July 11, 2018 @qualcomm Webinar

Qualcomm

How can CoMP extend 5G NR to high capacity and ultra-reliable communications?

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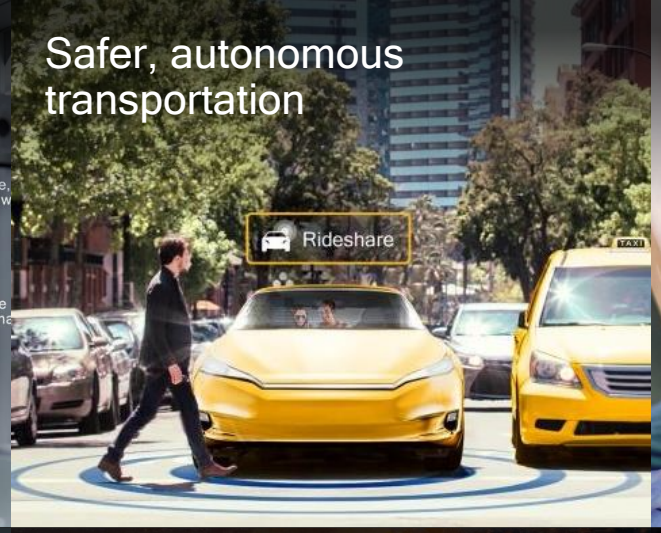
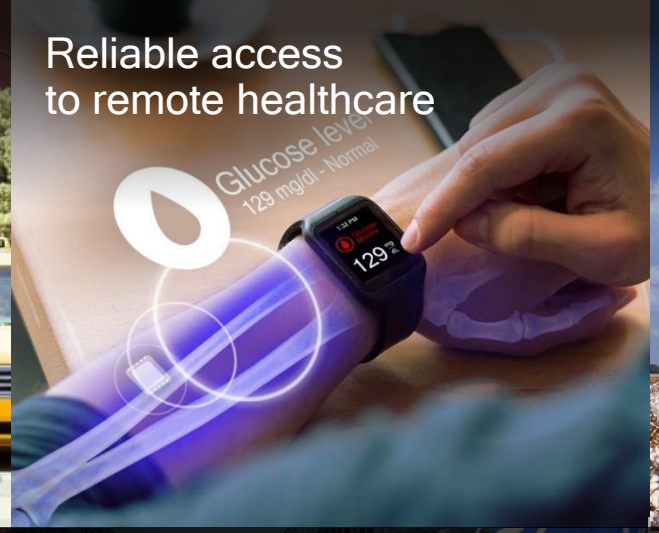
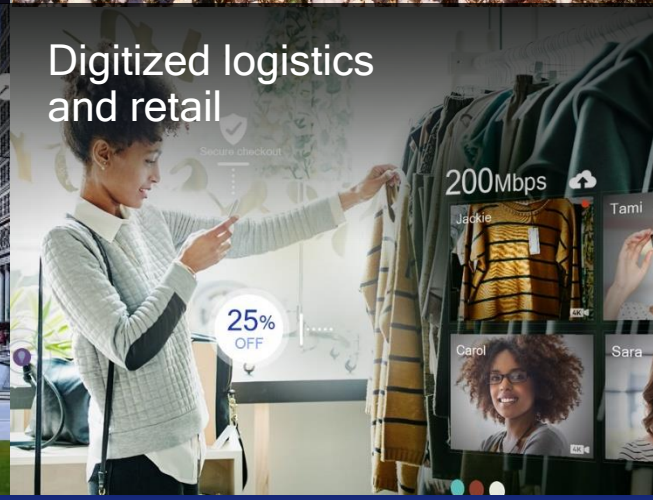
Qualcomm Technologies, Inc.







5G

5G will expand the mobile ecosystem to new industries

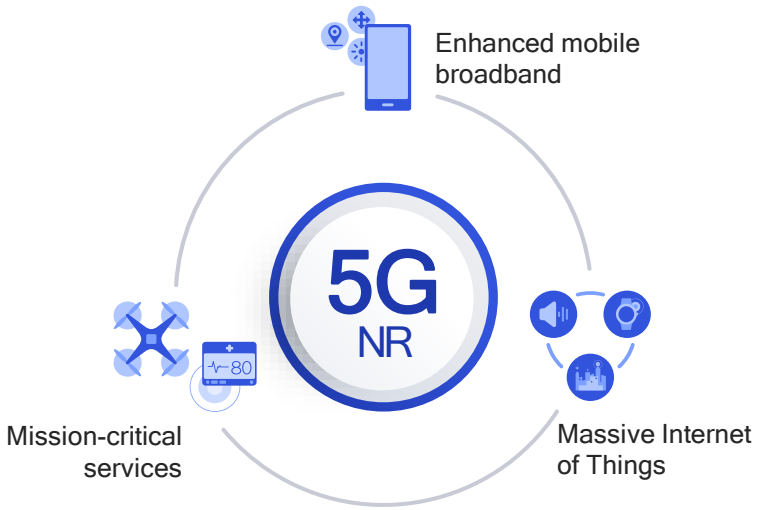
Powering the digital economy

>$12 Trillion

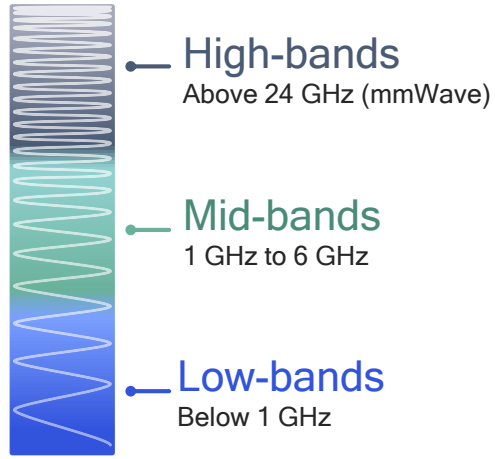
In goods and services by 2035*

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

Designing a unified, more capable 5G air interface



Diverse services



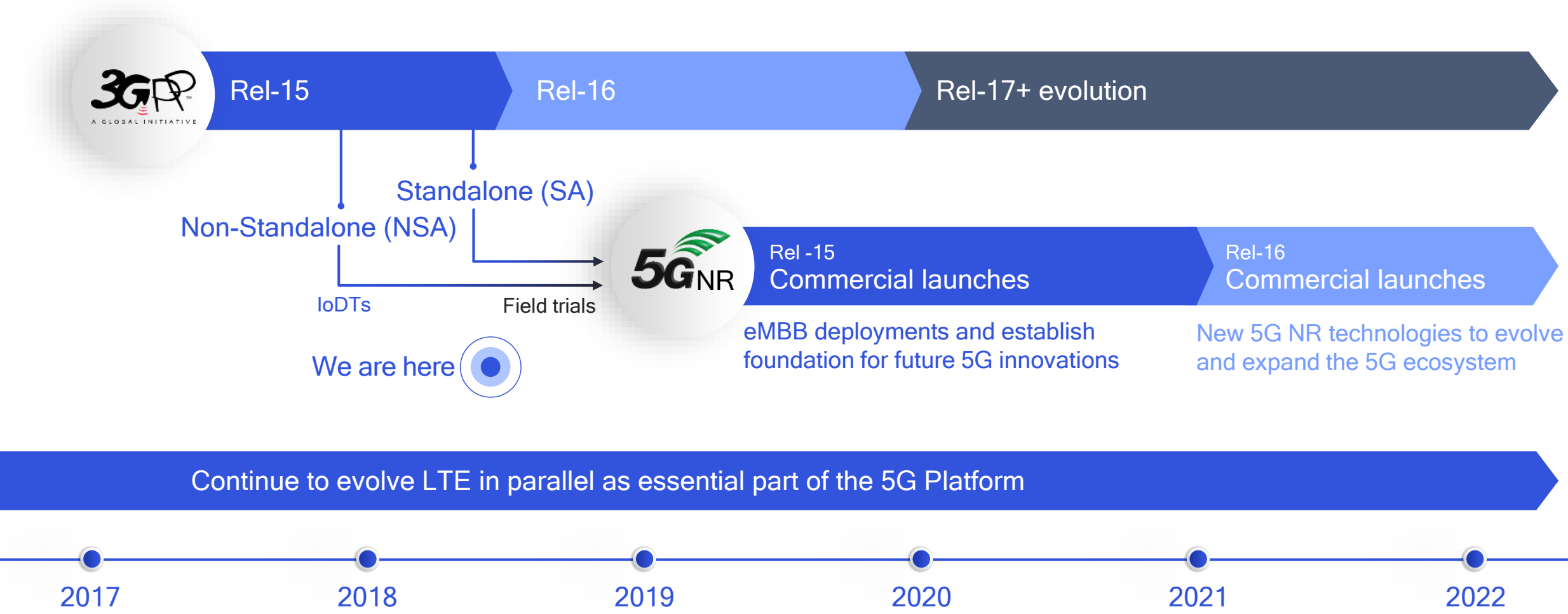
Licensed/shared/unlicensed

Diverse spectrum

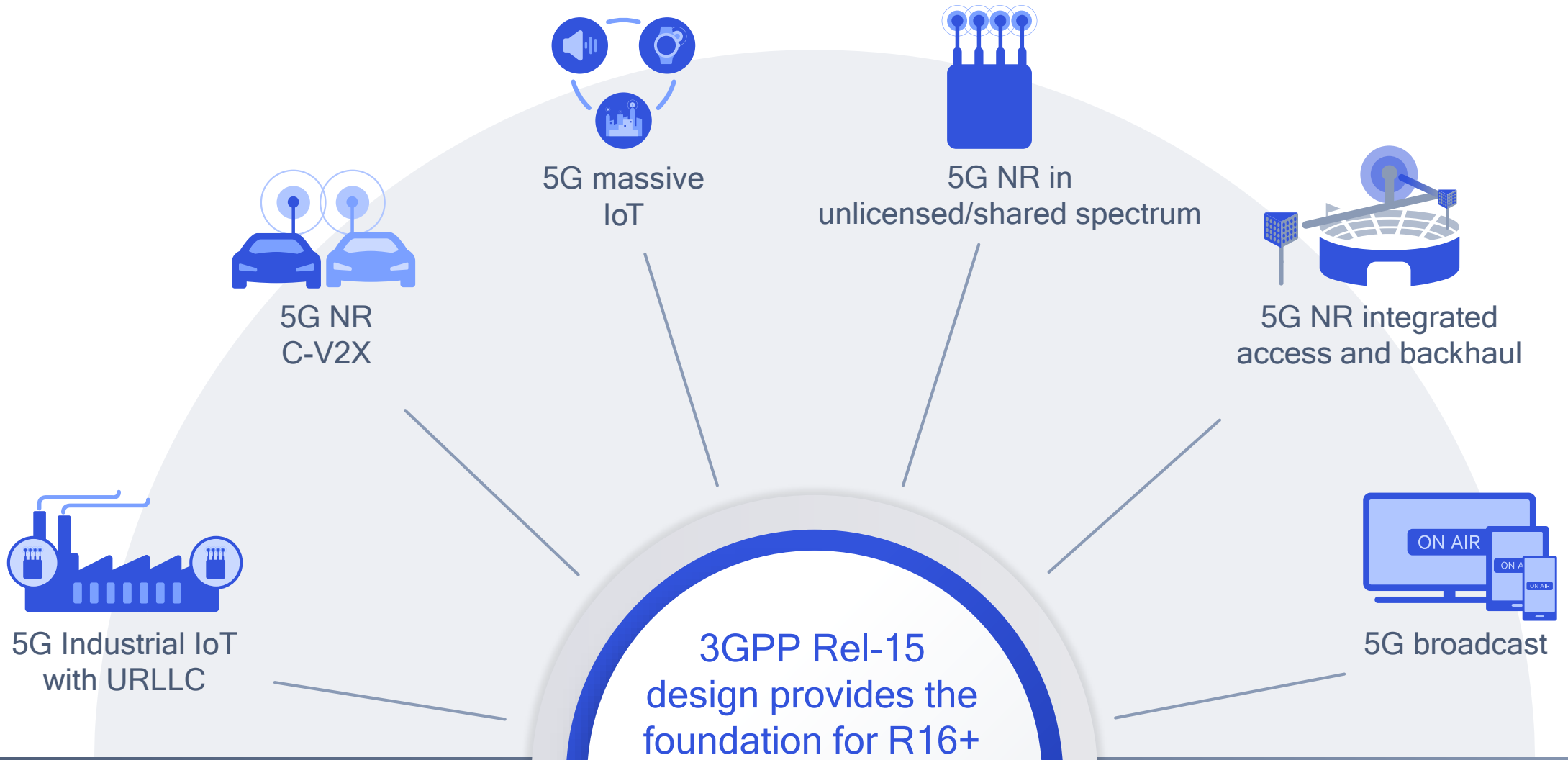
Diverse deployments

Existing, emerging, and unforeseen services – a platform for future innovation

Driving the 5G roadmap and ecosystem expansion

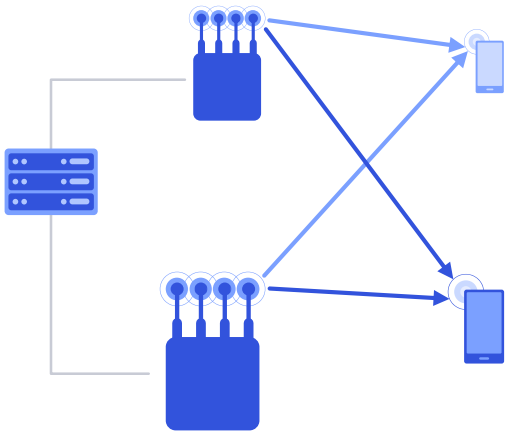


Driving a rich 5G roadmap in Release 16 and beyond



5G CoMP

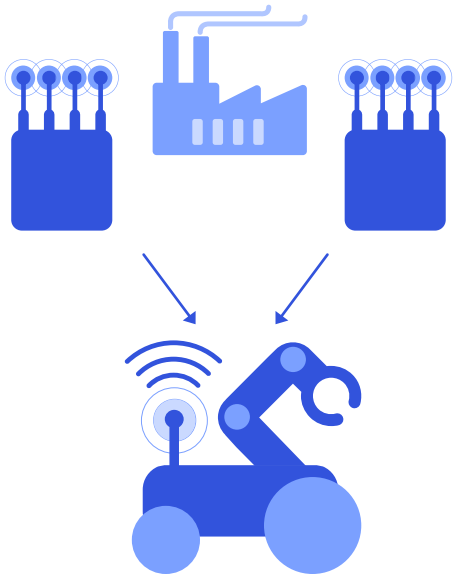
5G expansion into new use cases & verticals



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

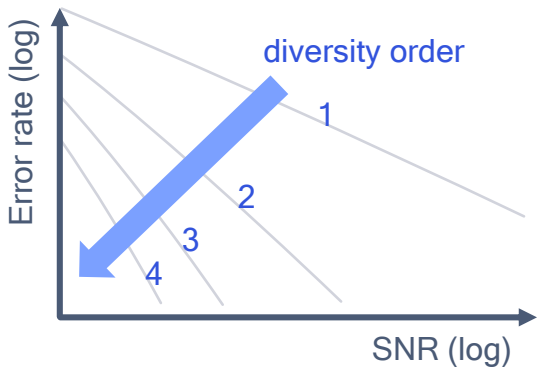
Spatial diversity can overcome radio shadowing in challenging radio environments

Key technology to provide ultra reliability for challenging industrial IoT applications

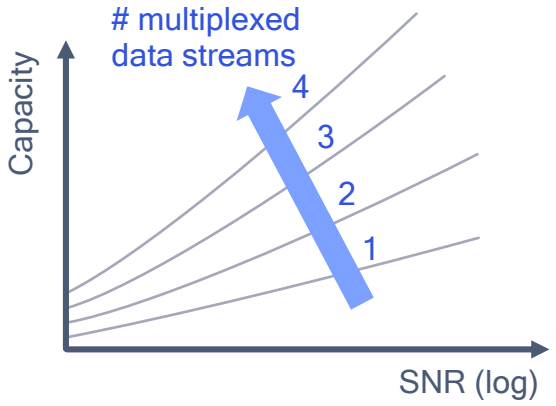
Theoretical tradeoff between multiplexing and diversity

Multiple transmit and receive antennas with uncorrelated signal paths create spatial dimensions

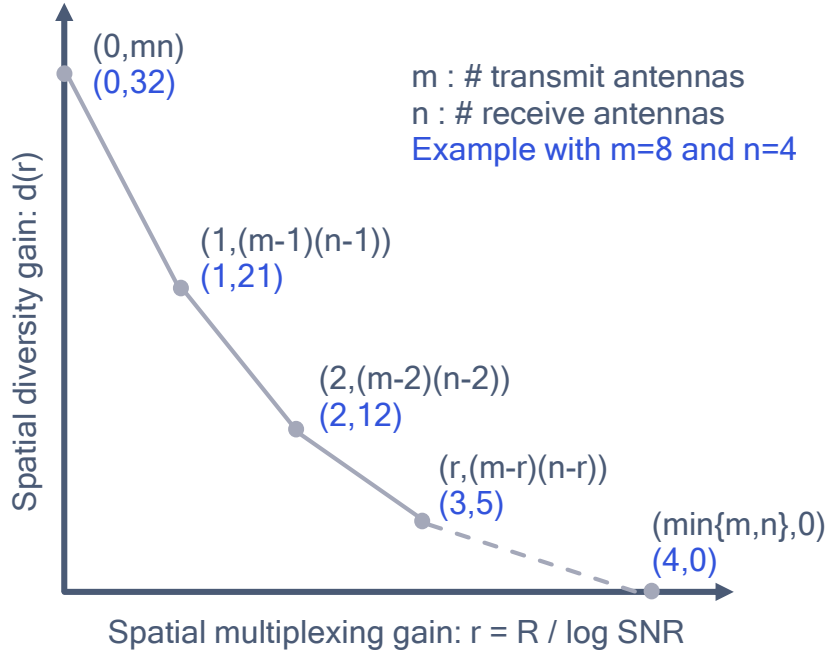
Using spatial dimensions for diversity reduces the error rate



Using spatial dimensions to multiplex multiple data streams increases capacity

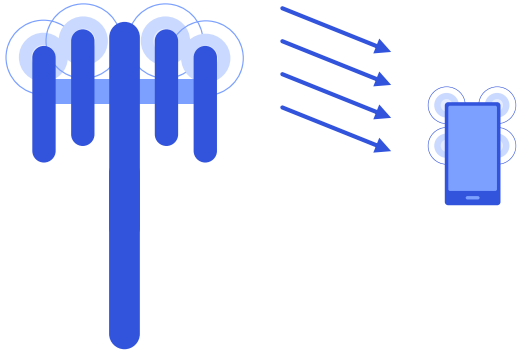


There is a tradeoff between spatial multiplexing gain and spatial diversity gain[1]



1. L. Zheng and D. N. C. Tse, "Diversity and multiplexing: A fundamental tradeoff in multiple antenna channels," IEEE Trans. Inform. Theory, vol. 49, May 2003.

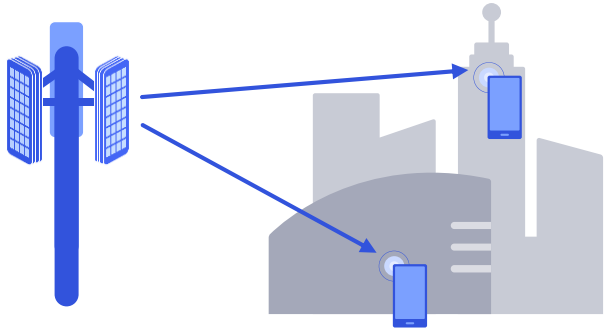
Exploiting spatial domain–from LTE MIMO to 5G CoMP



LTE MIMO

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

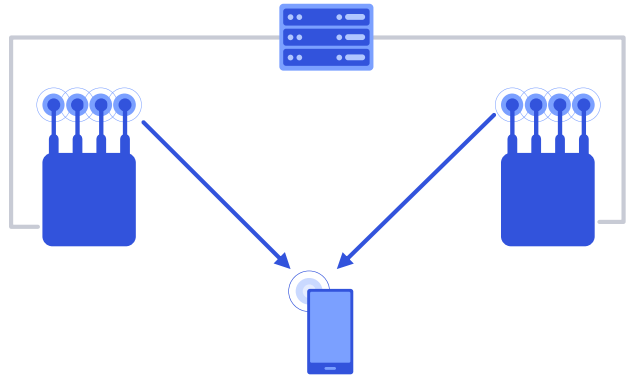
Example: 2 or 4 antennas for transmit and receive



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



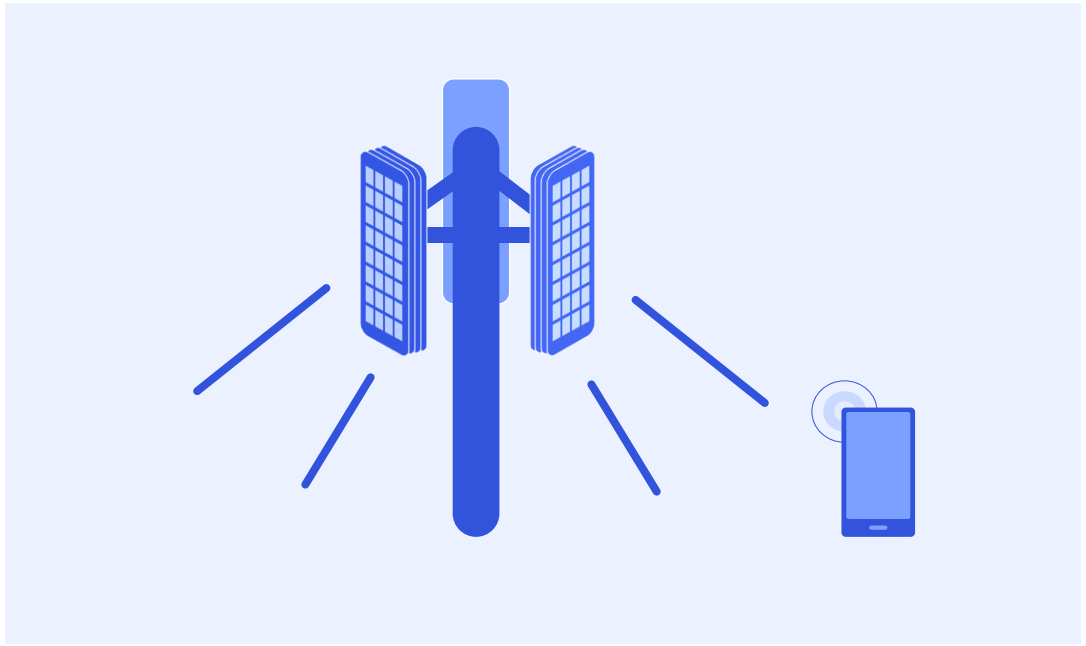
5G CoMP

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)

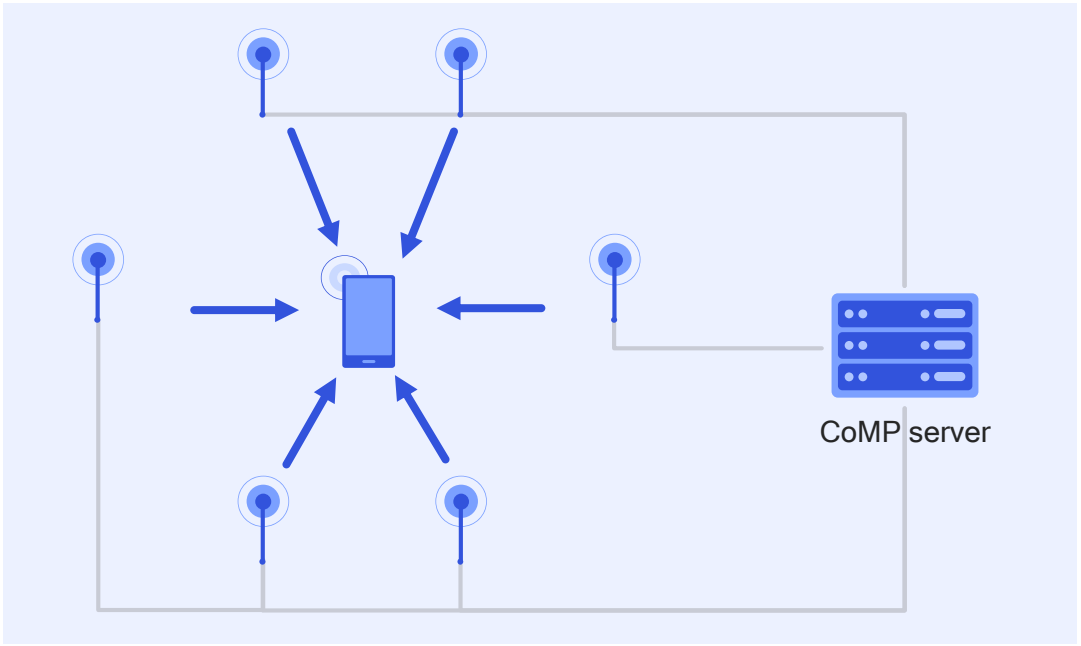
CoMP is an extension of MIMO



Massive MIMO

Utilizes a large number of antennas to create multiple spatial dimension from multi-path propagation to increase capacity and coverage and cell edge.

Example: Macro deployment

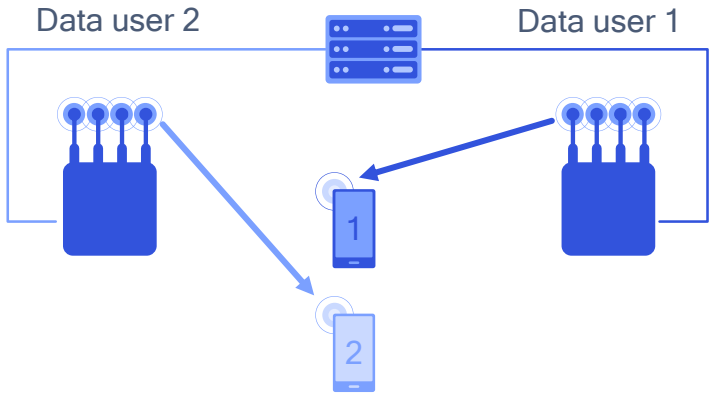


CoMP aka Distributed MIMO

Utilizes a large number of distributed antennas to create multiple spatial dimensions for increased capacity and/or spatial diversity for reliability

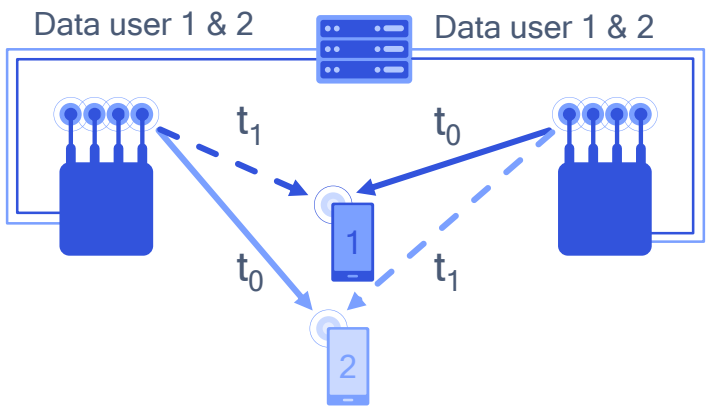
Example: Small-cell deployment

5G CoMP–different flavors



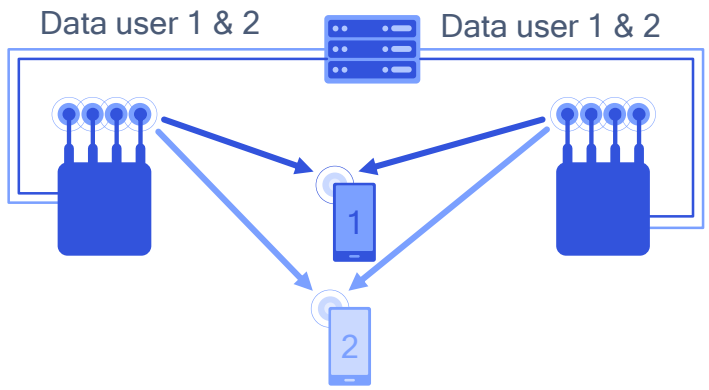
Coord. Sched./Beamforming

- Data via one base station
- Coordinated beamforming between base stations to improve overall signal quality[1]
- Coordinated scheduling to maximize resource utilization



Dynamic Point Selection

- Data via multiple base stations[2]
- Transmission from a single base station at each time instance
- Which base station is transmitting is dynamically changing on a subframe basis

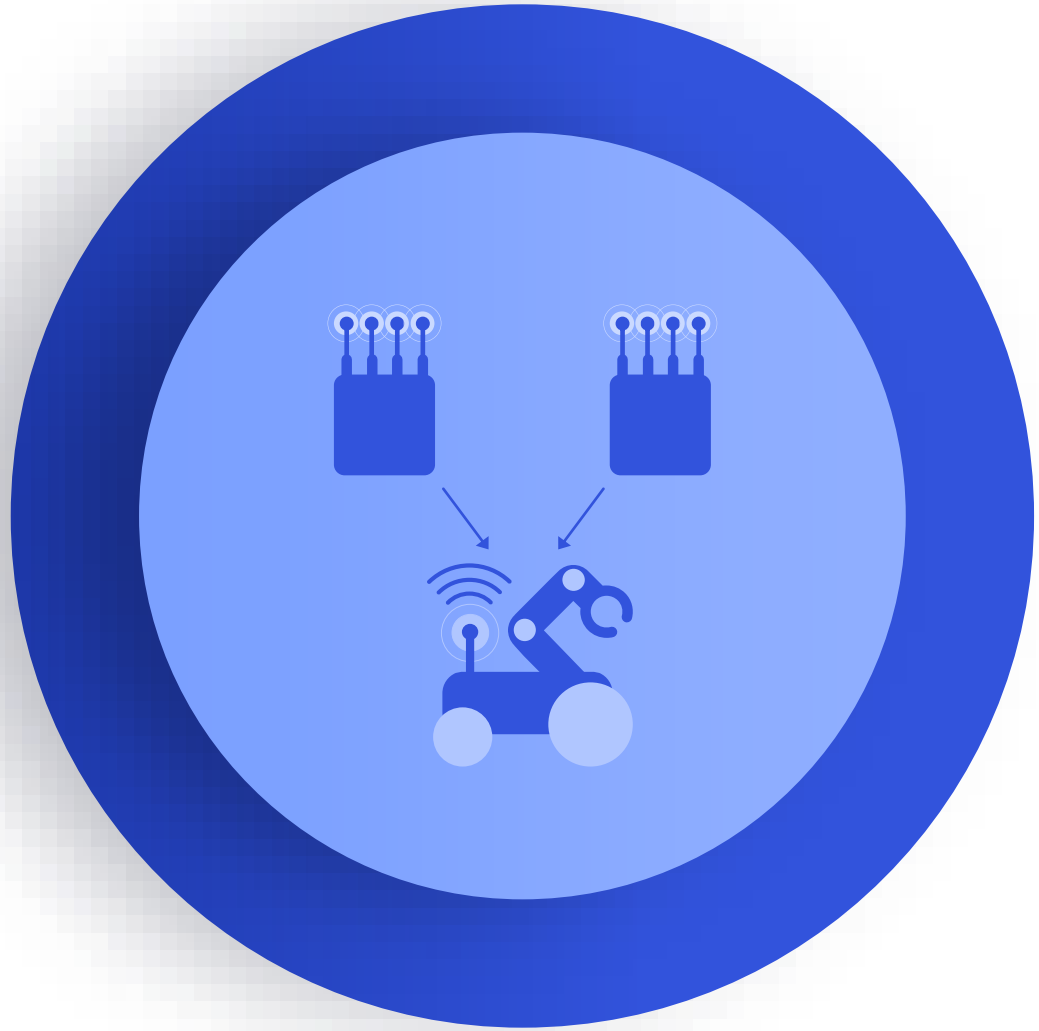


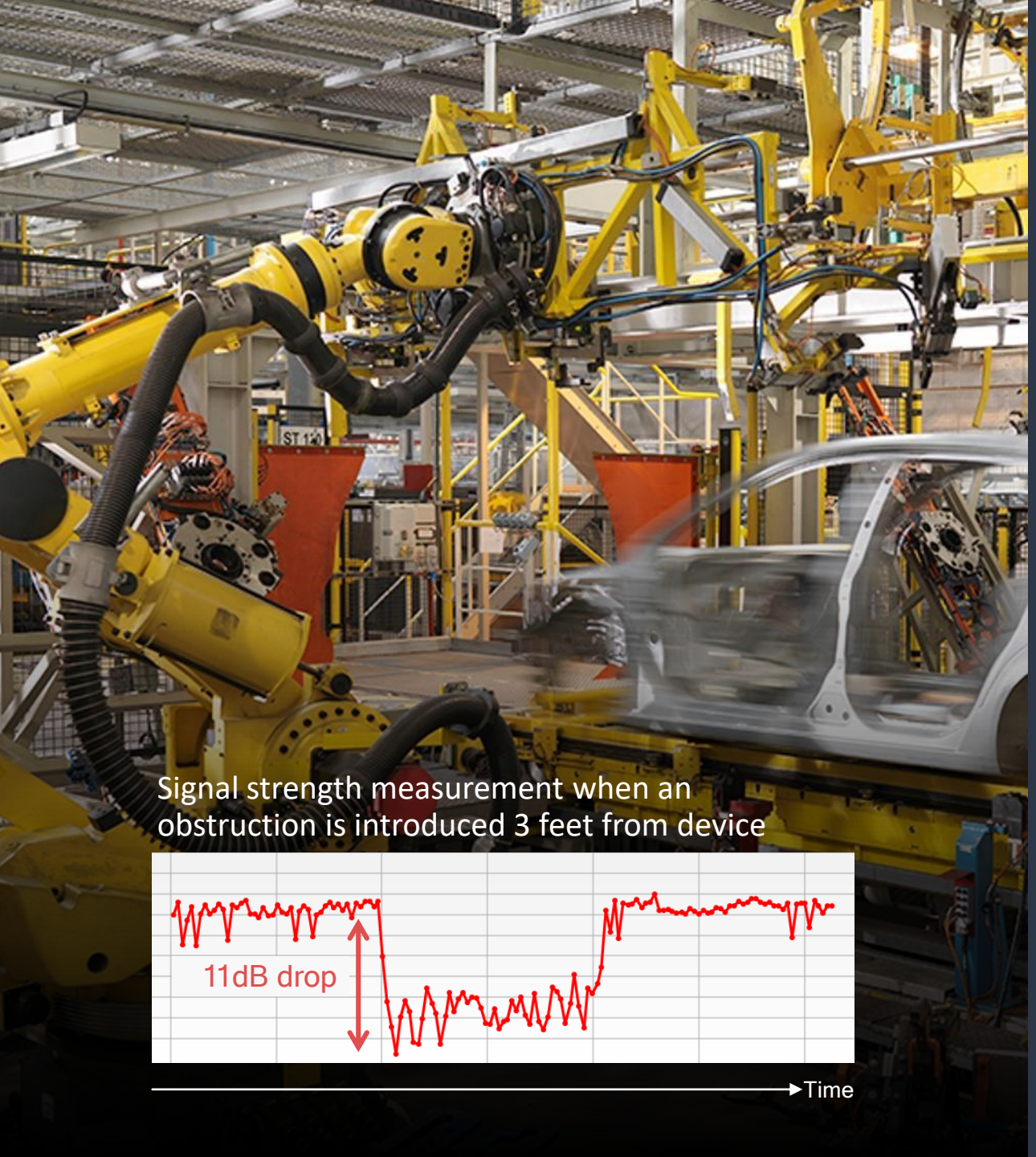
Joint Transmission (JT)

- Data via multiple base stations[2]
- Multiple base stations transmit same data with beamforming
- Coherent JT enables nulling; requires channel knowledge and antenna calibration

1) For example maximize the minimum signal to noise plus interference ratio; 2) This is referring to downlink. For uplink Joint Reception (JR) can be used.

5G CoMP for reliability





Factories have challenging RF environments

Blockage and reflections by fast moving metal objects such as AGV[1], cranes and conveyor belts

Blockage can cause sudden drop in signal strength

Reflections can lead to rapidly varying interference from far-away cells

Collecting RF measurements to establish a propagation model for factory environments

1. Automated Guided Vehicle (AGV)

Diversity schemes

Time diversity

- Example: Hybrid ARQ
- Gains limited by latency

Frequency diversity

- Wider bandwidth / many channels
- Not effective against blockage

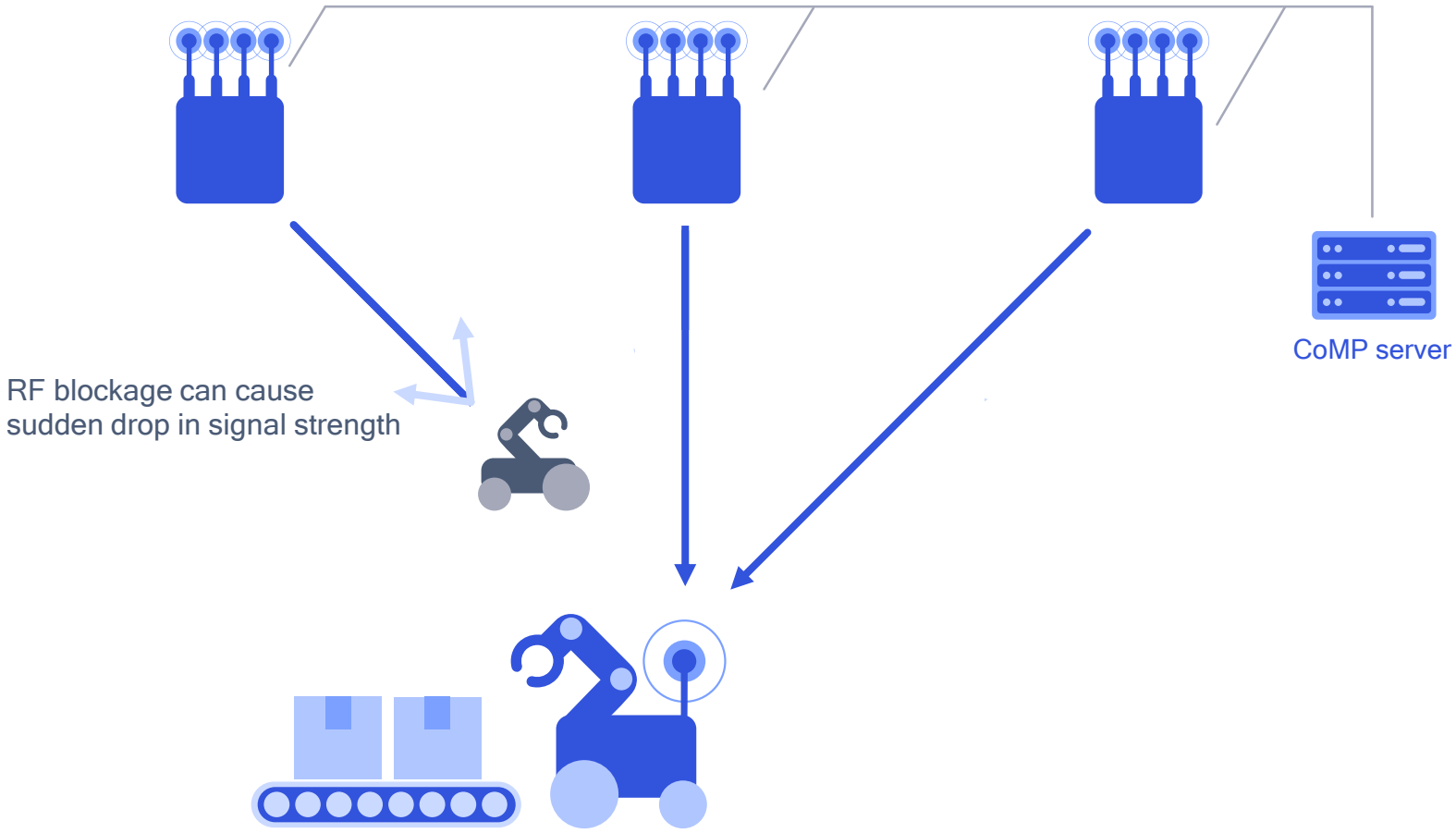
Radio diversity

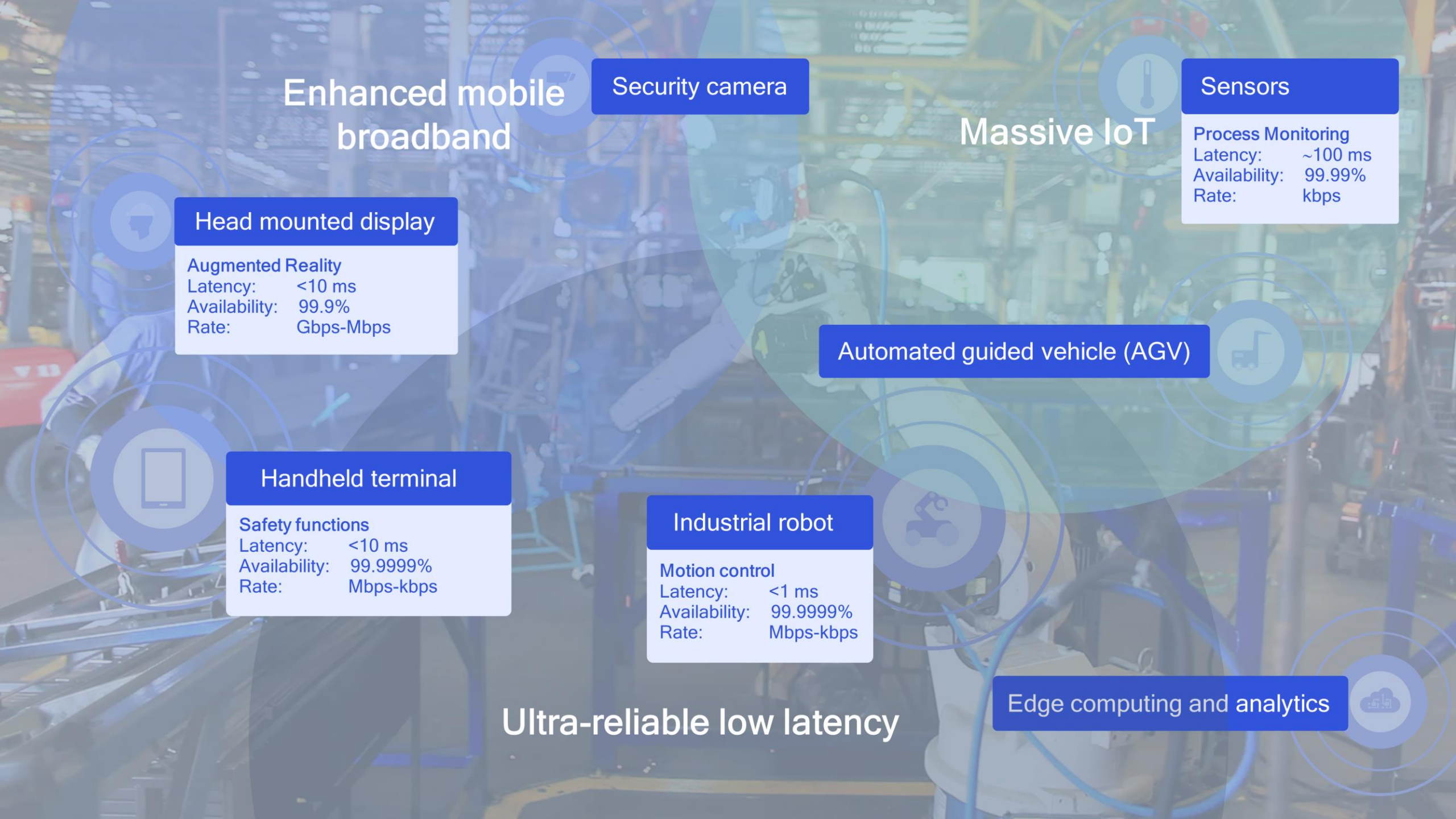
- Multi-connectivity: NR, LTE, Wi-Fi
- Not effective against blockage

Spatial diversity

- MIMO or CoMP with multiple antennas
- CoMP effective against RF blockage

CoMP spatial diversity key for reliability

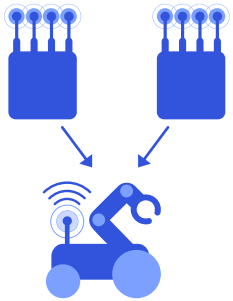



Enhanced mobile broadband
Security camera
Massive IoT
Sensors
Process Monitoring
Latency: ~100 ms
Availability: 99.99%
Rate: kbps
Head mounted display
Augmented Reality
Latency: <10 ms
Availability: 99.9%
Rate: Gbps-Mbps
Automated guided vehicle (AGV)
Handheld terminal
Safety functions
Latency: <10 ms
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

Key Industrial IoT functionality targeted for 3GPP rel.16

Ultra Reliable, Low Latency Communication (URLLC)

Enhanced latency and reliability

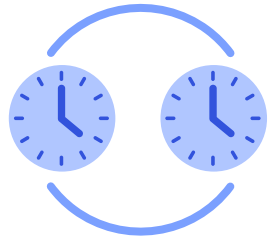


CoMP multi-TRP[1] transmissions

Time Sensitive Networks (TSN)

Handling of Ethernet switch functions

Enhanced Quality of Service (QoS)



Microsecond time synchronization

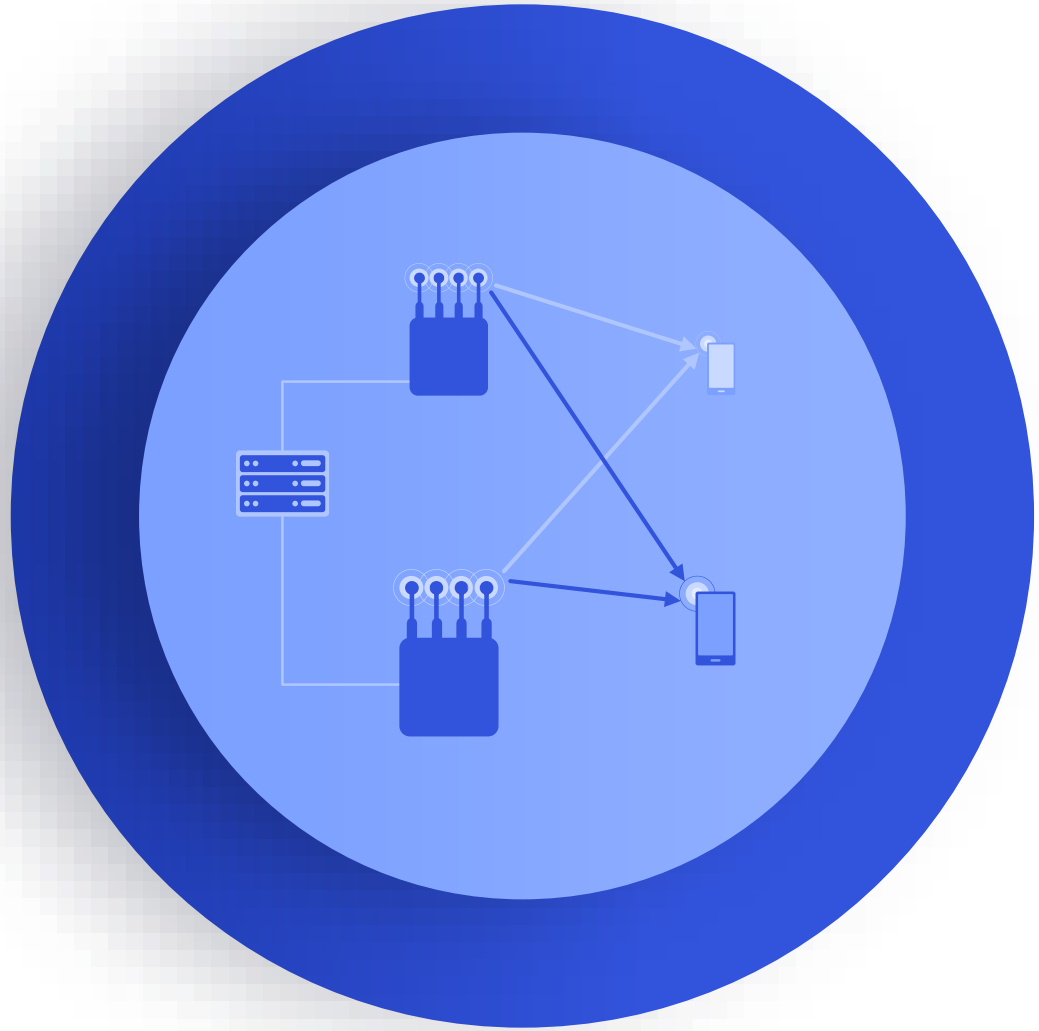
Spectrum

5G NR in licensed, shared or unlicensed spectrum

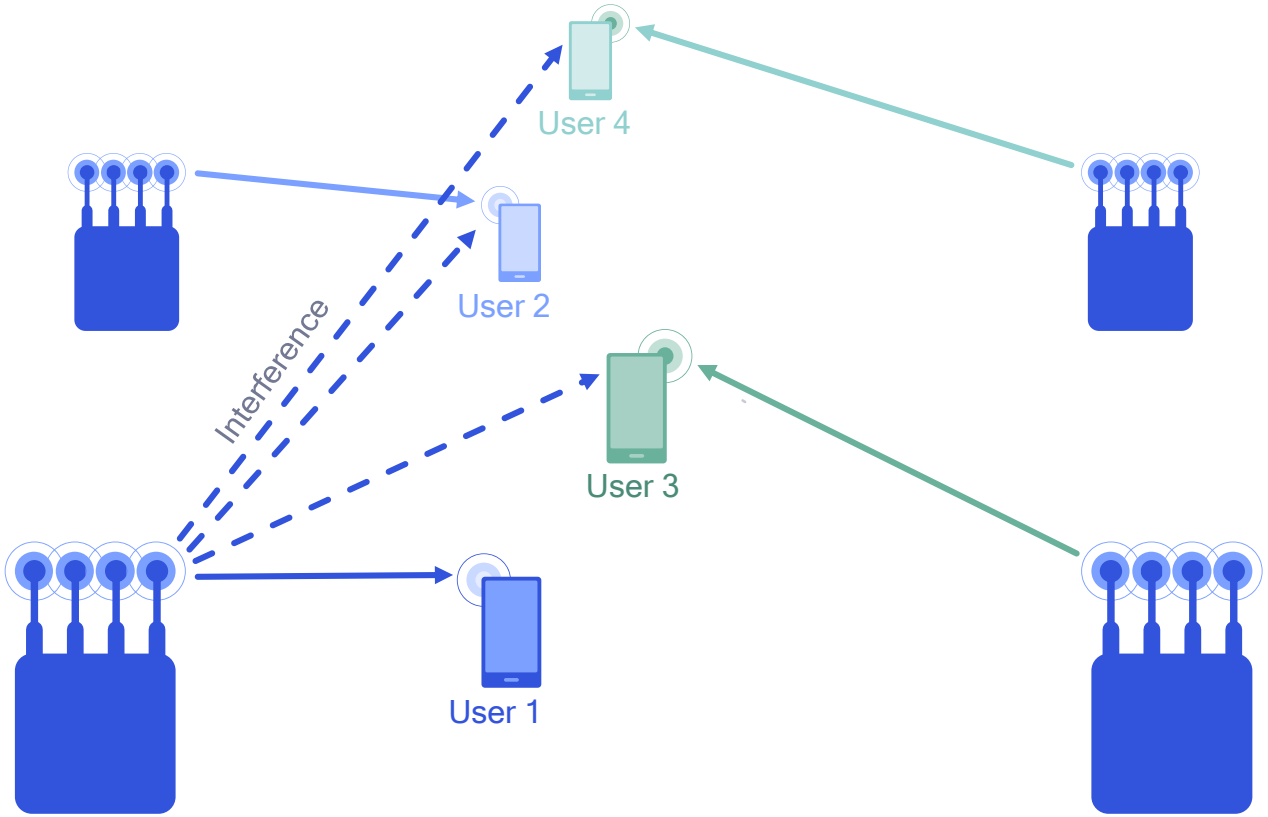
1) Transmission and Reception Point (TRP)

To support new applications such as wireline replacement of industrial Ethernet for the reconfigurable factory of the future

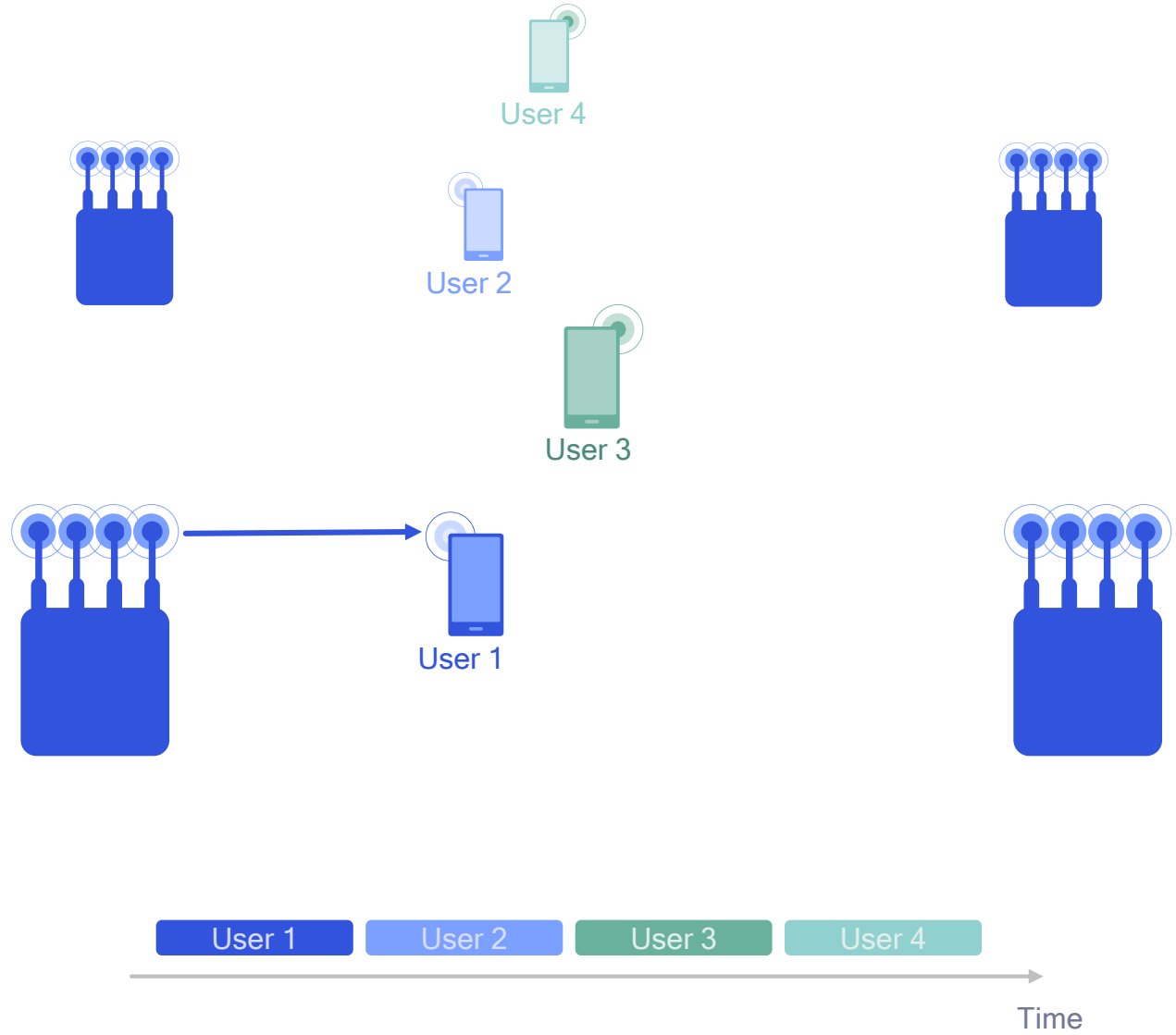
5G CoMP for capacity



Simultaneous transmission causes interference



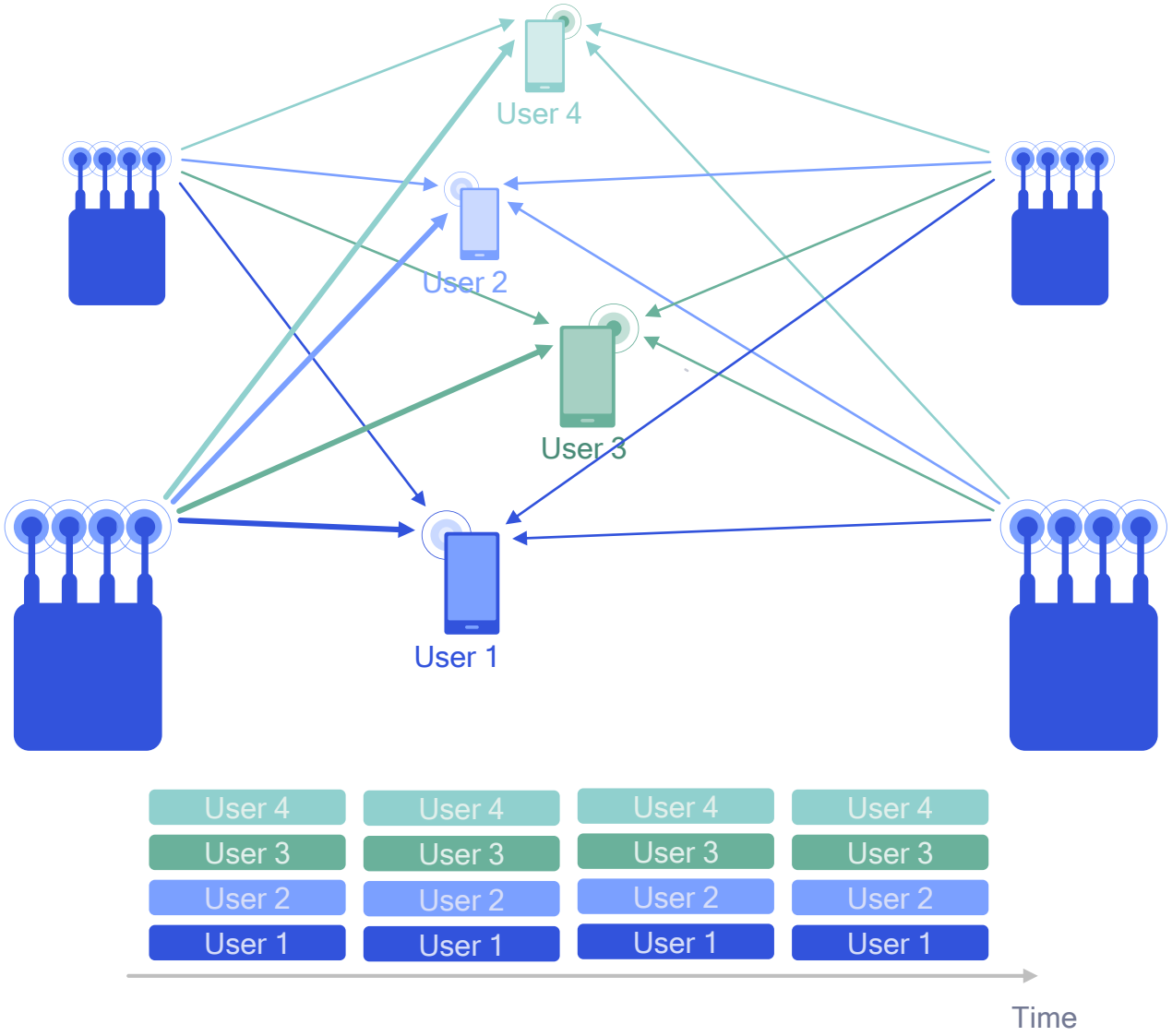
TDM avoids interference, but only one user served at a time



5G CoMP increases system capacity from spatial multiplexing

CoMP combines antennas from multiple small-cells to create more spatial dimensions

Additional spatial dimensions allows simultaneous transmission to multiple users in the same geographical area while minimizing interference



5G CoMP capacity gains have many applications

Mobile broadband

Increased mobile broadband capacity such as small-cell deployments in venues and private 5G networks

Spectrum sharing

Efficient spectrum sharing with multiple operators using the same spectrum in the same area simultaneously

URLLC

Tradeoff some capacity gains against higher reliability such as 99.9999% for industrial IoT motion control[1]

1) 3GPP TR 22.804 v16.0.0 “Study on Communication for Automation in Vertical Domains”

5G NR in Shared Spectrum (NR-SS)

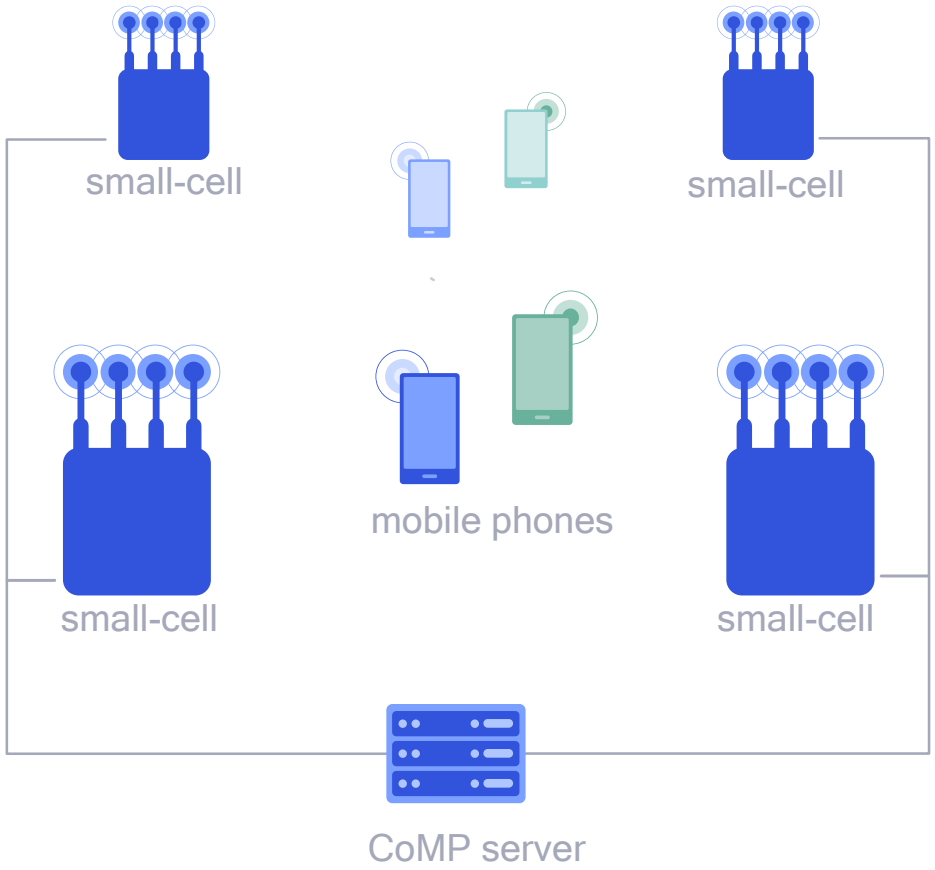
Targeting green-field bands such as 5.9-7.1 GHz and 66-71 GHz bands

5G

Flexible NR framework	• Flexible framework with forward compatibility • Fast turn-around and self-contained operation
Time synch. and coordination	• Time synchronization for more efficient sharing • Coordinated sharing to improve QoS
Guaranteed QoS	• Guaranteed bandwidth for each operator • Opportunistic sharing of unused bandwidth
Exploit spatial domain	• CoMP with spatial sharing to increase capacity • Spatial Listen Before Talk (LBT) and on-demand LBT
Vertical & horizontal sharing	• Native support for different priority levels (vertical sharing) • Flexible framework to support various spectrum landscapes

Over-the-air testbed

5G CoMP testbed



Setup

- 100 MHz bandwidth
- 3.5 GHz band

4 small-cells

- Two X-pol antennas
- 4x4 MIMO capable

4 mobile phones

- Two omni antennas
- 2x2 MIMO capable

CoMP server

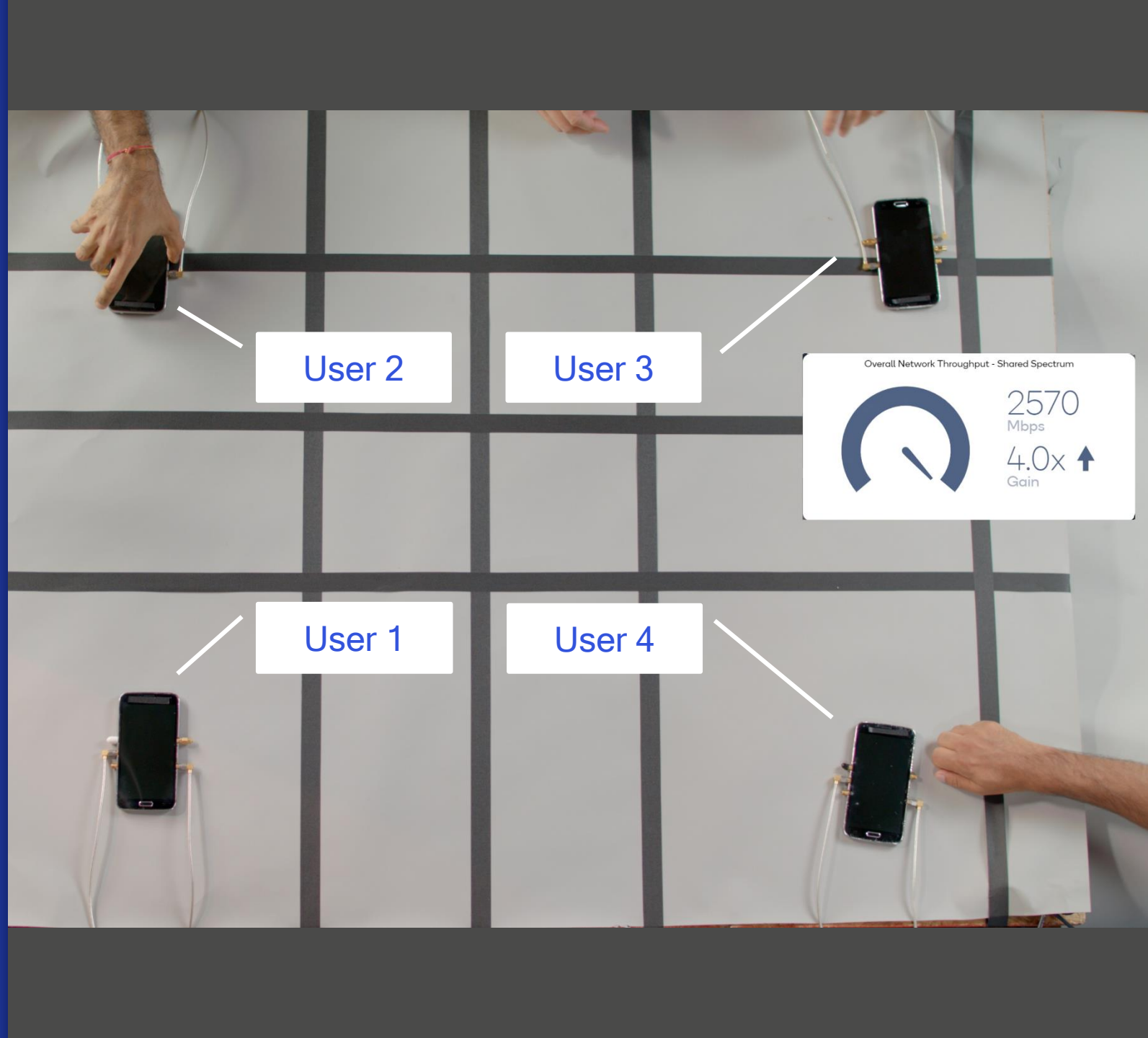
- High perf. compute
- Beamforming


Qualcomm / 5G NR CoMP OTA
UE
gNB
gNB 2
0.0 Mbps
5G
gNB 3
0.0 Mbps
5G
UE 2
UE 3
UE 4
UE 1
gNB 1
0.0 Mbps
5G
gNB 4
514 Mbps
5G
Overall Network Throughput - Shared Spectrum
642.6
Mbps
Baseline
Without CoMP
With CoMP
Tech Focus


Qualcomm / 5G NR CoMP OTA
UE
gNB
gNB 2
643 Mbps
5G
gNB 3
643 Mbps
5G
CoMP
UE 2
UE 3
UE 4
UE 1
gNB 1
643 Mbps
5G
gNB 4
643 Mbps
5G
Overall Network Throughput - Shared Spectrum
2570
Mbps
4.0x
Gain
Without CoMP
With CoMP
Tech Focus

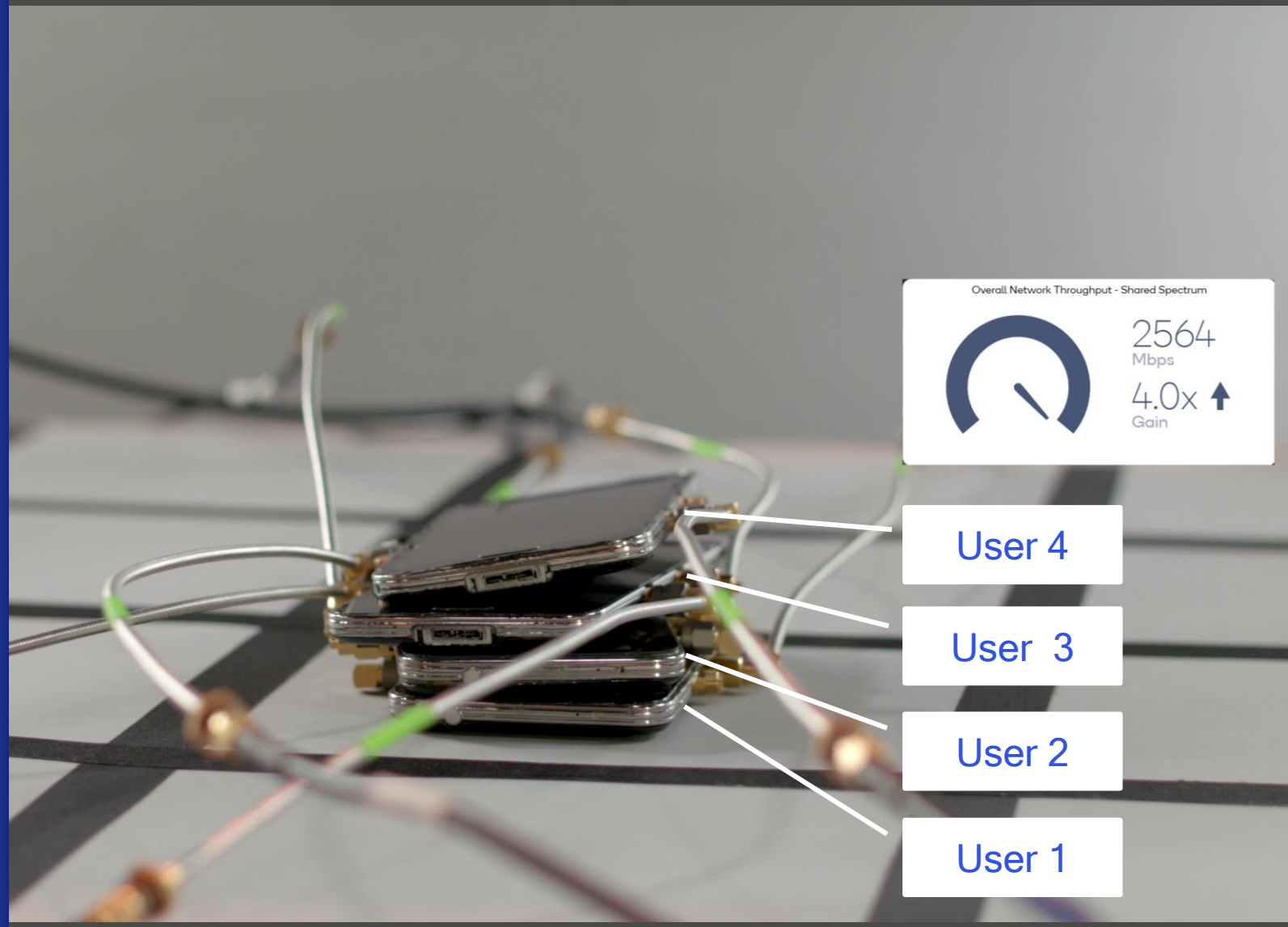
How close can the phones be and still be spatially separated?

CoMP with spatial sharing with five feet separation between the phones



Answer:
Very close!

System throughput barely changes when all four phones are literally stacked on each other

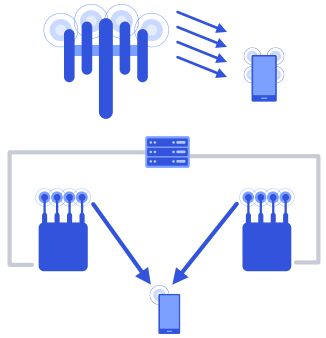


Qualcomm

5G NR

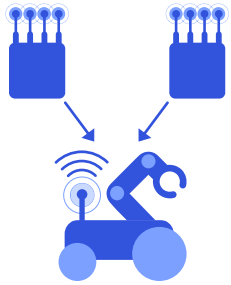
Making 5G NR a commercial reality for 2019 eMBB deployments

Driving the expansion of 5G NR ecosystem and opportunity



LTE MIMO → 5G CoMP

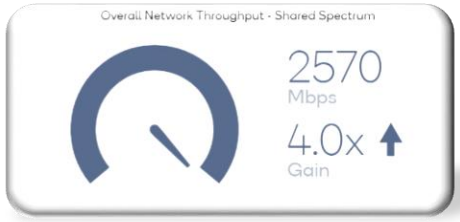
Continue to exploit the spatial domain to extend 5G to new use cases and verticals



99.9999% reliability

5G CoMP for reliability

Using CoMP spatial diversity to provide ultra reliable connectivity for Industrial IoT applications



5G CoMP for capacity

Using CoMP spatial multiplexing increases system capacity; 4X gains shown in OTA testbed.

Learn more at www.qualcomm.com / 5G

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