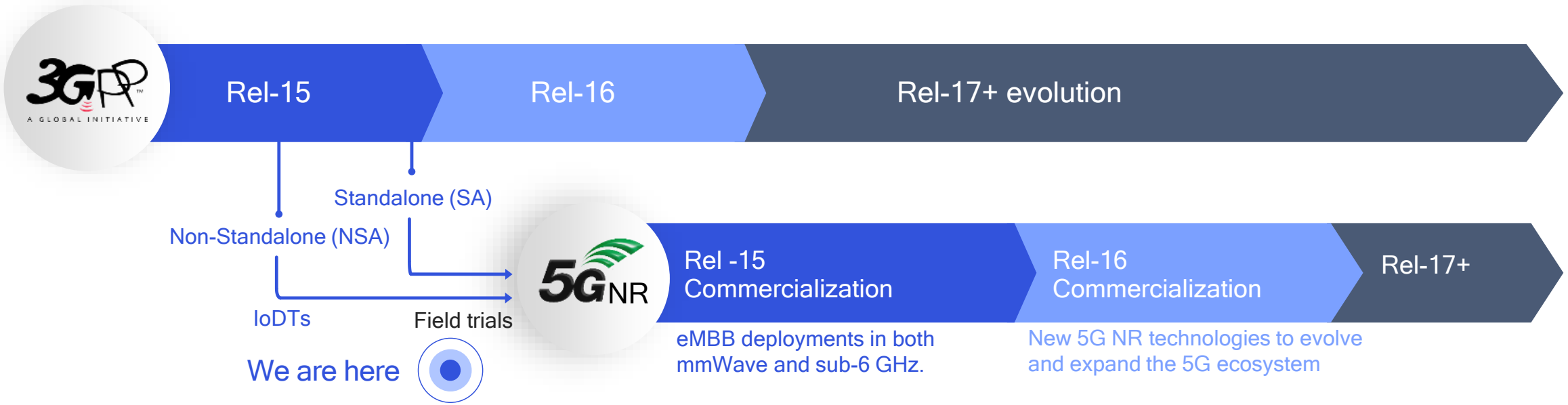
Qualcomm

New business opportunities for 5G NR

5G


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

Driving the 5G roadmap and ecosystem expansion



Private 5G networks will expand the market

Wide range of industries from manufacturing and seaports to venues and enterprise

>$100B

addressable market for private IoT networks in 2023 [1]

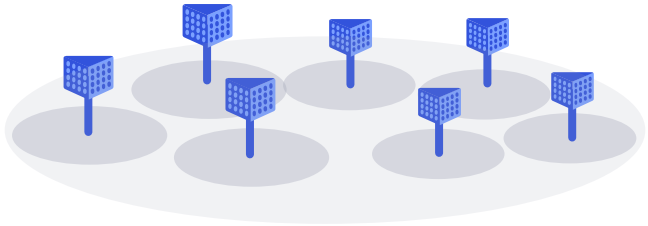
32% CAGR

1. Harbor Research “The Private LTE Opportunity for Industrial and Commercial IoT”

Extending mmWave indoors with private 5G networks

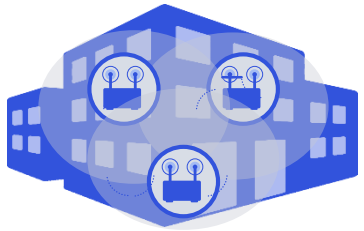
Operator's public mmWave network

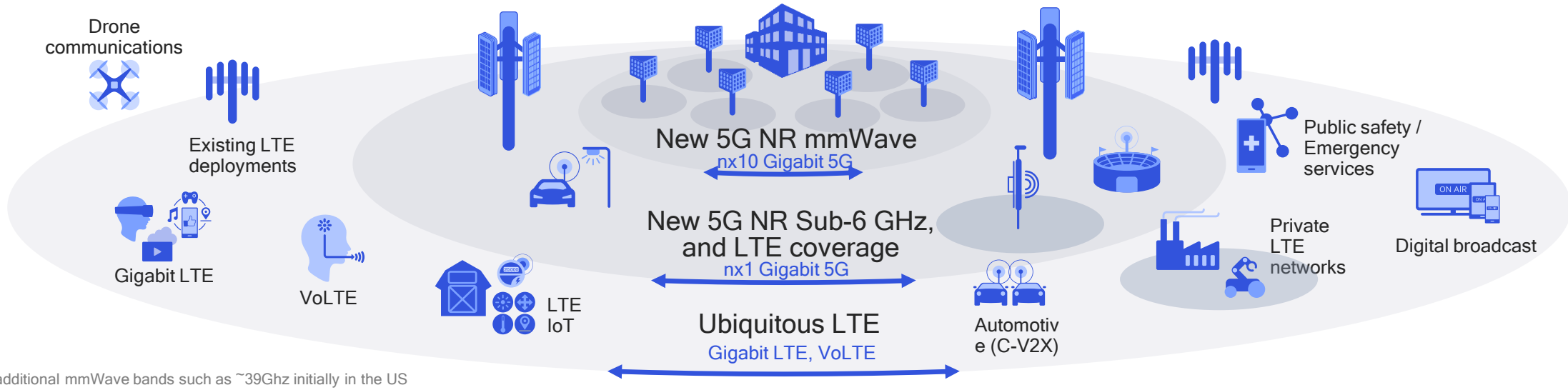
- Unlimited data, elevated experiences
- Anchored in LTE (non-standalone)
- Global mmWave spectrum ~28 GHz[1]



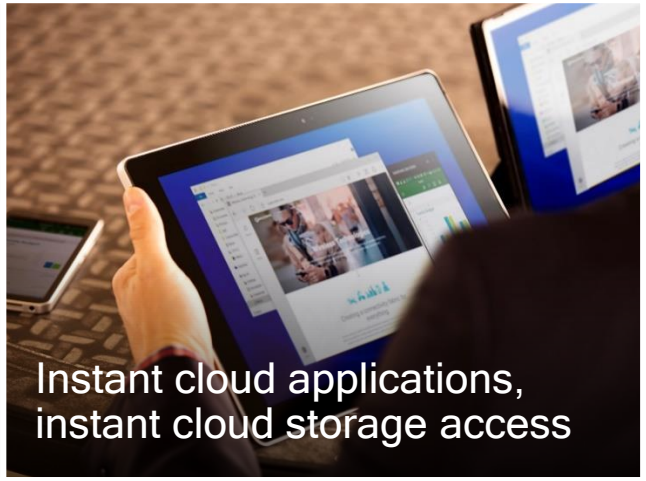
Private indoor mmWave enterprise network

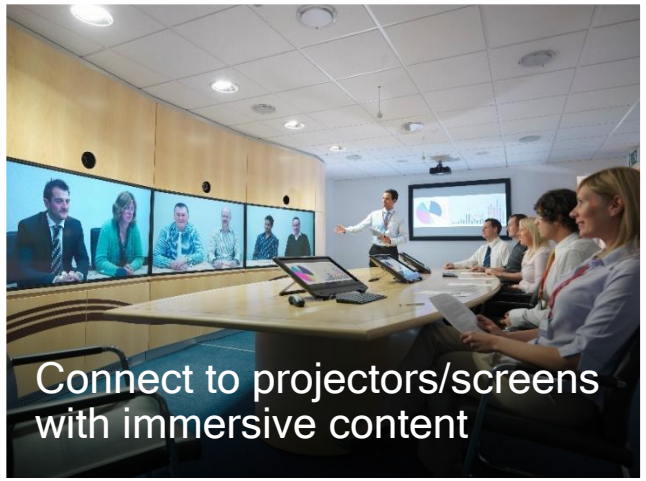
- 5G NR mmWave complements Wi-Fi
- Standalone, no dependency on public network
- Reuse spectrum (in/out isolation), common device solution

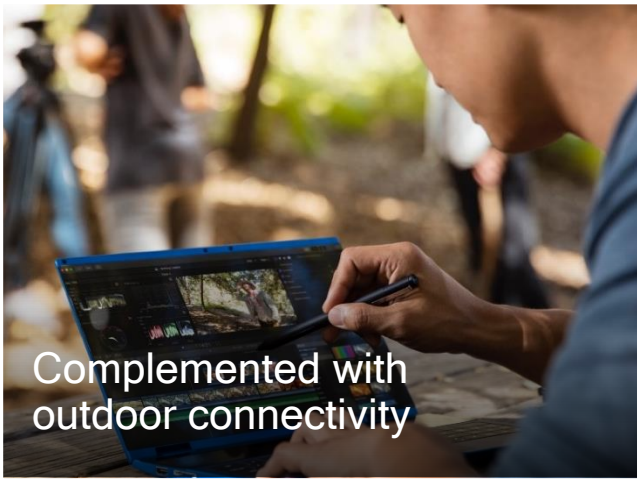




1) Plus additional mmWave bands such as ~39Ghz initially in the US







Enterprise networks: 5G NR mmWave + Wi-Fi

Always connected laptops and tablets[1]

- Multi-Gigabit speeds with virtually unlimited capacity
- Reuse licensed spectrum– in-/outside mmWave isolation
- Private 5G NR indoor network with cellular grade security

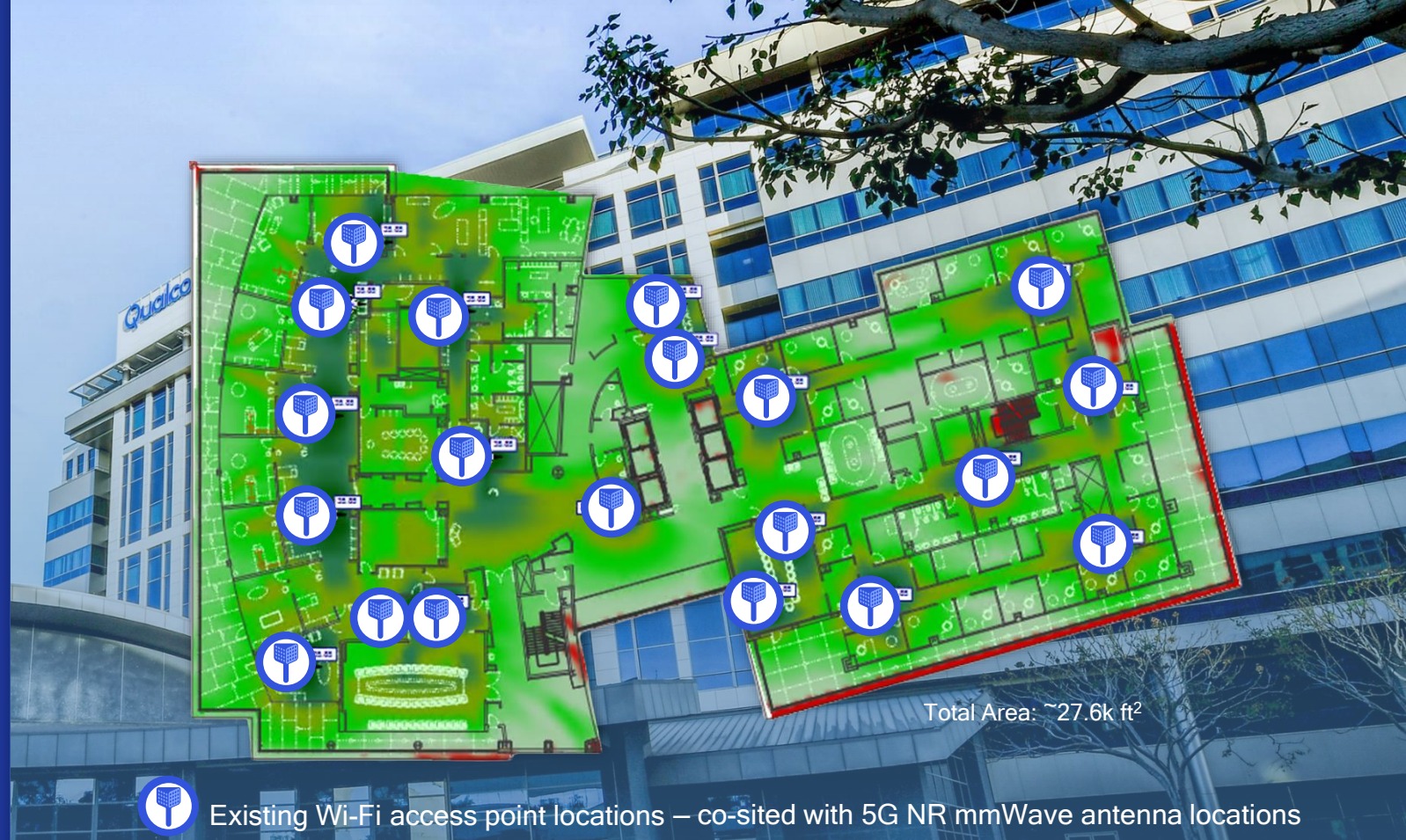
1) Requires network connectivity; 2) Expected coverage in typical office environments, actual coverage and performance depends on propagation and deployment.

5G NR mmWave boosts performance in Enterprise networks

Downlink/uplink coverage comparable to Wi-Fi with 1:1 or partial co-site

Realize multi-Gigabit burst rate with wider bandwidths (e.g., 800 MHz)

Complement indoor Wi-Fi deployments

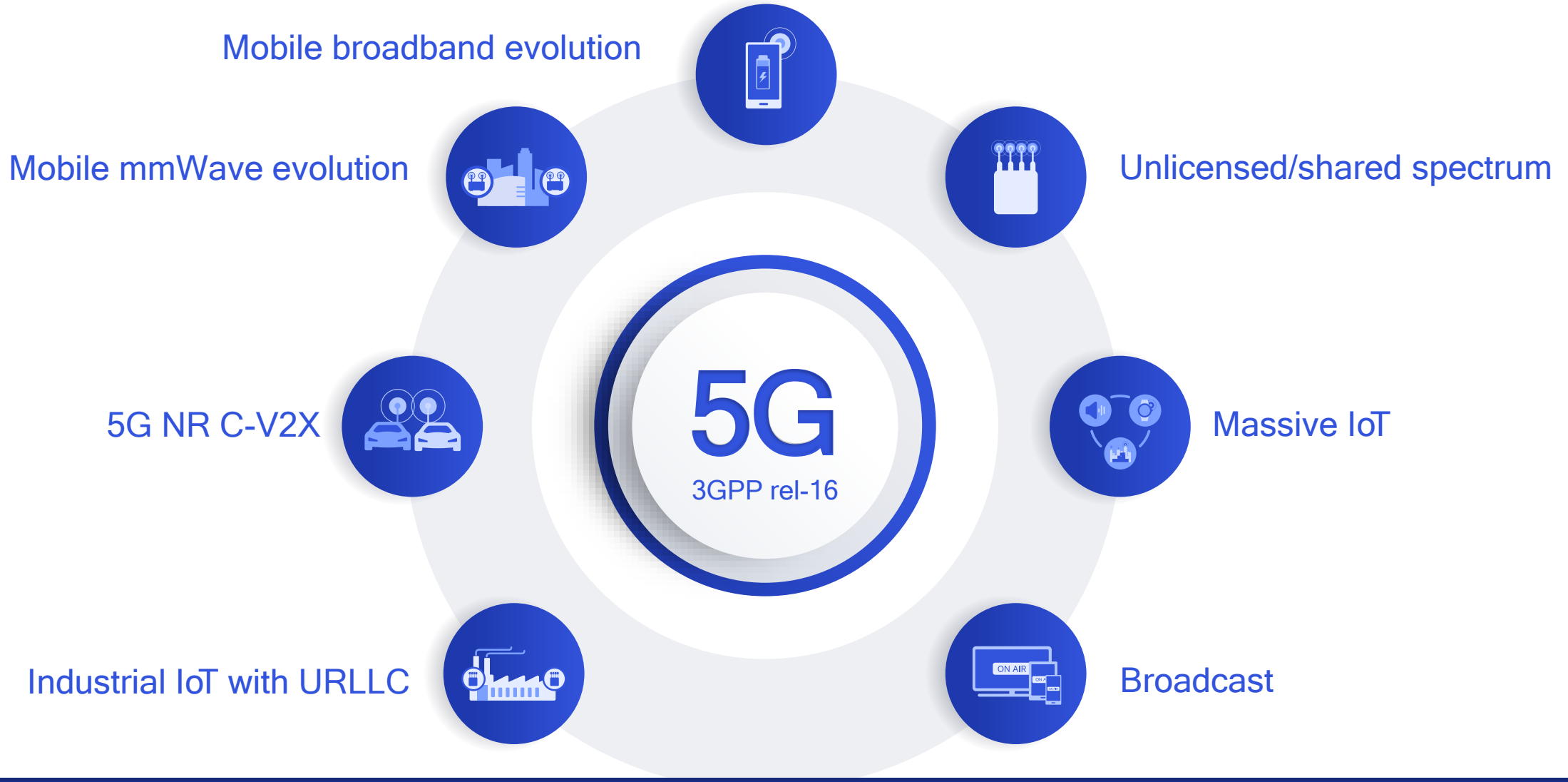


Existing Wi-Fi access point locations – co-sited with 5G NR mmWave antenna locations

Complete coverage at 28 GHz[1] at Qualcomm headquarters

- ~98% Downlink coverage with 1:1 co-siting
- ~99% Uplink coverage with 1:1 co-siting
- 5 Gbps downlink median burst rate[3]

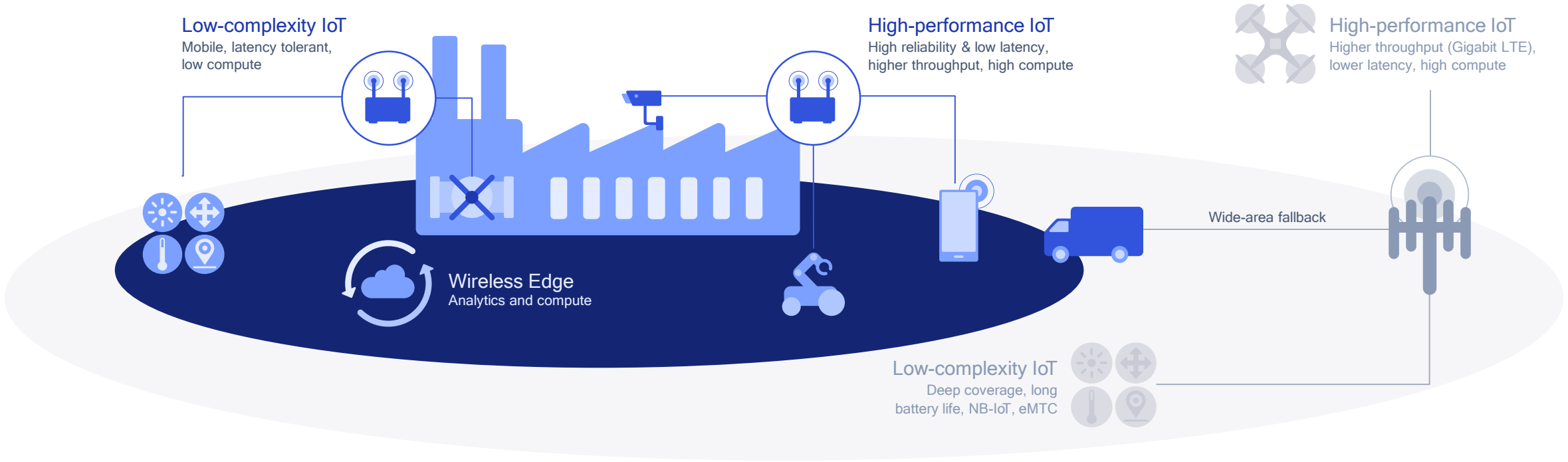
Coverage simulation based on MAPL (maximum allowable path loss) analysis with ray tracer propagation model and measured material and propagation loss; minimum 0.4/0.1 bps/Hz for downlink/uplink data and control; 2 Maximum Allowable Path Loss; DL: 115 dB, UL 117 dB 3 Using 800 MHz DL bandwidth and 100 MHz uplink bandwidth with 7:1 DL:UL TDD



5G NR is expanding to new use cases and verticals

Addressing unmet needs: dedicated, local and optimized

Opportunity for both licensed and unlicensed spectrum



Private 5G/LTE network [1]

Dedicated network for local services

Optimized for specific use case

Secure

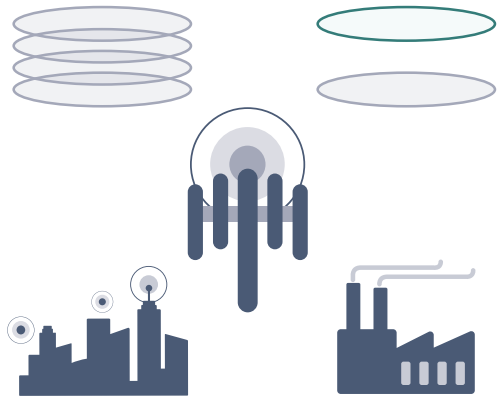
Public 5G/LTE network

Wide-area coverage

1) A private 5G/LTE network can also support generic traffic as a neutral host, for example at an hospital it can provide dedicated services for employees/equipment and also operate as a neutral host for visitors.

Private 5G networks – an opportunity for mobile operators

To deploy, manage, or offer as a service, both in licensed and unlicensed spectrum

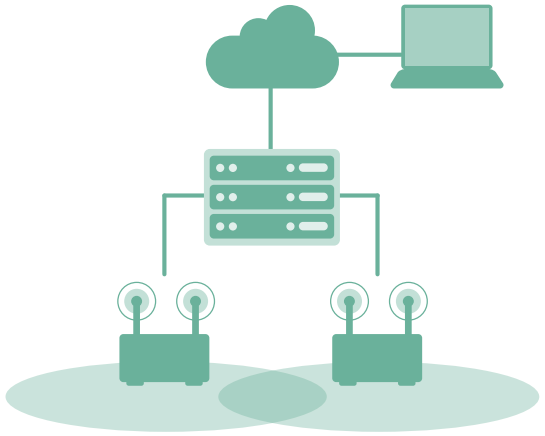


Licensed spectrum assets

Dedicate a portion for private networks

Spectrum may be under-utilized in industrial areas

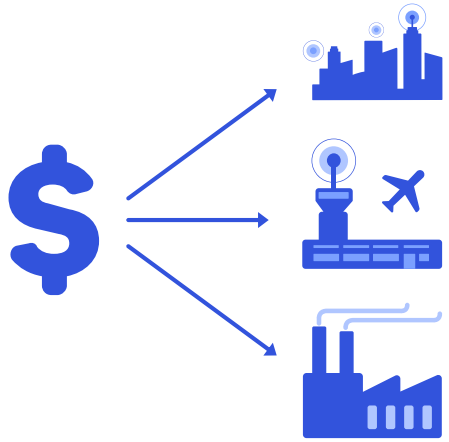
Reuse mmWave spectrum indoors, such as for private enterprise network



Expertise in mobile networks

Relevant expertise in deploying, optimizing, operating mobile networks

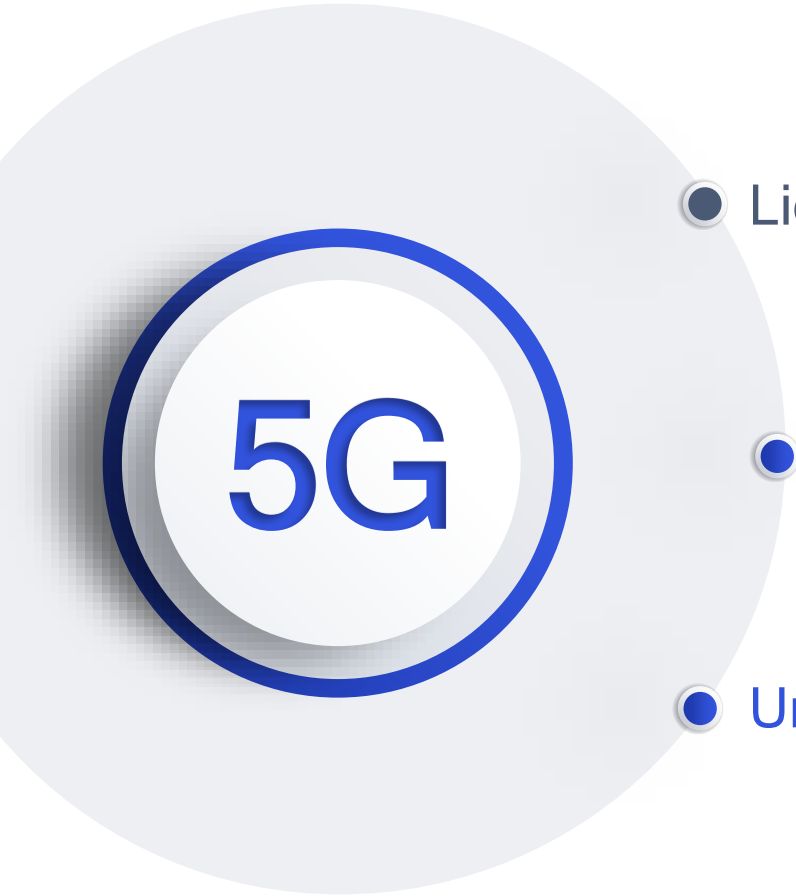
Existing ecosystem relationships



Existing sales channels

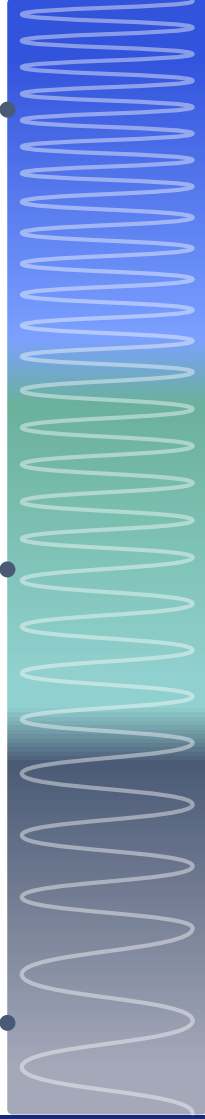
Already provide services to many industrial and enterprise customers

Multiple business opportunities, from deploy to offer private network as a service



- Licensed spectrum
- Shared spectrum
- Unlicensed spectrum

- Unlocks more spectrum
- New markets/verticals
- New deployment scenarios



Shared and unlicensed spectrum creates new opportunities and expands the ecosystem

5G NR-U valuable for wide range of deployments

3GPP study on 5G NR in unlicensed spectrum, fair coexistence with LAA, Wi-Fi

Licensed assisted NR-U

Boosting existing deployments

Better user experience with higher speeds

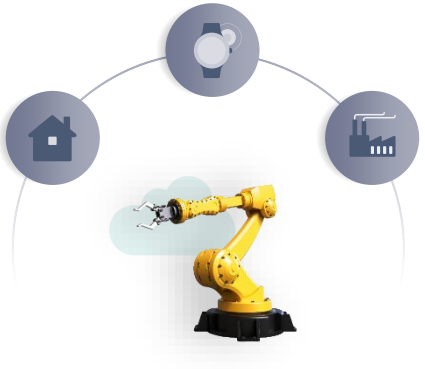
Stand-alone NR-U

Open mobile broadband

Neutral host, neighborhood network

Private networks[1]

Industrial IoT, enterprise broadband

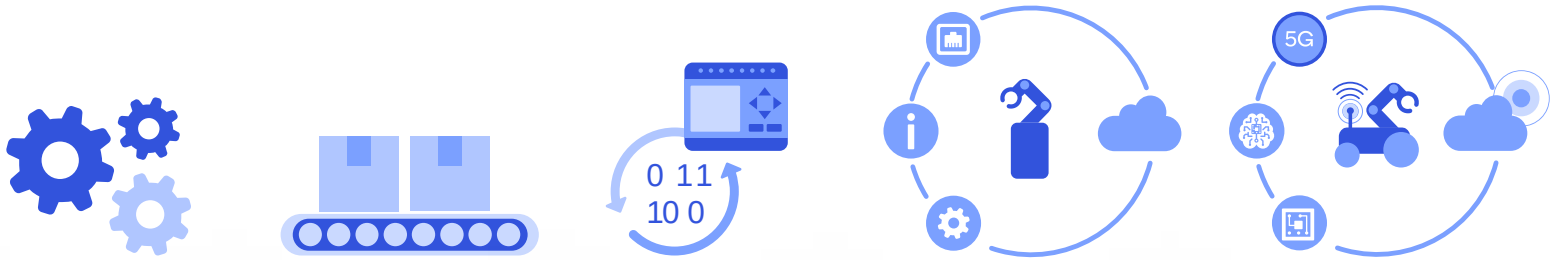


Aggregating licensed and unlicensed spectrum

Expanding 5G market with new types of deployments

1) A private network can also support generic traffic as a neutral host, for example at an hospital it can provide dedicated services for employees/equipment and also operate as a neutral host for visitors.

The next industrial revolution is on its way and will be augmented by 5G



Industry 1.0
Mechanization

Industry 2.0
Electrification

Industry 3.0
Digitalization

Industry 4.0
Connectivity

Industry 4.0 + 5G
At wireless edge

Compute • Security • Connectivity

On-device processing and sensing

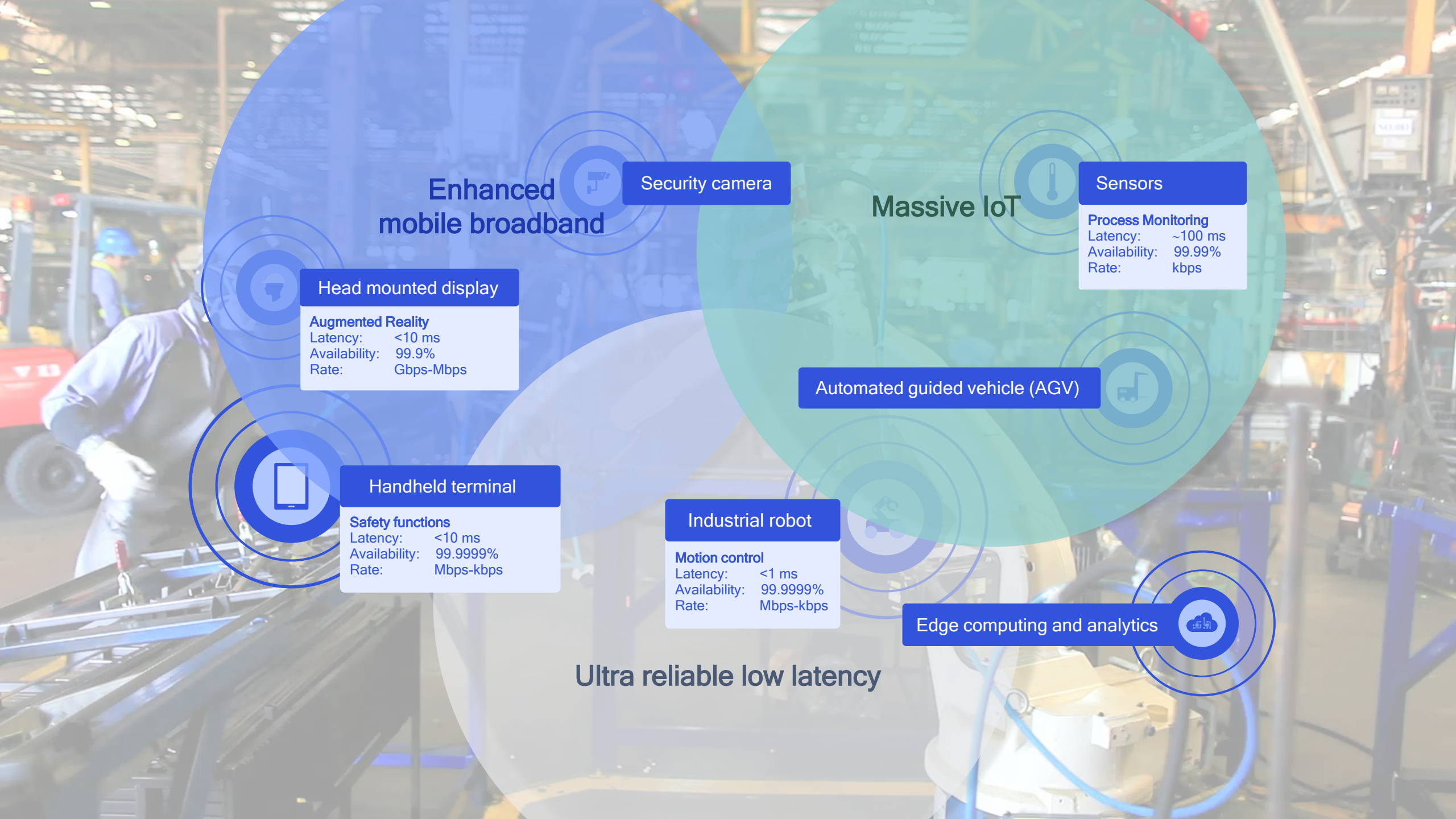
CV and AI for autonomous robots

Edge services and data privacy

Single futureproof 5G network

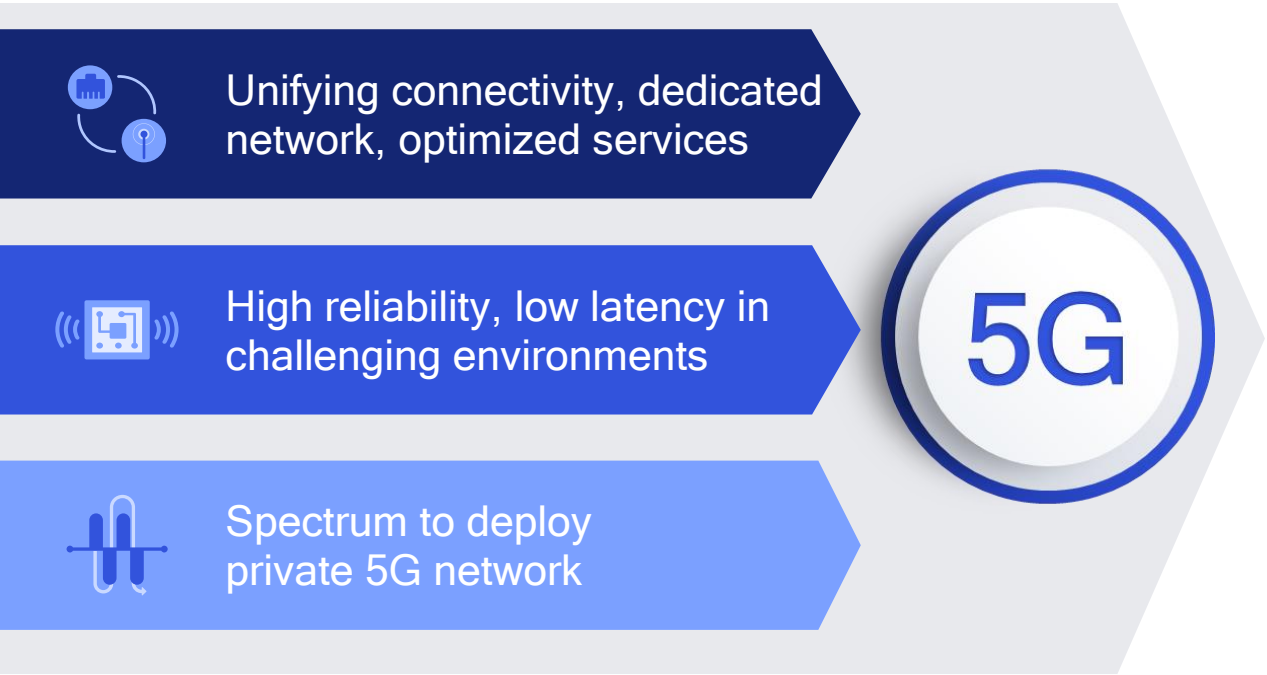
Scalable capacity and reliability

Flexibility with wireless Ethernet


Enhanced 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 computing and analytics
Ultra reliable low latency

Designing 5G to meet industrial IoT requirements

Key challenge: wireless industrial Ethernet for reconfigurable factories



Private futureproof 5G network for all services: eMBB, massive IoT, URLLC

Ultra Reliable Low Latency Communication (URLLC)

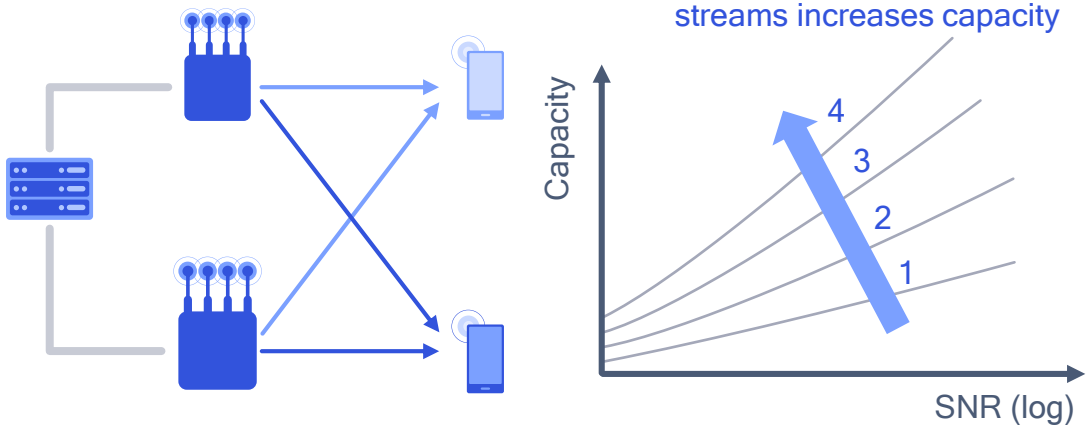
Coordinated Multi-point (CoMP)

Time Sensitive Networking (TSN)

Up to 99.9999% reliability required for industrial Ethernet

Dedicated licensed, shared/unlicensed spectrum or regional, e.g. 3.7GHz GER

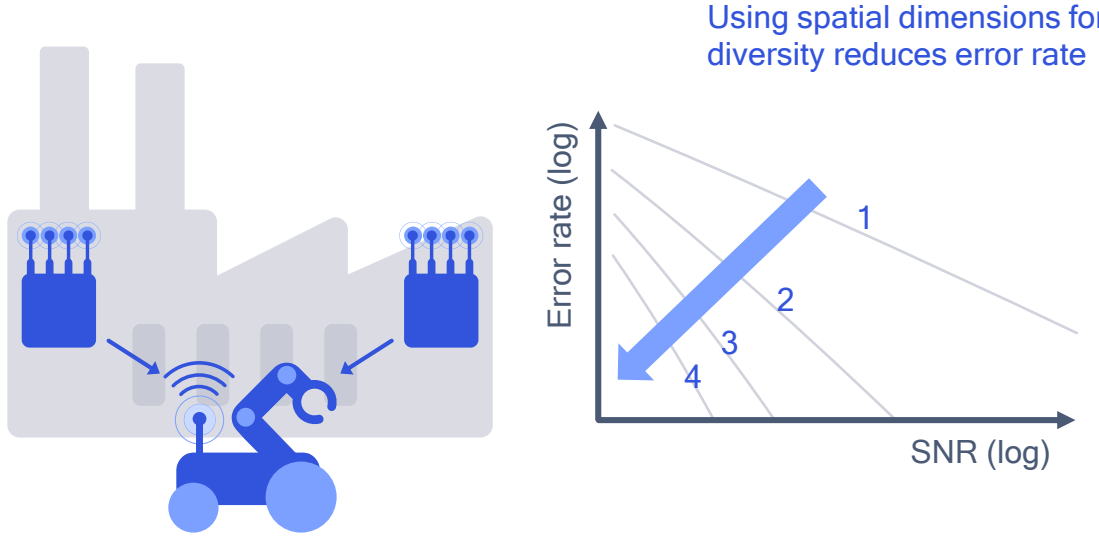
CoMP expands 5G: capacity or ultra-reliability tradeoff



Capacity from spatial multiplexing

Allows multiple transmissions at the same time to multiple location without interfering

Can also be used to by multiple operators to share spectrum more efficiently



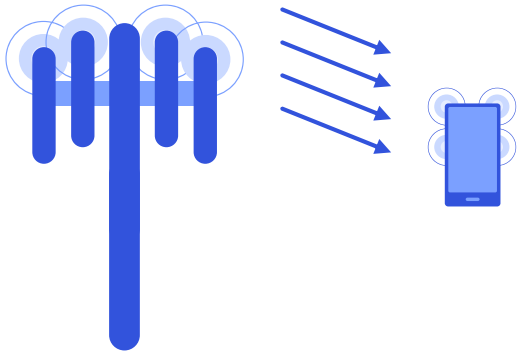
Reliability from spatial diversity

Spatial diversity can overcome radio shadowing in challenging radio environments

Key for URLLC1 to meet 99.9999% reliability and challenging industrial IoT applications

1) Ultra reliable low latency communication

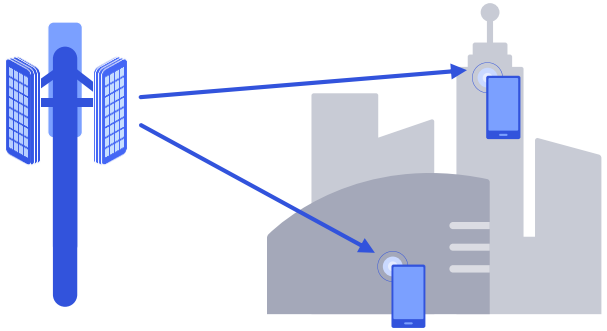
Exploiting spatial domain–from LTE MIMO to 5G CoMP



LTE MIMO

2 Gbps peak-rates with 4x4 MIMO[1], carrier aggregation and higher order modulation

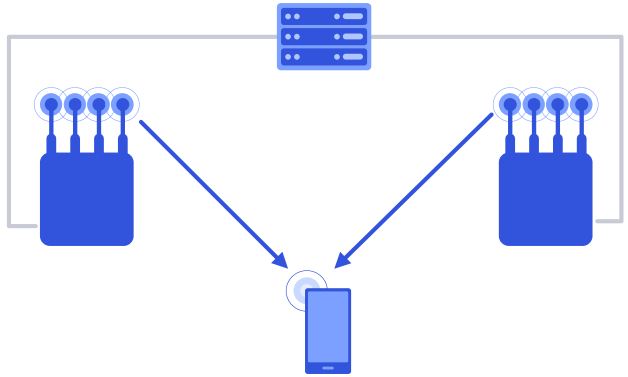
Example: 2 or 4 antennas for transmit and receive



5G Massive MIMO

Multi-user MIMO and 3D beamforming for better capacity and cell edge performance,

Example: 128 or 256 antenna elements for macro deployments



5G CoMP

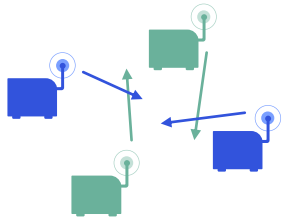
Leveraging CoMP[2] diversity and multiplexing to extend 5G to new use cases and verticals

Example: Multiple small-cells with 4 antennas

1) Multiple-input multiple-output (MIMO); 2) Coordinated Multi-Point (CoMP)

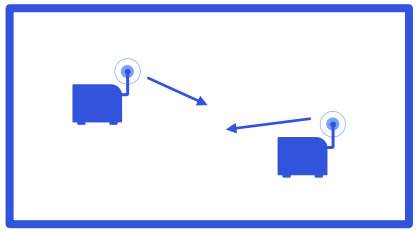
Unlicensed spectrum can support demanding Industrial IoT

Not possible with regular LBT[1] using random access



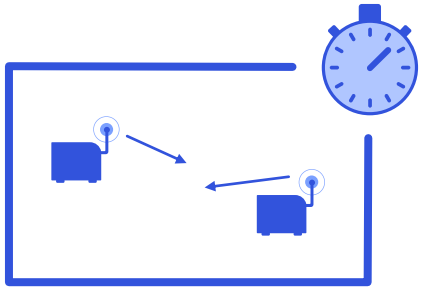
Results in random delays – demanding IIoT[2] apps require predictable latency

Controlled private environment improves latency



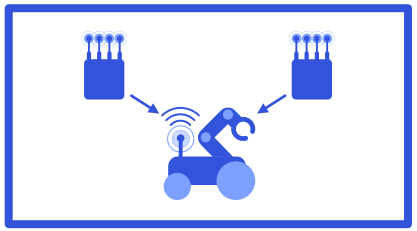
No interference from other networks, but still random delays within private network

Synchronization in time is key for predictability



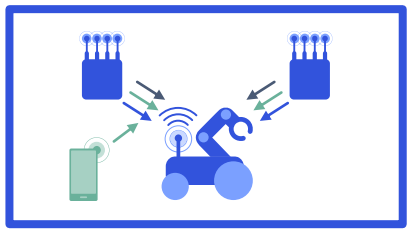
Current regulation allows synchronized FBE[3] based sharing for predictable low latency

CoMP improves capacity and reliability



Time synchronization also allows for spatial 5G COMP – a key technology for URLLC

Frequency diversity adds more reliability



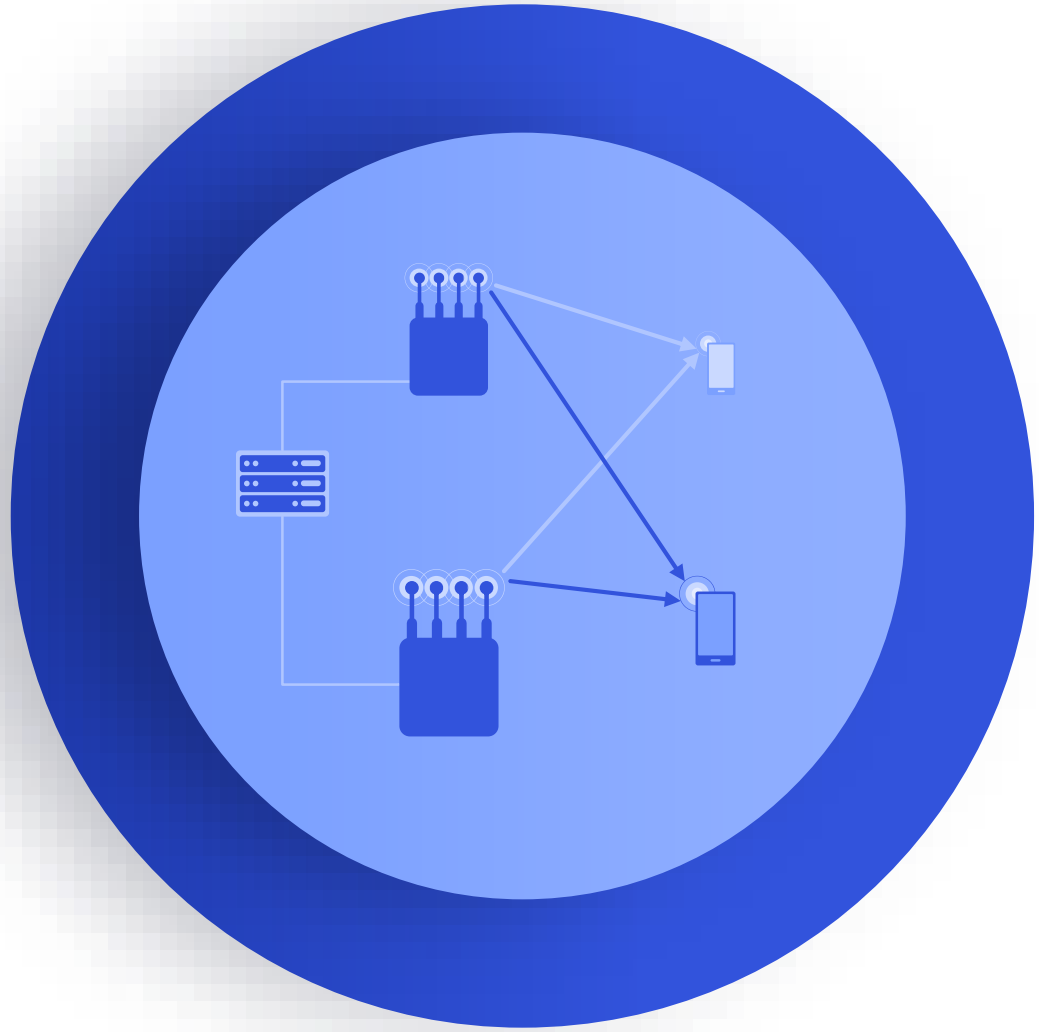
Frequency diversity provide reliability against rouge devices trying to access

1) Listen before talk (LBT) with load based equipment rule (LBE), such as CSMA/CA (Carrier Sense Multiple Access/Collision Avoidance); 2) Industrial IoT; 3) Frame Based Equipment

URLLC services feasible using time synchronized NR-U in controlled environments and today's regulation rules

Spectrum sharing among operators

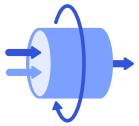
Time synchronization allows for predictability and enables CoMP and spatial sharing for capacity



Opportunity to introduce new sharing paradigms in 5G NR

Evolutionary path

NR unlicensed (NR-U)–existing coexistence rules



LAA NR-U

Stand-alone NR-U

Synchronized NR-U

Fair co-existence:
Wi-Fi, LTE-LAA...

5G

Time synchronization

provides great potential to share spectrum more efficiently

Revolutionary path

NR spectrum sharing (NR-SS)–potential for new rules

Predictable resources

5G CoMP

Spatial sharing

Flexible sharing

What is possible when not constrained by existing rules?

5G

Revolutionary path

NR spectrum sharing (NR-SS)–potential for new spectrum sharing rules
For green-field bands such as global 6GHz and regional bands such as 37-37.6 GHz

Time synchronization

Predictable resources

- Prioritized resources for each operator → predictable service
- Opportunistic sharing of unused resources

5G CoMP

- Exploiting the spatial domain with 5G CoMP
- Significantly increased capacity and reliability

Spatial sharing

- Spatial sharing between multiple operators
- Allows for simultaneous use of same spectrum in same location

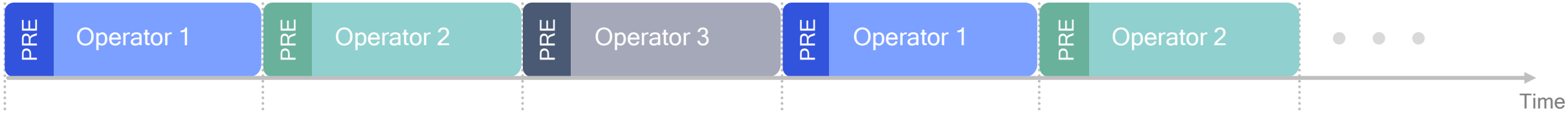
Flexible sharing

- Native support for sharing with different priority levels
- Flexible framework to support various regional sharing needs

Predictable resources with opportunistic sharing

A new sharing paradigm enabled by time synchronization

Each operator assigned guaranteed resources in time, example with 3 operators



A guaranteed resource not used becomes an opportunistic resource for anyone to use

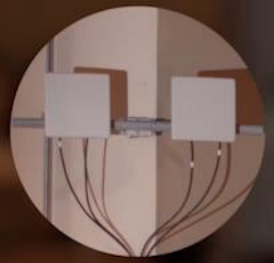
Example: Operator 2 is not using its slots, so operator 1 and 3 contend for unused slots

1. Listen before talk (LBT)

Setup

Two operators

100 MHz bandwidth



4 small-cells

Two X-pol antennas

4x4 MIMO capable

2 CoMP Servers

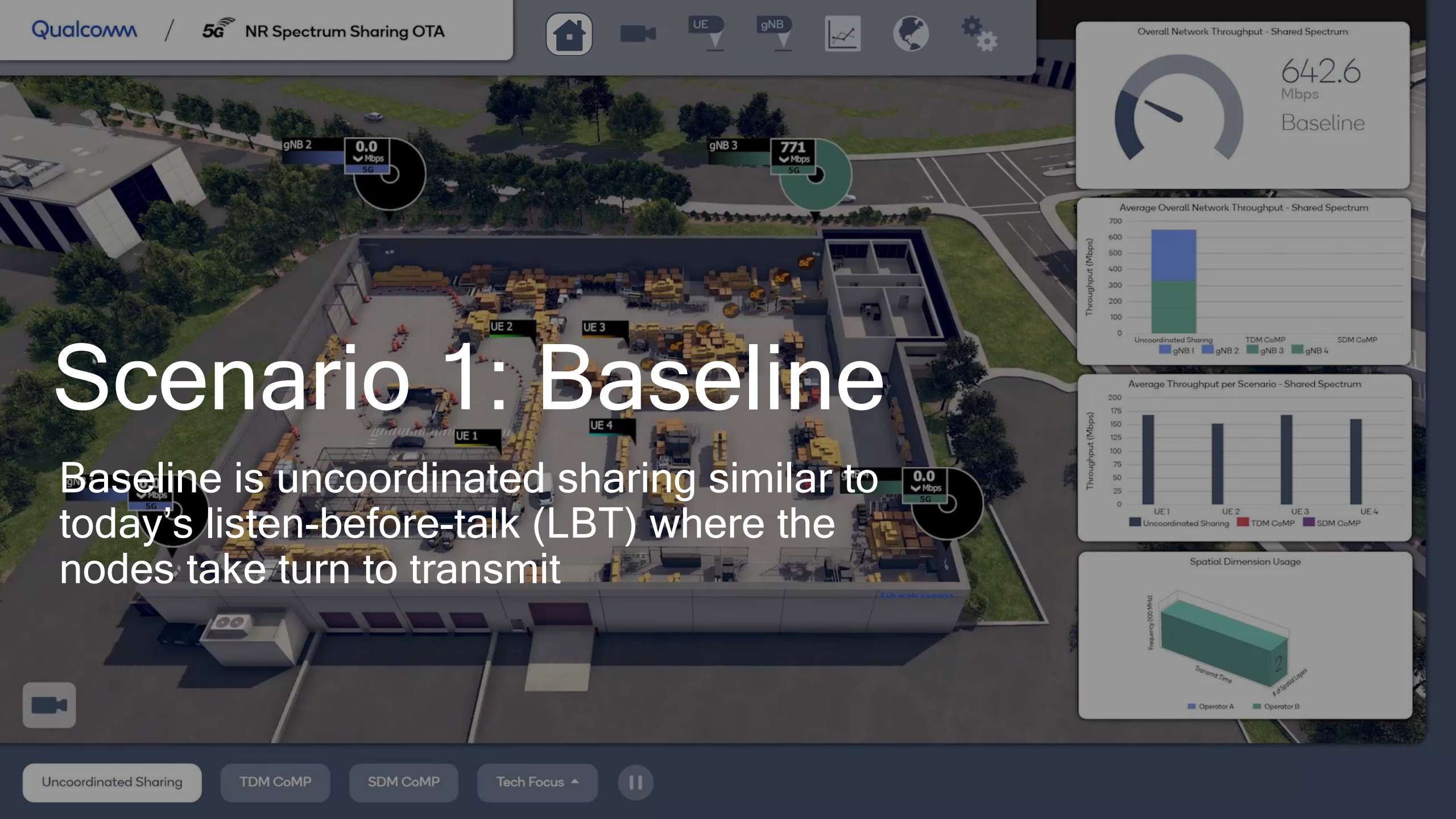
High perf. compute

Beamforming

4 Mobile Phones

Two Omni Antennas

2x2 MIMO capable

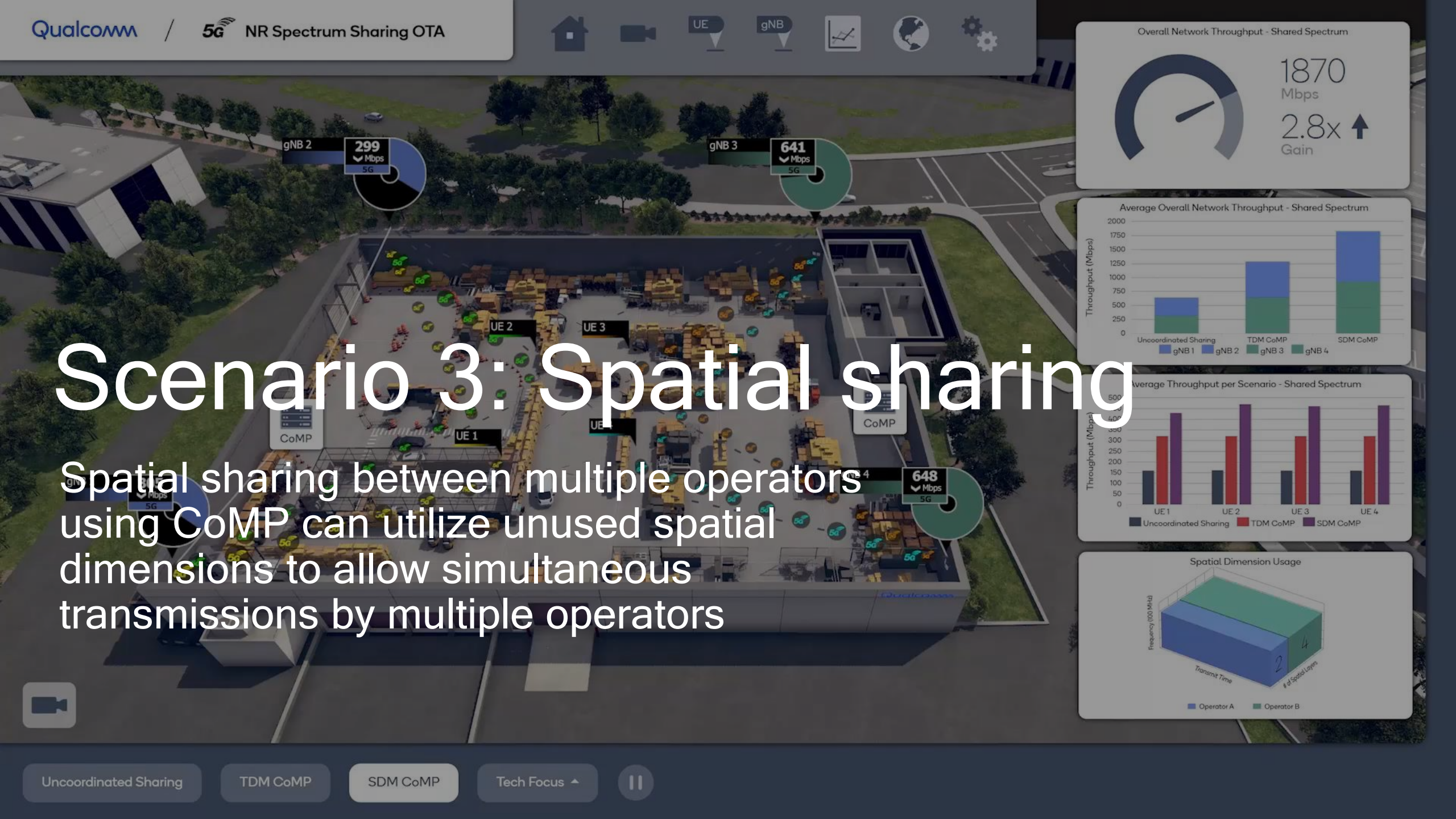


Scenario 1: Baseline

Baseline is uncoordinated sharing similar to today's listen-before-talk (LBT) where the nodes take turn to transmit

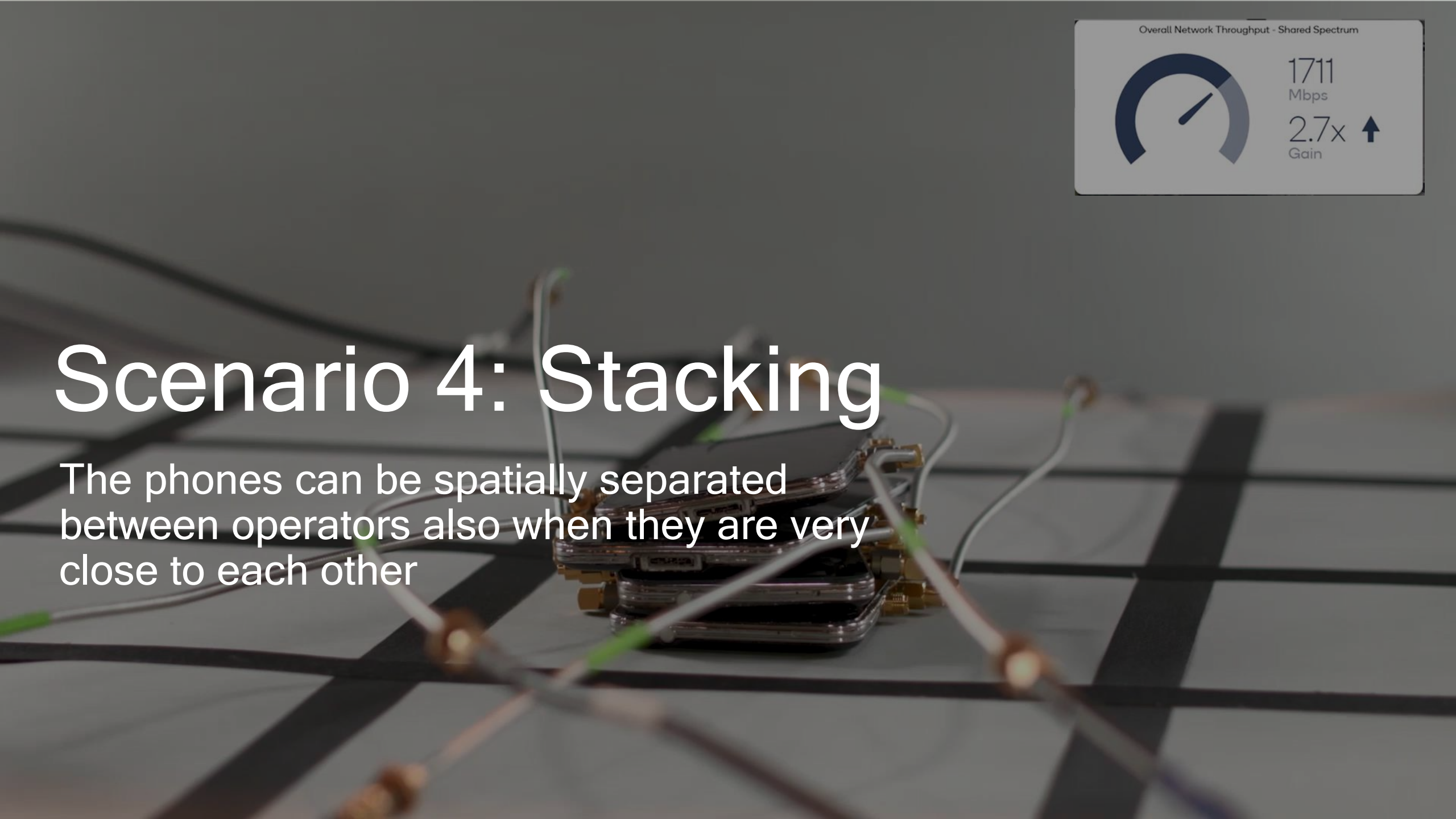
Scenario 2: CoMP

TDM with CoMP (Coordinated Multi-Point) allows simultaneous access by nodes within each operator's network while taking turn between the operators



Scenario 3: Spatial sharing

Spatial sharing between multiple operators using CoMP can utilize unused spatial dimensions to allow simultaneous transmissions by multiple operators



Scenario 4: Stacking

The phones can be spatially separated between operators also when they are very close to each other

New business opportunities for 5G NR

Private networks

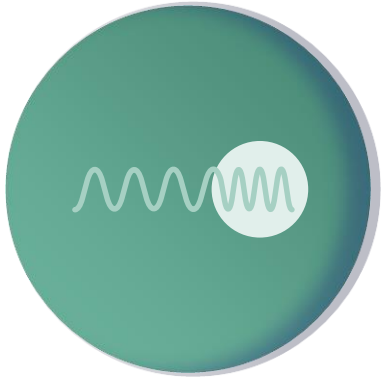
Expand 5G market to new verticals

Initially in licensed spectrum, later also unlicensed spectrum

Industrial IoT

New capabilities such as URLLC, TSN and CoMP

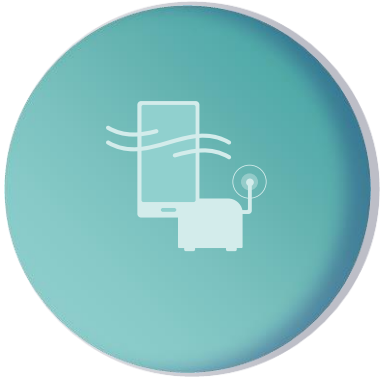
Wireless industrial Ethernet for flexible manufacturing



Enterprise mmWave

Private 5G NR mmWave networks indoors for enterprise

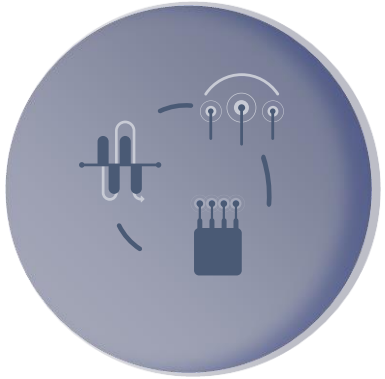
Opportunity for MNO to re-use their licensed spectrum



5G NR in unlicensed

MNO can deploy, manage, or offer private 5G networks as a service

New entities can deploy own networks



New sharing paradigms

Opportunity to define new rules in greenfield spectrum, e.g. synchronization.

Novel sharing paradigms with revolutionary benefits

Qualcomm

Thank you

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