Qualcomm

7 December 2021

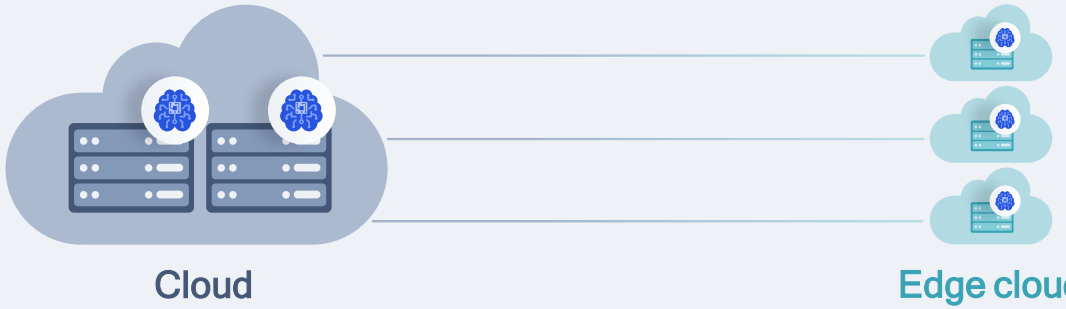
@QCOMResearch

5G: Bringing precise positioning to the connected intelligent edge

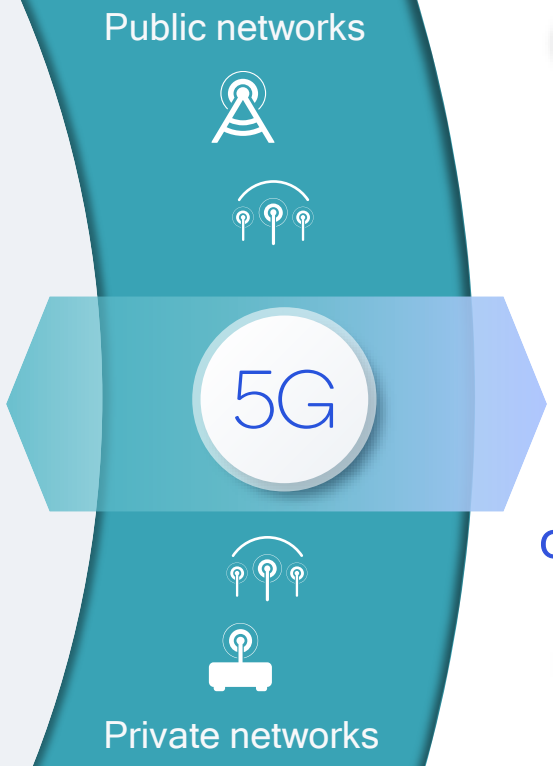
Positioning complements the Connected Intelligent Edge

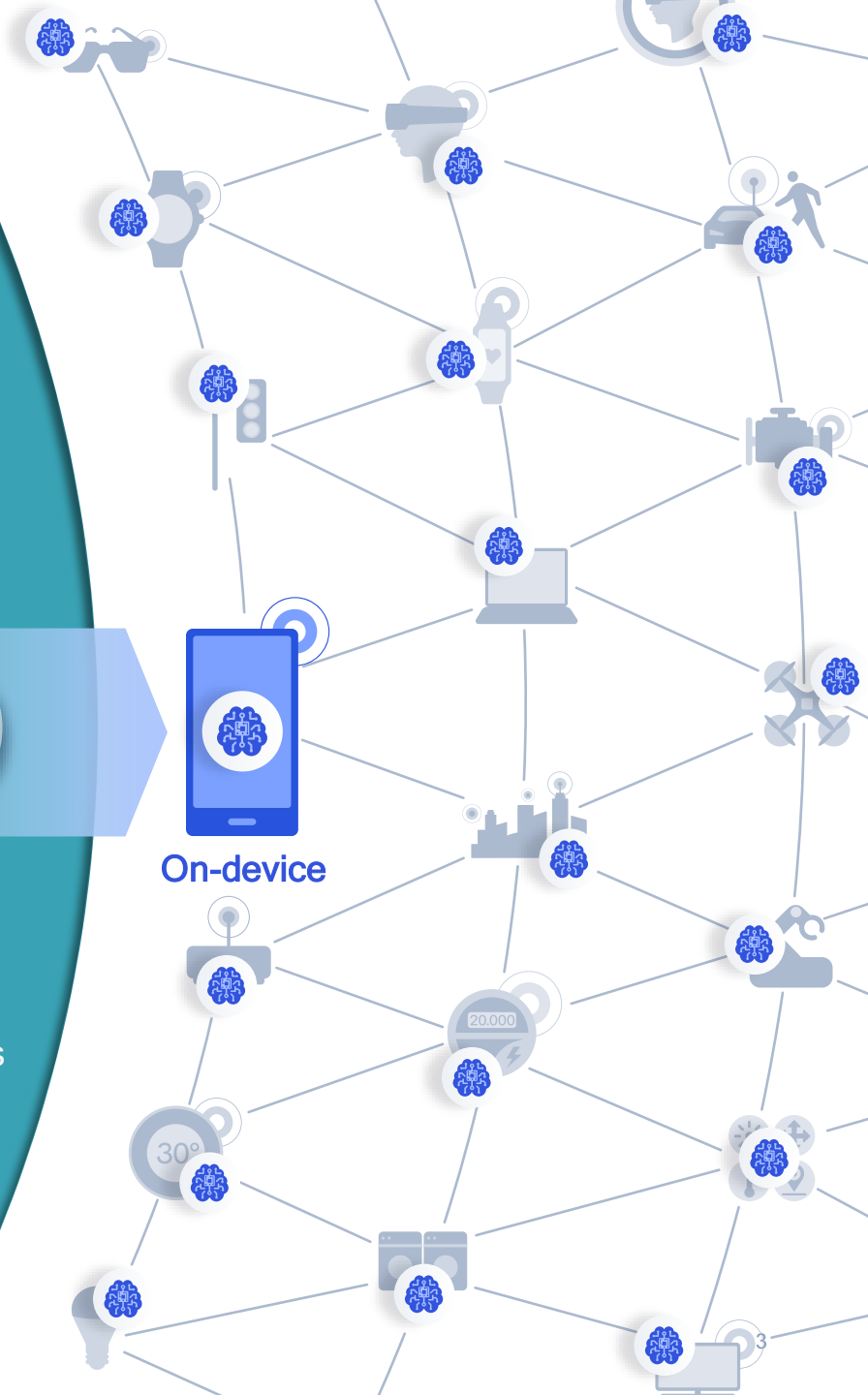
Bringing new value to virtually all devices

Transformation of the connected intelligent edge has begun at scale



Processing data closer to devices at the edge helps to scale more efficiently and derives new system values (e.g., lower latency, enhanced privacy)





In this new era, devices are becoming more intelligent

Edge cloud AI

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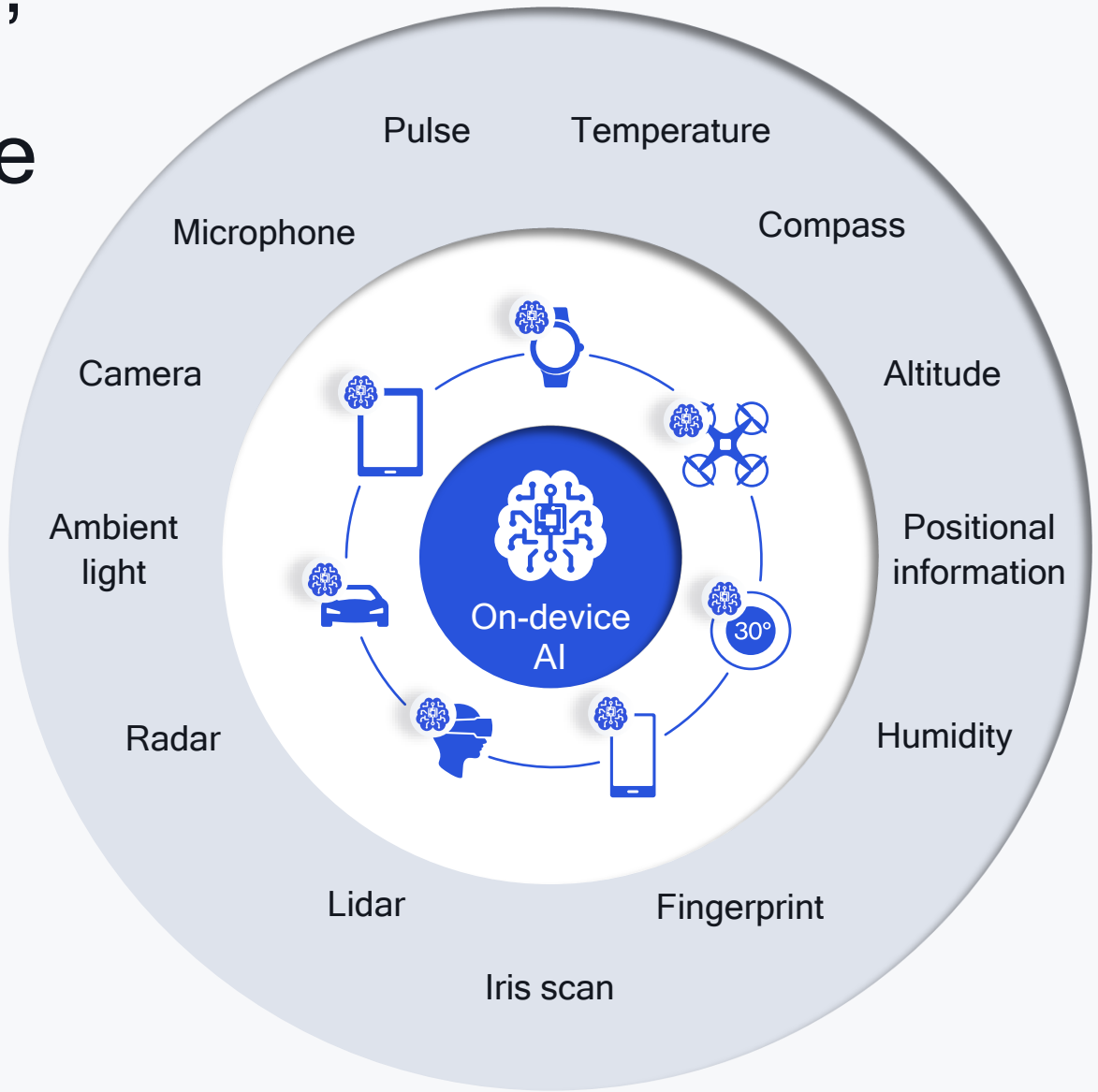

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Actionable insights

Based on growing AI processing capabilities and expanded availability of diverse data inputs (e.g., sensors)

Positioning is a key dimension for the intelligent edge

Using a diverse set of technologies

Precise positioning

Wireless

Cellular

Wi-Fi

Bluetooth

Ultra-wide band (UWB)

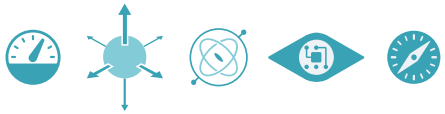
GNSS

Multiple GNSS constellations

Multi-frequency GNSS

Server-assisted GNSS

Sensor-assisted GNSS



Sensors

Accelerometer

Gyroscope

Compass

Camera

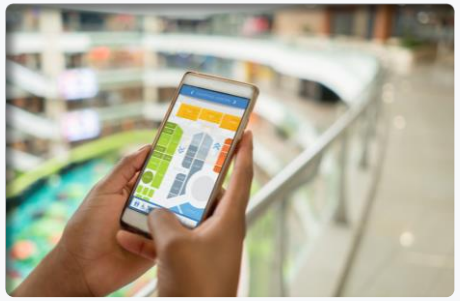
Radar

Lidar

GNSS: Global navigation satellite system

Precise positioning

Can deliver tangible benefits for a diverse set of wireless use-cases



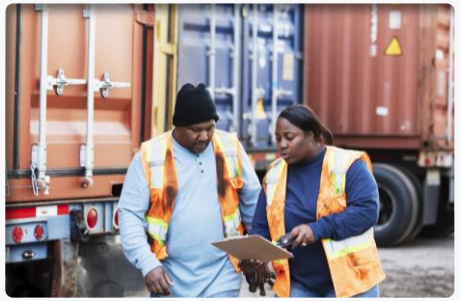
Indoor navigation

Drone tracking

Public safety

Geofencing

Vehicular navigation

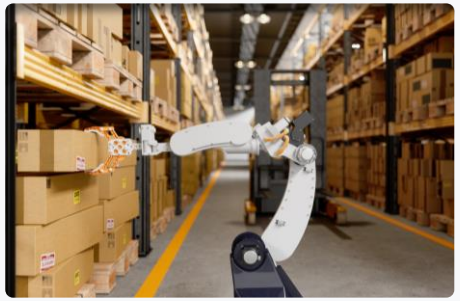


Fleet management

XR optimization

User insights

Asset tracking



AGV tracking

Cellular positioning

Expanding capabilities and enhancing user experiences

Cellular positioning

Complements other technologies for reliable precision

- Stationary, pedestrian, and vehicular mobility
- Indoors and outdoors
- Broad range of devices
- Spectrum flexibility
- Diverse use cases

Identifying the opportunities for cellular positioning

Addressing the need to improve overall positioning capability

GNSS limitations

Poor accuracy in dense urban environments

Long cold start and acquisition times when un-assisted

Significant power consumption for mobile devices

Vulnerable to jamming or spoofing

Sensor limitations

Drift from ground truth accumulates over time

Unsuitable for absolute positioning

WLAN, Bluetooth, & UWB limitations

Local solutions

Limited mobility

UWB: Ultra-wideband

Positioning

Has always been a core part of cellular technology

1990s
Digital voice
IS-95 (CDMA)

2000s
Wireless internet
CDMA2000/EV-DO
WCDMA/HSPA+

2010s
Mobile broadband
LTE, LTE Advanced,
Gigabit LTE

2020s
Connected Intelligent Edge
5G New Radio (NR)

Cell-ID / eCID

EOTD / UTDOA

TOA / TDOA / OTDOA

A-GPS / DGPS

IPDL / AFLT

OTDOA-IPDL

gpsOne™ / Wireless-Assisted GPS

OTDOA / UTDOA

Inter-RAT RSTD

DL-AoD / UL-AoA

DL-TDOA / UL-RTOA

Multi-cell RTT

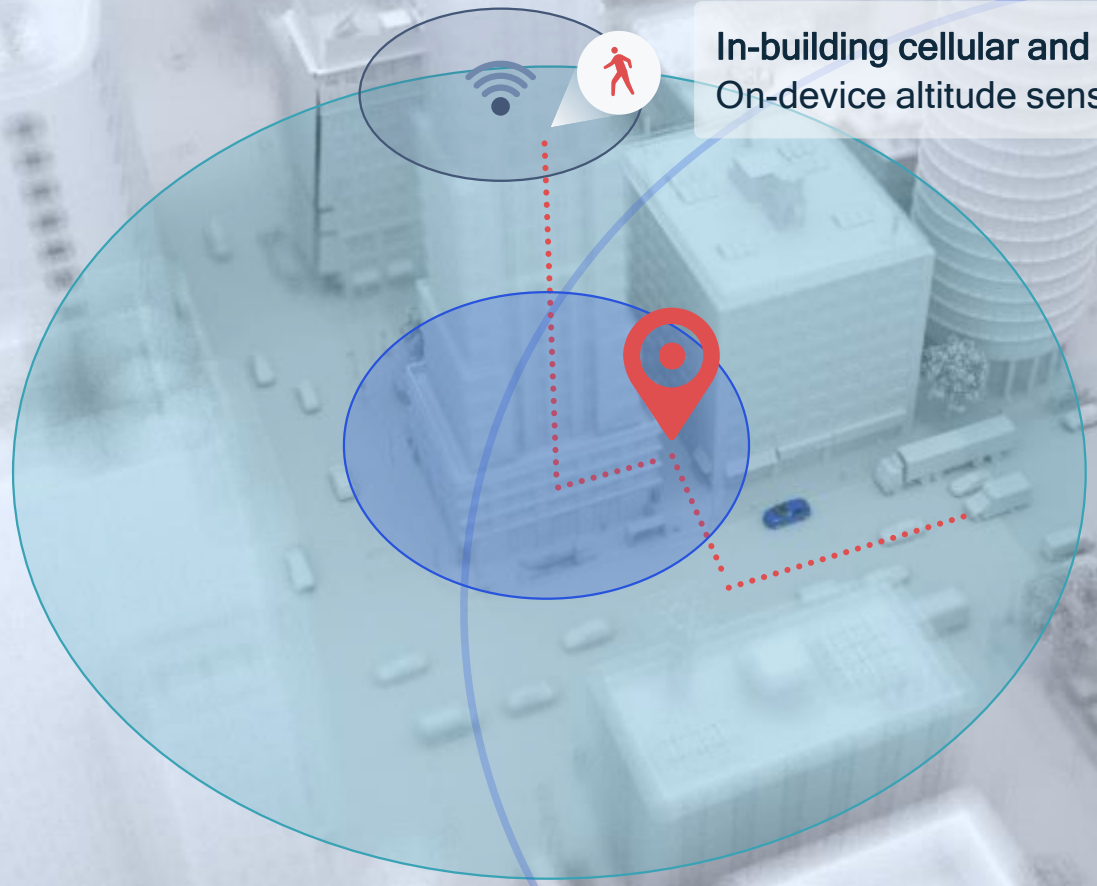
AFLT: Advanced forward link trilateration; A-GPS: Assisted GPS; AoA: Angle of arrival; AoD: Angle of departure; DGPS: Differential GPS; eCID: Enhanced cell ID; EOTD: Enhanced observed time difference; IPDL: Idle period down link; RAT: Radio access technology; OTDOA: Observed time difference of arrival; RSTD: Reference signal time difference; RTOA: Relative time of arrival; RTT: Round trip time; TDOA: Time difference of arrival; TOA: Time of arrival; UTDOA: Uplink time difference of arrival

Reliable emergency positioning requires multiple positioning technologies and sensors for accuracy and robustness

Assisted GNSS
GNSS assistance delivered over cellular or Wi-Fi

In-building cellular and WLAN location
On-device altitude sensor for vertical positioning

LTE and 5G-NR
Terrestrial positioning

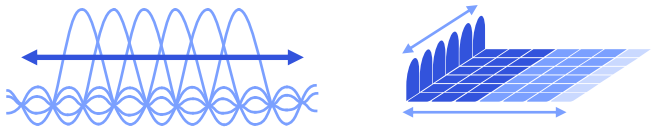


Powering a new wave of precise positioning opportunities with 5G

Breaking technology barriers

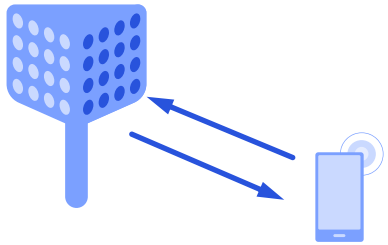
Qualcomm

5G NR includes key innovations for positioning



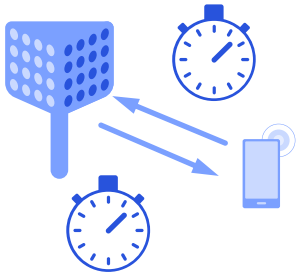
Flexible/scalable bandwidth

Leveraging wider bandwidths in a variety of spectrum and deployment scenarios for precise time of flight



Beam selection

Improving beam selection accuracy by correlating downlink and uplink signals



Group delay calibration/compensation

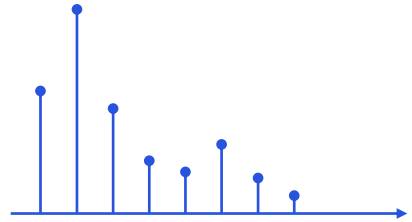
Integrating methods for measuring, reporting, and compensating for processing delays

Beam-centric PRS design

Leveraging massive antenna array for 3D location estimation using finer beam widths

Robust Rx/Tx beam determination

Positioning using serving and neighboring cells with a purpose-built standard



Robust time of arrival (ToA) estimation

Including joint beam direction and ToA estimation to mitigate the effects of multipath

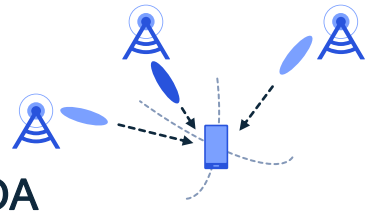
NR: New radio; PRS: Positioning reference signals; Rx: Receive; Tx: Transmit

5G brings multiple positioning techniques

For different deployment scenarios and use-cases

Cell-ID

The network reports the location of the cell-site serving the device or the centroid of its coverage

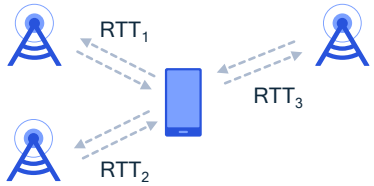


DL-TDOA

The device measures the time difference of arrival (TDOA) of downlink positioning reference signals (PRS) from different cells and cell-sites

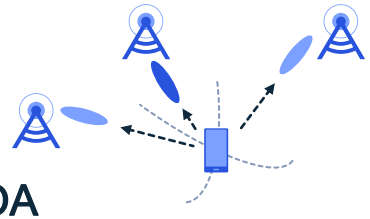
DL-AoD

The device measures and reports the strength with which it receives PRS for each beam, where the angle of the beam is known



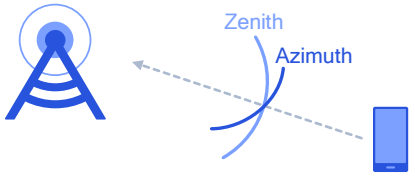
MC-RTT

Time differences between downlink PRS from multiple cells and uplink SRS are reported either by the cell-site or the device



UL-RTOA

The network measures the relative time of arrival (RTOA) of the device's sounding (SRS) from different cells and cell-sites



UL-AoA

The network measures the azimuth and zenith of arrival of SRS from the device relative to a reference direction

AoA: Angle of arrival; AoD: Angle of departure; DL: Downlink; MC: Multi-cell; PRS: Positioning reference signals; RTT: Round-trip time; SRS: Sounding reference signals; UL: Uplink

Leveraging time of flight and angular resolution to deliver precise positioning

A joint communication and positioning/sensing technology platform for Industry 4.0

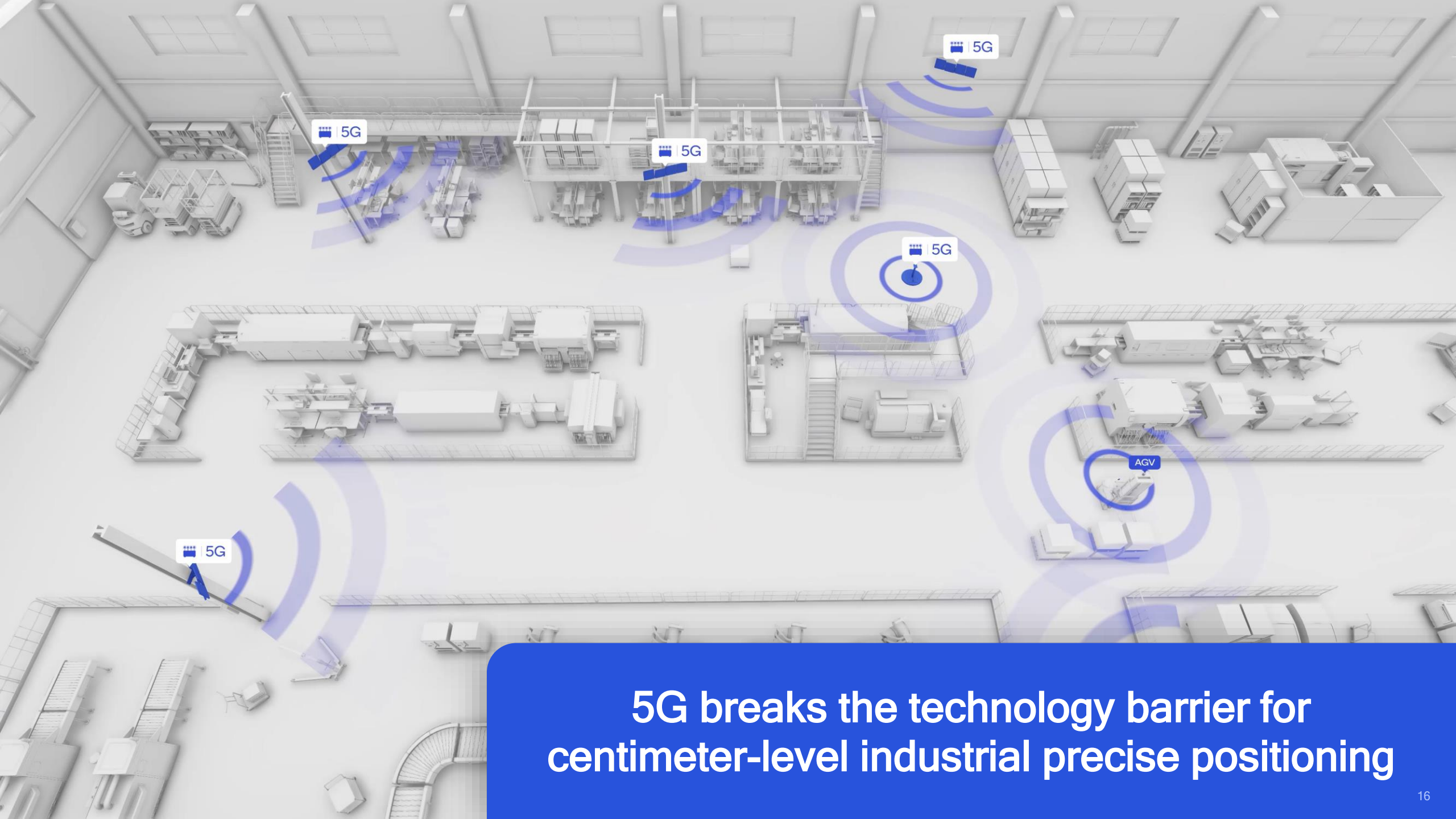
5G

- Private 5G network
- Licensed, shared and unlicensed Spectrum
- Ultra Reliable Low Latency Communication (URLLC) and 5G Sidelink
- Ethernet and Time Sensitive Networking (TSN)
- Precise positioning

Dedicated and reliable networks optimized for local services

Scalable wireless connectivity on a future proof platform

Capabilities for new use-cases e.g., seamless mobility with wireless Industrial Ethernet



5G breaks the technology barrier for centimeter-level industrial precise positioning

5G brings robust positioning to drone use cases

Inspection

Critical infrastructure inspection (e.g., cell towers, bridges)

Inspection of hard-to-reach assets (e.g., oil & gas, wind turbines)

Agriculture

Crop visual inspections

Automated planting

Livestock tracking

Public safety

Emergency services

Cellular coverage for first responders

Search and rescue

Film and Entertainment

Consumer flying cameras

Movies and news media

Real estate

Sporting events

Delivery

Package delivery

Transport of medicines and vaccines

Mobile XR

PC-tethered XR

5G

High capacity
Low latency
Edge compute

Seamless mobility
Precise positioning

Boundless XR

Contextual photorealism everywhere

Believable photorealism with split-rendering over 5G, high capacity and low latency 5G connectivity, and the freedom of seamless mobility with precise positioning

Pushing forward with the 5G positioning technologies

Release 16

Establishing foundation

Achieving accuracy of 3m/10m (indoor/outdoor) for 80% of time

Supporting RTT[1], AoA/AoD[2], TDOA[3], single-cell positioning

Including new evaluation scenarios, i.e., industrial IoT

Release 17

Enhancing performance

5G Positioning Evolution

Meeting centimeter-level absolute accuracy requirement of down to 0.3m

Reducing positioning latency to as low as 10 ms
Scaling to higher capacity for millions of simultaneous devices (e.g., IoT, automotive)

5G Advanced in Release 18+

Improving performance, expanding to new devices and deployments

Sidelink positioning and ranging

Defining reference signals, measurements, procedures for out-of-range, absolute and relative (e.g., ranging) sidelink positioning

Improved positioning performance

Specifying higher layer solutions for RAT[4] dependent positioning techniques, accuracy improvement based on PRS/SRS[5] bandwidth aggregation, carrier phase measurements, and positioning accuracy in heavy NLOS[6] with AI/ML

NR-Light[7] positioning

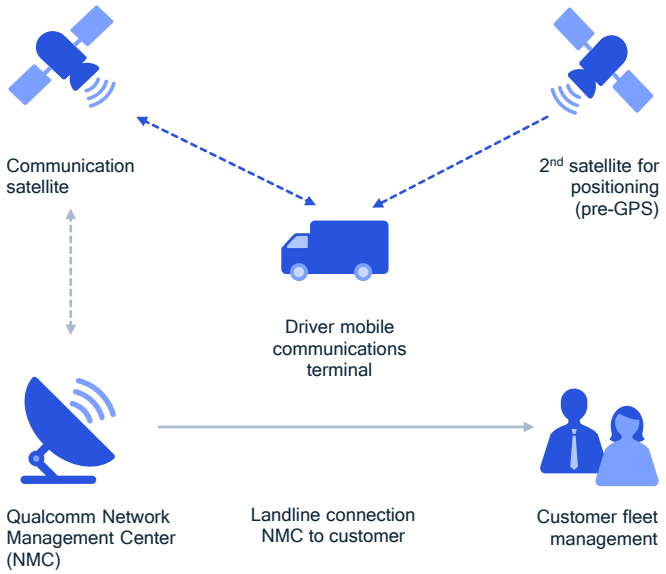
Setting performance requirements, evaluating performance for R17 positioning procedures, and identifying potential enhancements

Source: RP-211660 Expanded and improved Positioning. 1. Roundtrip Time; 2. Angle of Arrival, Angle of Departure; 3. Time Difference of Arrival; 4. Radio Access Technology; 5. Positioning Reference Signal, Sounding Reference Signal; 6. Non-line of sight; 7. aka. RedCap

Positioning technology at Qualcomm

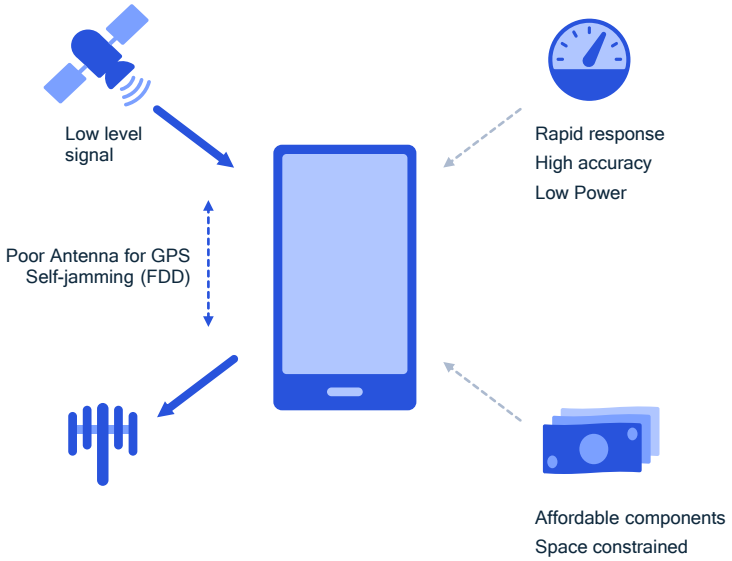
Longstanding technology leadership
and continued innovation for the future

A long history of innovation in wireless positioning



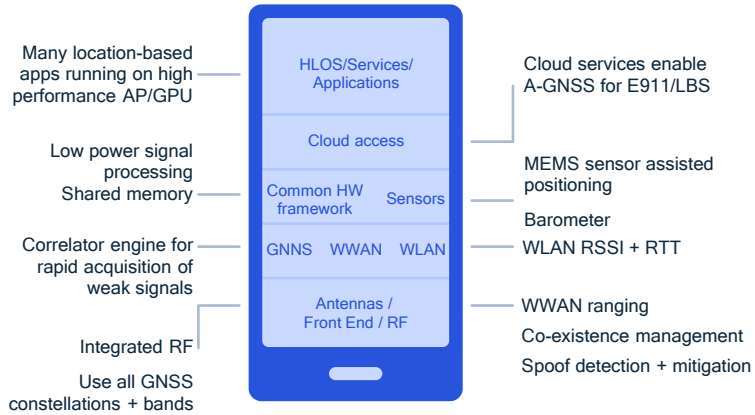
Pre-GPS fleet management

Two-way data communication with OmniTRACS and Qualcomm two-satellite positioning



Introducing GPS receivers to CDMA mobile phones

Significant progress made in mitigating low satellite signal levels, adjacent channel interference, space and power constraints, long response times, and poor accuracy



Integrated mobile platforms for robust positioning

Multiple radio access technologies, multiple GNSS constellations, multiple sensors, and multiple positioning algorithms for a broad range of precision based on signal quality

Qualcomm Technologies

#1 in location technology across mobile, automotive and IoT [1]

20+ Years in mobile location tech [2]

~10B Devices shipped with our location capabilities [2]

100+ Mobile OEMs [2]

100+ Operator deployments [2]

1. QYResearch, Ranking of Global Top GNSS Chip Manufacturers by Revenue, Apr. '20
2. Internal data

Qualcomm®

Location Suite

Mobile Automotive IoT

- Concurrent multi-constellation, multi-frequency GNSS
- GNSS assistance service
- Dead reckoning
- Vision-enhanced positioning
- Global terrestrial positioning
- Operator-certified Location for commercial and emergency services

Meet the positioning requirements for diverse applications with a broad set of location technologies

Qualcomm flight RB5 5G platform

World's 1st 5G

World's first 5G and AI drone platform

Autonomy

Visual inertial odometry (VIO)

Path planning

GPS-denied navigation

BVLOS flight

Follow-me flight mode

Obstacle avoidance

Multi-object detection and tracking

BVLOS: Beyond visual line of sight

Setting the bar in 5G positioning at MWC Barcelona 2021

Wide-area 5G positioning

Over-the-air outdoor demo

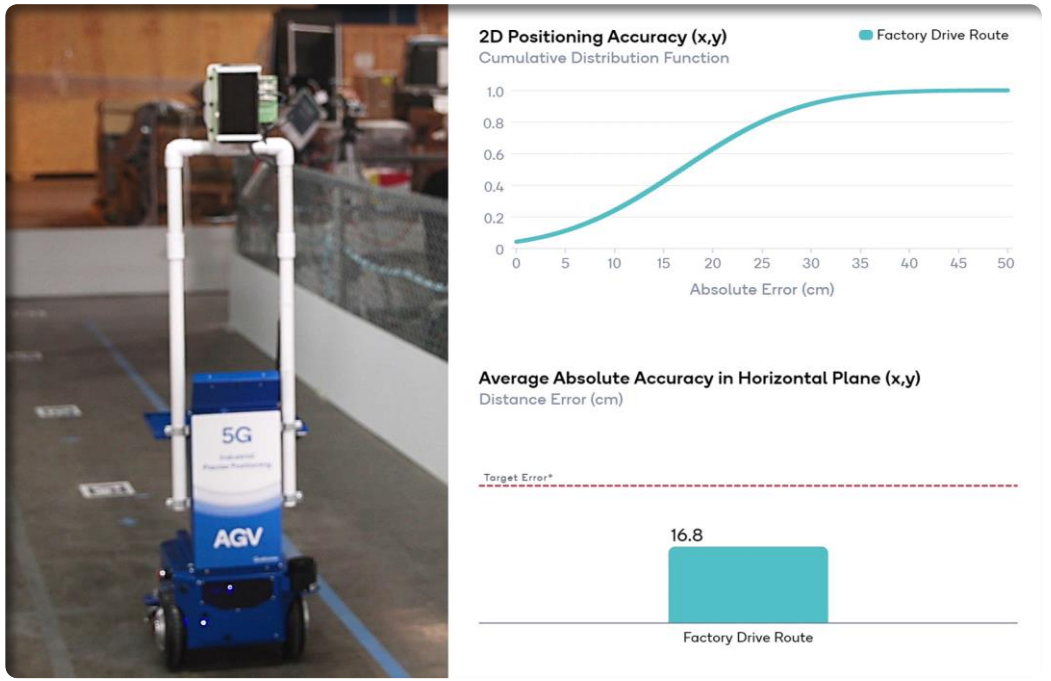
Release-16 Single-cell and Multi-cell positioning

Round-trip time (RTT) and angle of arrival (AoA) positioning techniques combined for single-digit meter-level precision

Showcasing the benefits of ML and sensor fusion

5G industrial precise positioning

Over-the-air indoor demo



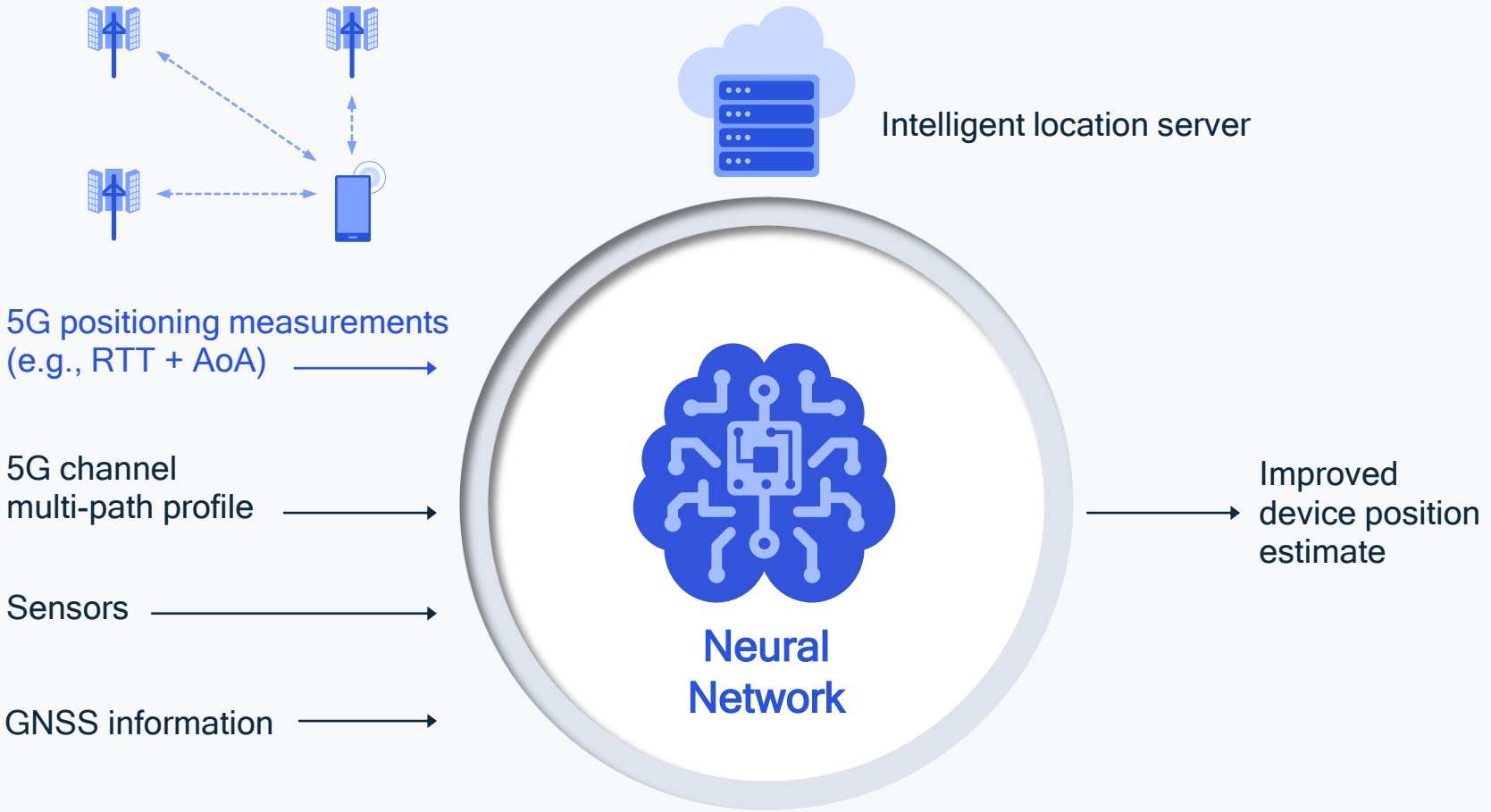
AGV with Uplink TDoA for Release-16 centimeter-level precision

Onboard Inertial sensor and CoMP for robustness against RF blocking

Deployment-friendly 100 MHz carrier in Sub-7 GHz

AI/ML

for enhanced 5G positioning performance



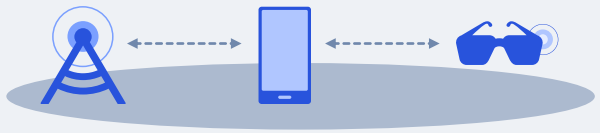
5G Sidelink in 3GPP Rel-18 and beyond

Brings flexibility to positioning in different operational scenarios and with multiple spectrum options

Operational scenarios

In coverage

Uu-only or Uu + SL cooperative positioning when 5G UEs are within network coverage area



Partial coverage

Uu + SL cooperative positioning when only some UEs are within network coverage area

Out of coverage

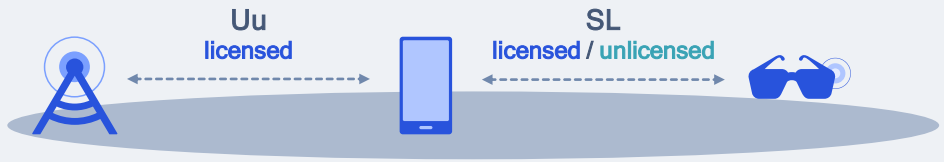
5G Sidelink ranging when network coverage is not available

Spectrum options for 5G sidelink

Licensed or unlicensed spectrum

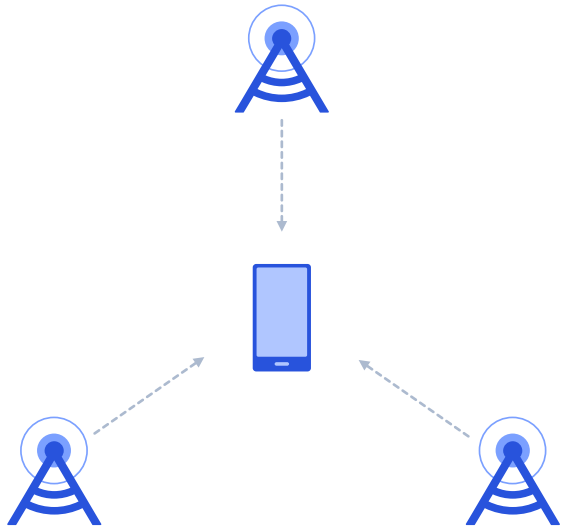
Licensed-assisted positioning on unlicensed spectrum

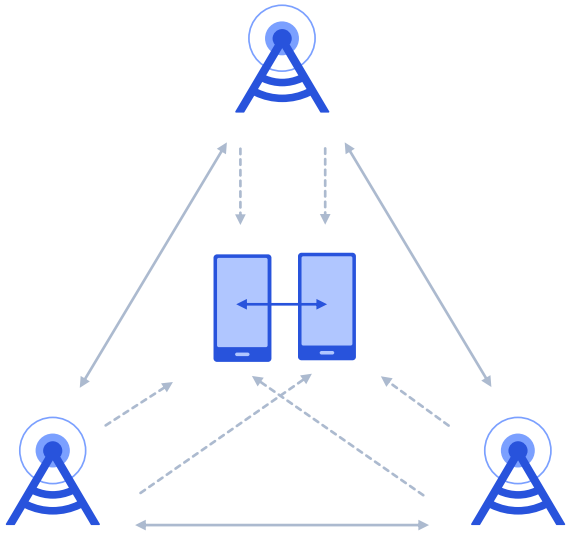
NR sidelink operation on licensed or unlicensed spectrum

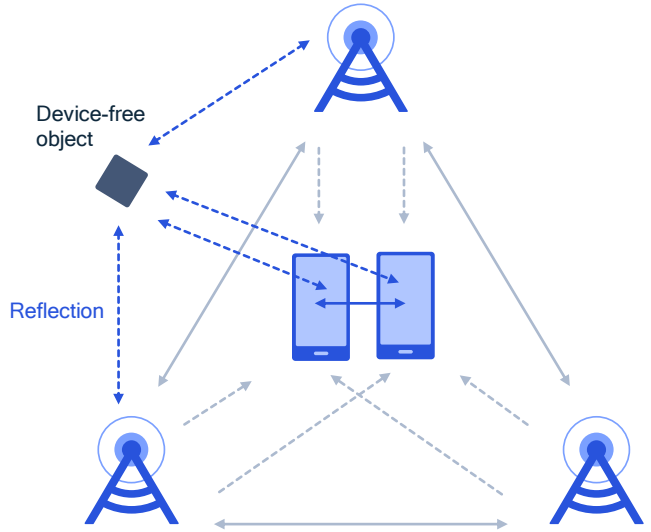


Advancing 5G positioning with 5G sidelink and RF sensing

3GPP Release 18 and beyond







5G NR positioning

3GPP Release 16

Use positioning reference signals (PRS) over the 5G NR air interface (Uu) to estimate the position of a 5G device

Cooperative positioning with 5G sidelink

3GPP Release 18+

Exploit more line-of-sight opportunities by using 5G sidelink (SL) PRS for ranging between devices, in addition to PRS over the Uu interface to estimate the position of multiple 5G devices simultaneously and cost-effectively

Cooperative sensing with 5G sidelink

3GPP Release 18+

Simultaneously estimate the position of passive device-free objects and 5G devices by using PRS over the Uu and SL interfaces, and by measuring reflected paths

Learn more on location and positioning technology

with the Qualcomm Wireless Academy

Gain a competitive advantage by developing a greater understanding of location and positioning

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Be recognized for your knowledge with a certificate of completion from Qualcomm Technologies

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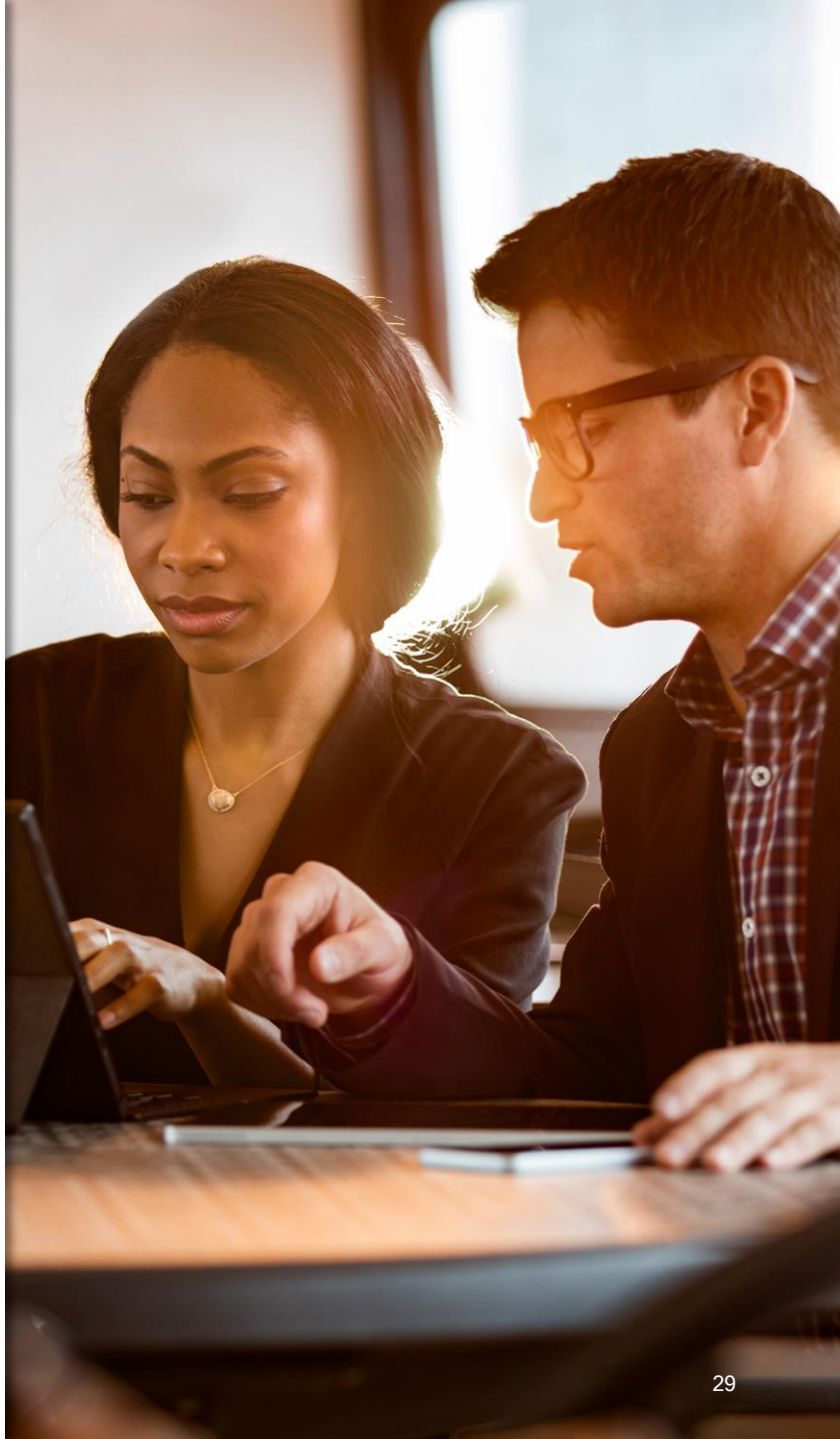

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