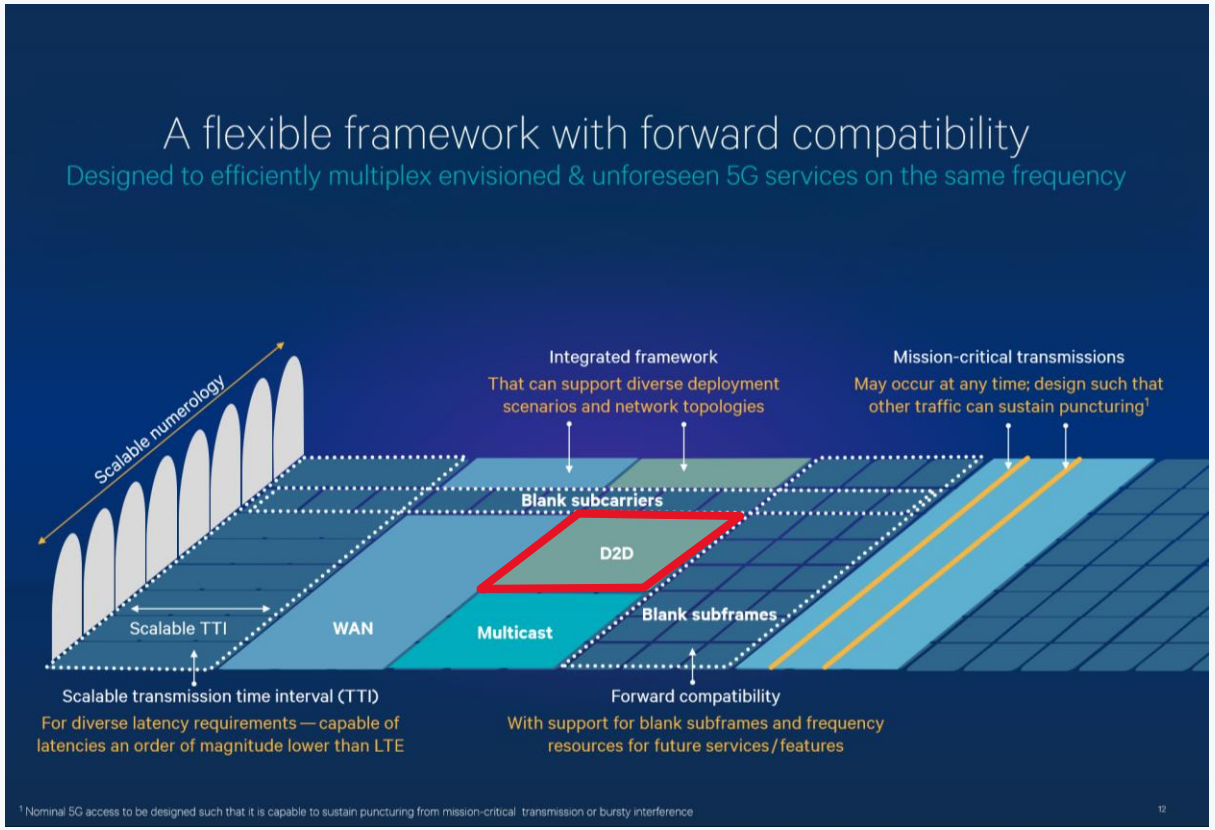
Qualcomm @QCOMResearch San Diego, CA September 8th, 2022

How will sidelink bring a new level of 5G versatility?

For diverse devices and services beyond automotive – smartphones, IoT, and more

Sidelink is a core topology of the 5G system design

Further extending the connected intelligent edge



Qualcomm Technologies' 5G Vision, circa 2015

Original 5G vision

Envisioned to be part of the 5G NR flexible framework with forward compatibility

New system values

Offering a wide range of benefits to complement network-to-device (i.e., Uu) communication

Service coexistence

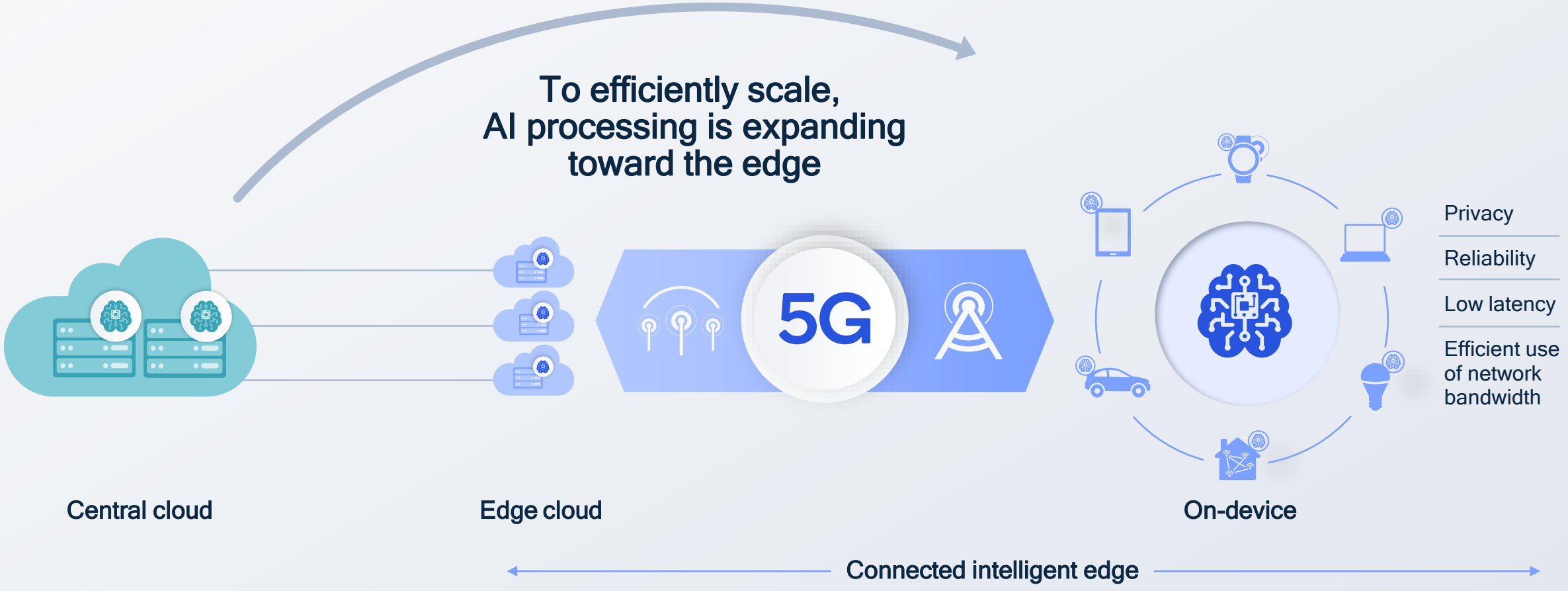
Multiplexing seamlessly with other 5G NR communication in time and frequency domain

Technology foundation

Building on the learnings of LTE Direct (Rel-12+) technology, its evolution, and deployments

Sidelink is a core topology of the 5G system design

Also known as direct communication or D2D (Device-to-Device)



Qualcomm is leading the realization of the Connected Intelligent Edge

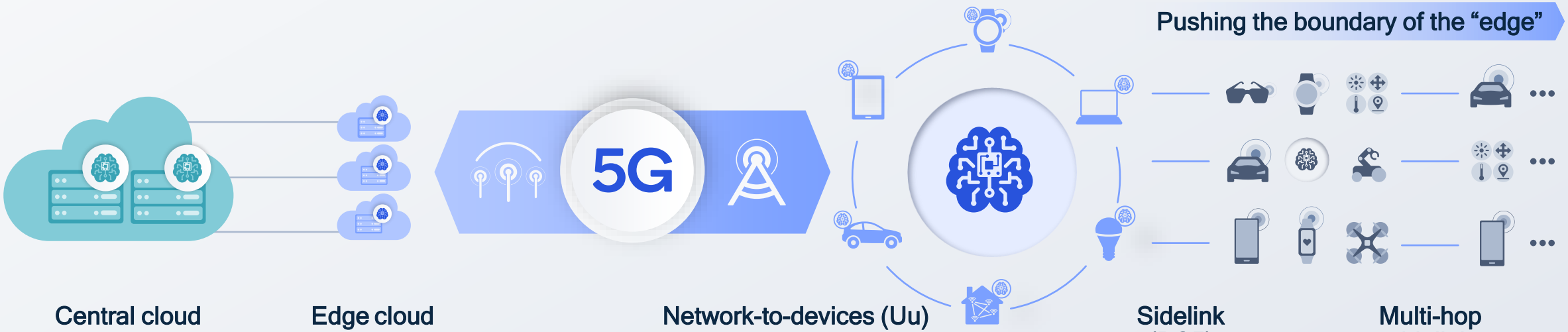
Convergence of:

Wireless connectivity

Efficient computing

Distributed AI

Unleashing massive amount of data to fuel our digital future



Sidelink can further extend the connected intelligent edge

Extending beyond network-to-device communications to connect more devices closer to the end-users

Sidelink is being designed to meet diverse 5G system requirements

Complementing network-to-device communications, starting in 3GPP Release 16

5G Sidelink

Wide range of devices

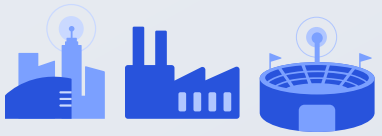
Smartphones, wearables, XR, cars, robots, sensors, IoT, etc.

Diverse services

Data offload, peer discovery, public safety, automotive, etc.

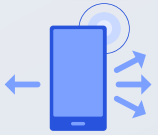
All spectrum

Sub-7 GHz, mmWave, licensed, unlicensed, shared, etc.



Broad deployments

Public network, private networks, mesh, ad-hoc, etc.



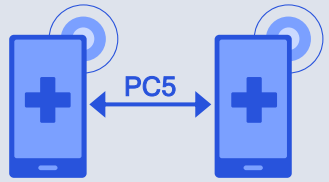
Multiple communication modes

Broadcast, multicast, unicast messaging

Sidelink can operate in different spectrum configurations

Dedicated

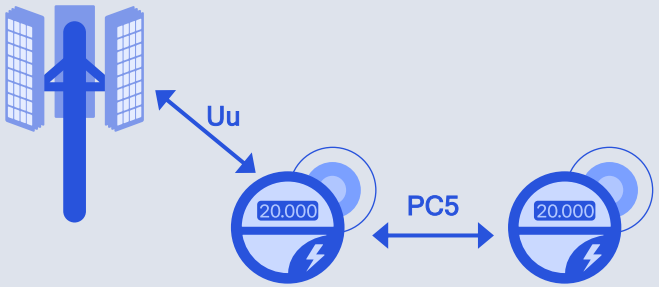
Applications-specific spectrum allocated for specialized use cases



E.g., 700 MHz (B14) has been allocated for public safety

In-band licensed

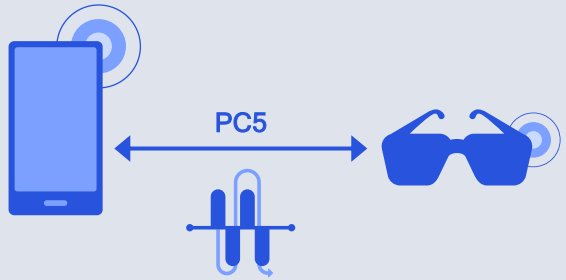
Network dynamically allocating spectrum for Uu and PC5



E.g., wide-area bands such as 3.5 GHz can be used for device access and device relay

Unlicensed

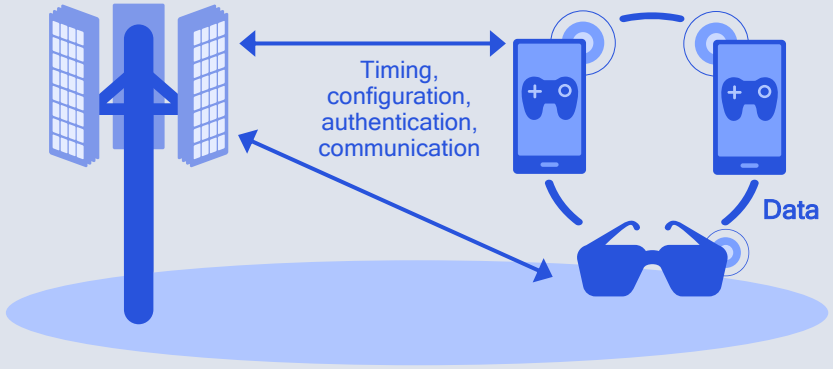
Contention-based access suitable for best-effort services



E.g., 5 GHz, 60 GHz unlicensed band can be used for data offload in private networks

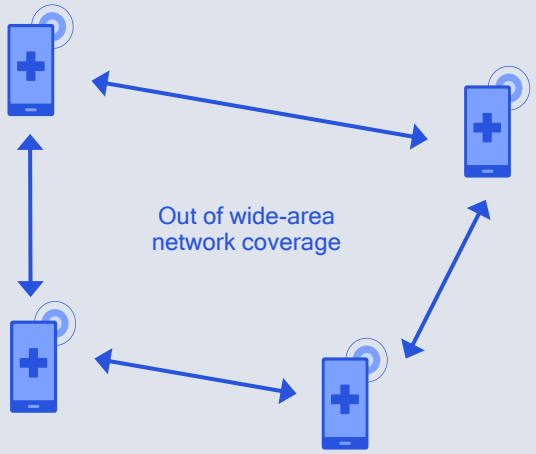
Flexibility to support a wide range of devices, bandwidth requirement, quality of service, and deployment scenarios

Centralized control sidelink (NCIS[1])



- Resources managed by mobile operators
- Requires wide-area network coverage and a SIM[2]
- Timing derived from network

Dynamic and self-organizing sidelink



- Resources managed dynamically by connected devices
- Does not require network coverage or a SIM
- Timing derived from GNSS[3] or synchronized to one node

Two possible approaches to sidelink network management

1 Network controlled interactive service – including split rendering XR, multi-player gaming; 2 Subscriber identity module; 3 Global navigation satellite system

Mobile operators

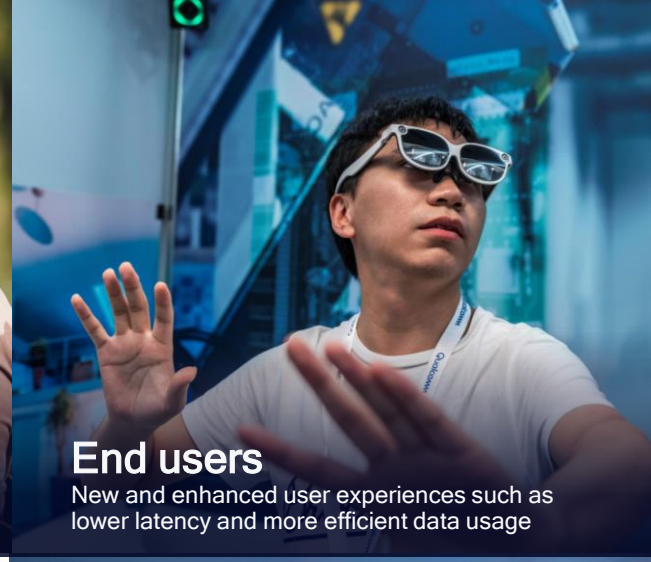
Differentiated services that can bring new revenue streams (e.g., ubiquitous asset tracking)

Private network operators

More flexible capacity and performance in e.g., industrial and enterprise settings

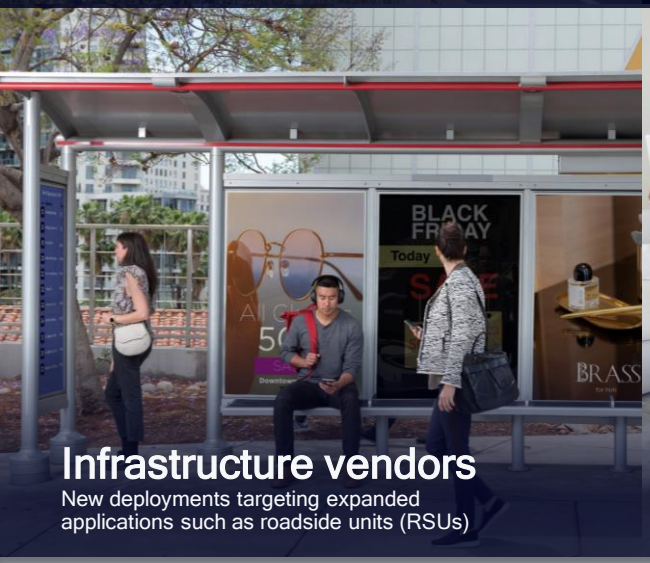
Governments

More secure, robust, self-reliant public safety and low-visibility tactical communication



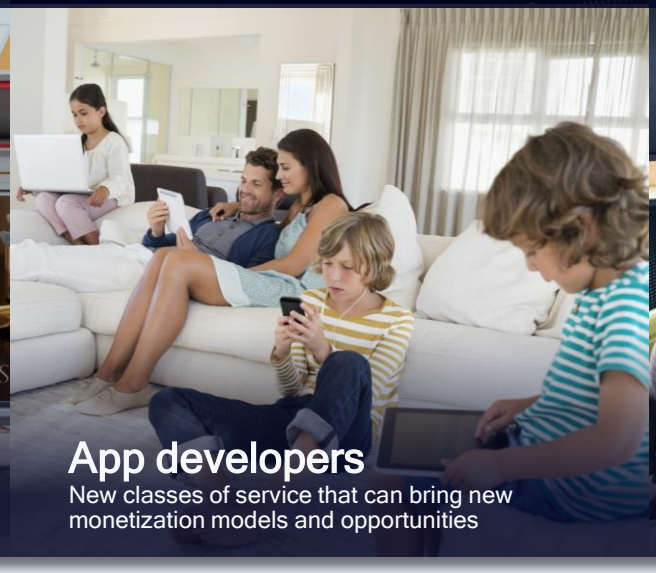
End users

New and enhanced user experiences such as lower latency and more efficient data usage



Infrastructure vendors

New deployments targeting expanded applications such as roadside units (RSUs)

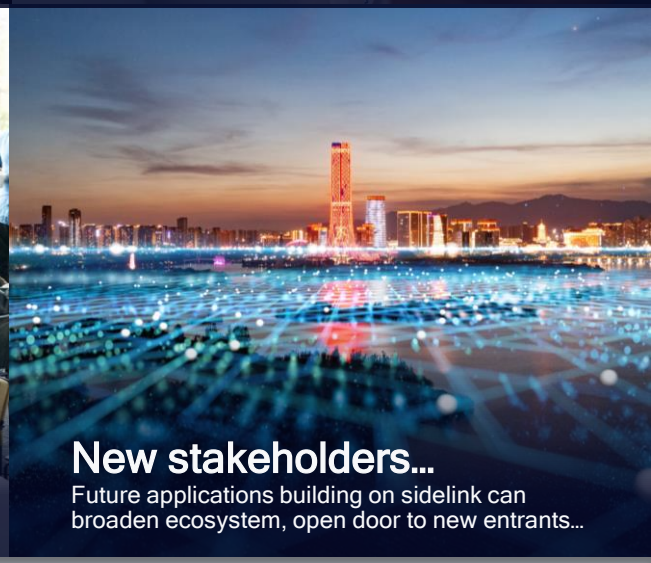


App developers

New classes of service that can bring new monetization models and opportunities

Device manufacturers

More efficient design implementations and new device types (e.g., device relays)



New stakeholders…

Future applications building on sidelink can broaden ecosystem, open door to new entrants…

5G sidelink creates new business opportunities for the entire ecosystem

Sidelink delivers a broad set of system benefits

Supporting diverse 5G devices, use cases, and deployments

Sidelink delivers a broad set of benefits for the overall 5G system

Supporting a diverse ecosystem of 5G devices and use cases

Network benefits

Expanded coverage

Extending coverage with device relays for many 5G use cases (e.g., IoT)

Increased capacity

Providing efficient data offload from wide-area network to meet growing capacity needs

Deployment flexibility

Enabling sidelink in infrastructure (i.e., relays) can greatly improve deployment efficiency

Device/service benefits

Extended battery life

Supporting low power consumption capabilities by reducing output power in devices

Lowered Latency

Providing supplementary connectivity in the edge to further enable low-latency communications

Improved Reliability

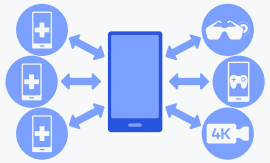
Establishing an additional link to meet real-time communication and mission-critical demands

Automotive safety and beyond

Allowing vehicles, devices, and infrastructures to connect amongst themselves, enhancing overall performance and efficiency

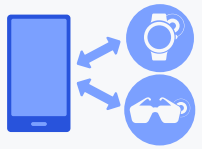
Public safety and tactical communication

Enhancing existing LTE-based system to provide services over 5G NR, including one-to-many device broadcast



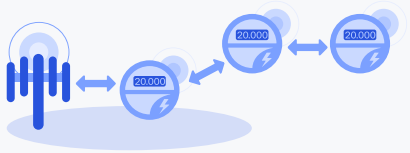
Data offload

Providing high-capacity/ throughput to devices in proximity, for use cases such as gaming, and data backup



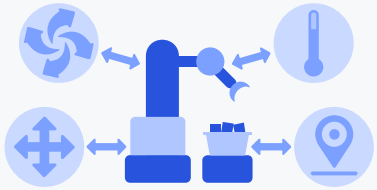
Wearable connectivity

Creating a personal area network to connect the smartphone directly to wearables such as smart watches, XR, and more



Range extension

Extending coverage via direct communication (e.g., massive IoT devices such as meters) with multi-hop mesh relays



Industrial IoT capacity

Expanding system capacity with direct communications between automation controllers (i.e., PLCs[1]) and sensors / actuators

Expanded positioning

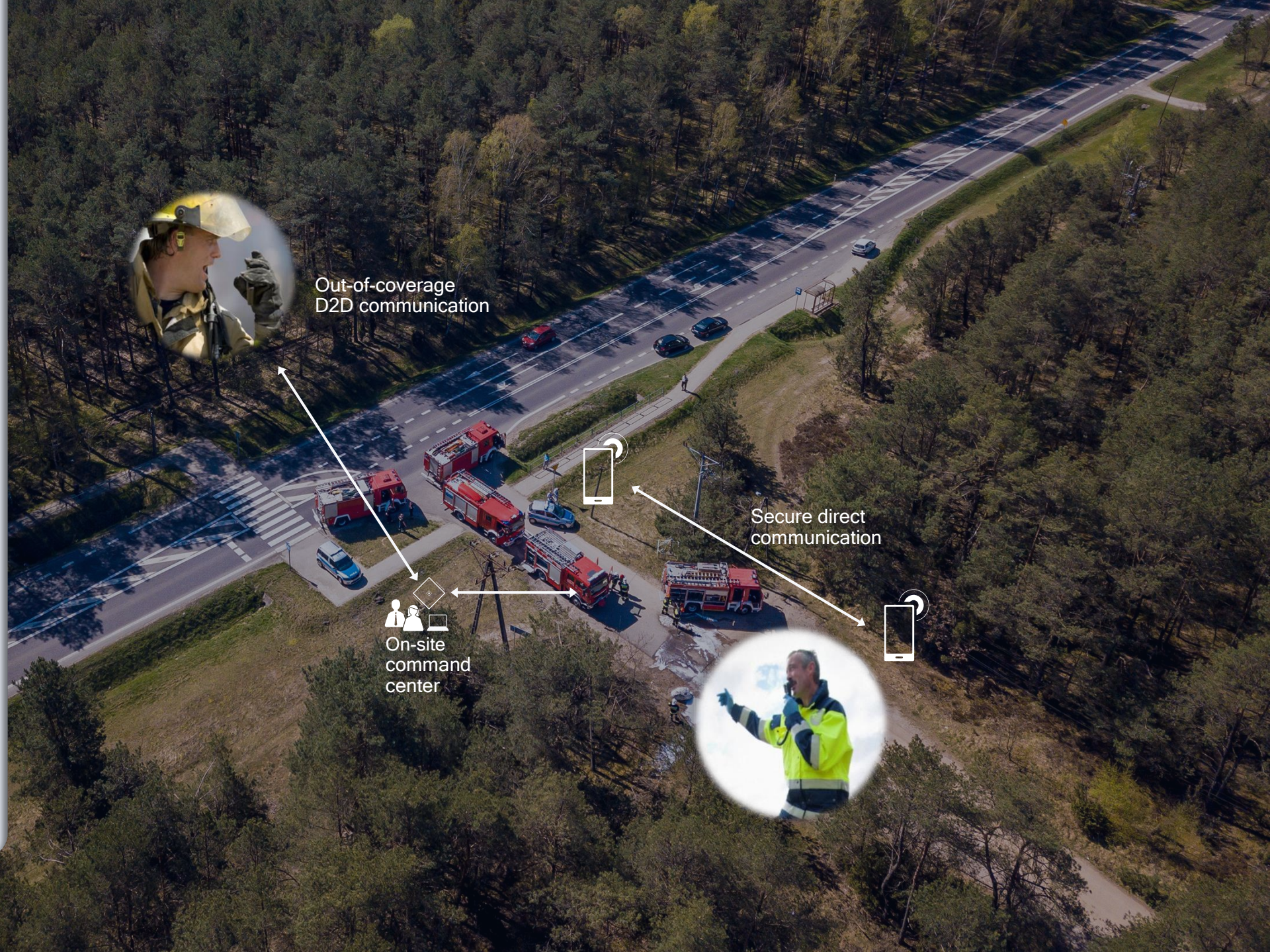
Improving positioning accuracy for all situations including challenging scenarios such as dense urban areas and tunnels

Sidelink can enable new benefits for a wide range of new use cases

1 Programmable Logic Controller

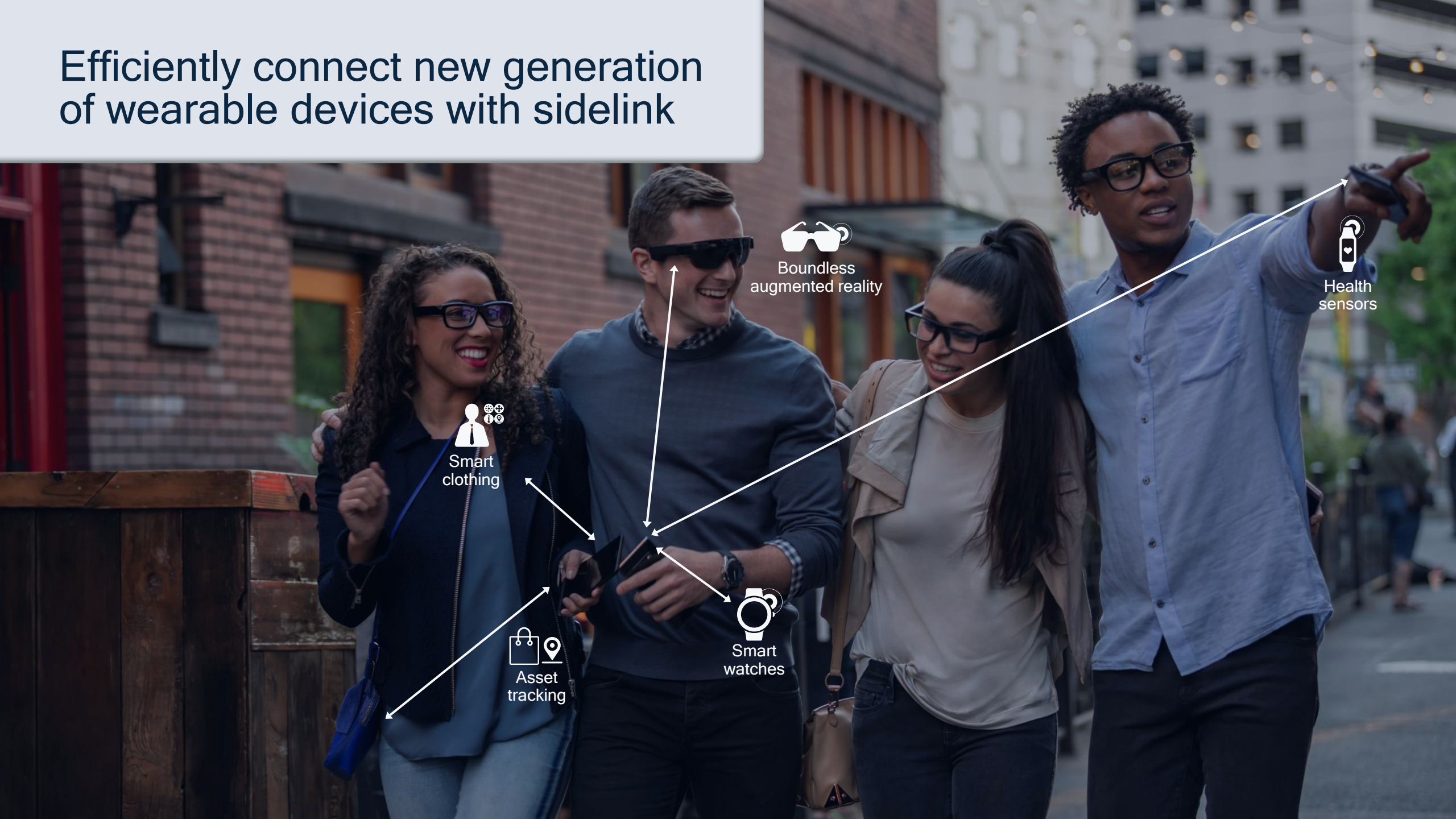
Connecting emergency services in challenging areas for enhanced public safety

- More reliable, secure, and interoperable networks
- Readily available capacity and coverage
- Enhanced awareness, safety, and coordination for first responders in emergencies
- Innovations leveraging large established device and apps ecosystem
- For firefighters, police, EMT, and others



Sidelink can provide efficient data offload for additional capacity and improved experience

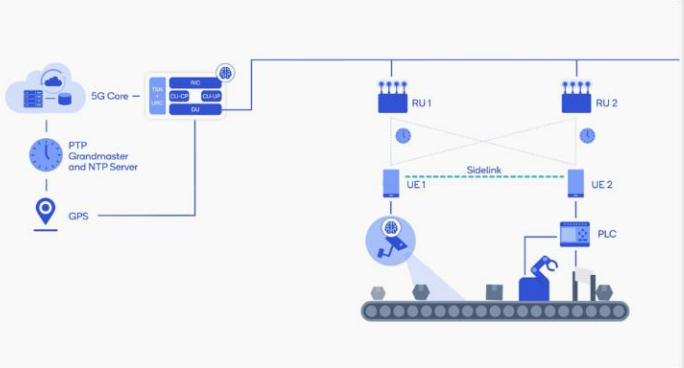
Efficiently connect new generation of wearable devices with sidelink



Extending service coverage for wide-area 5G use cases such as multi-hop IoT mesh

Utilizing sidelink communication to extend network coverage for 5G NR-Light IoT services, enables cost-efficient connectivity for multiple devices through a single wide-area connection

Sidelink can greatly expand system capacity to enable large-scale industrial IoT deployments

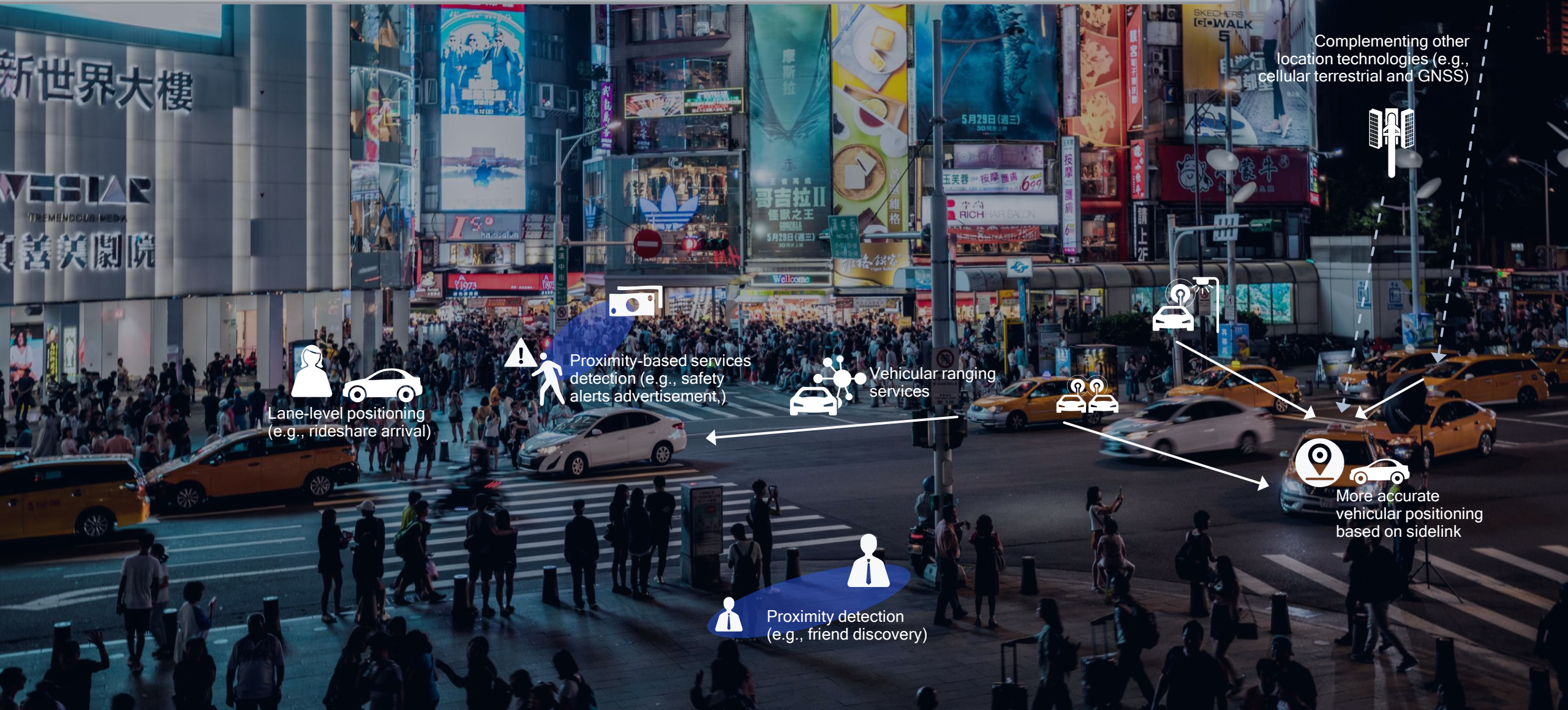


Dynamic switching between sidelink and network-to-device communication

Improved accuracy with sidelink positioning, complementing traditional techniques

Direct communication between PLC and sensors / actuators

Sidelink can complement existing location technologies to provide more robust and precise positioning



Sidelink continues to evolve in 5G Advanced and beyond

Standardized and commercialized today

Sidelink

Continued sidelink technology evolution into 5G Advanced and beyond

Advanced Research
Our foundational system research for sidelink communications began around 2010

Release 12 / 13
LTE device-to-device (D2D) support first adopted in 3GPP standards, aimed to provide proximity services and public safety applications

Release 14 / 15
D2D enhancements and expansion to automotive that brings improved road safety

Release 16
Establishing the 5G technical foundation for broader applications and evolution to support advanced automotive use cases

Release 17
Expansion of 5G sidelink beyond automotive, including device relays that can efficiently extend network coverage

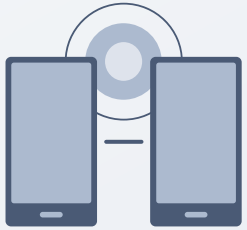
Release 18+
5G Advanced evolution of sidelink that brings improved performance, efficiency and further use case expansion

The sidelink technology foundation began more than a decade ago

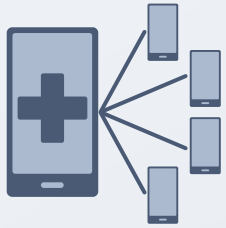
Sidelink

Release 12

Technical foundation for sidelink or D2D



D2D discovery and communications
(1000s of devices/services in ~500m)

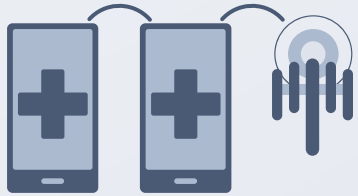


One-to-many communications
(in- and out-of-coverage)

Release 13

Enhancements focusing on public safety

Flexible discovery such as
private and inter-frequency

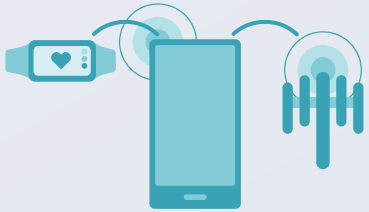


Device-to-network
relays

Release 14 / 15

Expanding into automotive and broader use cases

Sidelink for
automotive



Additional D2D
communication capabilities

A rich technology history for sidelink communication

Began with LTE Advanced and continues into 5G evolution and beyond

Sidelink

Release 16

5G NR Sidelink

Release 16

Technical foundation applicable for broader sidelink use cases

5G sidelink brings many improvements over previous direct communications design

Lower latency

Sidelink supports a flexible sub-carrier spacing (i.e., 15, 30, 60, 120 kHz) enabling shorter slots delivery and lower transmission latency

Wider bandwidth

Sidelink supports a 2x2 MIMO scheme enabling a higher data rate for direct communications

Expanded applications

Sidelink supports various cast types such as broadcast, multicast/ groupcast, and unicast

Improved reliability

HARQ[1] procedure is introduced on the sidelink interface providing retransmissions based on the receiver's feedback

Flow-based QoS framework

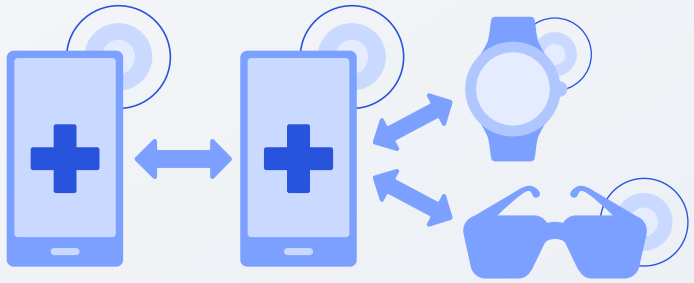
Full-fledged mechanism for sidelink provides the means to meet QoS requirements of direct communications for public safety services

5G support for sidelink started in 3GPP Release 16

1 Hybrid Automatic Receive Request

Sidelink

Release 17



Sidelink Enhancements
Release 17

For public safety, IoT, commercial use cases and beyond

Updated sidelink evaluation methodology
Reusing existing evaluation assumption and performance metric[1], based on feedback from car manufacturers

Improved resource allocation
Reducing device latency, power consumption, and improving reliability (e.g., half duplex, collision detection indication, control forwarding, inter-device coordination)

Power saving enhancements
Defining sidelink DRX for broadcast, groupcast, unicast, and power-efficient resource selection for devices

New sidelink frequency bands
Ensuring sidelink and network communication coexistence in the same and adjacent channels in licensed spectrum

Geographic confinement
Limiting sidelink operations to be within a predetermined area for a given frequency range in non-ITS[2] bands

Sidelink relay
L2/L3 device-to-network relay for coverage extension. Follow-up work item for device-to-device relay in scope for Release 18

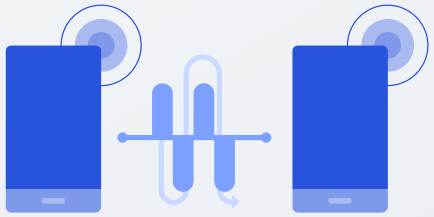
Release 17 expands sidelink to new use cases

Source: RP-202846 (NR Sidelink enhancement); RP-212601 (NR Sidelink Relay)
1TR 36.843 and/or TR 38.840; 2 Intelligent Transport System

Sidelink

Release 18

Unlicensed spectrum

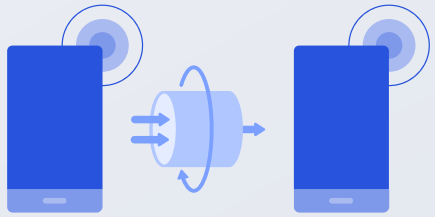


Supporting optimized sidelink operations over unlicensed bands such as 5 GHz

Multi-beam operation

Supporting sidelink beam management by reusing and enhancing existing framework and concepts

Sidelink carrier aggregation



Supporting enhanced use cases that can benefit from wider bandwidths

Expanding foundational 5G Sidelink capabilities in Release 18

For use cases that require increased data rate over sidelink

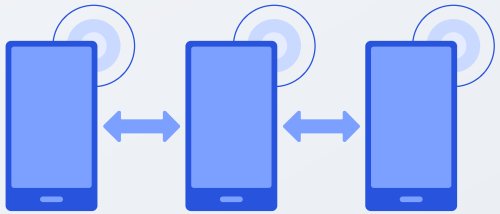
Source: RP-213678 (Sidelink enhancements)

Sidelink

Release 18

Device-to-device relay

Support for device-to-device relay is essential for the overall sidelink coverage extension use case

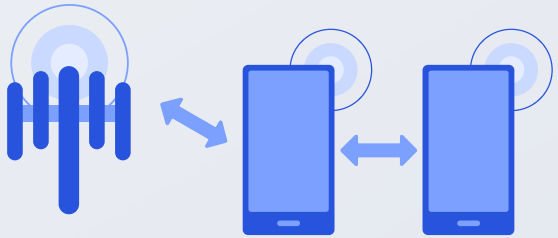


Support for L2/L3 device-to-device relay

Allowing single-hop operation with forward compatibility for more hops

Device-to-device relay

Service continuity enhancements in device-to-network relay are necessary to cover the mobility scenarios not supported in Release 17



Supporting inter-gNB path switching and service continuity

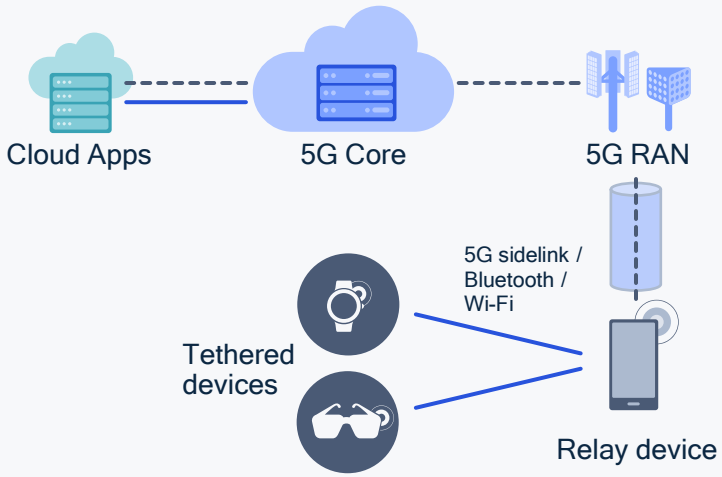
Enhancing reliability and throughput with multi-path connectivity[1]

Completing features such as DRX[2] for sidelink relay operations

Further extending 5G Sidelink relay capabilities in Release 18

RP-213585 (Sidelink Relay Enhancements); 1 Support for 1 direct Uu + 1 indirect PC5 within the same cell; 2 Discontinuous reception

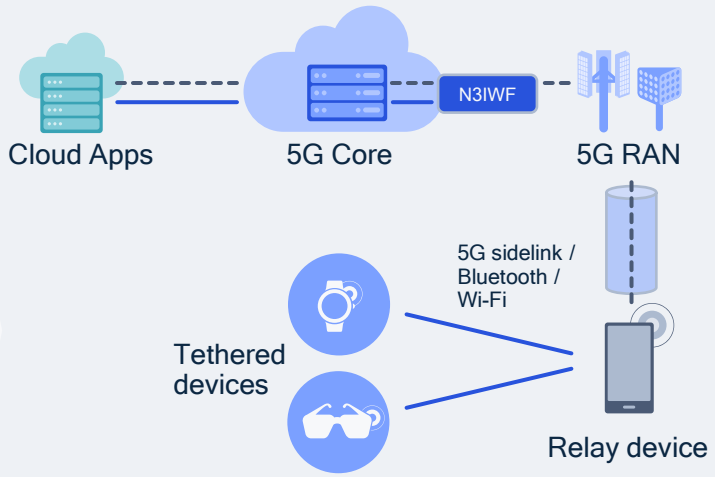
Layer 3 (L3) Relay



No 5G connection to the tethered device

Application-level quality-of-service (QoS) supported on the tethered device

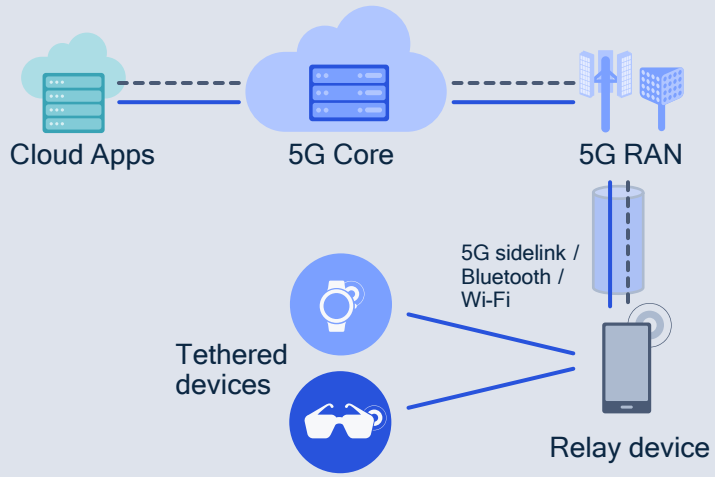
L3 Relay with N3IWF[1]



5G core network connection is extended to the tethered device

Some 5G performance benefits can be realized on the tethered device

Layer 2 Relay



5G core and radio access network connection is extended to the tethered device

Full 5G performance optimization can be realized on the tethered device

Relay device traffic

Tethered device traffic

Device disaggregation technology evolution

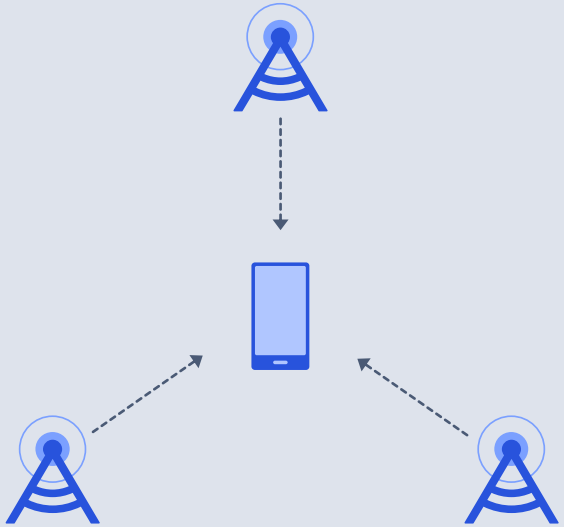
Proposed to 3GPP Release 18 – extending direct connection user experience over tethered device connection

1 Non-3GPP Interworking Function

5G NR positioning

3GPP Release 16

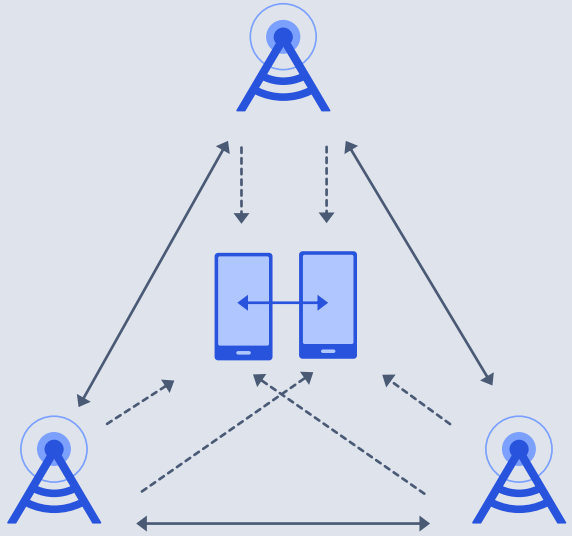
Use positioning reference signals (PRS) over the 5G NR air interface (Uu) to estimate the position of a 5G device



Cooperative positioning

3GPP Release 18+

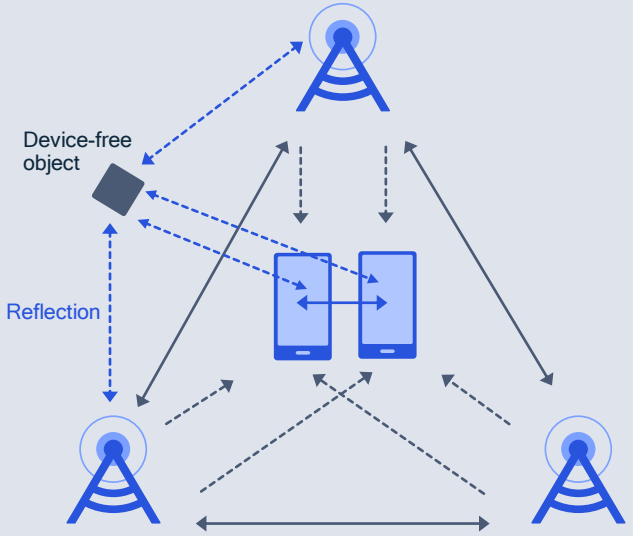
Exploit more line-of-sight opportunities by using 5G sidelink (SL) PRS for ranging between devices, in addition to PRS over the Uu interface to estimate the position of multiple 5G devices simultaneously and cost-effectively



Cooperative sensing with 5G sidelink

3GPP Release 18+

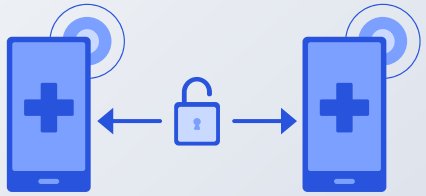
Use positioning reference signals (PRS) over the 5G NR air interface (Uu) to estimate the position of a 5G device



Advancing 5G positioning with sidelink and RF sensing

3GPP Release 18 and beyond

Strengthening security for critical 5G sidelink use cases



5G Sidelink Security Requirements

Provisioning of security credentials to support various use cases

Support of flexible deployment options across multiple operators

Secure relaying operations, including device-to-network and device-to-device relay scenarios

Areas of 5G Sidelink Security Enhancements

Rel-16/17

Security provisioning at scale and on-demand

Secure group member and service discovery

Flexible configuration of security and privacy per application

Unicast, multicast, and broadcast security

Support of device-to-network relay

5G Advanced

Support of device-to-device relay, i.e., multi-hop discovery and unicast communication

Support of emergency services

Secure ranging and sidelink positioning at scale

Others

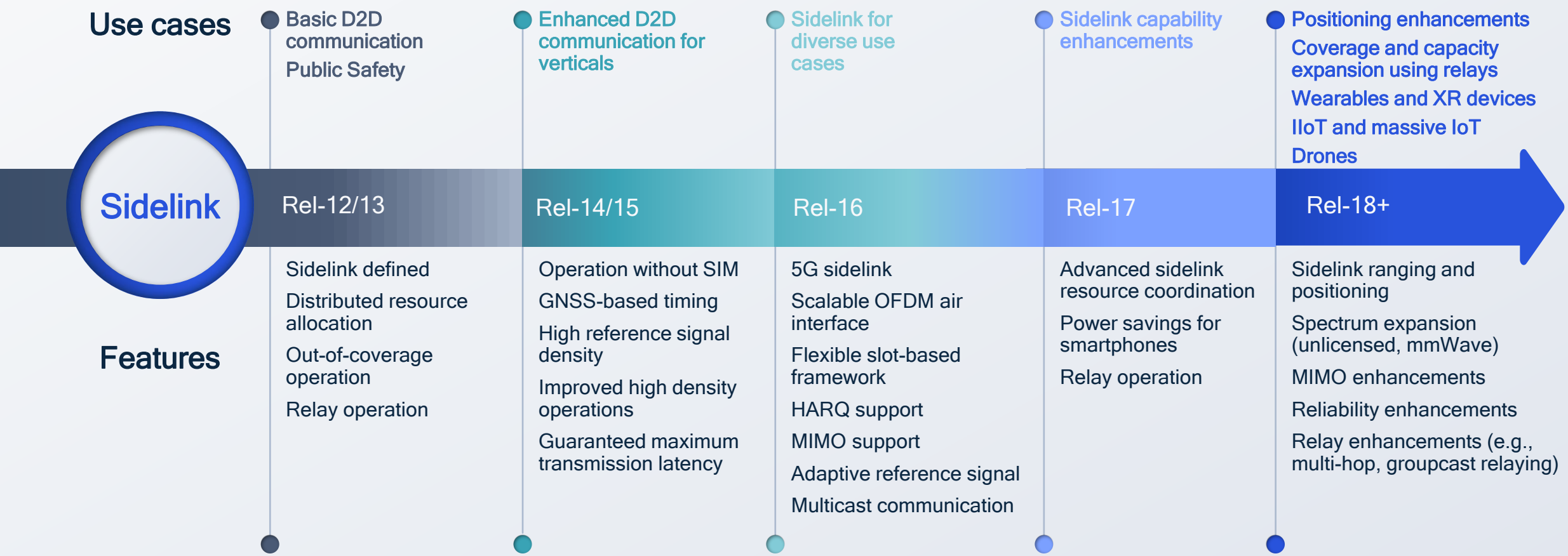
Device authentication and/or attestation based on hardware root-of-trust as proof of integrity

Physical-layer resource randomization for LPI/LPD[1] and jamming resilience

Physical-layer encryption of control information and reference signals for ultra-secure communication, e.g., military use cases

1 Low Probability of Intercept/Detect

Sidelink technology evolution in 3GPP standards



Pushing the technology boundary for sidelink in 5G Advanced

Foundational technology that will expand to many applications

Qualcomm is leading the way

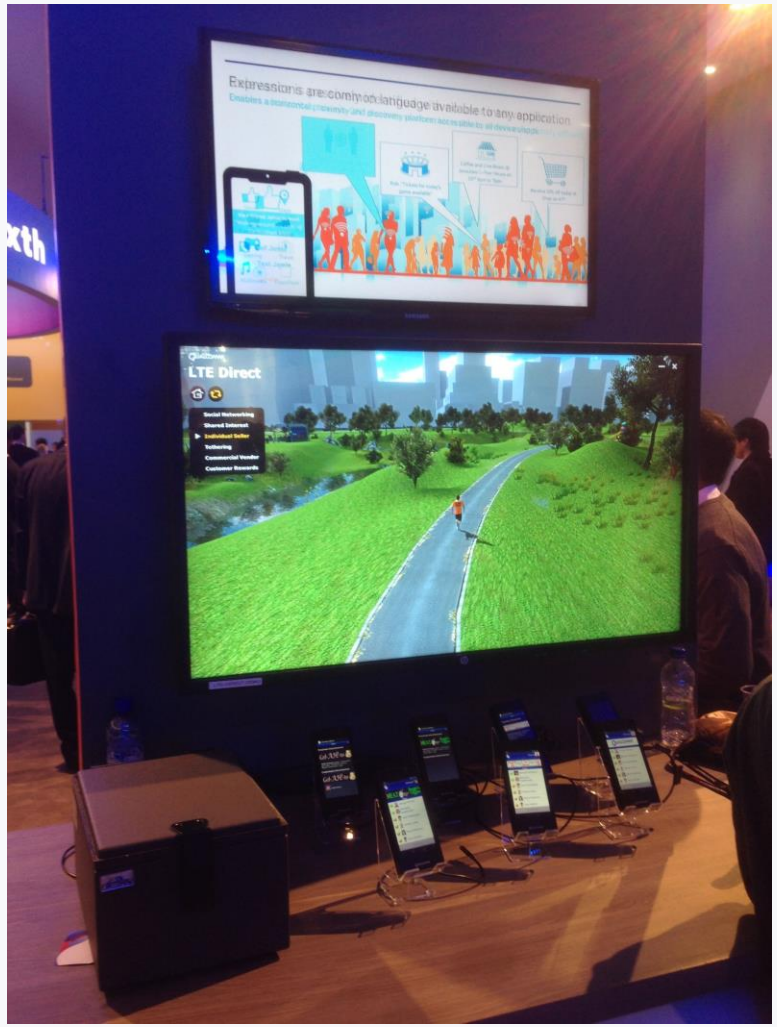
Driving future 5G sidelink technologies and new use cases

Qualcomm drove direct communications into global cellular standards

LTE Direct is part of 3GPP Release 12

3GPP RAN1 #72
Malta Feb 2013

MWC 2013
Qualcomm pioneered device-to-device communication and showcased LTE-Direct proximity services over-the-air demos



Initial D2D efforts led to many new use cases

- Public safety
- Coverage extension
- Automotive safety

C-V2X has been commercialized based on sidelink

C-V2X

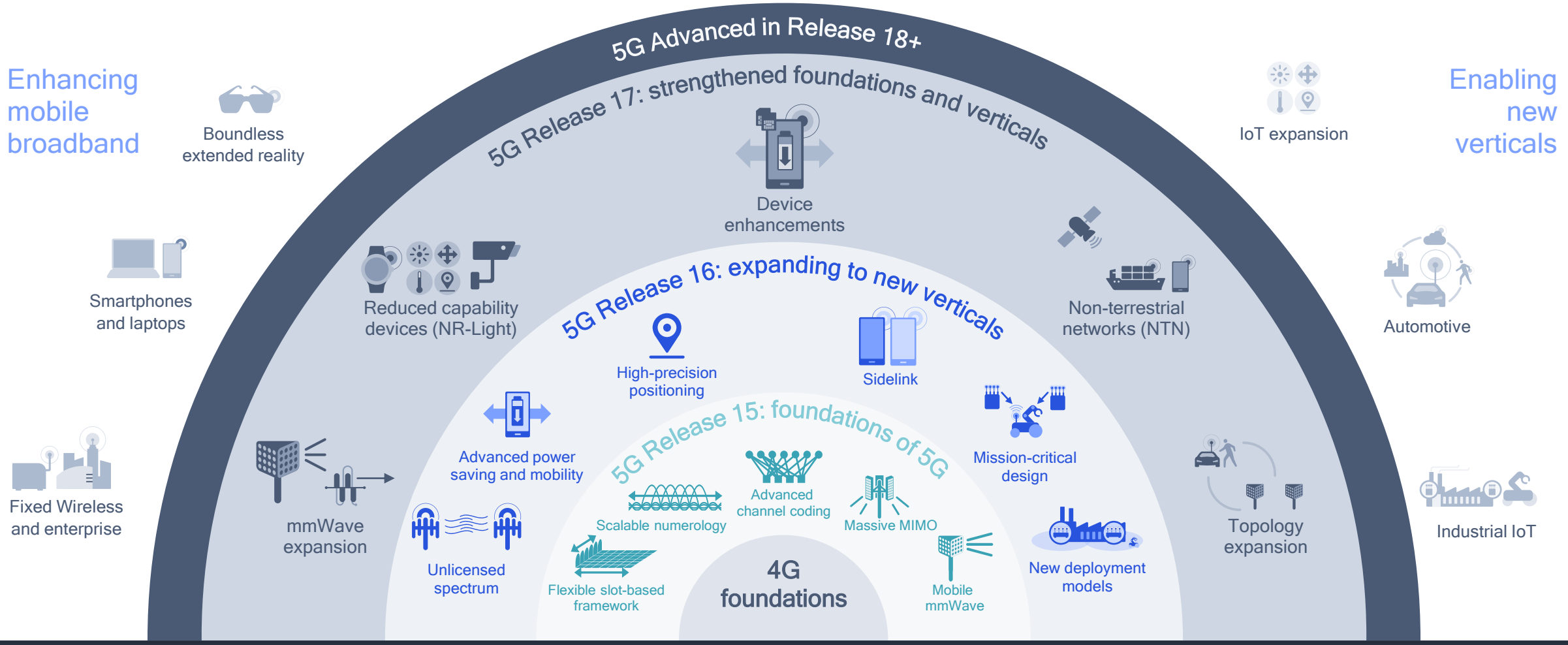
Introduced in 3GPP Release14

Qualcomm® 9150 C-V2X chipset commercialized starting 2018

Integration of C-V2X into the Snapdragon ® Auto Platforms

C-V2X already deployed commercially in China; U.S. deployment in progress

Broad industry support with 3GPP, 5GAA, GSMA, SAE, ITE, NEMA, IEEE, and 5G Americas



Our innovations expand the foundation of 5G

Foundational Qualcomm innovations lead 3GPP Releases 15,16 and 17

Our Release 16 inventions expand the 5G NR foundation

Unlicensed spectrum

Shared spectrum, LAA, standalone operation

For improved capacity and new use cases

Advanced power saving & mobility

WUS, faster CA, full-power UL, dual connectivity

For better device performance and coverage

High-precision positioning

OTDOA, PRS, UE-based positioning, multi-cell RTT

For more accurate indoor and outdoor positioning

Sidelink

Direct communication between devices

For broader use cases, e.g., smartphones, IoT

Mission-critical design

Multi-TRP, CoMP, service multiplexing & preemption

For meeting ultra-high reliability of up to 99.9999%

New deployment models

Non-public network, TSN, IAB, in-band eMTC/NB-IoT

For new deployments such as IIoT & enterprise

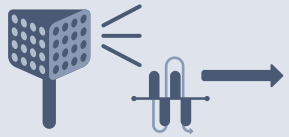
Early R&D investments

Cutting-edge prototypes

Fundamental contributions to 3GPP

Qualcomm innovation leadership in 3GPP Release 17

mmWave expansion



For more capacity, new use cases and deployments

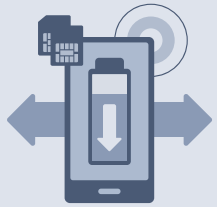
Licensed and unlicensed spectrum operations in 52.6-71 GHz

Reduced capability devices (NR-Light)

For expanded IoT: wearables, sensors, surveillance cameras

Lower complexity devices with 20 / 100 MHz max bandwidth in sub-7 / mmWave with 1 or 2 Rx antennas

Device enhancements



For enhanced device user experience and performance

More antennas, higher throughput, battery life, mobility, coverage, positioning accuracy, multi-SIM

Non-terrestrial networks (NTN)

For ubiquitous coverage and expanded use cases

Satellite communications for mobile devices and IoT, leveraging 5G NR framework

Topology expansion

For more efficient deployments, public safety, and others

Enhanced IAB, relay, broader use cases for smartphones and beyond

Early R&D investments

Cutting-edge prototypes

Fundamental contributions to 3GPP

Demonstrating 5G sidelink technologies delivering new capabilities and benefits for diverse use cases

Industrial IoT capacity expansion

Release 18+ | Over-the-air testing

Leveraging direct communication, with dynamic path switching, between devices and PLC (Programmable Logic Controller) over 5G sidelink to expand system capacity

Multi-hop mesh coverage extension

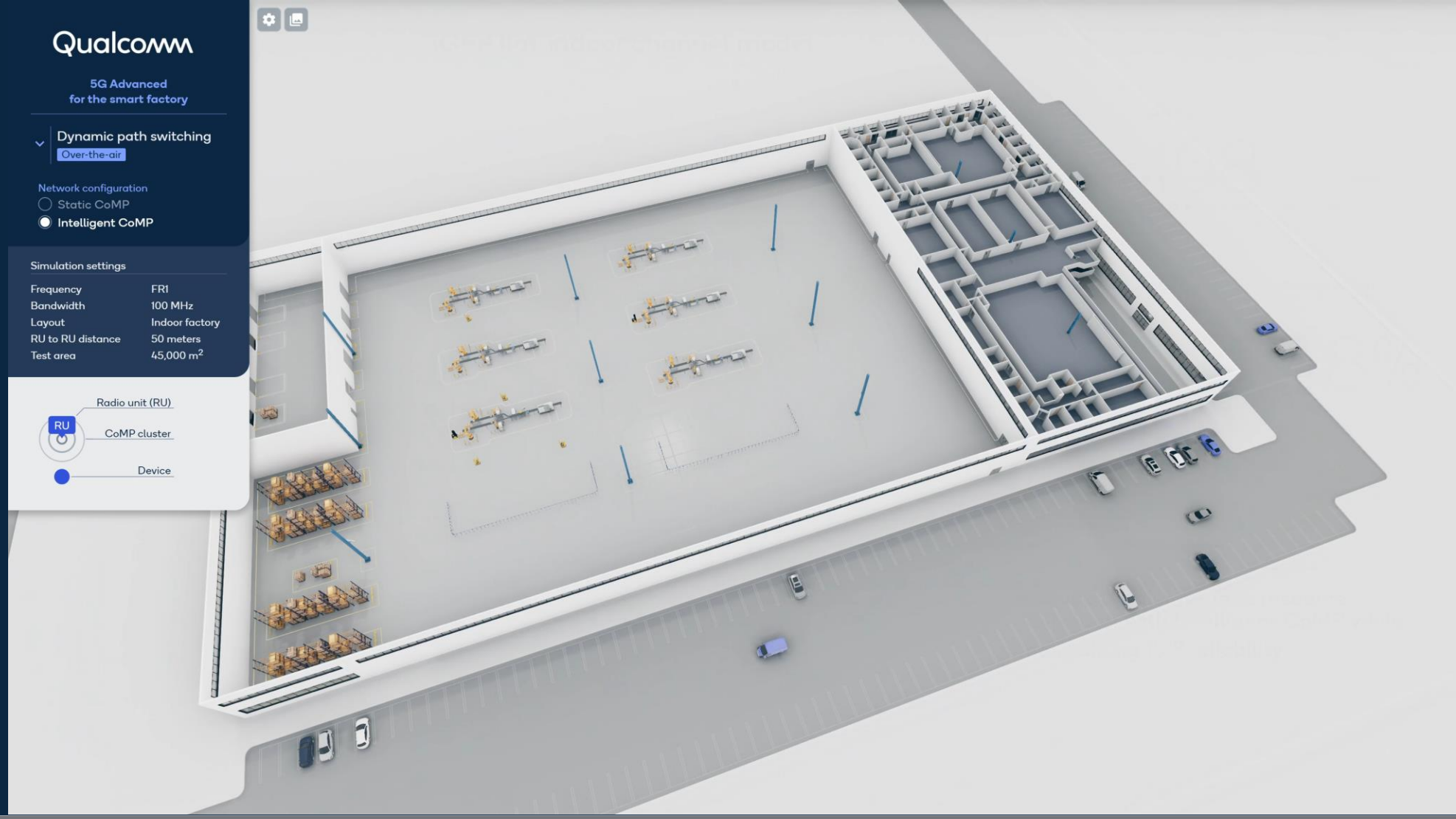
Release 18+ | System Simulation | Over-the-air testing

Utilizing sidelink communication to extend coverage for 5G NR-Light IoT, enabling cost-efficient connectivity for multiple devices through a single wide-area connection

Industrial IoT Capacity Expansion

Release 18+

Over-the-air testing

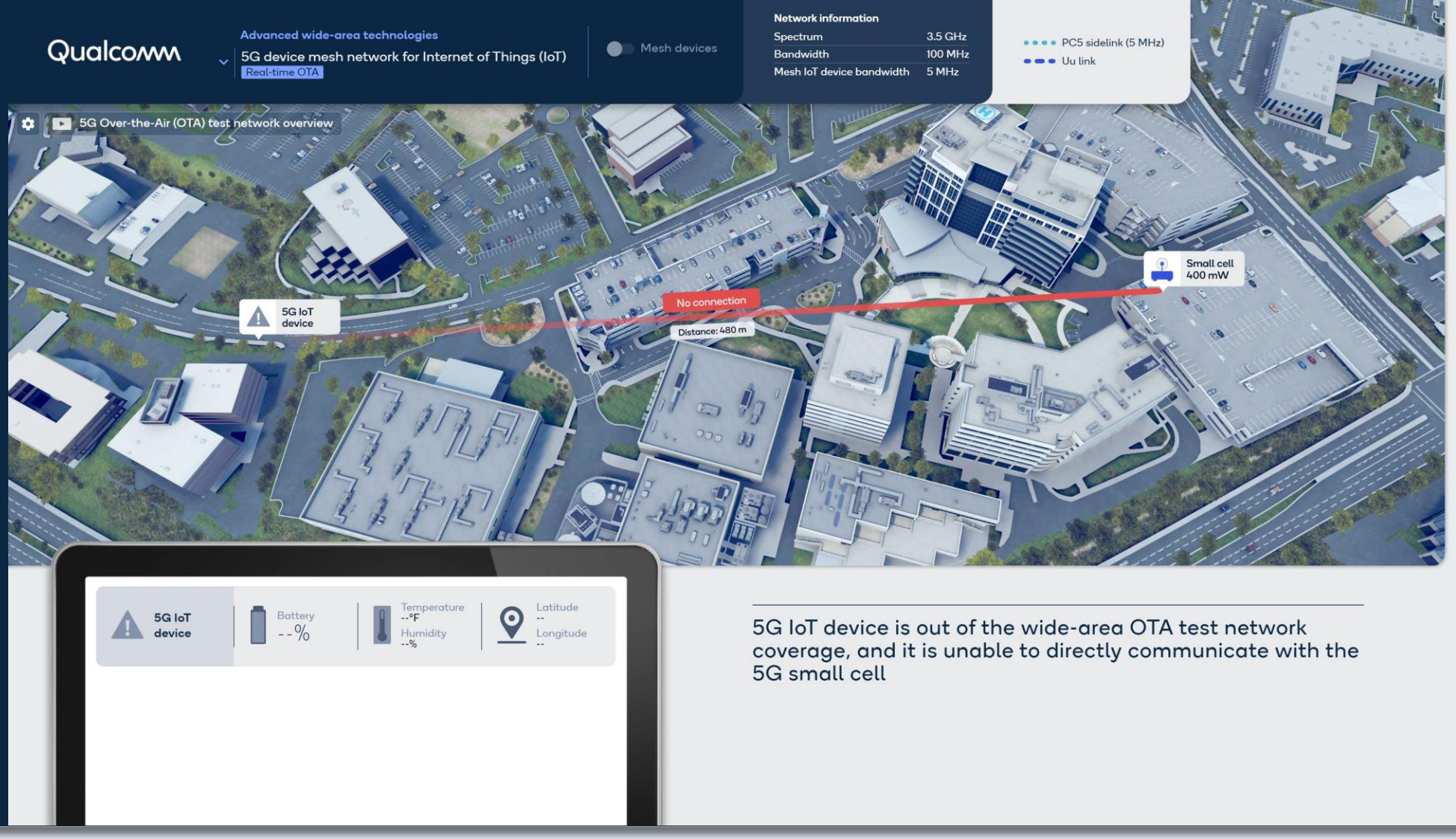


5G sidelink facilitates direct communication, with dynamic path switching, between devices and PLC, delivering expanded system capacity

Multi-hop Mesh Coverage Extension

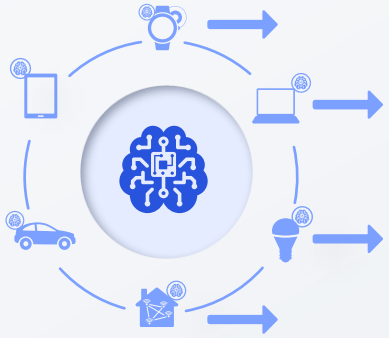
Release 18+

Over-the-air testing



5G IoT device is out of the wide-area OTA test network coverage, and it is unable to directly communicate with the 5G small cell

5G sidelink can extend NR-Light coverage, enabling cost-efficient IoT connectivity for multiple devices through a single wide-area connection

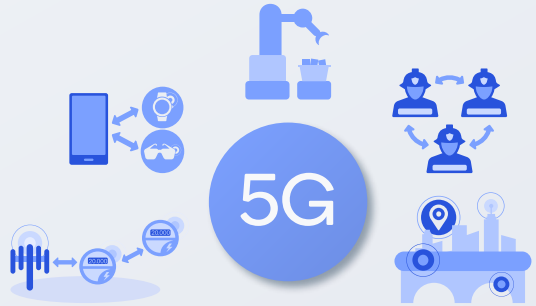


Sidelink is a core topology of the 5G system design that can further extend the Connected Intelligent Edge

Sidelink is commercialized today and continues to evolve in the 5G era and beyond

Bringing next-level 5G versatility with sidelink

To enable new system efficiencies and vertical use cases



Sidelink delivers a broad set of system benefits to diverse 5G devices, use cases, and deployments

Qualcomm

Qualcomm is leading the way driving future 5G sidelink technology evolution and into new use cases

Thank you

Qualcomm

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