What Innovations Can 5G NR Bring to Shared & Unlicensed Spectrum?

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Sponsored by Qualcomm
Today’s Presenters

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Agenda

• Importance of Shared Spectrum – Heavy Reading

• 5G Spectrum Sharing – Qualcomm

• Q&A Session
Types of Spectrum

**Licensed**
- Exclusive use by license holder
- Foundation of public mobile networks (<6GHz today)
- Also critical to satellite, government & military

**Shared**
- Many possible sharing schemes
- Increase availability of spectrum and efficiency of spectrum use
- Established regulatory frameworks to build on

**Unlicensed**
- Open use within regulatory limit
- Extensive adoption by professional and amateur users
- Enabler of “permission-less innovation”

A Role for Three Categories of Spectrum in Advanced 4G and 5G Networks
Three Advantages of Shared Spectrum

1. Unlock spectrum that is lightly used by incumbents – e.g. satellite or military

2. Opportunity to increase spectrum utilization by multiple operators sharing the band

3. Attract new providers; enable new service models; support new deployment types (e.g. verticals)
Shared Spectrum Use by Mobile Operators

**Carrier WiFi**
(2.4 & 5GHz)

**MulteFire**
(3.5 & 5GHz)

**LTE-U & LTE-LAA**
(5GHz)

**Citizens Broadband Radio Service (CBRS) & Licensed Shared Access (LSA)**
(2.3 & 3.5GHz)

**LPWA**
(800 & 900 MHz)

**E-Band & V-Band**
(60, 70 & 80 GHz)

**mmWave**
5G NR
5G Spectrum Sharing

Dr. Mingxi Fan
VP, Engineering
Qualcomm Technologies, Inc.
November 17, 2016
@qualcomm #whywait
New spectrum sharing paradigms—opportunity to innovate

Can enable more efficient utilization of, and access to, scarce resources

**Licensed spectrum**
- Exclusive use
- Over 40 bands globally for LTE

**Shared spectrum**
- New shared spectrum paradigms
- Example: 2.3 GHz Europe / 3.5 GHz USA

**Unlicensed spectrum**
- Shared use
- Example: 2.4 GHz / 5 GHz / 60 GHz global

5G Spectrum Sharing
Spectrum sharing is important for 5G

Unlocking more spectrum
Shared spectrum can unlock spectrum that is lightly used by incumbents

High spectrum utilization
Spectrum sharing has the potential to increase spectrum utilization

A lot of spectrum may be shared/unlicensed
FCC recent decision on high-band spectrum included a significant portion of shared/unlicensed

1) FCC ruling FCC 16-89 on 7/14/2016 allocated 3.25 GHz of licensed spectrum and 7.6 GHz of shared/unlicensed spectrum.
Multiple dimensions of spectrum sharing

**Vertical sharing**

Multiple deployments in the same geographical area operating at different priority tiers, where lower tiers are not interfering higher tiers.

Example: LSA\(^2\)

**Horizontal sharing**

Multiple deployments in the same geographical area are sharing the spectrum with the same priority.

Example: MulteFire with LBT\(^1\)

**Combined sharing**

Multiple vertical priority tiers, where horizontal sharing is used in at least one of the tiers.

Example: CBRS\(^3\)

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1) Listen before talk (LBT); 2) Licensed Shared Access (LSA); 3) Citizen Broadband Radio Service (CBRS)
Better spectrum utilization from dynamic spectrum sharing

Static allocation → Dynamic vertical sharing

Static allocation → Dynamic horizontal sharing

Increased spectrum utilization
Spectrum sharing valuable for wide range of deployments

Extrem bandwidth from dynamic spectrum aggregation
Allows operators to opportunistically aggregate more spectrum to provide extreme bandwidths

Enhanced local broadband
Enables entities without licensed spectrum to deploy 5G, e.g., enterprise

Internet of Things verticals
Opens up opportunity to service different IoT verticals, e.g., dedicated IoT networks
Leading the way with mobile Wi-Fi

Large scale horizontal spectrum sharing

Led the way for multi-band Wi-Fi ecosystem with 802.11ad

11ad
2GHz / SISO
8 GHz, MU-MIMO

60GHz

11bg 11n 11ac 11ac Wave-2 11ax

2.4GHz / 5GHz

20 MHz / SISO
40 MHz / MIMO 4x4
160 MHz / 5 GHz support
Downlink MU-MIMO
OFDMA

Uplink MU-MIMO

Introduced industry’s first 802.11ac Wave 2 SOC
Pioneered multiple spectrum sharing technologies in LTE

1. **Licensed Shared Access (LSA)**
   - Technically extensive pilot in France with Ericsson and Red in Jan 2016

2. **LTE-U**
   - We designed the original proposal, commercialized by the LTE-U forum

3. **LAA**
   - First over-the-air trials, LAA with DT Nov. 2015 and eLAA with SKT Sep. 2016

4. **MulteFire**
   - A founder of the MulteFire Alliance, first over-the-air connection Oct 2016

5. **CBRS**
   - A founder of the CBRS Alliance and a key contributor to coexistence

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1) Licensed Shared Access (LSA); 2) Licensed-Assisted Access (LAA), enhanced LAA (eLAA), Deutsche Telekom (DT), SK Telecom (SKT); 3) Citizen Broadband Radio Service (CBRS)
Announced first MulteFire over-the-air connection

An important milestone for the industry’s effort to broaden the LTE ecosystem
CBRS\(^1\) introduces 3-tier vertical shared spectrum in USA

Opens up 150 MHz spectrum for new services

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**Tier 1**
- **Incumbents**

**Tier 2**
- **Priority Access Licenses (PAL)**

**Tier 3**
- **General Authorized Access (GAA)**

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<thead>
<tr>
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<th>Tier 2</th>
<th>Tier 3</th>
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<tbody>
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<td>PAL</td>
<td>GAA</td>
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</tbody>
</table>

**Military radar, e.g., Navy**

**Fixed satellite service\(^2\)**

**Wireless ISP\(^3\)**

**Incumbents** are protected from interference from PAL and GAA

**PAL** has priority over GAA, licensed via auction, 10 MHz blocks, up to 7 licenses

**GAA** can use any spectrum not used, yields to PAL and incumbents

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1) Citizen Broadband Radio Service (CBRS); 2) Fixed satellite service - receiving only; 3) Wireless ISP transitioning from incumbent to PAL/GAA after 5 years
Multiple high performance LTE options can coexist in CBRS

Possible to launch with LTE-TDD and introduce LBT later

1. General Authorized Access (GAA) is tier 3 in the CBRS 3-tier licensing model for shared 3.5 GHz in USA; 2. Licensed-Assisted Access, also includes enhanced LAA (eLAA); 3. Listen before talk; 4. Channels can be reused with sufficient RF isolation.
MulteFire helps CBRS scale to multiple deployments

Multiple deployments share a wide channel—better spectrum utilization & peak-rate

Multiple LTE-TDD deployments with reduced channel size, spectrum may become underutilized\(^1,^2\)

MulteFire brings improved spectrum utilization from dynamically sharing a wide channel\(^1,^3\)

1) Example with one deployment (#1) with a high traffic load and two deployments (#2 and #3) with medium traffic loads; 2) Spectrum cannot always be evenly split; 3) Trunking benefits depend on relative traffic loads.
We are pioneering 5G spectrum sharing today
Building on LTE-U/LAA, LWA, CBRS, LSA and MulteFire

<table>
<thead>
<tr>
<th>Spectrum sharing technologies</th>
<th>5G New Radio (NR) Sub 6GHz + mmWave</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectrum aggregation</td>
<td>LTE-U / LAA</td>
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<tr>
<td></td>
<td>NR based LAA</td>
</tr>
<tr>
<td>Radio aggregation</td>
<td>LWA (LTE + Wi-Fi)</td>
</tr>
<tr>
<td></td>
<td>Multi-connectivity: NR,LTE,Wi-Fi</td>
</tr>
<tr>
<td>Tiered sharing (incumbents)</td>
<td>CBRS, LSA</td>
</tr>
<tr>
<td></td>
<td>NR based tiered sharing</td>
</tr>
<tr>
<td>Standalone unlicensed</td>
<td>MulteFire</td>
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<tr>
<td></td>
<td>NR based MulteFire</td>
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LTE Advanced Pro
Spectrum below 6 GHz

1) Licensed-Assisted Access (LAA), LTE Wi-Fi Link Aggregation (LWA), Citizen Broadband Radio Service (CBRS), Licensed Shared Access (LSA)
Anyone can talk about 5G. We are creating it.
Accelerating 5G NR, the global standard for 5G

- **5G study items**
  - 3GPP 5G NR R14 study item
  - R15 5G work items
  - R16 5G work items
  - R17+ 5G evolution

- **Accelerating 5G NR**
  - with trials & early deployments
  - 5G NR R15 launches
  - 5G NR R16 launches

- **Gigabit LTE & LTE IoT deployments**
  - Continue to evolve LTE in parallel to become a critical part of the 5G platform

- **2016 - 2022**
  - X50 samples
  - X50 products
  - Verizon 5GTF
  - KT-SIG

Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc. X50 sampling expected 2H 2017 Commercial devices expected in 1H 2018

Note: Estimated commercial dates. 1 The latest plenary meeting of the 3GPP Technical Specifications Groups (TSG#72) has agreed on a detailed workplan for Release-15; 2 Forward compatibility with R16 and beyond
5G NR R15\textsuperscript{1} will establish the 5G foundation

For enhanced mobile broadband and beyond

**Optimized OFDM-based waveforms**

With scalable numerology and TTI, plus optimized multiple access for different use cases

**A common, flexible framework**

To efficiently multiplex services and features with a dynamic, low-latency TDD/FDD design

**Advanced wireless technologies**

Such as massive MIMO, robust mmWave, advanced channel coding, and device-centric mobility

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Unified design across spectrum types and bands

For licensed and shared/unlicensed spectrum bands both below 6 GHz and above 6 GHz\textsuperscript{2}

\textsuperscript{1} 3GPP R16+ will bring continued eMBB evolution, plus new features for massive IoT and mission-critical; \textsuperscript{2} 3GPP R15 focused on spectrum bands up to ~40 GHz; R16+ will bring support for bands up to ~100 GHz
Designed to take advantage of new sharing paradigms

Flexible radio
- Scalable numerology: narrow-to-wideband
- Spectrum from sub-6GHz to mmWave
- Self-contained integrated sub-frames

Flexible unlicensed operation
- Unlicensed aggregation with licensed anchor
- Multi-connectivity: NR, LTE and/or Wi-Fi
- Stand-alone in unlicensed

Flexible spectrum sharing
- Dynamic sharing between deployments, technologies, priority tiers, etc.
- Enhanced spatial techniques with mmWave
- New spectrum sharing paradigms
Scalable numerology with scaling of subcarrier spacing

Efficiently address diverse spectrum, deployments and services

Outdoor and macro coverage
FDD/TDD <3 GHz
- Subcarrier spacing:
  - e.g. 15 kHz
  - e.g. 1, 5, 10 and 20 MHz

Outdoor and small cell
TDD > 3 GHz
- Subcarrier spacing:
  - e.g. 30 kHz
  - e.g. 80/100 MHz

Indoor wideband
TDD e.g. 5 GHz (Unlicensed)
- Subcarrier spacing:
  - e.g. 60 kHz
  - e.g. 160 MHz

mmWave
TDD e.g. 28 GHz
- Subcarrier spacing:
  - e.g. 120 kHz
  - e.g. 500 MHz

Example usage models and channel bandwidths
Self-contained integrated sub-frame

Supports new sharing scenarios as well as more flexible TDD switching

Spectrum sharing
Listen-before-talk headers e.g. clear Channel Assessment (CCA) and hidden node discovery

Adaptive UL/DL

Add’l headers | Ctrl (Tx) | Data (Tx)

Guard period

Example: TDD downlink

D2D, mesh and relay

ACK (Rx)

Massive MIMO
Opportunity to enhance spectrum sharing further

Leveraging LTE spectrum sharing to provide new solutions for 5G NR

**Fixed spectrum allocation**
Full control, partially loaded

**Uncoordinated sharing**
Higher peak rate and utilization

**Coordinated sharing**
Increased spectral efficiency
Enhancing existing and new spectrum sharing paradigms

Uncoordinated sharing
- Floating frame boundaries
- Medium access via enhanced LBT\(^1\) with robust interference management
- Enable prioritized medium contention

Coordinated sharing
- Deterministic frame reference
- Guaranteed QoS via coordinated medium access
- Effective utilization of excess capacity via opportunistic medium access

Targeting existing unlicensed spectrum

Targeting new shared spectrum

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\(^1\) Listen before talk (LBT) over-the-air contention mechanism
Potential for meaningful performance increases

Spectrum sharing can increase performance at both low and high traffic loads.

User perceived data rate

- **Tightly coordinated**
- **Loosely coordinated**
- **Uncoordinated**
- **Static FDM**

Opportunity for further enhancements

1) Two indoor deployment with multiple small-cells; 2) Static FDM baseline is uncoordinated.
Taking spectrum sharing to the next level in 5G

NR spectrum sharing prototype system

Drive 5G NR standardization
Drive and track standardization; NR designed with forward compatibility to support new spectrum sharing technologies

Enhance mobile broadband speeds
Higher levels of mobile broadband performance enabling fiber-like experiences

Extend 5G ecosystem
Extend 5G into new types of deployments, such as dedicated 5G networks for enterprise and industrial IoT

Enable impactful trials
Technology development in 2017, field trials with industry leaders to follow; adds to our existing 5G NR prototype systems
5G NR will natively support all different spectrum types

- **Licensed Spectrum**
  - Exclusive use
- **Shared Spectrum**
  - New shared spectrum paradigms
- **Unlicensed Spectrum**
  - Shared use

**High bands above 24 GHz (mmWave)**
- Extreme bandwidths

**Mid bands 1GHz to 6 GHz**
- Wider bandwidths for e.g. eMBB and mission-critical

**Low bands below 1 GHz**
- Longer range for e.g. mobile broadband and massive IoT
Thank you

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