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Qualcomm

How does unlicensed
spectrum with NR-U
transform what
5G can do for you?

Our presenters



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Today's agenda

How does unlicensed spectrum feature in the upcoming release from 3GPP?

How can mobile operators boost network performance with anchored NR-U?

How are 5G private networks enabled with standalone NR-U?

Questions

Delivering on the 5G vision

Where virtually everyone and everything is intelligently connected

5G

Indoor enterprise

Fixed wireless access

Factory

XR

Private networks

Extreme Broadband

Public networks

Smart transportation

Massive IoT

Extend 5G with unlicensed spectrum

Using all spectrum types and bands

5G



Licensed spectrum

Exclusive use

Over 40 bands globally for LTE, remains the industry's top priority



Shared spectrum

New shared spectrum paradigms

Ex: 3.5 GHz USA, 3.7 GHz Germany



Unlicensed spectrum

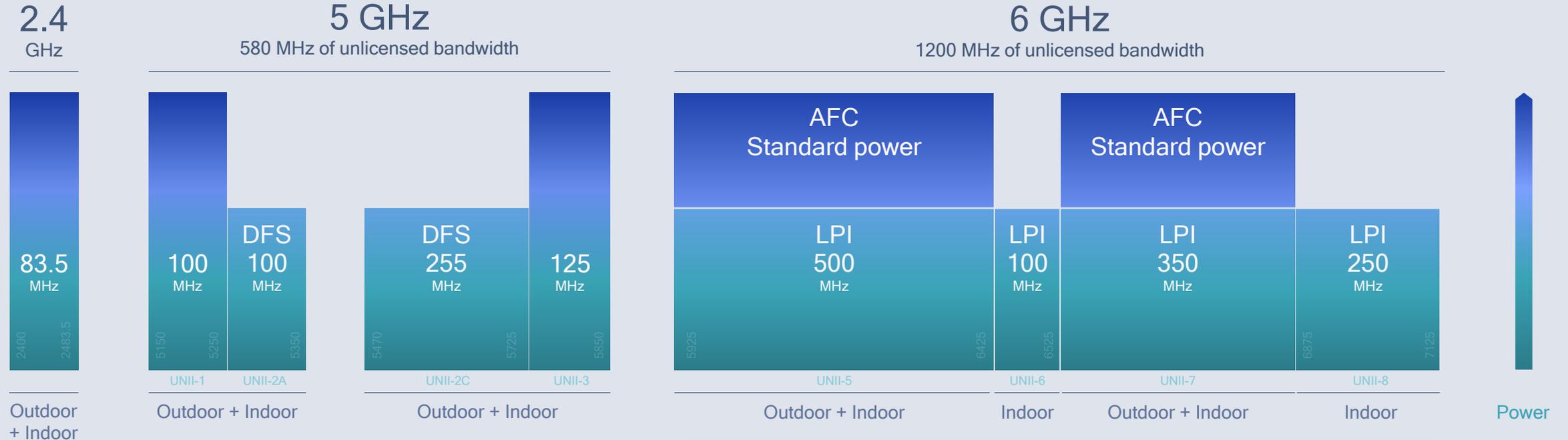
Shared use

Ex: 5 GHz / 6 GHz / 60 GHz global

- Unlock more spectrum globally
- New markets and verticals
- New deployment scenarios

6 GHz brings new unlicensed bandwidth for Wi-Fi and 5G

United States



1200 MHz  

A massive amount of new unlicensed spectrum is now available in the U.S. for Wi-Fi 6E and 5G

AFC= Automated frequency control, DFS= Dynamic Frequency Selection, LPI= Low power indoor

NR-U

First global cellular standard with both license-assisted and standalone use of unlicensed spectrum

<1 GHz
Low-bands (sub-1)

1-7 GHz
Mid-bands (sub-7)

24+ GHz
High-bands (mmWave)

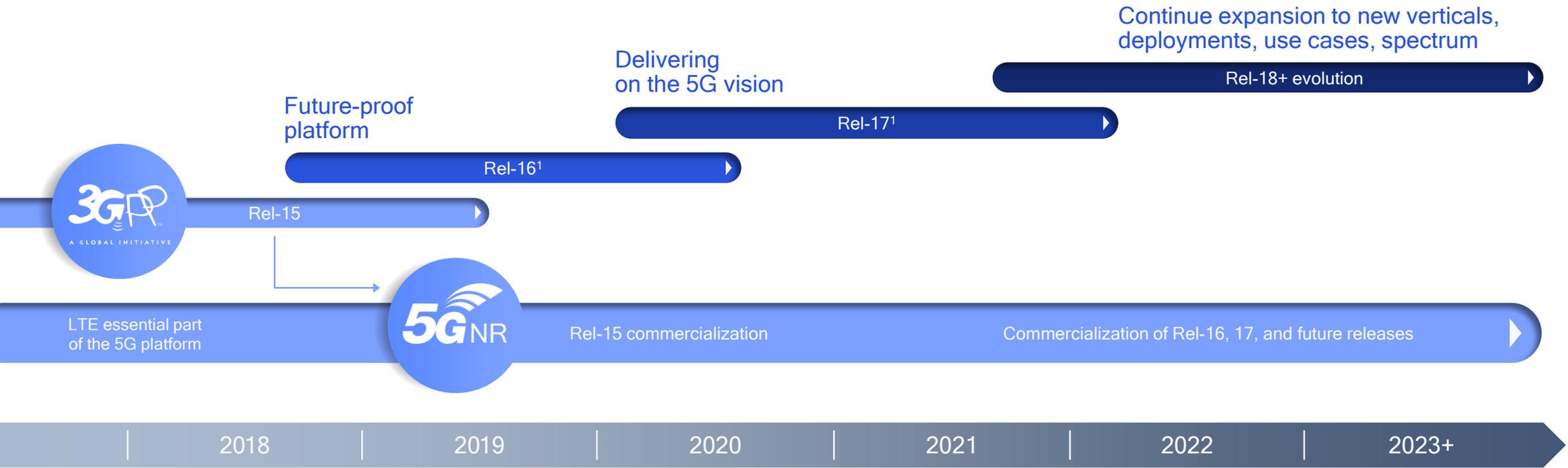


Unlicensed Spectrum Bands in 3GPP

— Available now
— Under study / review

Frequency Band	Availability	Region	Frequency Band	Availability
5.2-5.8 GHz	Available now	United States	5.9-7.1GHz	Under study / review
5.2-5.8 GHz	Under study / review		57-71GHz	Under study / review
5.2-5.9 GHz	Under study / review	Canada	57-71GHz	Under study / review
5.2-5.9 GHz	Under study / review		57-71GHz	Under study / review
5.2-5.9 GHz	Under study / review	European Union	57-71GHz	Under study / review
5.2-5.9 GHz	Under study / review		57-71GHz	Under study / review
5.2-5.7 GHz	Under study / review	United Kingdom	57-71GHz	Under study / review
5.2-5.7 GHz	Under study / review		57-71GHz	Under study / review
5.2-5.7 GHz	Under study / review	Germany	57-71GHz	Under study / review
5.2-5.7 GHz	Under study / review		57-71GHz	Under study / review
5.2-5.7 GHz	Under study / review	France	57-71GHz	Under study / review
5.2-5.7 GHz	Under study / review		57-71GHz	Under study / review
5.2-5.7 GHz	Under study / review	Italy	57-71GHz	Under study / review
5.2-5.7 GHz	Under study / review		57-71GHz	Under study / review
5.2-5.3; 5.7-5.8 GHz	Under study / review	China	59-64GHz	Under study / review
5.2-5.8 GHz	Under study / review		57-64GHz	Under study / review
5.2-5.8 GHz	Under study / review	South Korea	57-66GHz	Under study / review
5.2-5.8 GHz	Under study / review		57-66GHz	Under study / review
5.2-5.7 GHz	Under study / review	Japan	57-66GHz	Under study / review
5.2-5.7 GHz	Under study / review		57-66GHz	Under study / review
5.2-5.5; 5.7-5.9 GHz	Under study / review	India	57-66GHz	Under study / review
5.2-5.5; 5.7-5.9 GHz	Under study / review		57-66GHz	Under study / review
5.2-5.8 GHz	Under study / review	Australia	57-66GHz	Under study / review

Driving 5G technology expansion



Rel-15 eMBB focus

- 5G NR foundation
- Smartphones, FWA, PC
- Expanding to venues, enterprises

Rel-16 industry expansion

- NR-U
- Mi-Cr services, e.g., industrial IoT
- MIoT, e.g., in-band eMTC/NB-IoT
- NR-based C-V2X sidelink

Rel-17+ long-term expansion

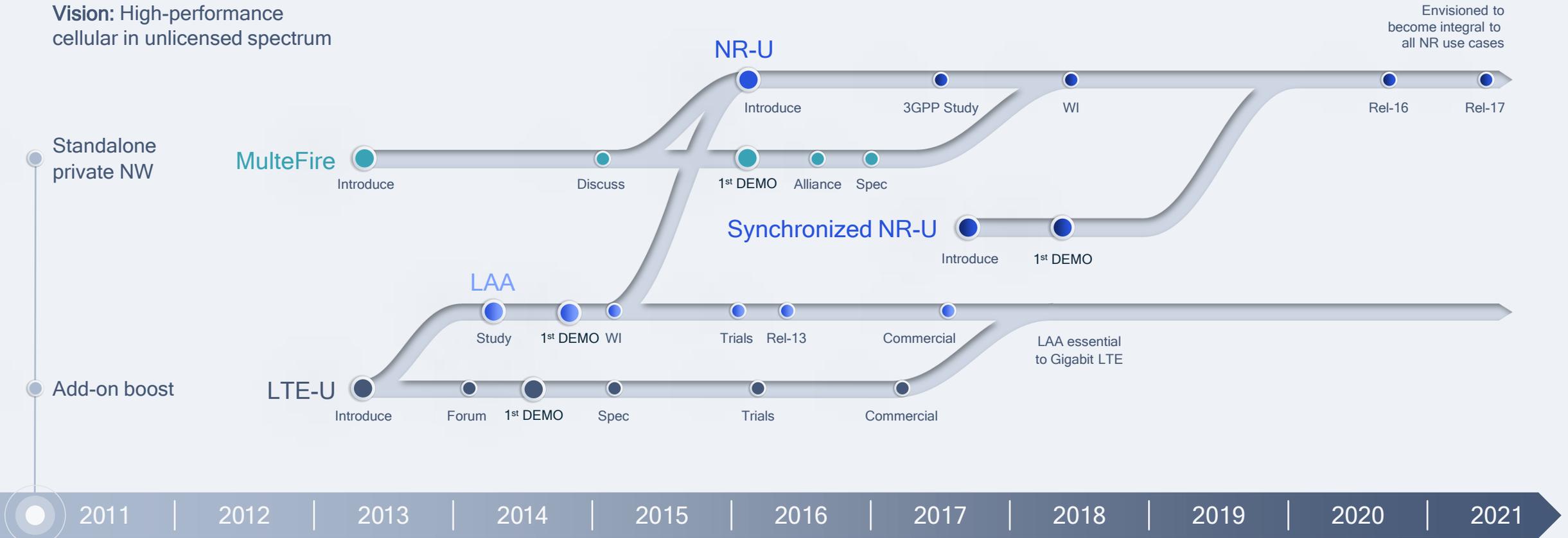
- Lower complexity NR-Light
- Boundless extended reality (XR)
- Higher precision positioning and more...

1. 3GPP start date indicates approval of study package (study item->work item->specifications), previous release continues beyond start of next release with functional freezes and ASN.1

Almost a decade of leadership in unlicensed spectrum

From LTE-U/LAA to NR-U

Vision: High-performance cellular in unlicensed spectrum



Continuous research, industry first over-the-air LAA, eLAA, MulteFire demos, co-existence with Wi-Fi

Rel-16 introduces NR in unlicensed spectrum

Anchored NR-U

Unlicensed spectrum is combined with other licensed or shared spectrum as anchor

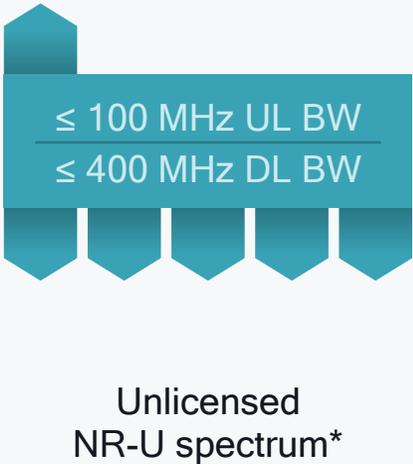


Licensed or shared anchor spectrum

Unlicensed NR-U spectrum*

Standalone NR-U

Only unlicensed spectrum is used



Unlicensed NR-U spectrum*

* Still under discussion in Rel-16

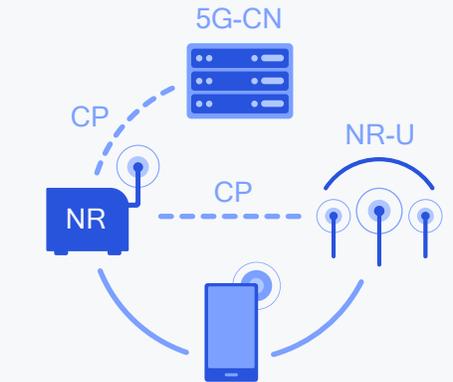
Unlock more spectrum globally

New markets and verticals

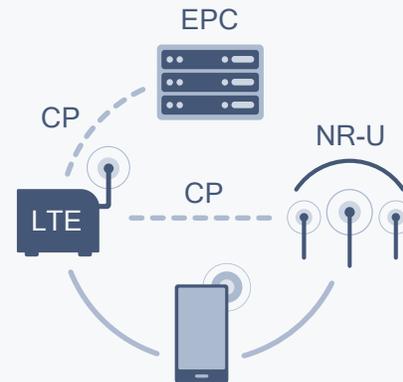
New deployment scenarios

NR-U deployment scenarios

Anchored NR-U



Scenario A
Carrier aggregation
NR with 5G-CN¹ and NR-U



Scenario B
Dual connectivity
LTE with EPC² and NR-U

Standalone NR-U



Scenario C
Standalone
NR-U with 5G-CN

Control Plane (CP) routes shown for Anchored NR-U; User Plane (UP) routes depend on network design; 1. 5G Core Network; 2. Evolved Packet Core

Enhance existing networks and enable new markets with unlicensed spectrum

Anchored NR-U to boost mobile network performance



In Rel-16 Dual Connectivity is supported with EN-DC

Anchored NR-U

Boosting existing
deployments

Better user experience
with higher speeds



Dense urban hotspots



Campuses



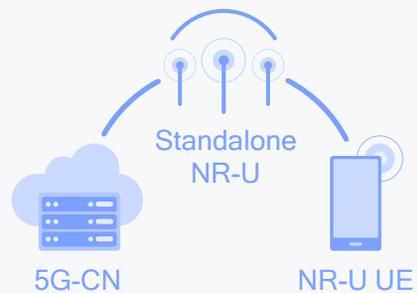
Malls

Anchored NR-U

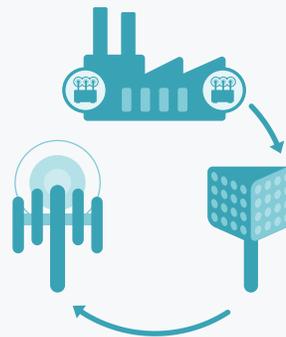
Manages congestion and mobility
Delivers a consistent 5G experience



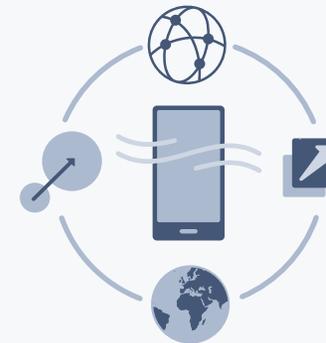
Fair coexistence with Wi-Fi and LTE-LAA



Simple network deployment with virtualized RAN and cloud core



From private networks initially to neutral hosts and mobility offload



Deploy networks and scale freely across markets with unlicensed spectrum

Standalone NR-U

Makes 5G private networks easy to deploy



Container ports



Mines



Warehouses

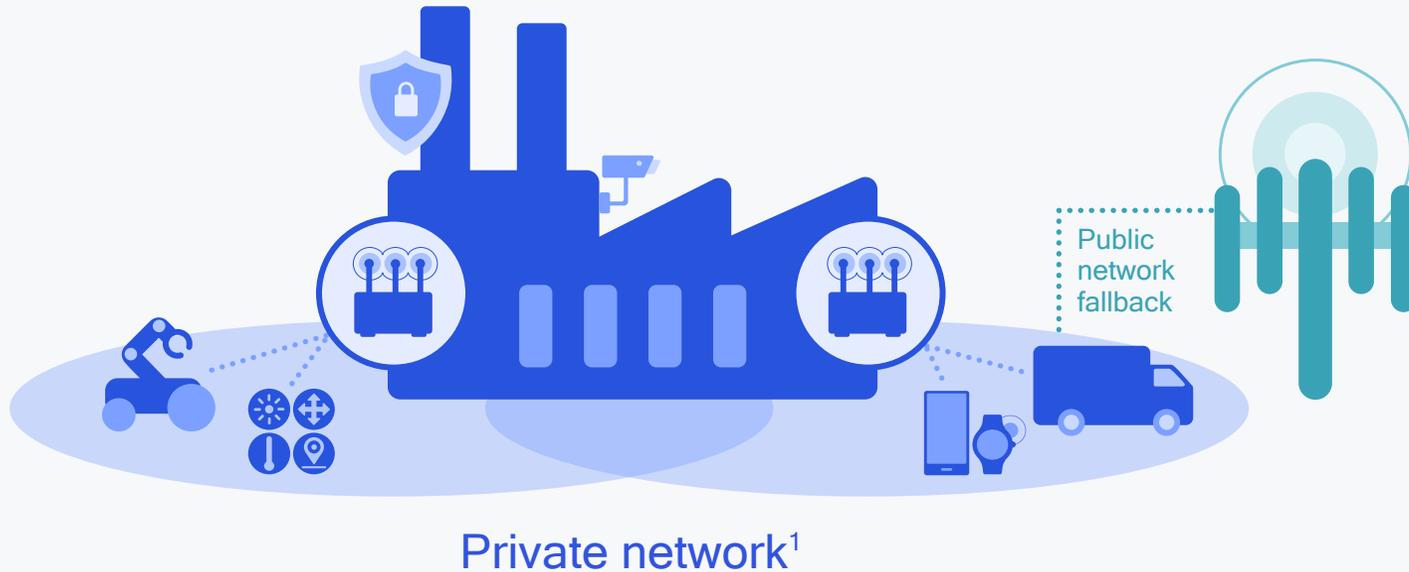
Standalone NR-U

Benefits a wide range of industrial IoT

5G private networks

in licensed, shared or unlicensed spectrum

5G private networks brings benefits to industrial IoT



Dedicated

Local network, dedicated resources, independently managed

Secure

Cellular grade security, sensitive data stays on-premise

Optimized

Tailored performance for local applications, e.g., low latency, QoS²



Coverage, capacity, and, mobility

Outdoor/indoor, high data speeds, seamless handovers, public network fallback

Reliability and precise timing

Industrial grade reliability, latency and synchronization (eURLLC³ and TSN⁴)

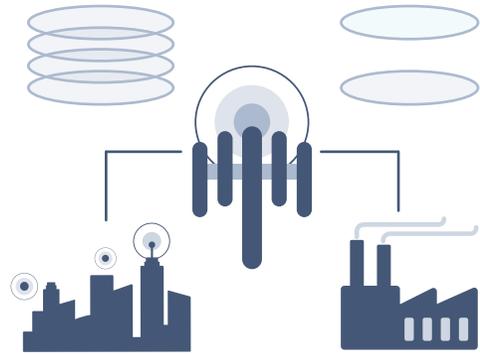
Interoperability

Global standard, vast ecosystem, future proof with rich 5G roadmap

1. Also referred to as non-public network (NPN); 2. Quality of service; 3. Enhanced ultra-reliable low-latency communication; 4 Time sensitive network

5G private networks: An opportunity for mobile operators

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

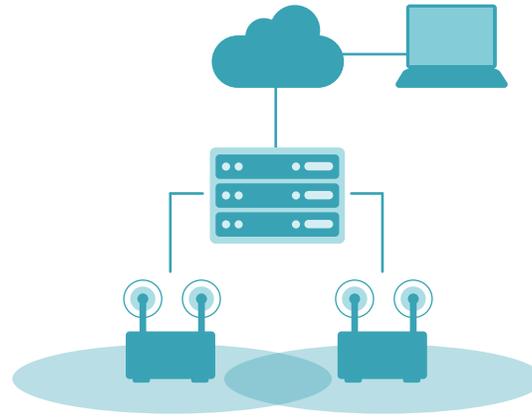


Licensed spectrum assets

Dedicate a portion for private networks

Spectrum may be under-utilized in industrial areas

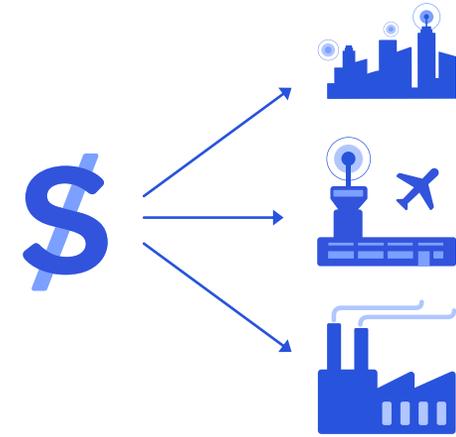
Reuse mmWave spectrum indoors, such as for private enterprise network



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

Enabling smarter logistics at container ports



Freight manifest upload



Autonomous container handling



AR-guided repairs



Site operator access



5G private network



Smart UHD surveillance



Monitoring sensors

On-premise data analytics and storage

Latency measures

Date

Spools shipped

Data protection

On-premise storage system

Real-time asset tracking

At port (Days)

3

Location

Real time inventory

Capacity

Camera



Autonomous trucks



Fall back to public network

Increasing productivity with connected remote mining operations





UHD surveillance cameras



Autonomous guided vehicle



Shelf sensors



Monitoring sensors



Automated asset routing

Real-time asset tracking

At port (Days): **2**

Location:

Cases shipped:

Capacity:

Camera:



Perishable item tracking



5G

private network

AGV control and insights

Executing task 14 of 65

Battery life: 82%

Route history:

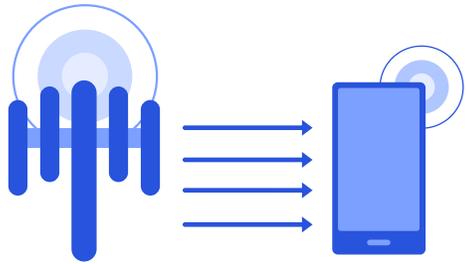


Identify precise cargo location

Enabling smarter warehouses

Coordinated Multi-Point and Synchronized Sharing

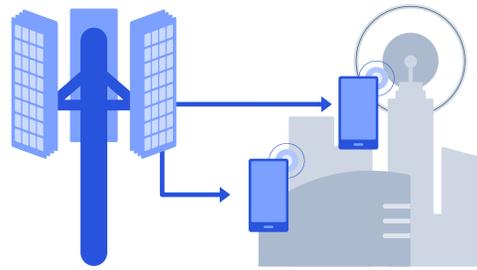
Exploiting spatial domain: From LTE MIMO to 5G CoMP



LTE MIMO

2 Gbps peak-rates with 4x4 MIMO¹, carrier aggregation and higher order modulation

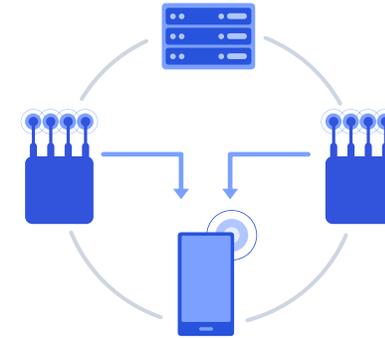
Example: 2 or 4 antennas for transmit and receive



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

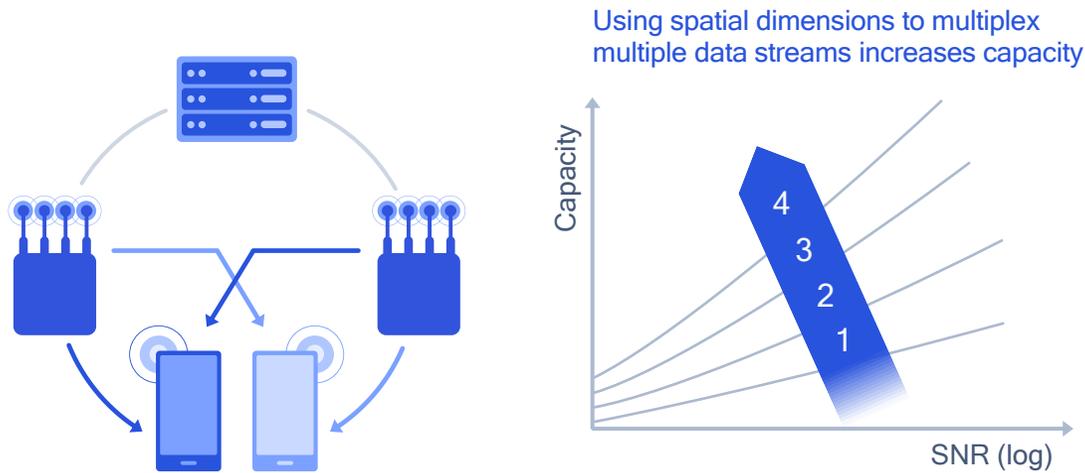


5G CoMP

Leveraging CoMP² diversity and multiplexing to extend 5G to new use cases and verticals

Example: Multiple small-cells with 4 antennas

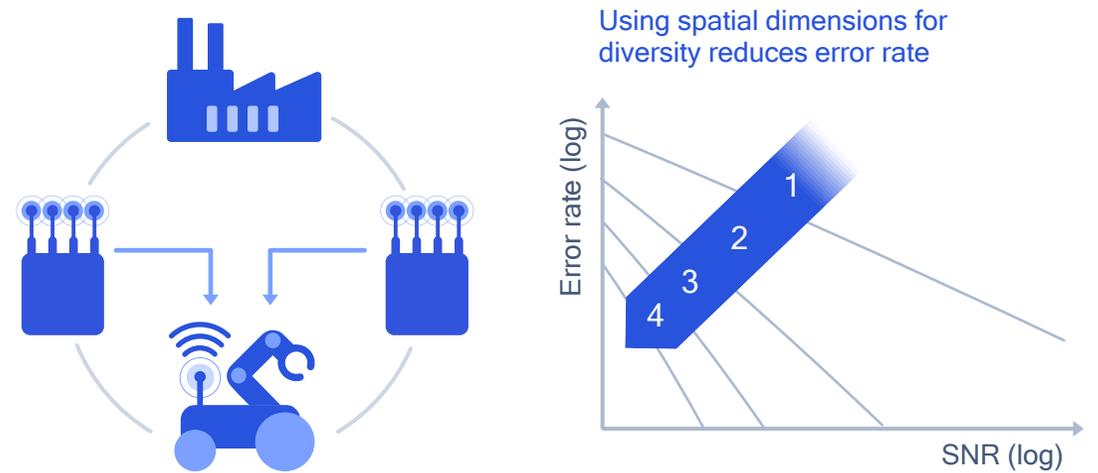
CoMP expands 5G: Capacity or ultra-reliability tradeoff



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

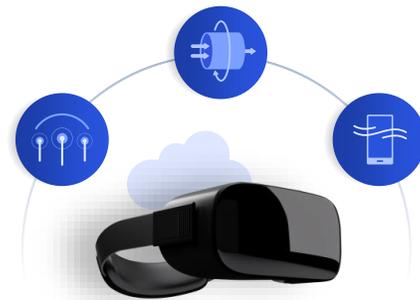
Key for URLLC to meet 99.9999% reliability and challenging industrial IoT applications

NR-U synchronized sharing brings higher performance

Opportunity for greenfield spectrum

Asynchronized sharing

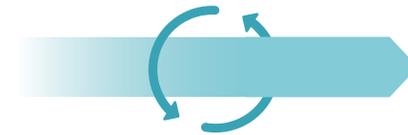
Evolutionary path: Existing coexistence rules in unlicensed spectrum



Anchored NR-U



Standalone NR-U

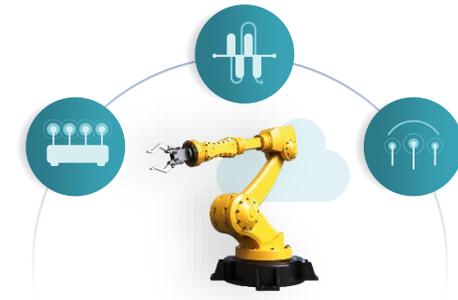


Time synchronization

Provides great potential to share spectrum more efficiently

Synchronized sharing

Revolutionary path: Time synchronized sharing in unlicensed and shared spectrum



5G CoMP, predictable sharing, and spatial sharing

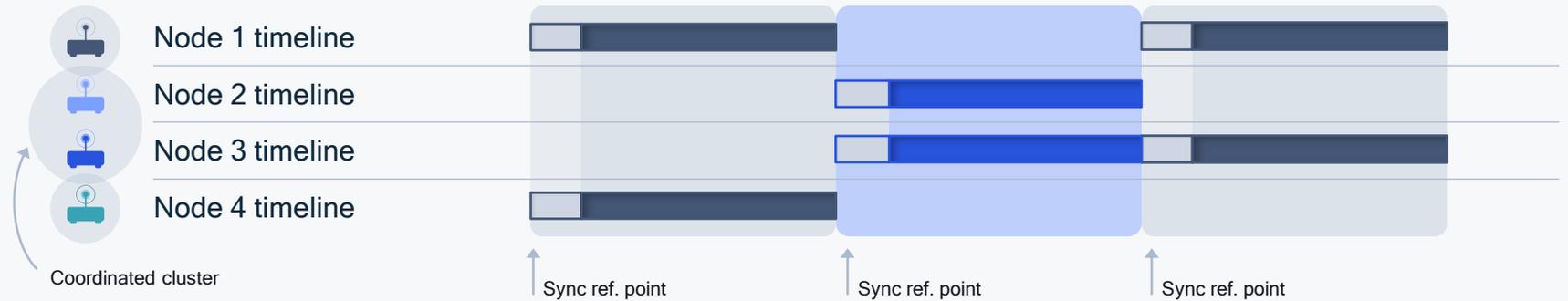
Unlicensed access with synchronized sharing

Synchronized sharing supports coordinated transmission which can provide high QoS with low latency and high reliability

Asynchronized sharing



Synchronized sharing



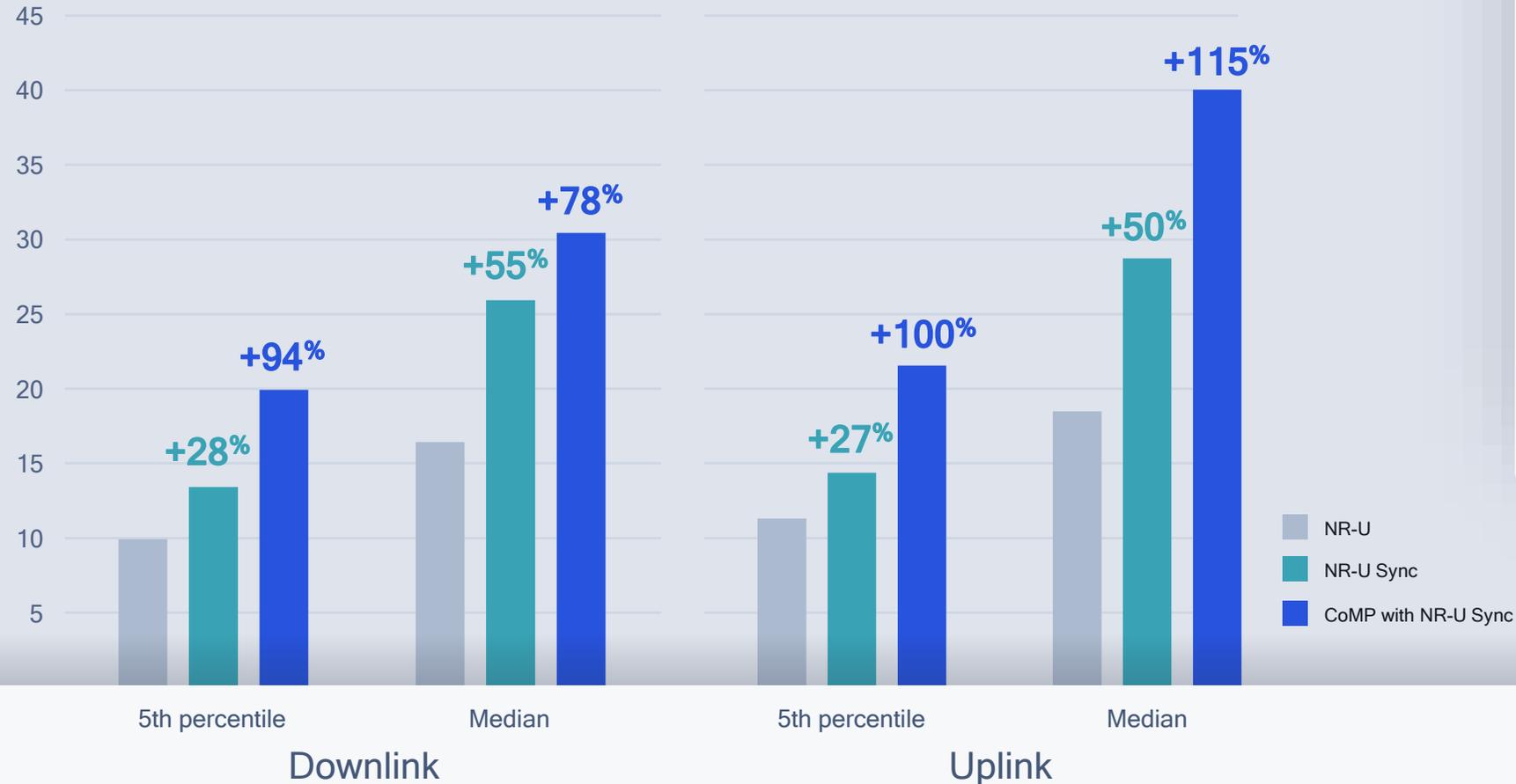
Synchronous access ends COT at a synchronization reference point to increase likelihood of synchronous contention

■ Contention Window (CW) ■ Channel Occupancy Time (COT)

Synchronized sharing brings significant performance gains

Indoor 3GPP simulation model

Per-UE Offered Load (Mbit/s)



Synchronized NR-U gains over asynchronous NR-U

27%-50%

Improvement in uplink capacity

28%-55%

Improvement in downlink capacity

CoMP gains over asynchronous NR-U

100%-115%

Improvement in uplink capacity

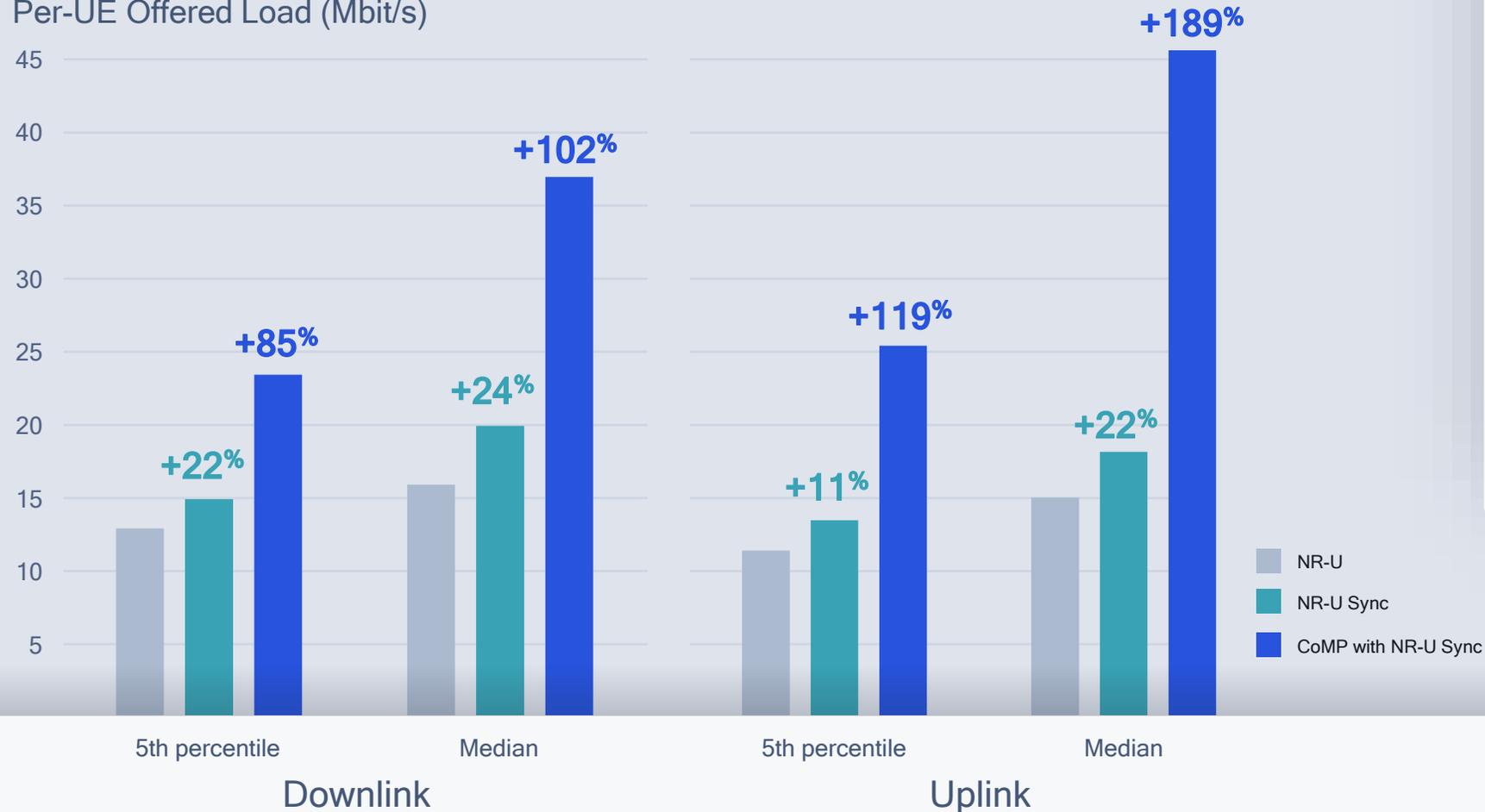
78%-94%

Improvement in downlink capacity

Synchronized sharing brings significant performance gains

Outdoor 3GPP simulation model

Per-UE Offered Load (Mbit/s)



Synchronized NR-U gains over asynchronous NR-U

11%-22%

Improvement in uplink capacity

22%-24%

Improvement in downlink capacity

CoMP gains over asynchronous NR-U

119%-189%

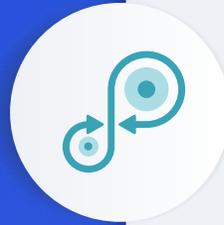
Improvement in uplink capacity

85%-102%

Improvement in downlink capacity

Synchronized sharing in unlicensed spectrum offers many benefits to all technologies

TRP: Transmission and Reception Point; CoMP: Coordinated Multi-Point



Synchronization can narrow the performance gap with licensed spectrum in challenging multi-technology deployments



Higher spectral efficiency and reliability with Multi-TRP and CoMP

More opportunities for simultaneous transmission and reception



Reduced access latency and improved fairness in multi-technology deployments

Periodic synchronous contention opportunities

Synchronization approach does not prevent asynchronous access, it only synchronizes contention after channel use



Can fairly share the same spectrum with asynchronous access

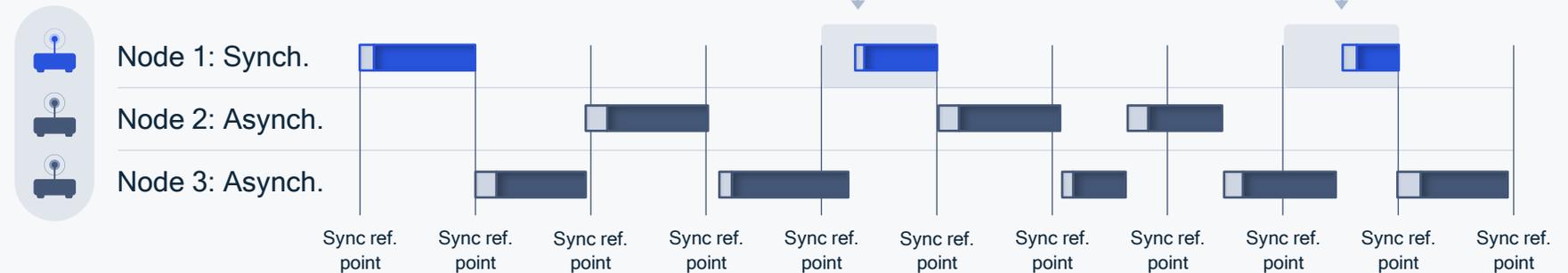
As more devices use synchronous contention, performance of all devices increasingly improves

COT extension can enable fair sharing

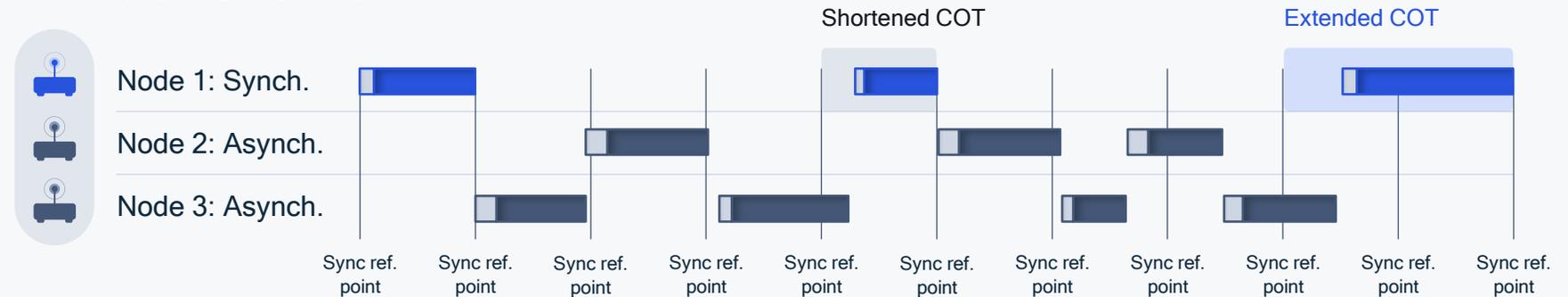
Without COT extension, synchronous access will not get a fair share of the channel when asynchronous nodes are present

Allowing synchronized nodes to extend COT can balance the access for fair sharing between synchronized and asynchronous nodes

Without COT extension



With COT extension



Contention Window (CW) Channel Occupancy Time (COT)

5G Industrial IoT



5G

Dedicated and reliable networks optimized for local services

Scalable wireless connectivity on a future proof platform

Capabilities for new use cases e.g. wireless Industrial Ethernet



5G private network



Licensed, shared and unlicensed Spectrum



Ultra Reliable Low Latency Communication (URLLC)



Time Sensitive Networking (TSN)

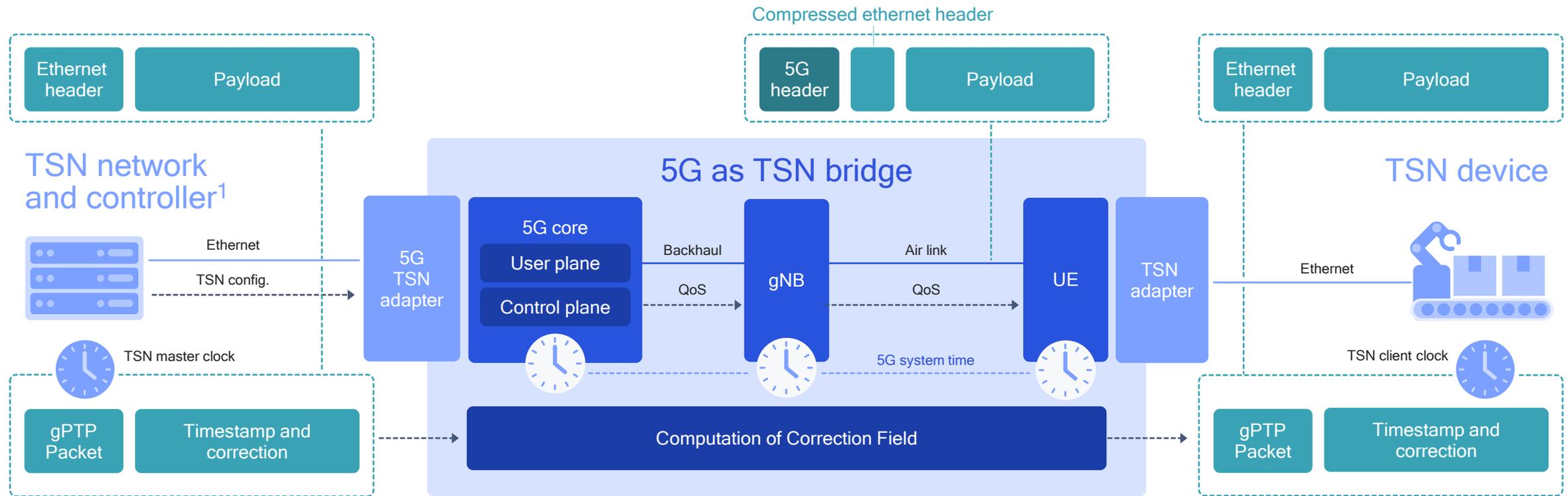


Positioning

Designing 5G to meet industrial IoT requirements

5G brings support for Time Sensitive Networking (TSN)

A requirement for industrial automation and many other industrial IoT applications



¹ The TSN network is controlled by a Central Network Controller (CNC). TSN and CNC are defined in a set of standards specified by IEEE 802.1.

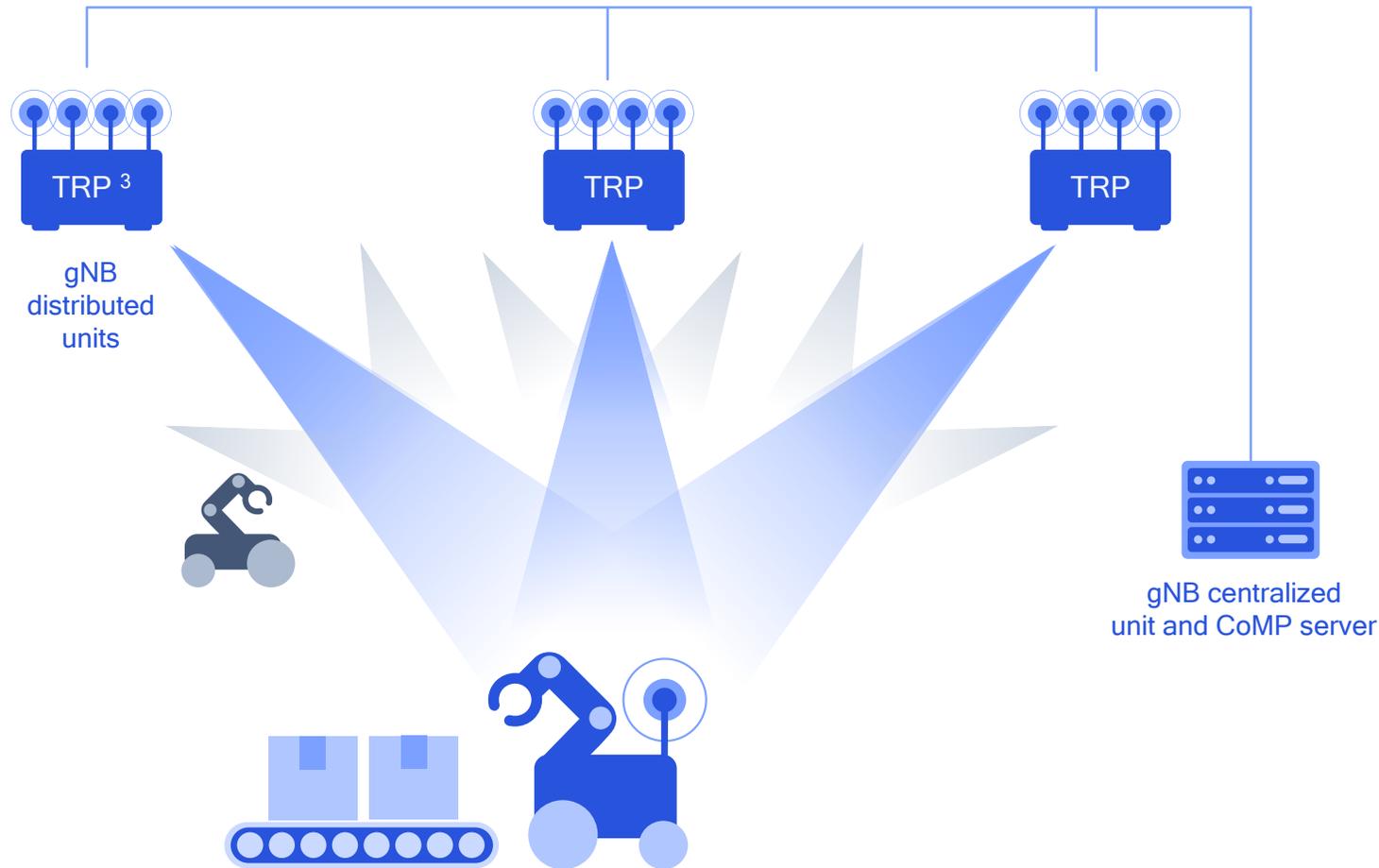
5G TSN adapters allow the 5G system to act as a TSN bridge with Ethernet connectivity

Mapping of TSN configurations to 5G QoS framework for deterministic messaging and traffic shaping

Precise time synchronization with generalized Precision Time Protocol (gPTP) at microsecond level

5G CoMP achieves ultra-reliability

Spatial diversity for eURLLC¹ to reach 99.9999% reliability²

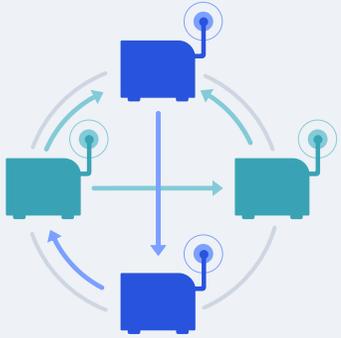


Coordinated Multi Point (CoMP) creates spatial diversity with redundant communication paths

- Other diversity methods such as frequency and time diversity are not sufficient for URLLC
- CoMP is facilitated by denser deployment of small cells with high bandwidth backhaul

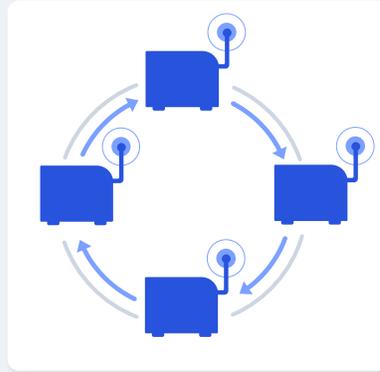
1. Enhanced ultra-reliable low latency communication; 2. A performance requirements for communication service availability in 3GPP TS 22.104; 3. Transmission/Reception Point

NR-U supports URLLC with synchronized sharing in controlled environments



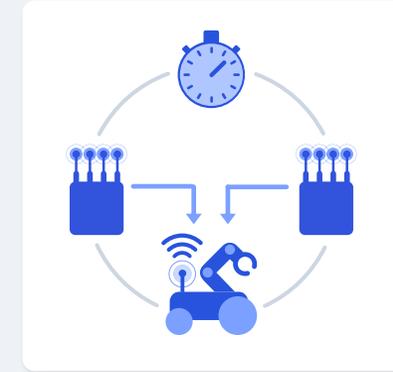
Today, unlicensed spectrum offers unpredictable QoS

Regular LBT¹ using random access results in unpredictable Quality of Service (QoS), e.g., latencies



In controlled environments, QoS becomes more predictable

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



Synchronized sharing enables CoMP and more predictable QoS

Today's regulation includes FBE², which supports predictable QoS and CoMP—a key technology for URLLC

Unlicensed spectrum can support demanding industrial IoT

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

Upcoming NR-U enhancements

Rel-16 functionality that could apply to NR-U



Industrial IoT and URLLC enhancements



Time-Sensitive Networking (TSN)



CoMP with Multi-TRP

Additional NR-U capabilities in Rel-17+



NR-U with 60 GHz



Precise positioning



Edge computing enhancements

How does unlicensed spectrum with NR-U transform what 5G can do for you?



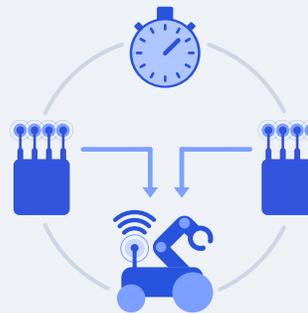
Anchored NR-U

Combine licensed or shared spectrum anchors with unlicensed spectrum to boost performance



Standalone NR-U

5G private networks and industrial IoT without spectrum licenses



6 GHz greenfield spectrum

Massive amount of new unlicensed spectrum available in the US and coming soon to other countries



Thank you

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