New business opportunities for 5G NR
A unifying connectivity fabric for future innovations

Like electricity, you will just expect it everywhere.

- Scalable to extreme simplicity
- On-device intelligence
- Extreme reliability
- Multi-gigabit speed
- Virtually unlimited capacity
- Ultra-low latency
Driving the 5G roadmap and ecosystem expansion

- **Rel-15** Commercialization
  - Standalone (SA)
  - Non-Standalone (NSA)
  - Field trials
  - IoT
  - We are here

- **Rel-16**
  - eMBB deployments in both mmWave and sub-6 GHz
  - Smartphone formfactor, connected laptops, CPE fixed access
  - Private networks, indoor mmW for enterprises, boundless XR,...

- **Rel-17+**
  - New 5G NR technologies to evolve and expand the 5G ecosystem
  - Expanded ecosystem: Industrial IoT, private network, 5G NR C-V2X, Integrated Access and Backhaul, unlicensed/shared spectrum,...
  - Continued eMBB evolution

Continue to evolve LTE in parallel as essential part of the 5G Platform

- 2017
- 2018
- 2019
- 2020
- 2021
- 2022
- 2023+
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

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

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

Multi-Gigabit speeds with virtually unlimited capacity

Reuse licensed spectrum— in-/outside mmWave isolation

Private 5G NR indoor network with cellular grade security

Next level of untethering— the mobile office of future

Instant cloud applications, instant cloud storage access

Extreme capacity for heavy use areas—conference room

Connect to projectors/screens with immersive content

Complemented with outdoor connectivity

Beyond laptops: Augmented and virtual reality (XR)
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

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; Using 800 MHz DL bandwidth and 100 MHz uplink bandwidth with 7:1 DL/UL TDD

Total Area: ~27.6k ft\(^2\)

Existing Wi-Fi access point locations – co-sited with 5G NR mmWave antenna locations
5G NR is expanding to new use cases and verticals

- Mobile broadband evolution
- Mobile mmWave evolution
- 5G NR C-V2X
- Industrial IoT with URLLC
- Unlicensed/shared spectrum
- Massive IoT
- Broadcast
Addressing unmet needs: dedicated, local and optimized
Opportunity for both licensed and unlicensed spectrum

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
Shared and unlicensed spectrum creates new opportunities and expands the ecosystem.

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

5G
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
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)

Spectrum to deploy private 5G network

Unifying connectivity, dedicated network, optimized services

High reliability, low latency in challenging environments

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
Exploiting spatial domain—from LTE MIMO to 5G CoMP

- **LTE MIMO**: 2 Gbps peak-rates with 4x4 MIMO, 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 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

Controlled private environment improves latency

Synchronization in time is key for predictability

CoMP improves capacity and reliability

Frequency diversity adds more reliability

Results in random delays – demanding IIoT\(^2\) apps require predictable latency

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

Current regulation allows synchronized FBE\(^3\) based sharing for predictable low latency

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

Frequency diversity provide reliability against rouge devices trying to access

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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...

**Revolutionary path**
NR spectrum sharing (NR-SS)—potential for new rules

- Predictable resources
- 5G CoMP
- Spatial sharing
- Flexible sharing

Time synchronization provides great potential to share spectrum more efficiently
What is possible when not constrained by existing rules?

**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

<table>
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<tr>
<th>Type</th>
<th>Description</th>
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| 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
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
Thank you

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