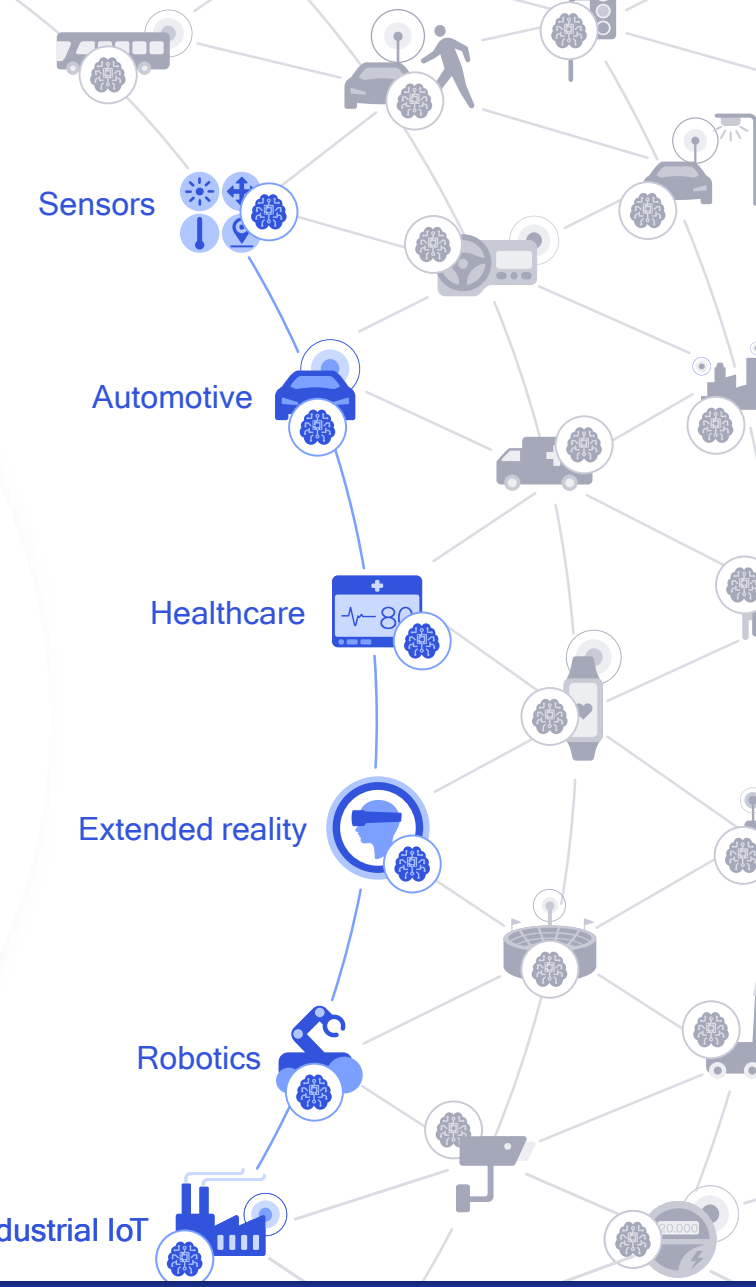
and the promise of massive on-device AI

Rapid replacement cycles

Superior scale

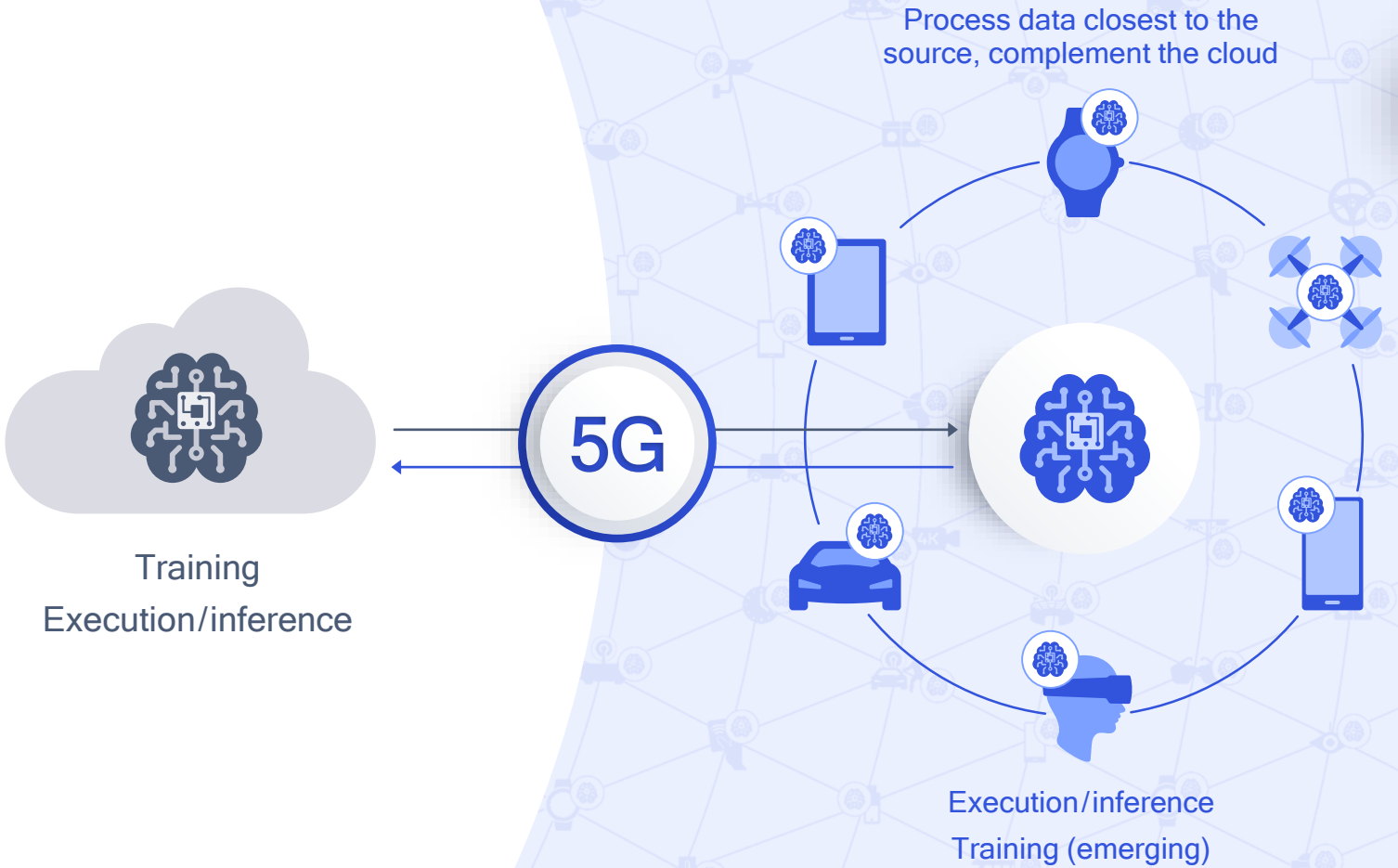
Power/thermal efficiency

Integrated/ optimized technologies



Driver safety	Virtual assistant	Enhanced security	Superior photography	Healthcare and more...

On-device intelligence is paramount



Perceive
Hear, see, monitor, and observe

Reason
Learn, infer context, and anticipate

Act
Intuitively, interact naturally, protect privacy

- Privacy
- Reliability
- Immediacy
- Efficiency
- Personalization

The challenge of AI workloads

- Compute intensive
- Large, complicated models
- Complex concurrencies
- Real-time
- Always-on

Constrained mobile environment

- Thermally efficient for sleek designs
- Requires long battery life for all-day use
- Storage/memory bandwidth limitations

Power and thermal efficiency

Critical to the promise of AI on a wide range of connected devices

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

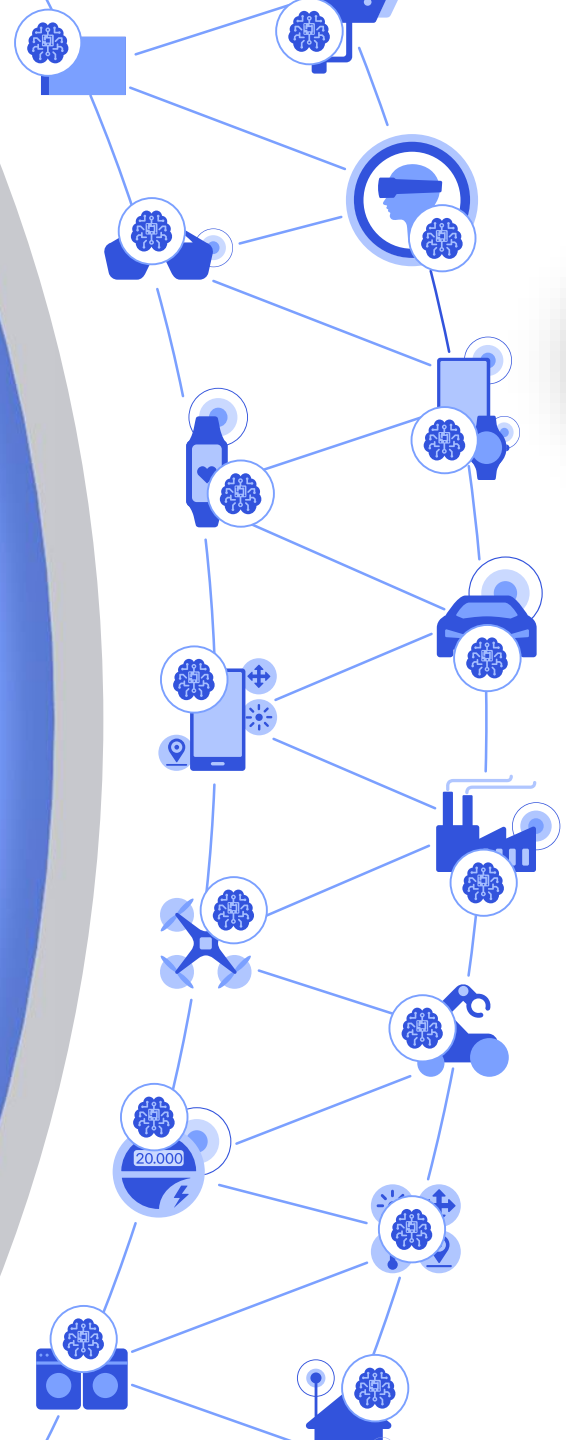
Sensing

CPU
DSP
GPU
Processing

Connectivity

Edge services

On-device AI



Perceive
Hear, see, monitor, and observe

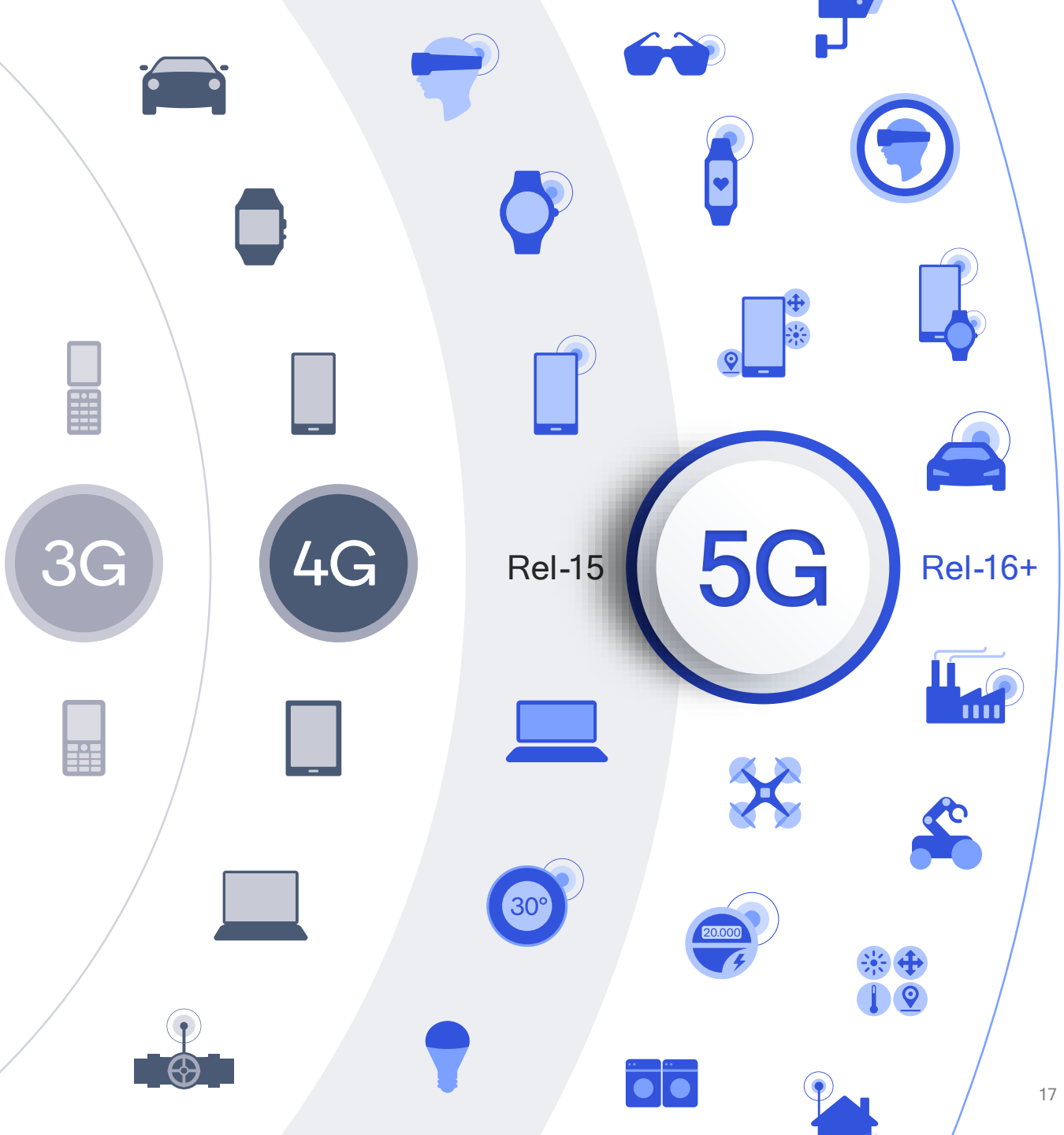
Reason
Learn, infer context, and anticipate

Act
Act intuitively, interact naturally, and protect privacy

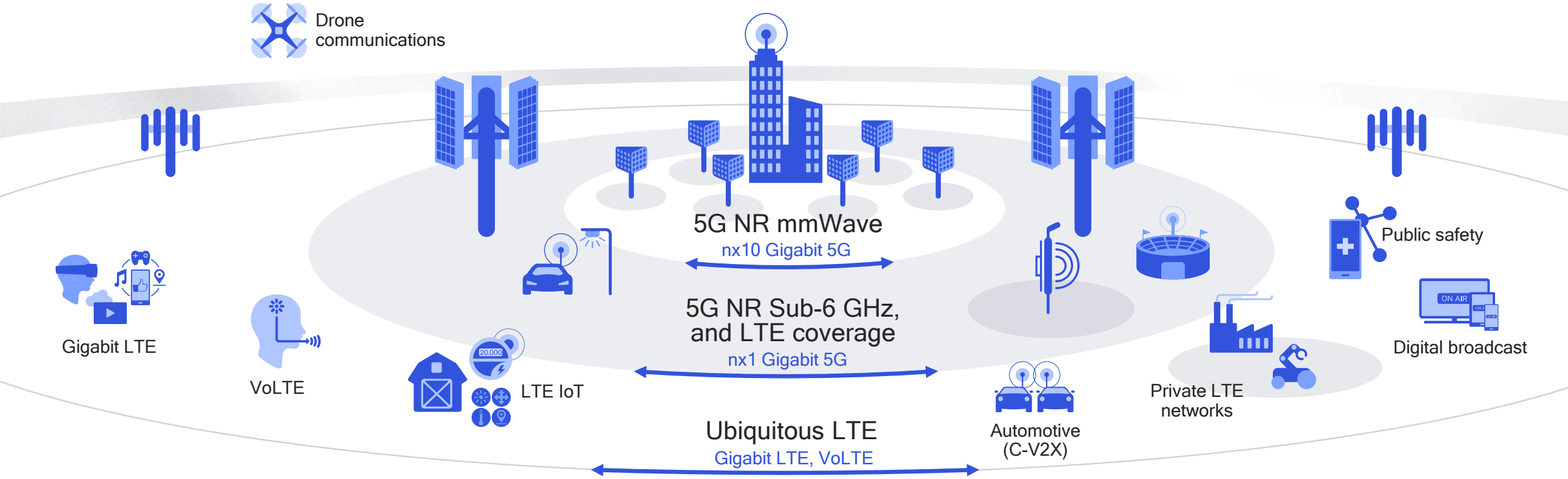

A unifying connectivity fabric for society
Like electricity, you will just expect it everywhere
5G
Scalable to extreme simplicity
Multi-gigabit speed
Ultra-low latency
Virtually unlimited capacity
Extreme reliability
On-device intelligence

Leading society to 5G

And the expansion of the 5G ecosystem



LTE Advanced Pro accelerates the ecosystem expansion



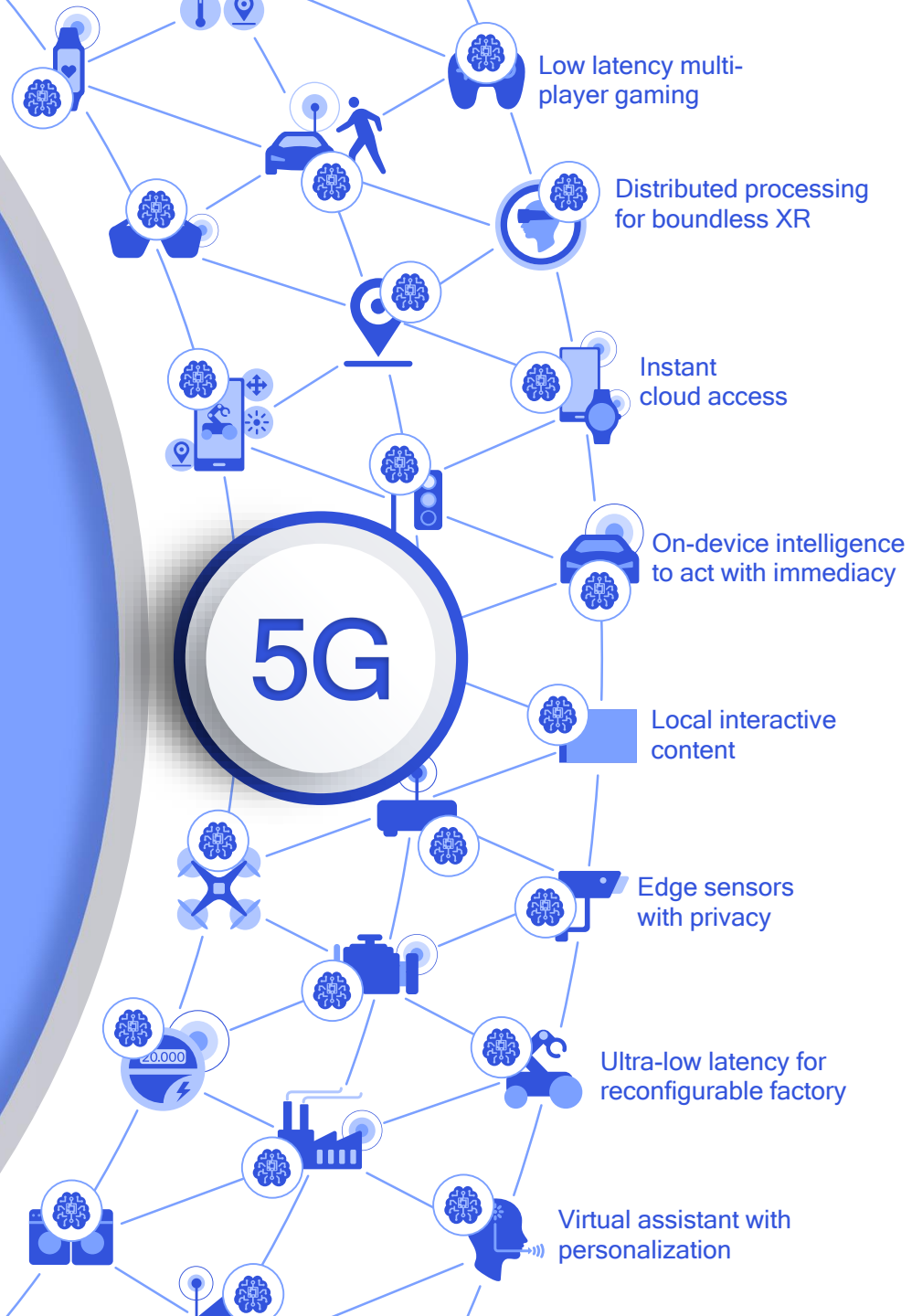
A unifying connectivity fabric for the wireless edge

Connecting virtually everything, an innovation platform for future services

- Extreme mobile broadband
- Mission-critical services
- Massive Internet of Things

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



Enhancing services, creating new services, new deployment models with our end-to-end expertise

Cloud

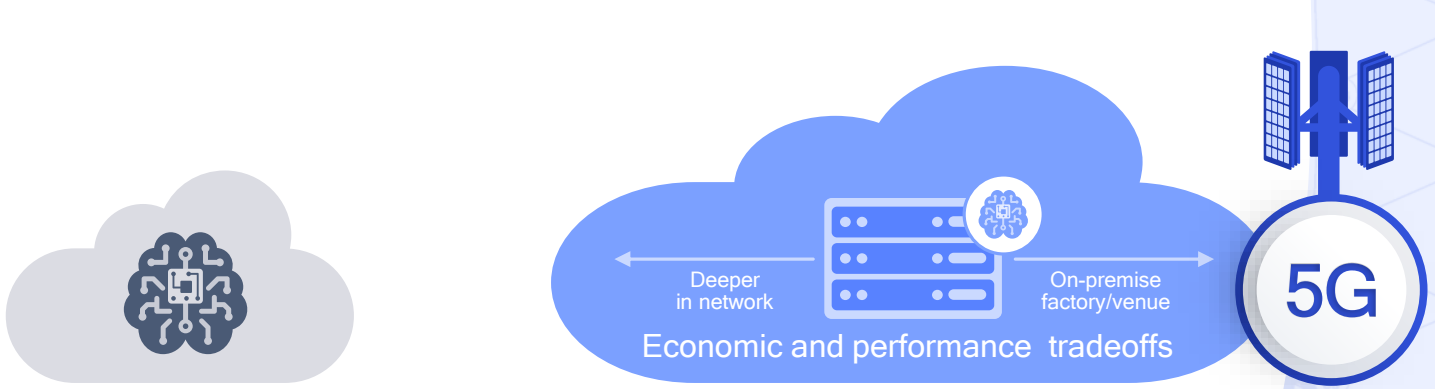
Big data, AI training, less delay sensitive content, storage,…

Augmented by edge cloud

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

Driving the best possible on-device capabilities

Sensing, processing, security, intelligence



Latency could be over 100s ms today

Latency as low as 1 ms

Cooperation between operators, infra vendors, OEMs, content providers, cloud providers,…

- Realize 5G's low latency
- Distributed/split functions over 5G
- Extract value – vs. 'dumb' data pipe
- Customization, local value
- New deployments, like private networks

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

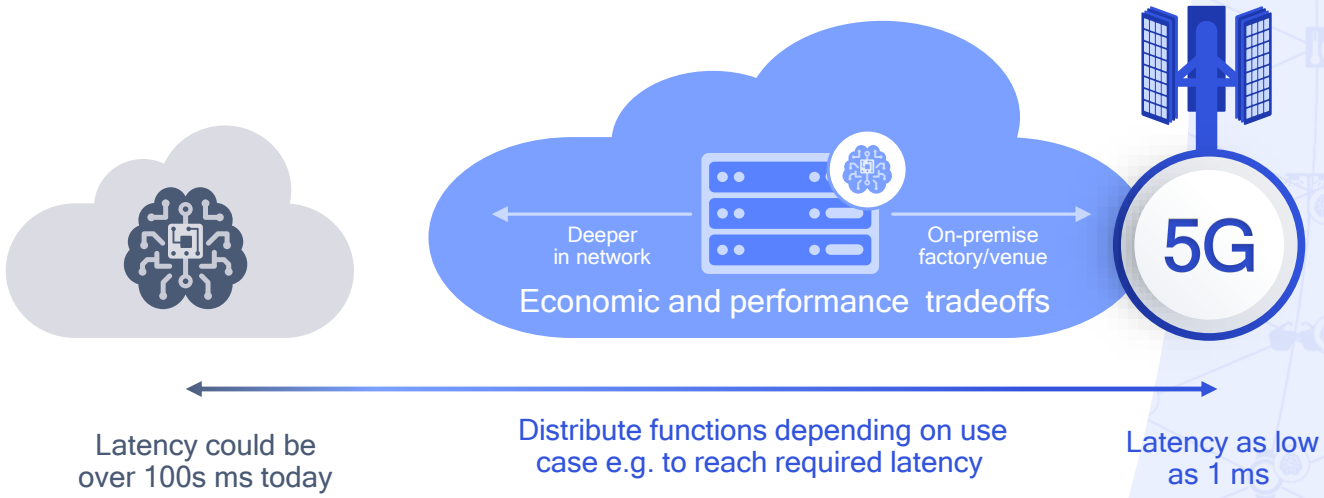
Distribute functions based on economic and performance tradeoffs for use case

Cloud

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

Edge cloud

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



Driving the best possible on-device capabilities

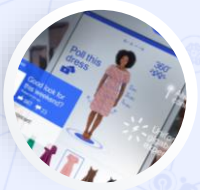
On-premise control for ultra-low latency in the reconfigurable factory

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

Distribute processing across device and edge cloud for boundless XR

?

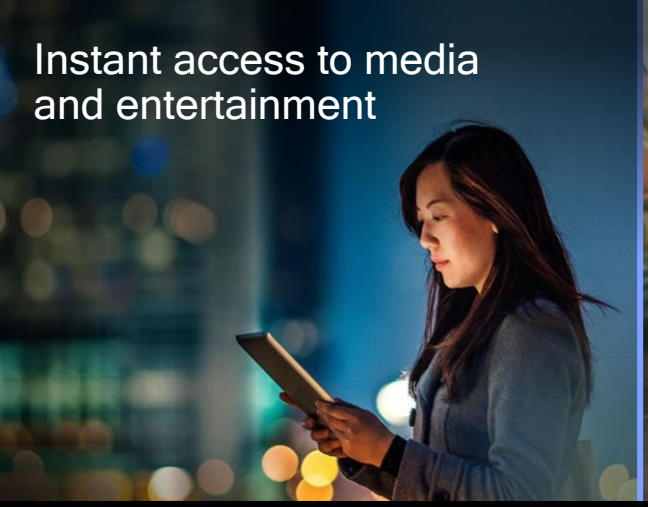
New services through distributed/split functions over 5G

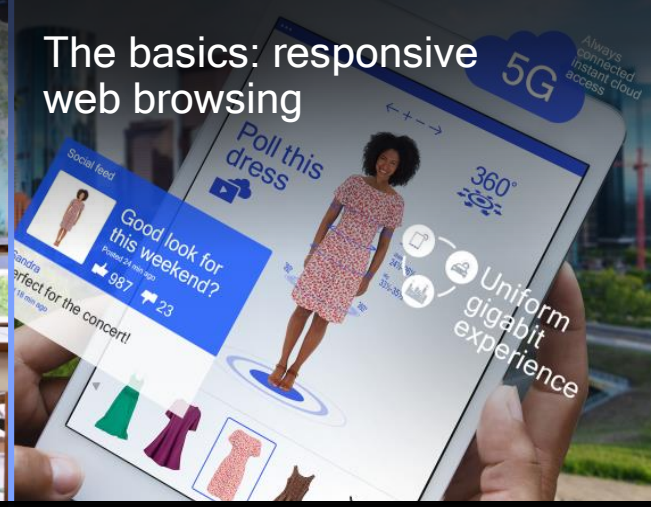


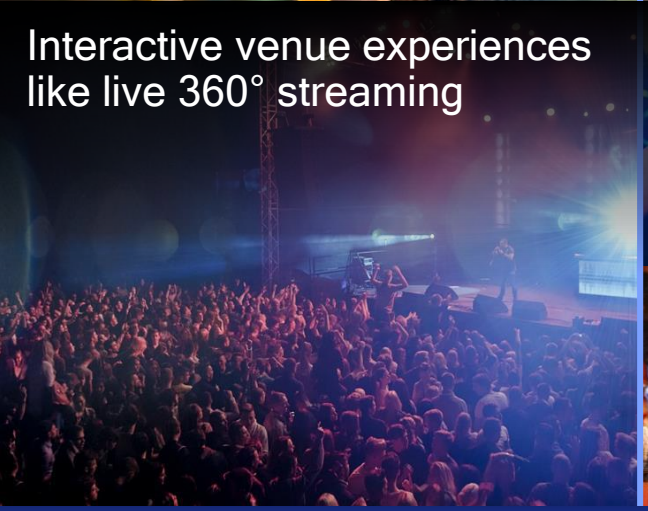
Content/control closer to user for instant access, real-time online gaming, etc.

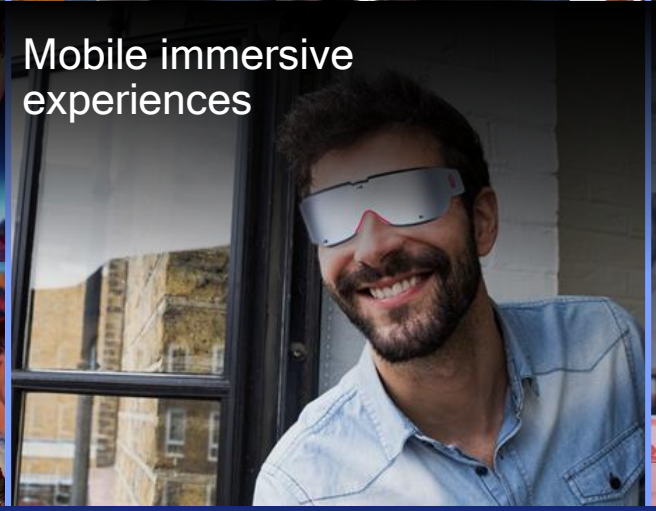
On-device virtual assistant for privacy and personalization– assistance from cloud

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









5G

- Fiber-like data speeds
- Low latency
- Uniform performance
- Massive capacity

+

- Content/control closer to user
- Realization of low latency
- Customized local value
- Augment on-device processing

=

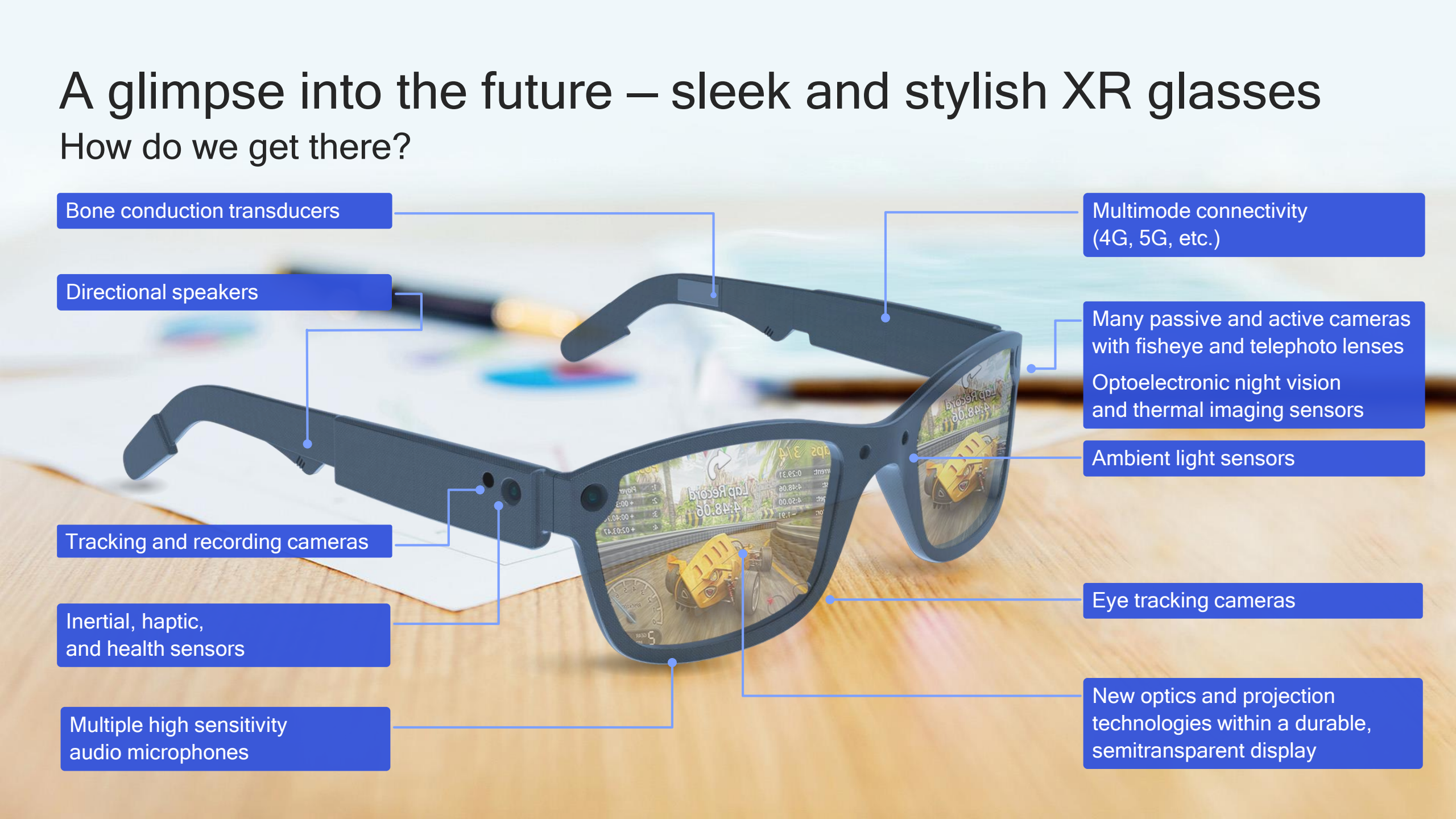
Enhanced and entirely new experiences

5G’s capacity and latency for shared venue experiences

Augment on-device processing for boundless photorealistic mobile XR

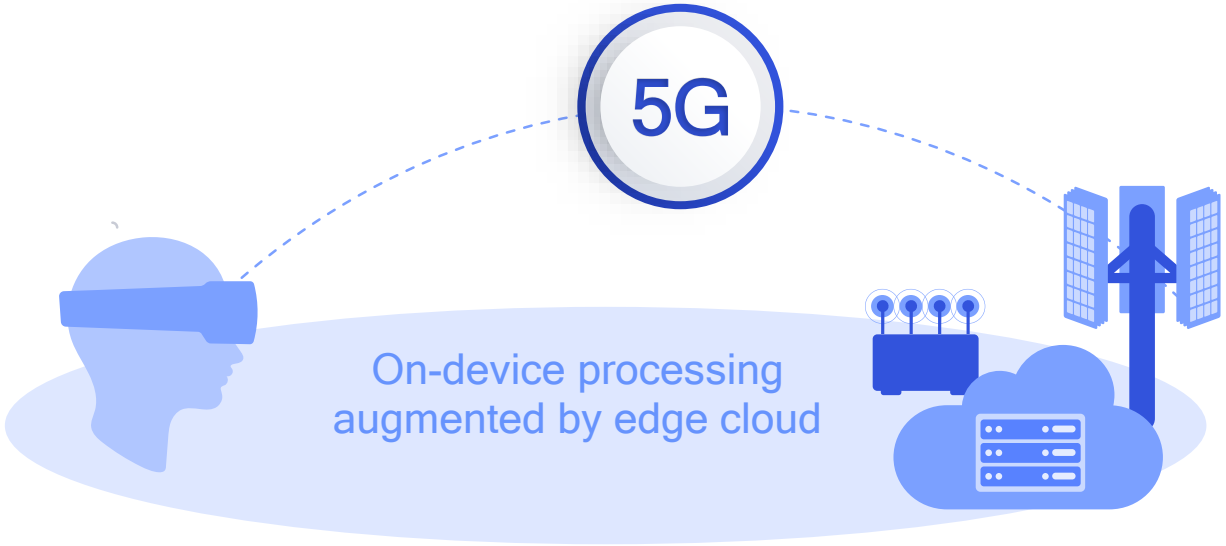
A glimpse into the future – sleek and stylish XR glasses

How do we get there?



Boundless mobile XR – experience the best XR anywhere

On-device processing,
access to rich content



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

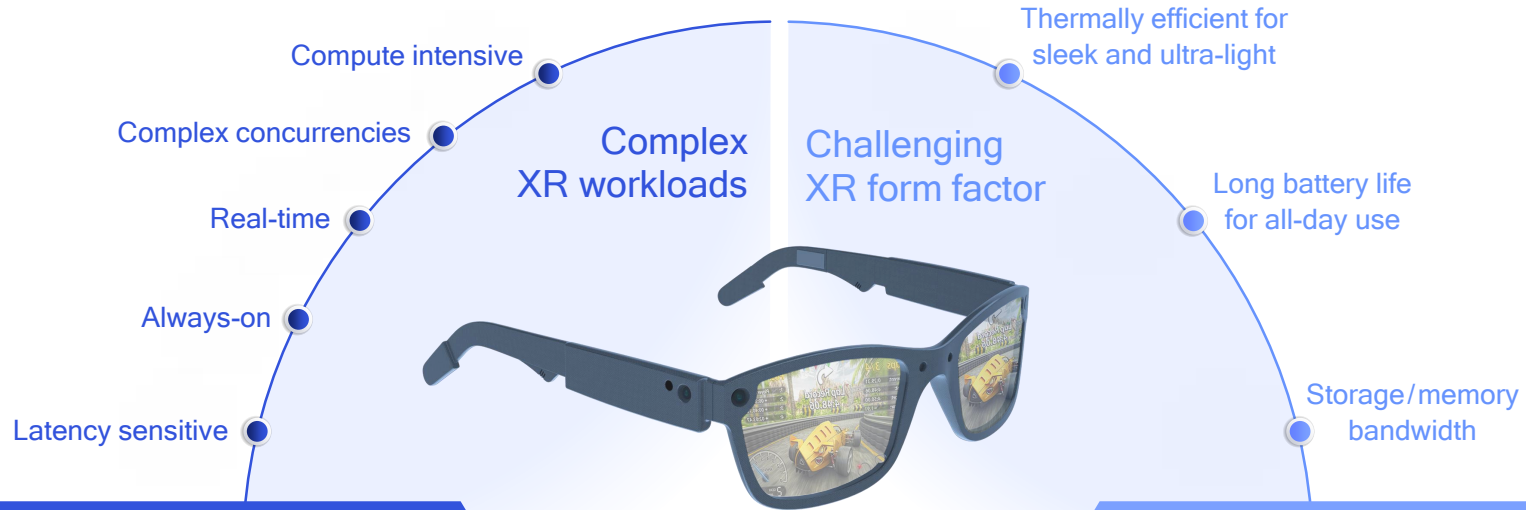
Photorealistic graphics and visuals

Enhanced experience where possible with new split-rendering architecture

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

We are working with the ecosystem to enable this

A new era in distributed processing



Essential on-device processing

Optimized under strict power, thermal, size constraints

Premium experiences today that continuously improve

Split rendering

5G

Low latency

High capacity

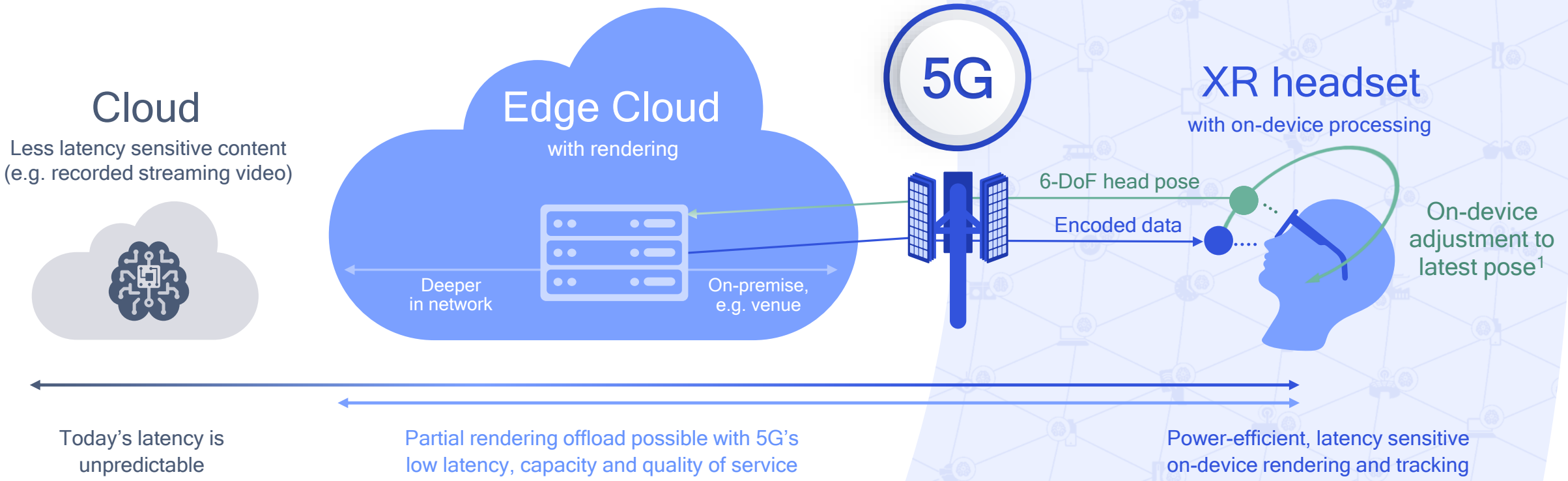
Reliable link

Augment by edge cloud processing

Significant higher power envelope–beyond PC class

Augment on-device rendering with edge cloud rendering

Augment on-device processing for boundless photorealistic mobile XR



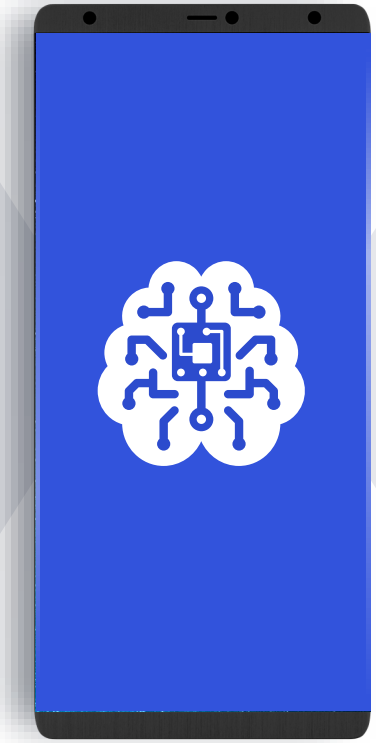
1. Asynchronous time warp reduces Motion to Photon (MTP) latency by using on-device processing based on the latest available pose. MTP below 20 ms generally avoids discomfort – has to be processed on the device

AI offers enhanced experiences and new capabilities for smartphones

True personal assistance

Extended battery life

Enhanced connectivity



Superior photography

Natural user interfaces

Enhanced security

A new development paradigm where things repeatedly improve

Voice is the transformative user interface (UI) we've been waiting for

Designed to be

Always-on

Conversational

Personal

Private

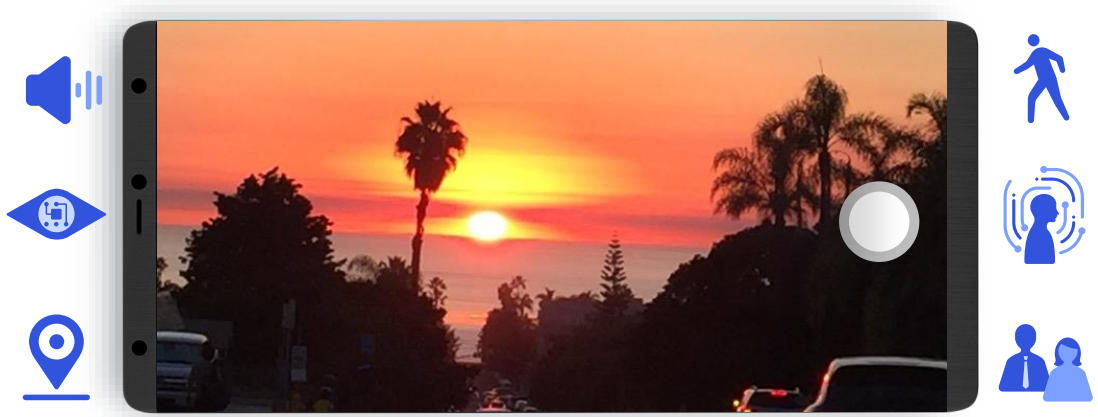
Critical to create a true virtual assistant

A context aware and personalized "digital me" sitting on the device

A true personal assistant is responsive and proactive

Responsive

Based on contextual analysis and prompting
(e.g. finding memories)



"Remember the time I was strolling with my son after the party at La Jolla beach?"

"Yes I do, here is a picture you took of the sunset. Should I share it with your family group on WeChat?"

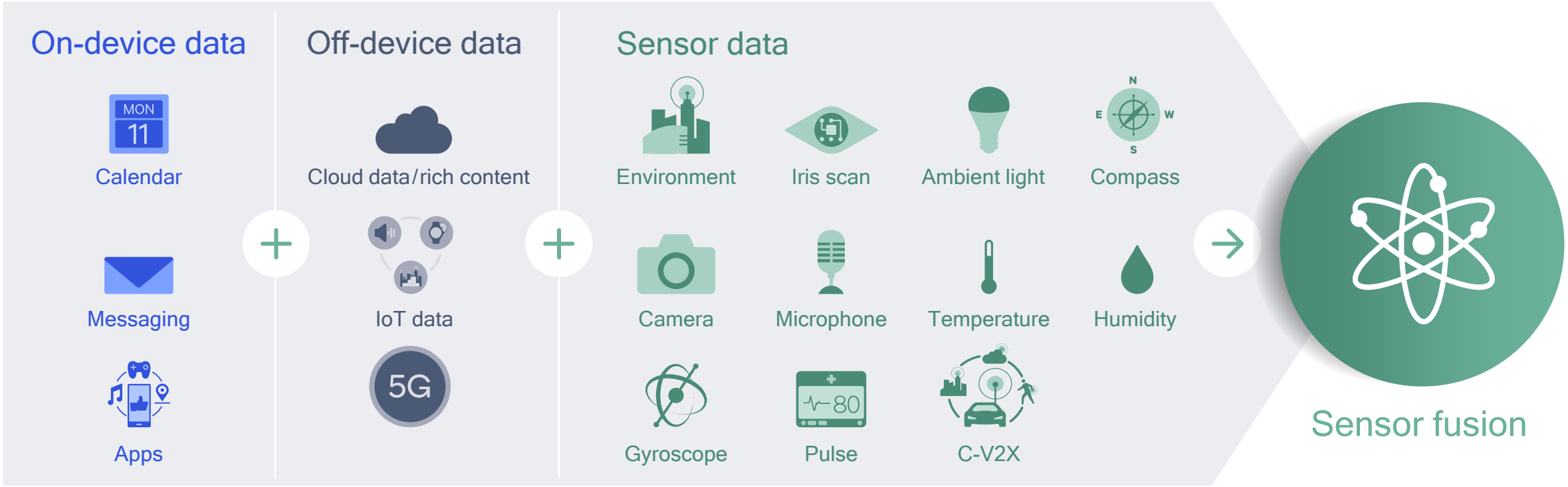
Proactive

Based on contextual analysis without prompting
(e.g. automatically sharing memories)

"I noticed that you are tired and stressed, I'm turning on the Rocky III soundtrack and navigating you to the gym for a workout and sauna."

"This music gets my blood going and a workout and sauna will help me relieve stress."

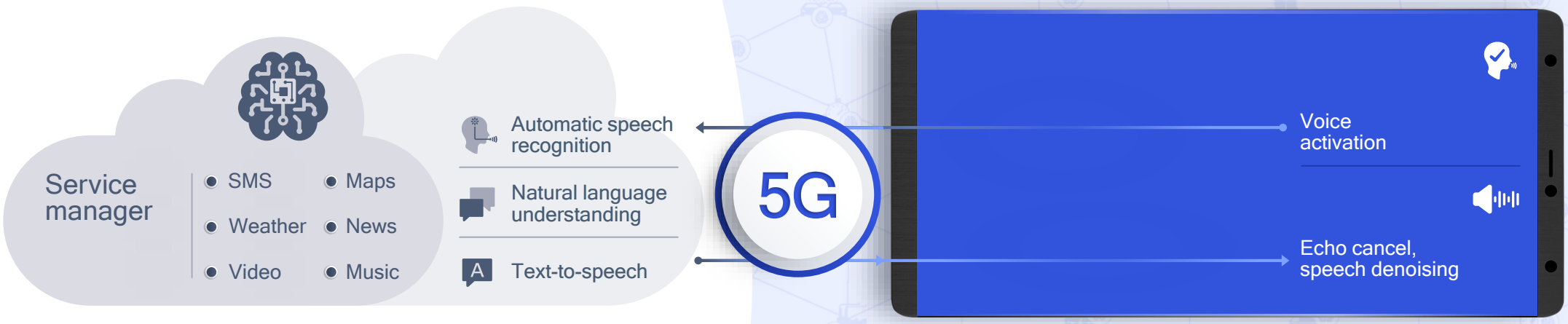
Contextual intelligence required for personalization



The local fusion of many types of sensors and personal information

On-device AI creates a true personal virtual assistant

Cloud-centric (today)



less privacy and personalization

Access to rich content

On-device (future)

Continuously learns personal knowledge and acts intuitively with immediacy

Both ends are needed – but AI functions gradually moving on to the device

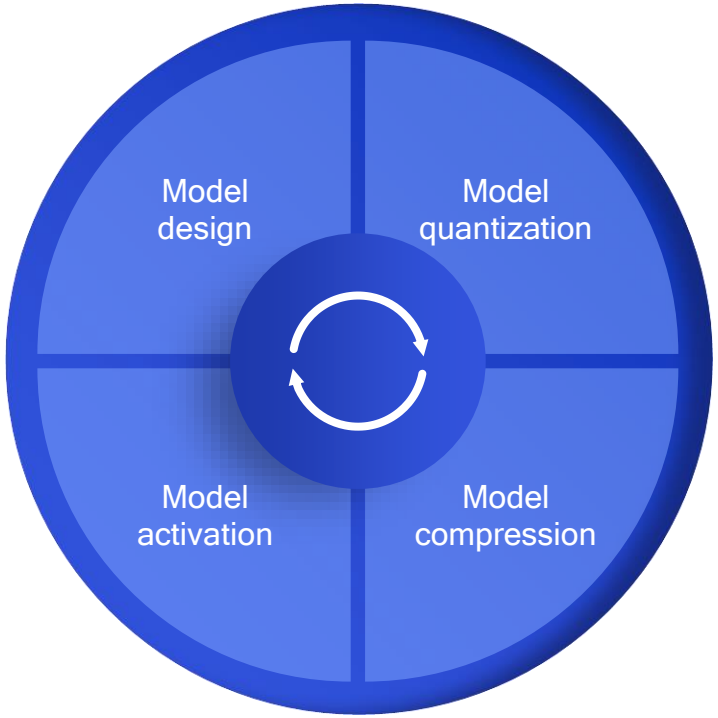
Qualcomm Technologies is making on-device AI ubiquitous

Efficient hardware

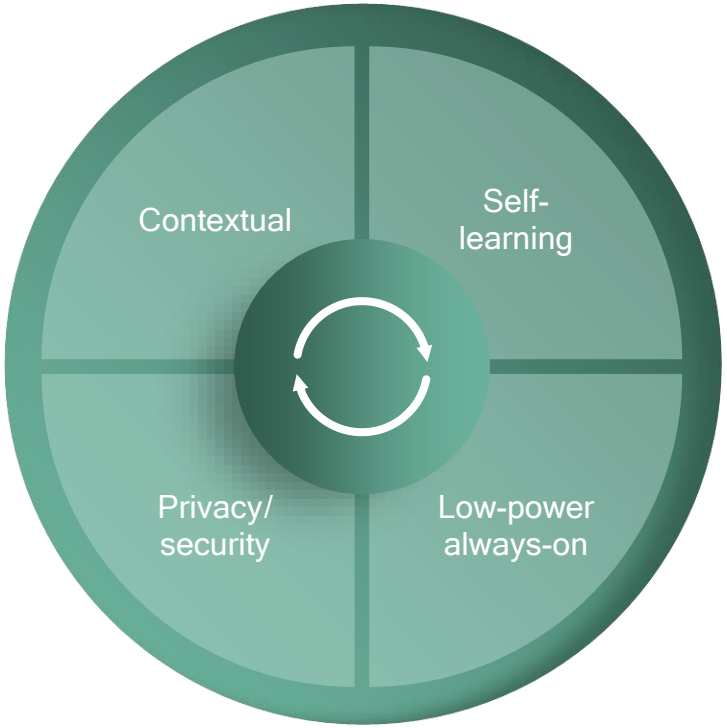
Algorithmic advancements

Software tools

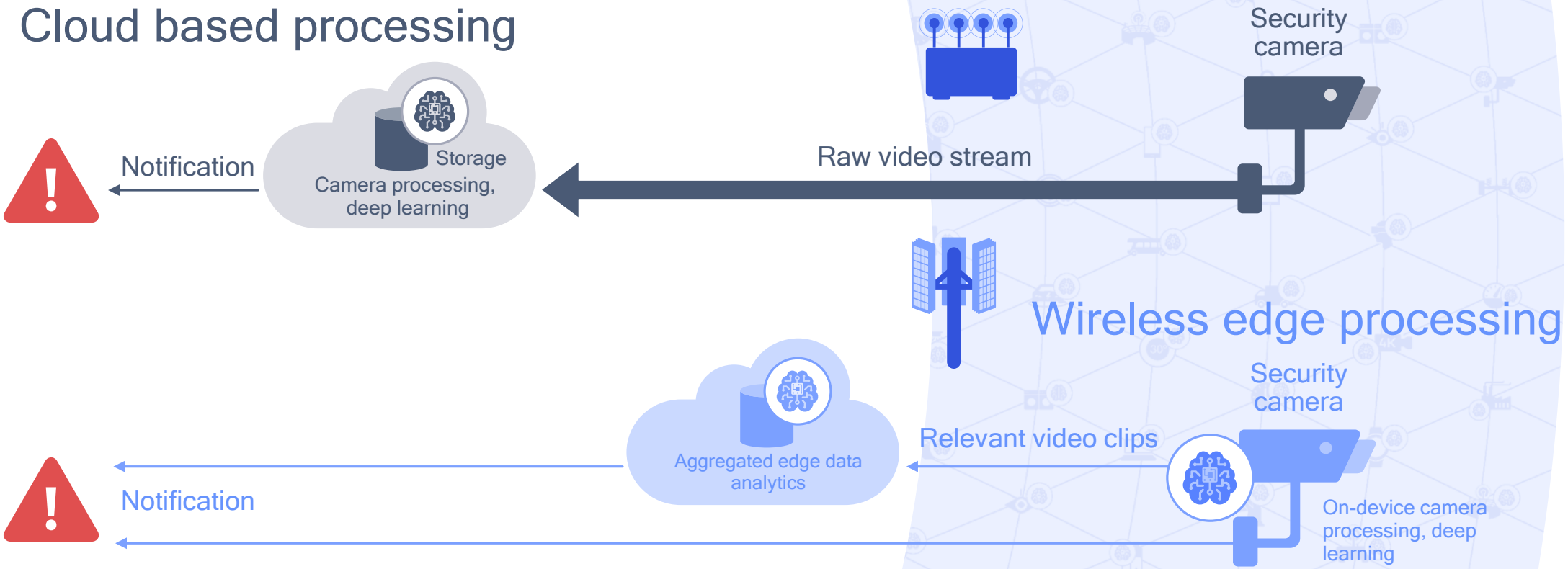
Power efficient AI



Personalized AI



All data should not go to the central cloud—especially private



Lower latency, privacy, on-device security, but also less bandwidth

AI in here. And everywhere.

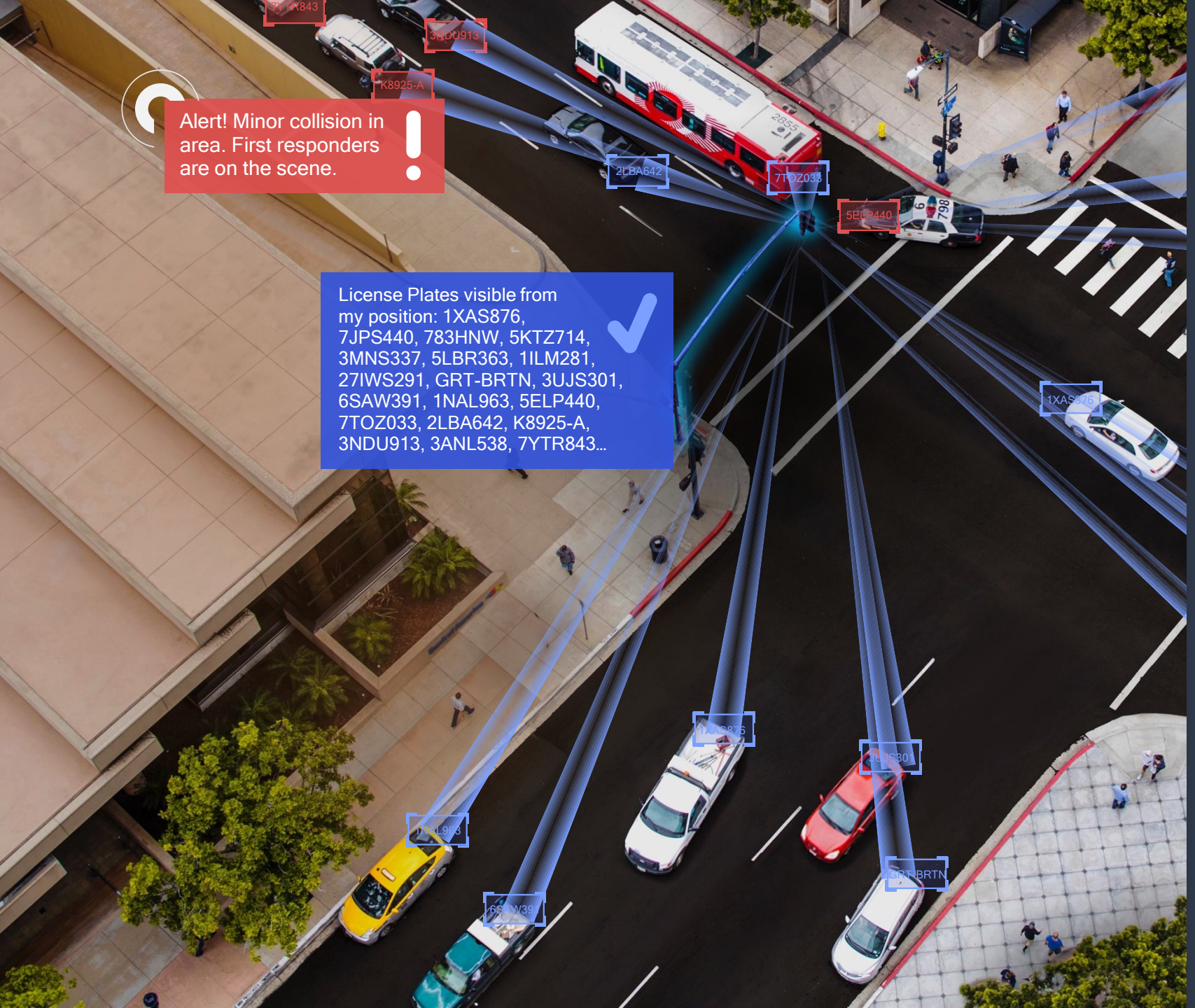
Advanced camera processing, powerful machine learning, and computer vision at the edge will allow new applications that push the boundaries of our connected world.

Intelligent cameras monitor and track what's inside.

Local at the edge processing means low latency and max efficiency.

Neural networks watch and learn your preferences.

Ubiquitous connectivity helps you avoid running out of critical food supplies



Intelligent Smart Cities

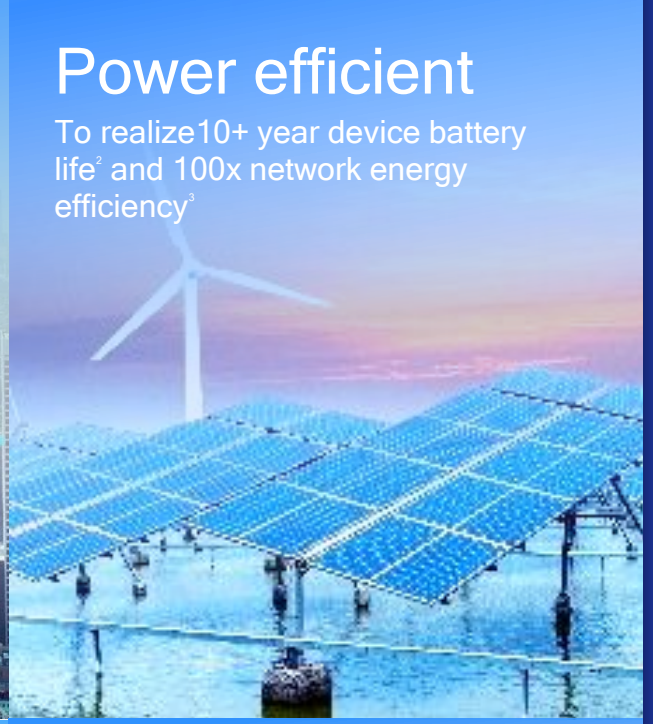
- Scene Classification
- License Plate Recognition
- Target Sound Detection

Massive scale

To efficiently support dense connections of 1+ million devices/km^2

Power efficient

To realize10+ year device battery life[2] and 100x network energy efficiency[3]

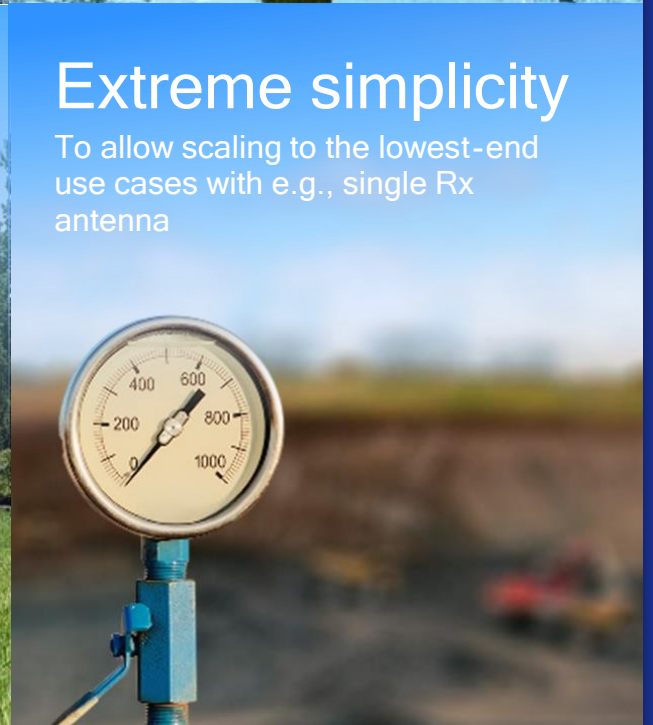


Long range

To reach challenging locations by achieving device link budget of 164 dB[1]

Extreme simplicity

To allow scaling to the lowest-end use cases with e.g., single Rx antenna



Scaling for the massive Internet of Things

Addressing growing needs of low-power, wide-area IoT use cases

1. Maximum Coupling Loss, assuming data rate of 160bps
2. Assuming 200B UL + 20B DL per day at 164 MCL with 5Wh battery
3. Compared to IMT-Advanced

5G IoT requires new solutions at the wireless edge

Opportunities

Monetize and manage massive amount of low-complexity things

Manage new, more intelligent devices and new use cases

New business and deployment model, like private networks for the Industrial IoT

Challenges

Trust and security

Large number of ecosystem participants

Total cost of ownership

HW/SW, life-cycle support, upgradeability

Our solutions

Trust environment rooted in HW

Device-cloud integration at scale

Zero-touch device life-cycle management

Trusted chipset services for enterprise and IoT providers

Trusted services to securely connect and manage devices

Qualcomm® wireless edge services cloud platform

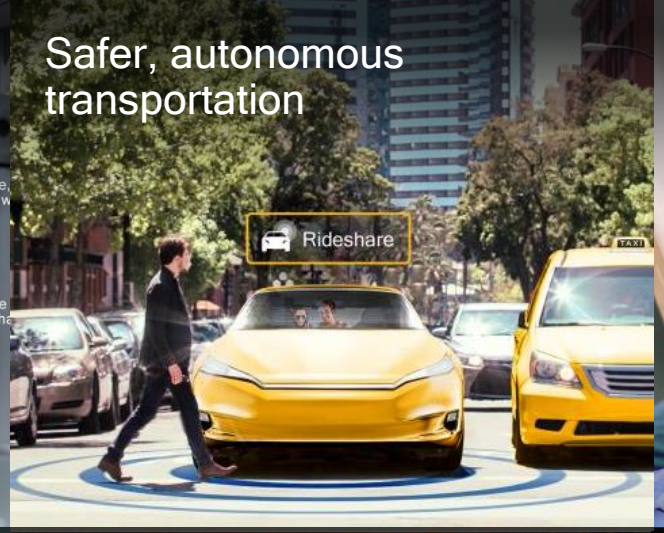
Unique device key embedded in chipset at factory

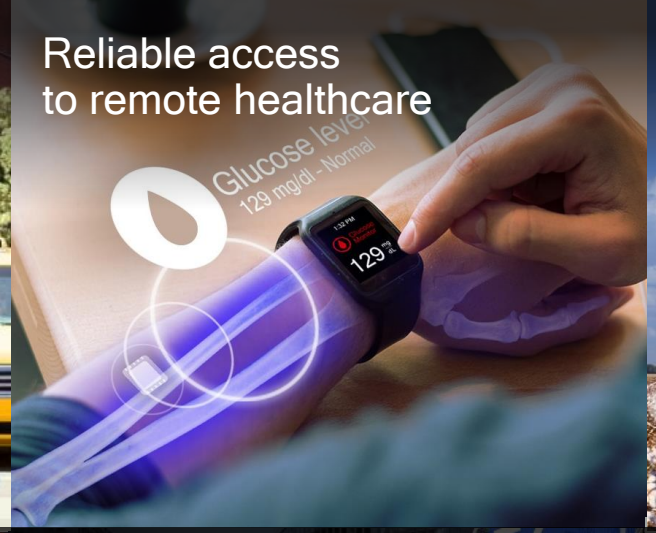
- Secure boot, debug
- Hardware root-of-trust
- Secure execution environment
- Runtime integrity checks

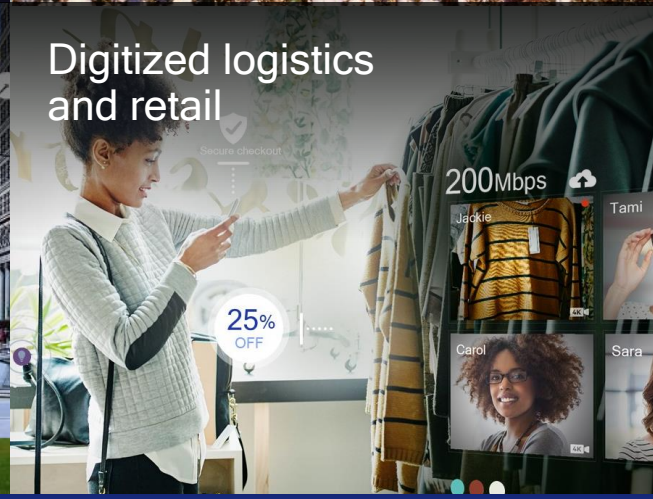
3rd party device management platform

Secure and trusted life cycle management

- Device attestation and connection integrity
- Device provisioning with plug-n-play on-boarding
- On-demand chipset upgrades and feature activation







5G

5G will expand the mobile ecosystem to new industries

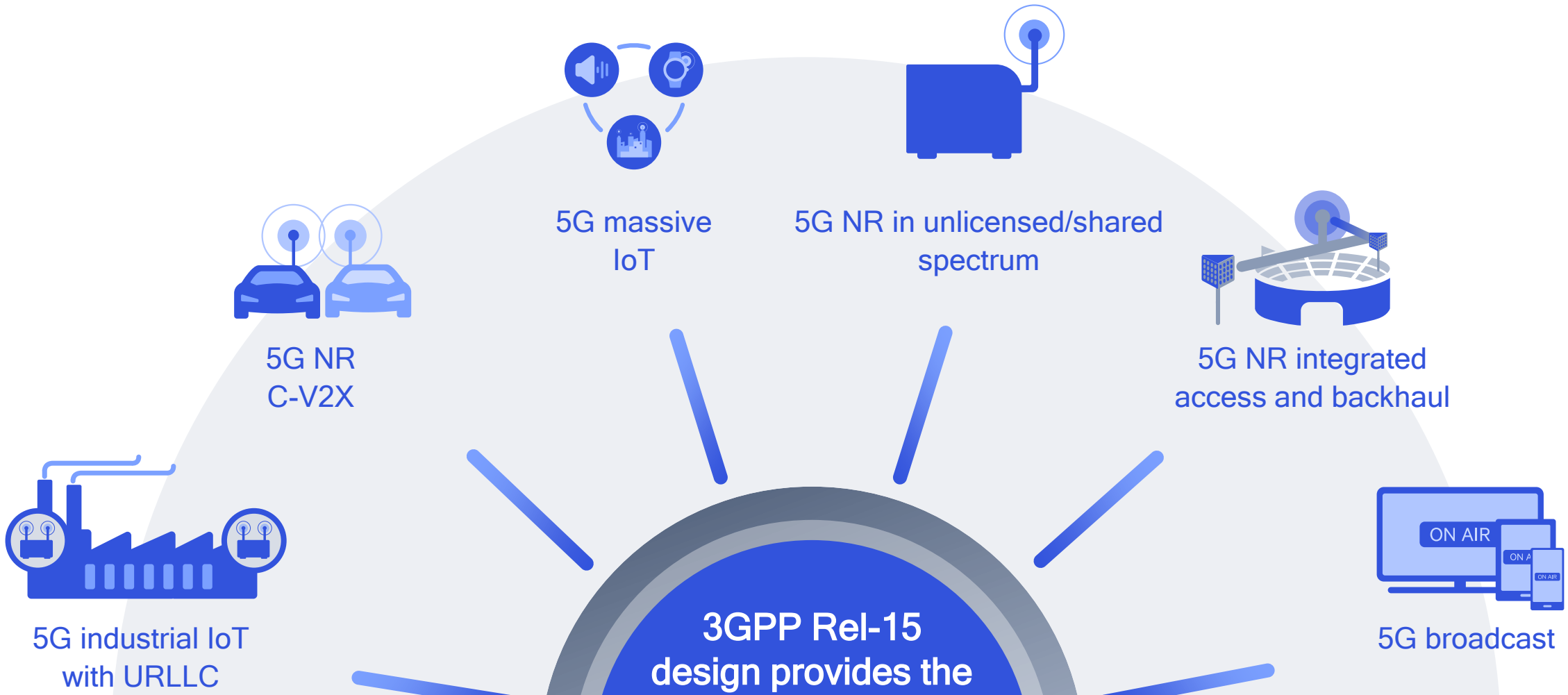
Powering the digital economy

>$12 Trillion

In goods and services by 2035*

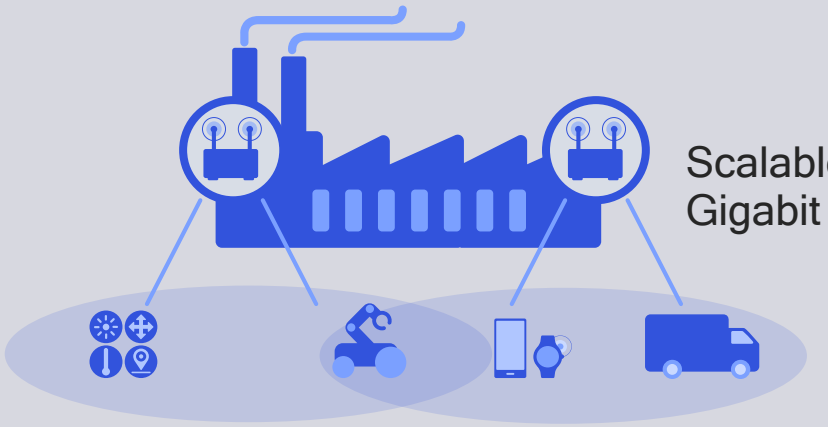
* The 5G Economy, an independent study from IHS Markit, Penn Schoen Berland and Berkeley Research Group, commissioned by Qualcomm

Driving a rich 5G roadmap in Release 16 and beyond



Private 5G networks for Industrial IoT use cases

Optimizing LTE today



Scalable from
Gigabit LTE to LTE IoT

New opportunities with 5G NR

Ultra-reliable
low-latency

Time-sensitive
networking

mmWave and
sub-6GHz eMBB

Wireline ethernet
replacement

Optimized
Tailored for industrial applications, e.g., QoS, latency

Dedicated
Local ‘edge’ network, easy to deploy, independently managed

Secure
Industrial grade security with LTE and 5G NR

>$5 Trillion[1]

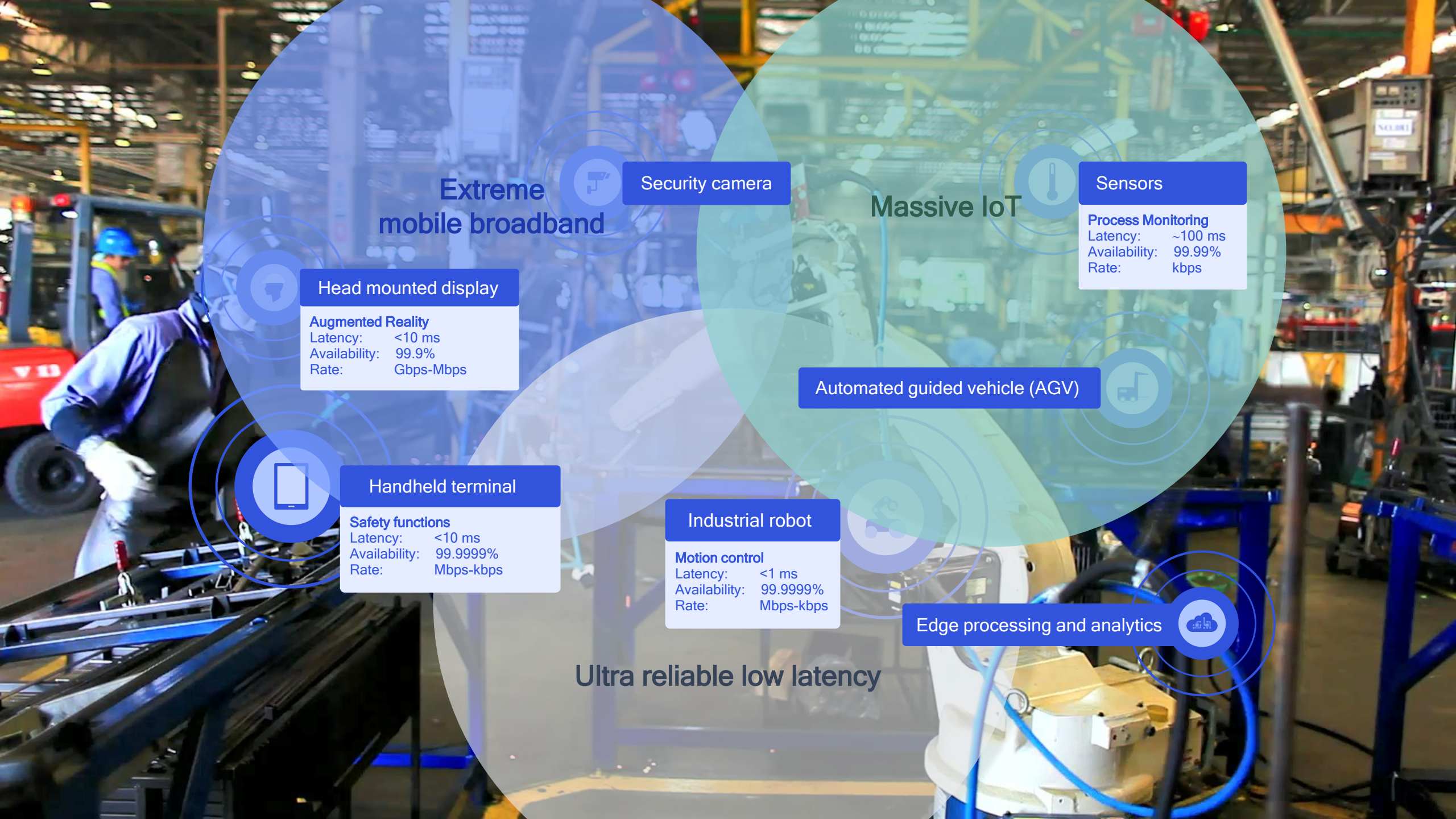
Global economic output in 2035 enabled by 5G in the following five categories

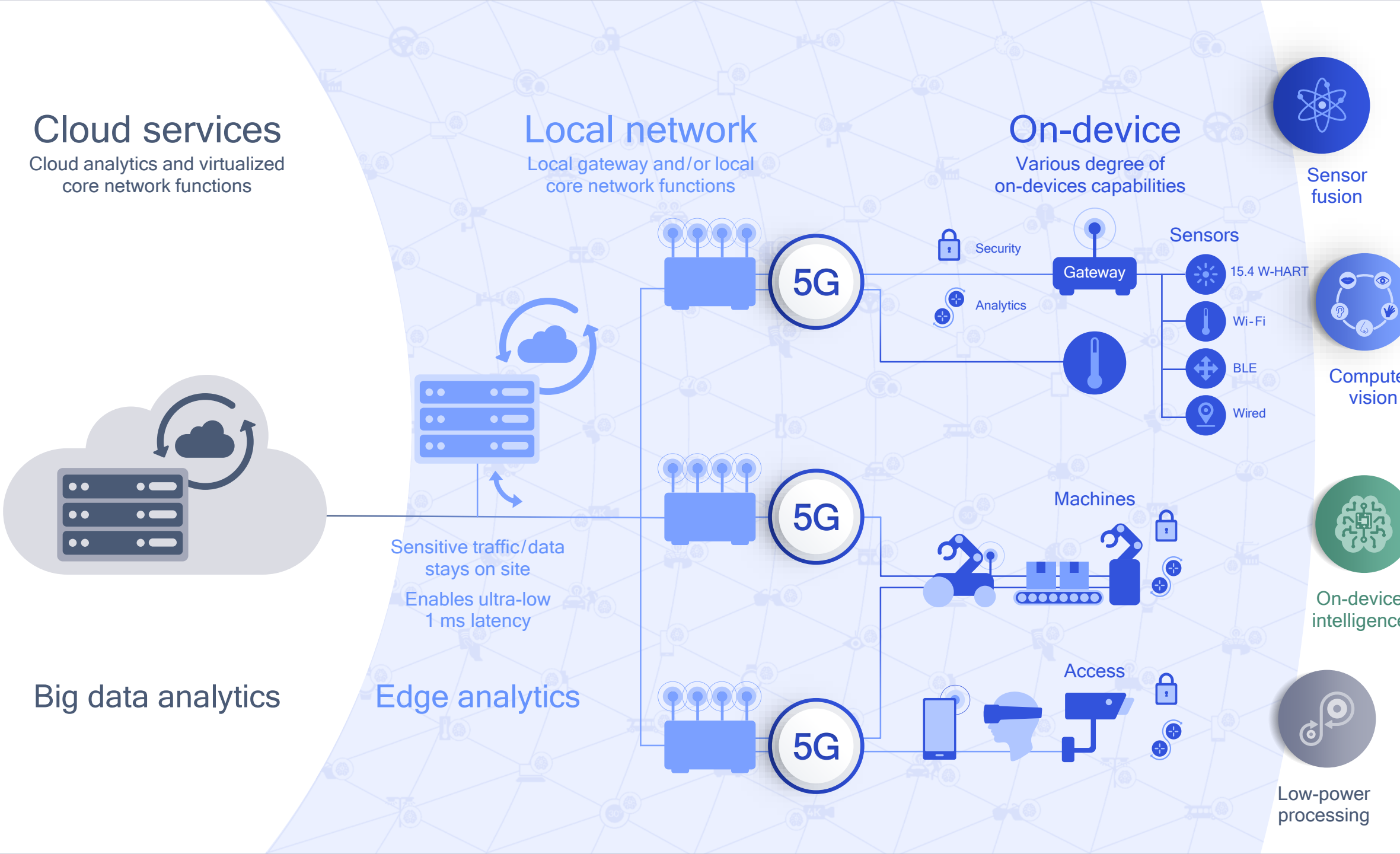
Manufacturing	Transport	Construction	Utilities	Mining
$3,364B	$659B	$742B	$273B	$249B

1. “The 5G economy: How 5G technology will contribute to the global economy” by IHS Economics / IHS Technology

Enabling reliable wireless IoT connectivity at transport hubs

The reconfigurable factory of the future will thrive on the wireless edge


Extreme
mobile broadband
Security camera
Head mounted display
Augmented Reality
Latency: <10 ms
Availability: 99.9%
Rate: Gbps-Mbps
Massive IoT
Sensors
Process Monitoring
Latency: ~100 ms
Availability: 99.99%
Rate: kbps
Automated guided vehicle (AGV)
Handheld terminal
Safety functions
Latency: <10 ms
Availability: 99.9999%
Rate: Mbps-kbps
Industrial robot
Motion control
Latency: <1 ms
Availability: 99.9999%
Rate: Mbps-kbps
Edge processing and analytics
Ultra reliable low latency


Cloud services
Cloud analytics and virtualized core network functions
Local network
Local gateway and/or local core network functions
On-device
Various degree of on-devices capabilities
Sensor fusion
Computer vision
On-device intelligence
Low-power processing
5G
5G
5G
Security
Analytics
Gateway
Sensors
15.4 W-HART
Wi-Fi
BLE
Wired
Machines
Access
Sensitive traffic/data stays on site
Enables ultra-low 1 ms latency
Big data analytics
Edge analytics

You don’t want your device to confirm with the cloud to take action

On-device intelligence is key for today’s and future autonomous cars

On-device intelligence is key for autonomous cars

Autonomous cars

Perceive

- Vision
- Radar
- Precise positioning
- Lidar
- C-V2X

Machine learning

Sensor processing algorithms

Reason

Automotive SoC

Machine learning

Sensor fusion

Mission planning

Behavioral analysis

Act

Safety MCU and SW

Fail-operational compute

Drive-by-wire vehicle controls

5G

Tele-operation

Data analytics

HD maps

Edge cloud for local data, e.g. HD maps

Central cloud for big data/training

Communicating directly with people and things

C-V2X

Establishes the foundation for safety use cases and a continued 5G NR C-V2X evolution for future autonomous vehicles

- Release 14 C-V2X completed in 2017
- Broad industry support, 5GAA
- Global trials started in 2017
- Our 1st announced C-V2X product in September, 2017

5G NR C-V2X

Brings complementary capabilities for autonomous driving

R14 C-V2X brings non-line of sight safety capabilities

Path planning

Intention and trajectory sharing for faster, yet safe maneuvers

Share perception

Sharing of high throughput sensor data and real world model

Real-time updates

Real-time sharing of local data with infrastructure and vehicles (e.g. 3D HD maps)

Coordinated driving

Exchanging intention and sensor data


Qualcomm
Our technologies are already transforming the wireless edge to realize the full potential of 5G
Learn more at www.qualcomm.com / 5G

Qualcomm

Thank you!

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