What can we do with 5G NR Spectrum Sharing that isn't possible today?

Qualcomm Technologies, Inc.
December 13th, 2017

Today's agenda

1

Global 5G spectrum update

2

5G spectrum sharing technologies

3

Questions and answers

Today's speakers

Dean Brenner
SVP, Spectrum Strategy and Technology Policy
Qualcomm Incorporated

Yongbin Wei
Sr. Director, Engineering
Qualcomm Technologies, Inc.

Global 5G Spectrum

Dean Brenner, SVP, Spectrum Strategy & Tech. Policy
Qualcomm Incorporated

Using all available spectrum types and spectrum bands

Licensed spectrum

Exclusive use

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

Shared spectrum

New shared spectrum paradigms

Example: 2.3 GHz Europe / 3.5 GHz USA

Unlicensed spectrum

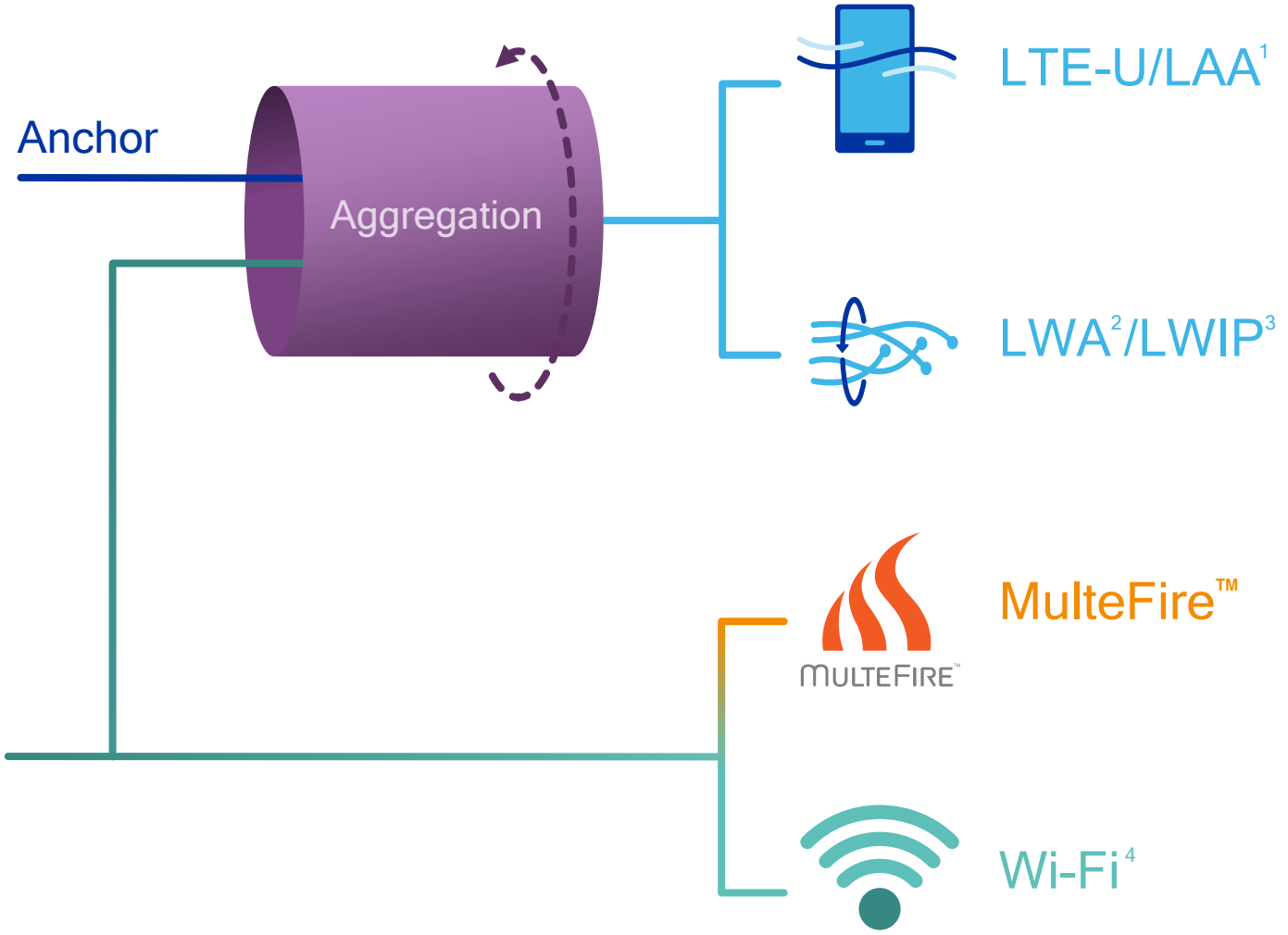
Shared use

Example: 2.4 GHz / 5-7 GHz / 57-71 GHz global

Making best use of shared/unlicensed spectrum

Licensed spectrum
Exclusive use

Unlicensed spectrum
Shared use



LTE-U/LAA[1]
Targeting mobile operators using LTE in unlicensed spectrum for new small cell deployments

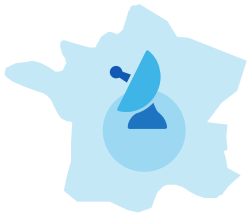
LWA[2]**/LWIP**[3]
Targeting mobile operators leveraging existing carrier Wi-Fi deployments

MulteFire™
Broadens LTE ecosystem to enhanced and new deployment opportunities, suitable for neutral host

Wi-Fi[4]
Evolving for enhanced performance and expanding to new usage models, used today as neutral host

1. Licensed-Assisted Access (LAA), also includes enhanced LAA (eLAA); 2. LTE WLAN Link Aggregation (LWA); 3. LTE WLAN radio level integration with IPsec tunnel (LWIP); 4. 802.11ac / .11ad / .11ax / .11ay

Pioneering shared spectrum technologies in LTE



LSA[1]

Technically extensive pilot in France with Ericsson and Red in Jan 2016

LTE-U

Designed the original technology, commercialized by the LTE-U Forum, deployed in the US

LAA[2]

First over-the-air trials with DT 2015, multiple commercial deployments globally and 2nd gen. Gigabit LTE tested 2017

MULTEFIRE™

A founder of the MulteFire Alliance, first OTA connection Oct. 2016, Release 1.0 specification Jan. 2017

ALLIANCE cbrs

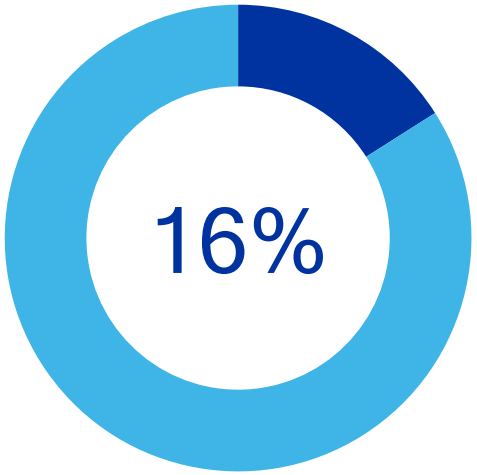
A founder of the CBRS[3] Alliance and a key contributor to coexistence

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)

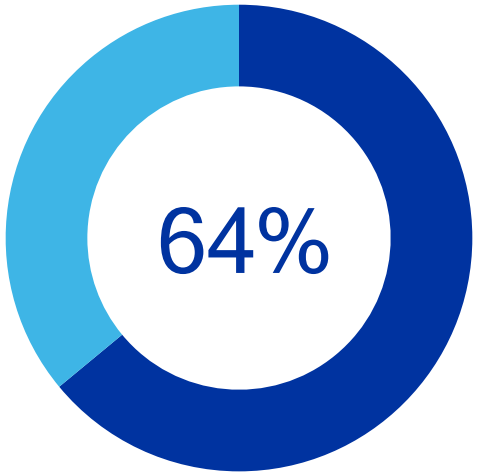
Enabling Gigabit LTE all over the world by using LAA

More operators can deliver Gigabit LTE using LAA in 5 GHz unlicensed spectrum

Share of operators who can deploy Gigabit LTE

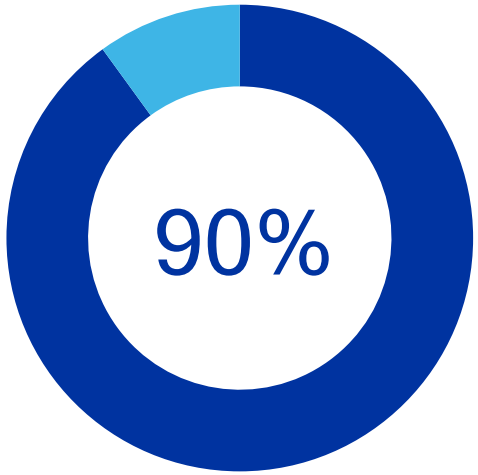


60 MHz licensed[1]



X16 LTE Modem

20 MHz licensed + LAA



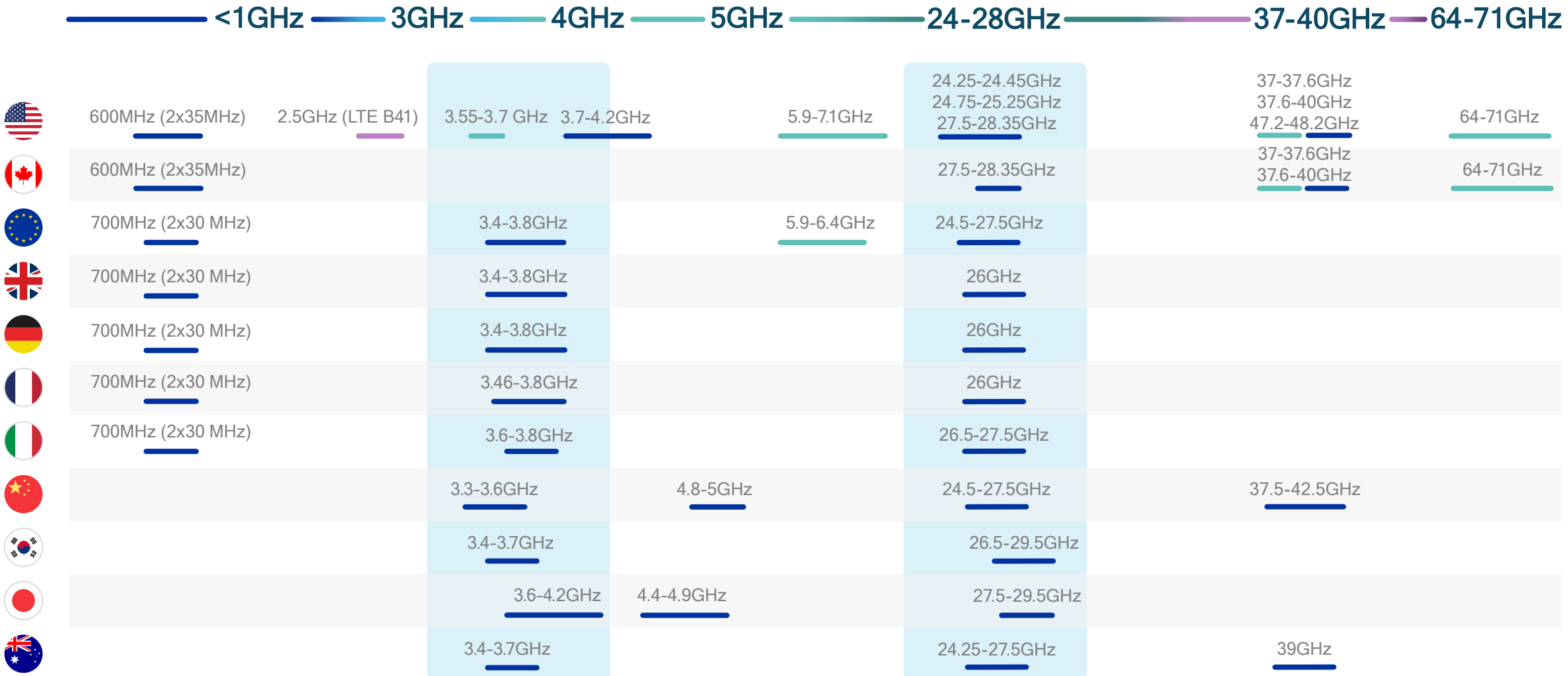
X20 LTE Modem

10 MHz licensed + LAA

Over 17 commercial devices, including smartphones, always connected PC, mobile broadband devices…

43 Operators in 25 countries with Gigabit LTE planned or trialed

Qualcomm Snapdragon is a product of Qualcomm Technologies, Inc.; 1) Assuming using 4x4 MIMO and 256-QAM



Global snapshot of 5G spectrum

Around the world, these bands have been allocated or targeted

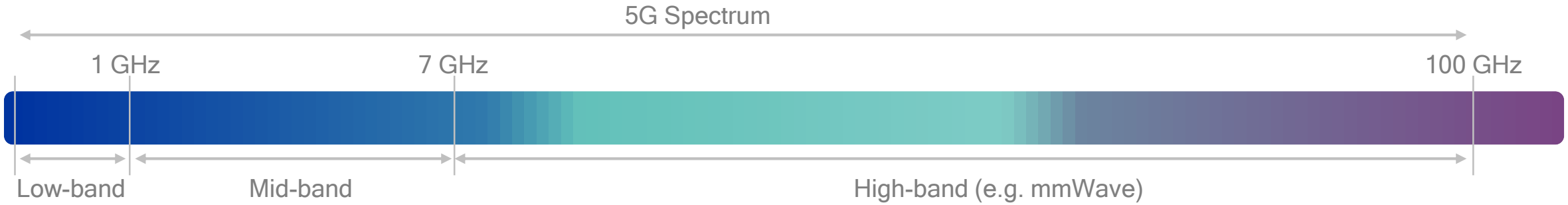
New 5G band

- Licensed
- Unlicensed / shared

Existing band

The FCC is driving key spectrum initiatives to enable 5G

Across low-band, mid-band, and high-band including mmWave



Low-band
Broadcast incentive auction

- Successfully auctioned a portion of the 600 MHz band that generated $19.8B in proceeds after assignment phase
- Includes 70 MHz (2 x 35 MHz) of licensed spectrum and 14 MHz for unlicensed use
- Spectrum availability timing aligns with 5G

Mid-band
Citizens Broadband Radio Service

- Opening up 150 MHz in 3.5 GHz band with 3-tier sharing with incumbents, PAL[1], GAA[2]
- FCC to improve PAL rules in 2017 to make them suitable for 5G
- CBRS Alliance formally launched to drive an LTE-based ecosystem
- FCC Notice of Inquiry on 3.7-4.2 GHz and 5.9-7.1 GHz

High-band
2016 Spectrum Frontiers Ruling[3] and second mmWave ruling in 2017

- In 2016, FCC announced opening up of 11 GHz in multiple mmWave bands, 70% of newly opened spectrum is shared or unlicensed
- Unanimously approved. FCC also asked for comment on other candidate bands identified for IMT-2020
- In Nov. 2017, FCC adopted second order allocating 24.25-24.45, 24.75-25.25 GHz, and 47.2-48.2 GHz

1 Priority Access Licenses to be auctioned; 2 General Authorized Access; 3 FCC ruling FCC 16-89 on 7/14/2016 allocated 3.25 GHz of licensed spectrum and 7.6 GHz of shared/unlicensed spectrum.

Opportunity to improve spectrum utilization by sharing

Key candidate global spectrum bands for 5G spectrum sharing

Existing uncoordinated sharing

Newly opened bands for sharing

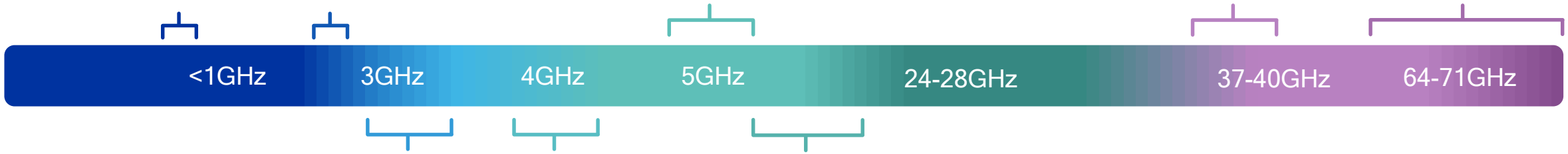
800/900 MHz (Global)
- 10's of MHz BW
- Incumbents: SRD, Wi-Fi, MF

2.4 GHz (Global)
- ~90 MHz BW
- Incumbents: Wi-Fi, BT, MF

5 GHz (Global)
- ~500 MHz BW
- Incumbents: Wi-Fi, LAA, MF

37-37.6 GHz (U.S.)
- 600 MHz BW
- Incumbents: fixed/mobile services, research, satellites

57-71 GHz (Global)
- 14 GHz BW
- Incumbents: Wi-Fi (11ad), wireless backhaul



3.5 GHz CBRS (U.S.)
- 150 MHz BW for 3-tier sharing
- Incumbents: radar, FSS, WISP

3.7-4.2 GHz (U.S.)
- 500 MHz BW
- Incumbents: satellites, fixed services

5.9-6.4/7.1 GHz (EU/U.S.)
- 500 MHz / 1.2 GHz BW
- Incumbents: satellites, fixed/mobile services

Also other higher 5G bands expected

New shared spectrum

Candidate bands for new sharing paradigms

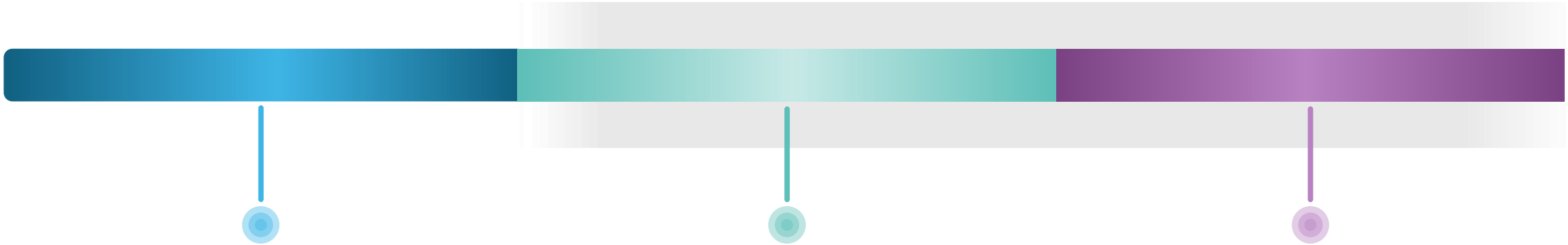
5G Spectrum Sharing

Yongbin Wei, Sr. Director Engineering
Qualcomm Technologies, Inc.

Spectrum sharing provides critical benefits for 5G

Spectrum sharing

- Unlocks more spectrum
- New deployment scenarios
- Increases spectrum utilization



Licensed spectrum

Shared spectrum

Unlicensed spectrum

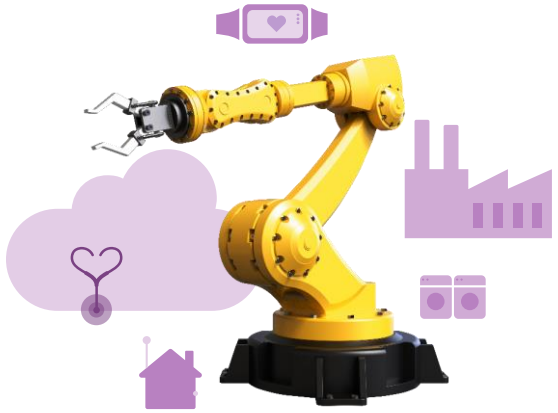
Spectrum sharing valuable for wide range of deployments

Licensed spectrum aggregation

Better user experience with higher speeds

Enhanced local broadband

Neutral host, neighborhood network



Private 5G networks

Industrial IoT, Enterprise

Enhancing existing deployments,

Examples today: Gigabit LTE with LAA[1]

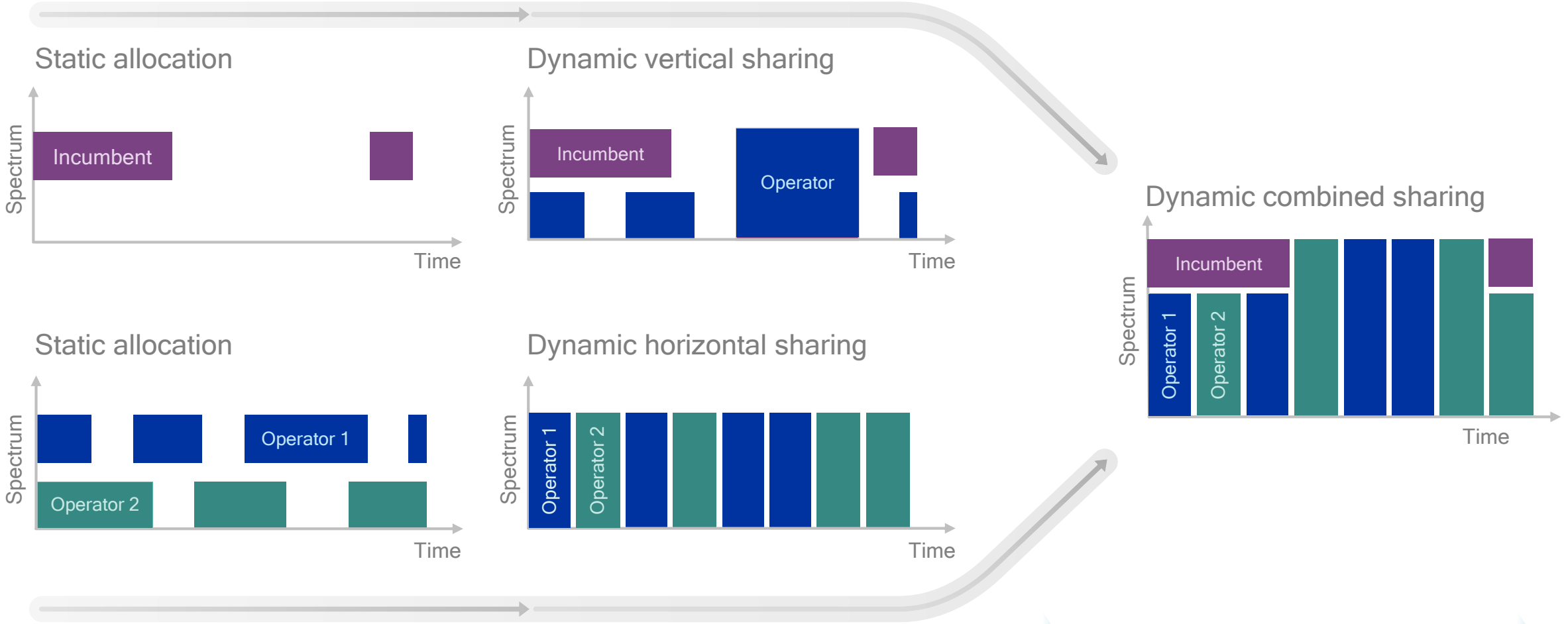
New types of deployments,

Examples today: Private LTE networks

1. Licensed-Assisted Access (LAA);

Spectrum can be shared both horizontally and vertically

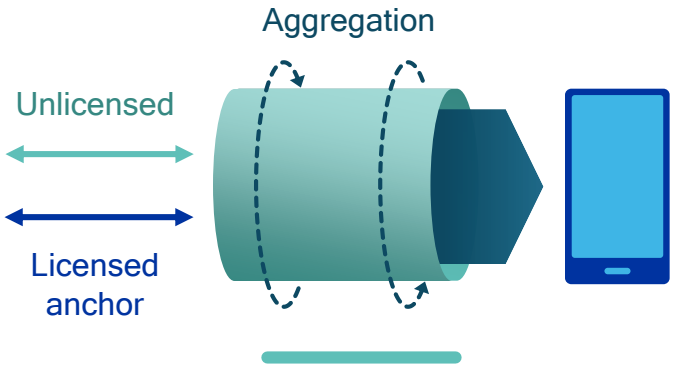
Better spectrum utilization from dynamic spectrum sharing



Spectrum not fully utilized → Increased spectrum utilization

3GPP study on 5G NR operation in unlicensed spectrum

First time 3GPP studies cellular technology operating stand-alone in unlicensed[1]

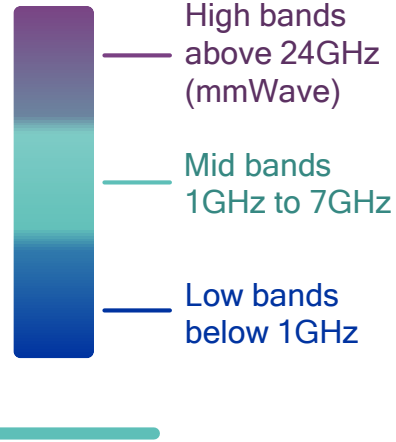


NR-based LAA

NR in unlicensed aggregated with LTE (dual-connectivity) or NR (carrier-aggregation) in licensed spectrum

Stand-alone unlicensed

NR operating standalone in unlicensed spectrum. This will become the MulteFire™ evolution path to 5G



Across spectrum bands

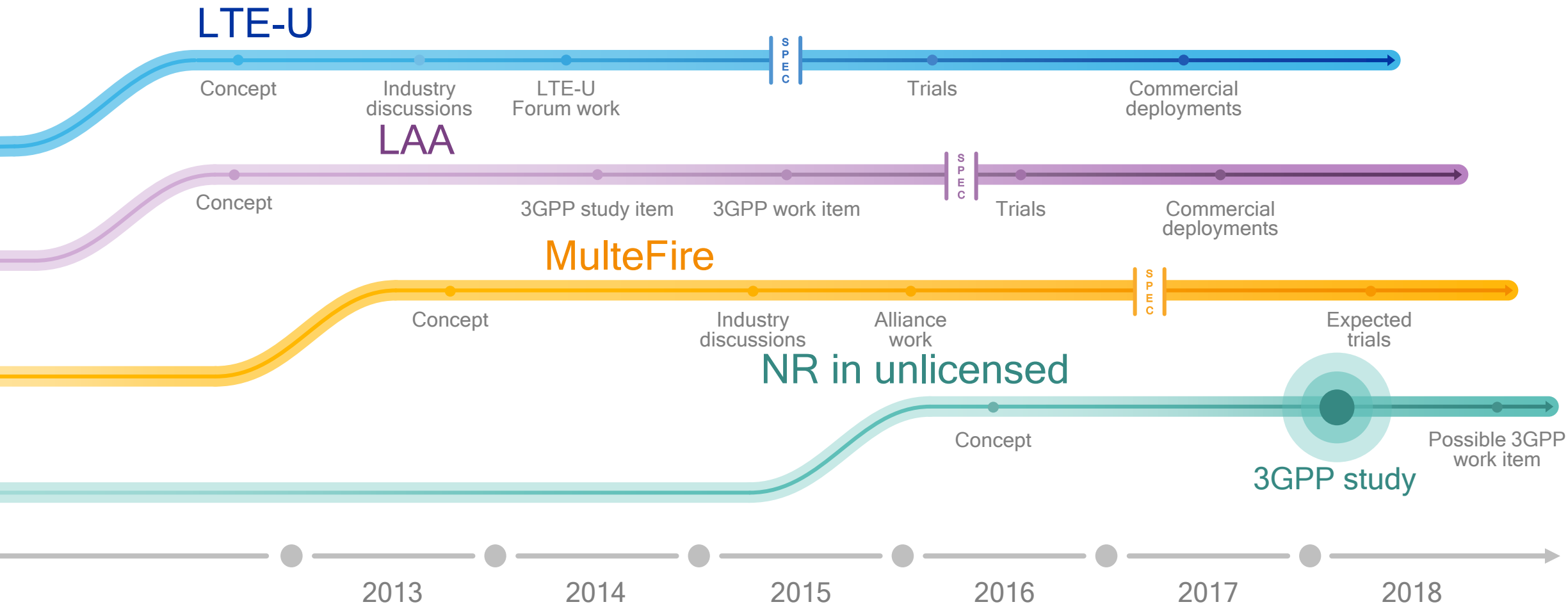
Both below and above 6 GHz, e.g., 5GHz, 37GHz, 60GHz* (*assuming no change to waveform)

Fair co-existence in any unlicensed spectrum: NR/NR, NR/LTE, NR/Wi-Fi

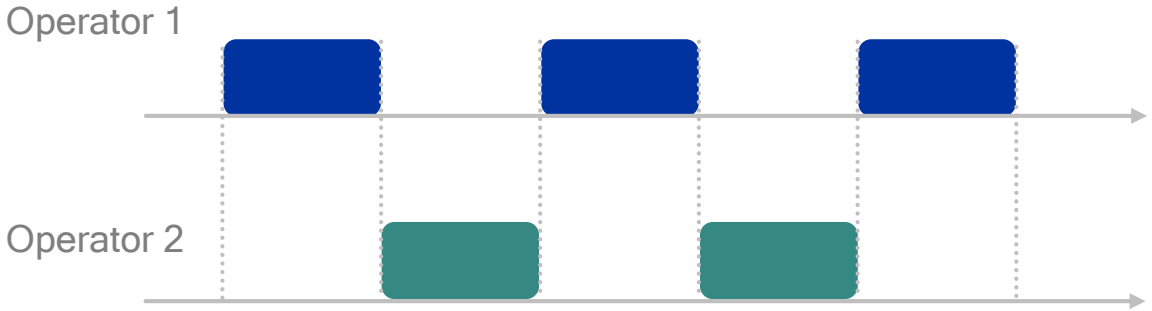
1.Study item in Rel.15 (RP-170828), which could be followed by a work item that is completed in Rel. 16.

Many years in the making to lead up to NR in unlicensed

Work started over 5 years ago when we first envisioned LTE in unlicensed



Opportunity to introduce also a revolutionary path



Evolution path, incremental gains

- Existing unlicensed spectrum
- Backwards compatible and fair co-existence with Wi-Fi, LAA, MulteFire
- Introduce principles from LAA and MulteFire to NR framework (e.g., wideband channels, advanced coding…)
- Uncoordinated sharing
- Incremental enhancements

Revolution path, significant gains

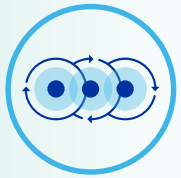
- Green-field shared/unlicensed spectrum
- Opportunity to introduce new sharing paradigms
- Introduce time synchronization between operators (over-the-air or via network functionality)
- Coordinated sharing
- Significant performance gains

What is revolutionary from previous sharing solutions?

New sharing paradigms

New 5G NR framework is friendly for efficient sharing from the beginning

Coordination and time synchronization among sharing entities to improve efficiency and robustness



Elevate support of guaranteed QoS services when sharing spectrum and greatly improve upon simple best-effort practice

Exploit spatial domain: High frequency bands and MIMO with many antennas naturally suitable for sharing and CoMP

Support flexible spectrum sharing, both vertical and horizontal spectrum sharing

Flexible NR framework supports new sharing paradigms

Building on spectrum sharing technologies that we are pioneering today for LTE

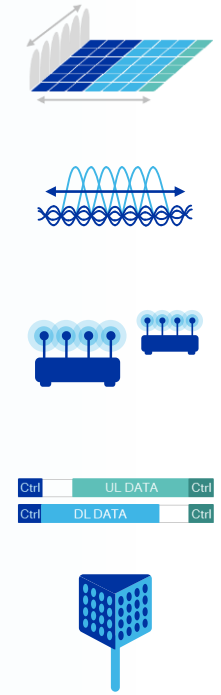
Today's spectrum sharing technologies

- LTE-U / LAA
- LWA
- MulteFire
- CBRS / LSA

Introducing new sharing paradigms

Flexible NR framework

- Flexible slot-based framework
- Scalable OFDM-based air interface
- Network MIMO
- TDD self-contained slot structure
- Mobile mmWave



1. 5G NR Spectrum Sharing (NR-SS)

Benefits of the 5G NR TDD self-contained slot structure

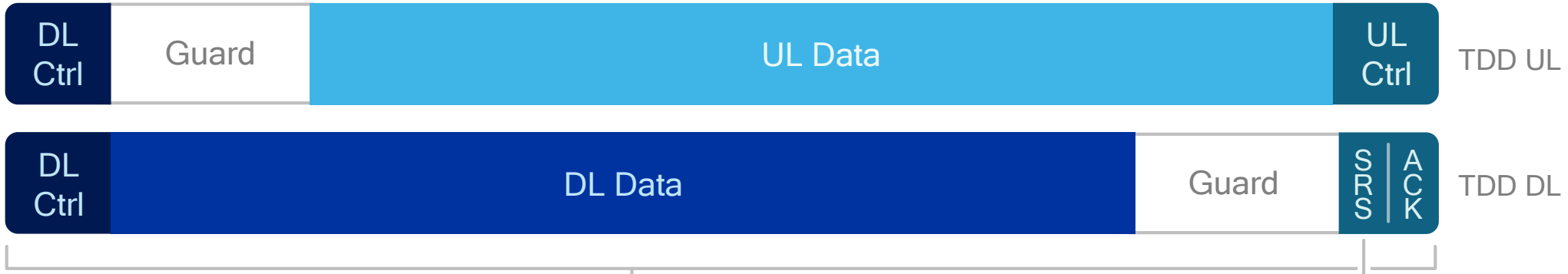
Much faster, more flexible TDD switching and turn around than 4G LTE

Flexibility for additional headers

E.g., channel reservation header
for unlicensed/shared spectrum

More adaptive UL/DL

Faster TDD switching allows for
more flexible capacity allocation



Low-latency

Faster TDD turn-around, with opportunity for
UL/DL scheduling, data and ACK in the same slot

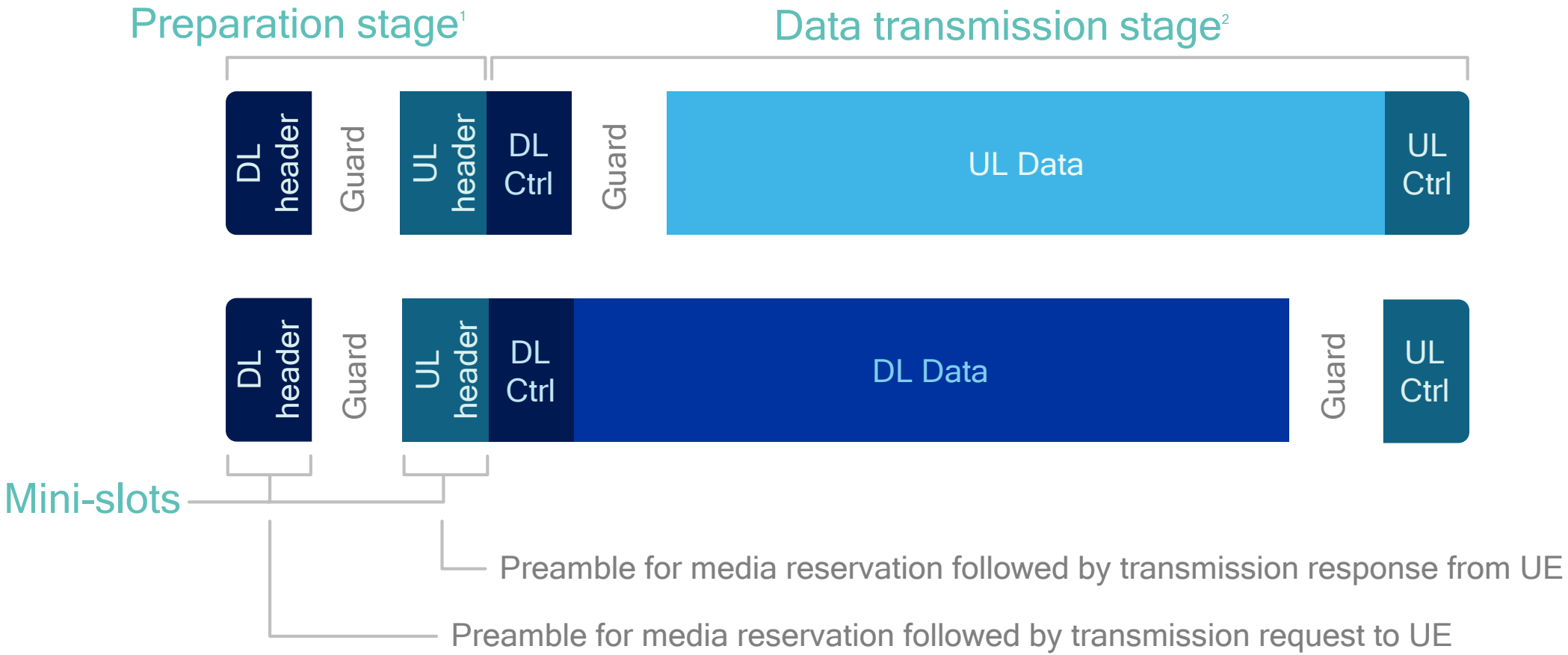
Efficient massive MIMO

Optimized TDD channel reciprocity
with opportunity for SRS[1] every slot

1. Sounding Reference Signal

Self-contained transmission for shared spectrum

Two stages for each transmission (TxOP): preparation and data transmission

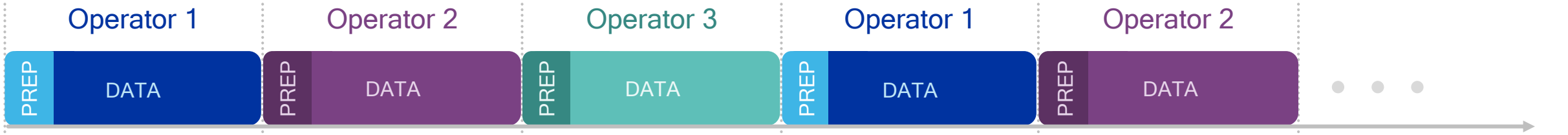


1. If uncoordinated sharing then LBT is used before transmissions in the preparation stage. 2) Each data transmission stage in an TxOP is self contained and could contain multiple self-contained slots

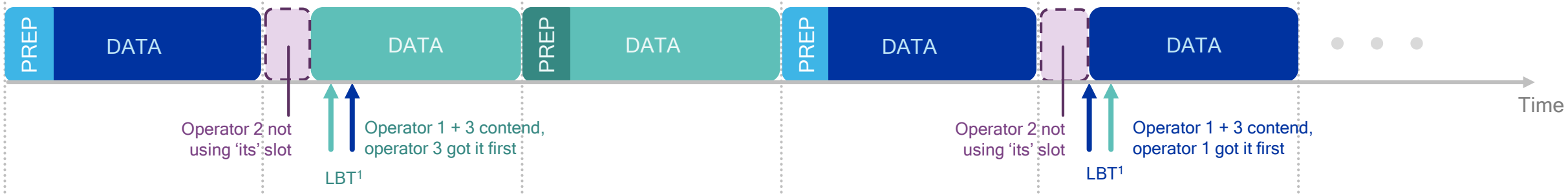
Guaranteed resources with opportunistic sharing

A new sharing paradigm enabled by time-synchronization

Each operator gets guaranteed resources in time in a rotating fashion, example below with 3 operators



If a guaranteed resource is not used, it becomes an opportunistic resource for anyone to use.
In example below, operator 2 is not using its slots, so operator 1 and 3 contend for them



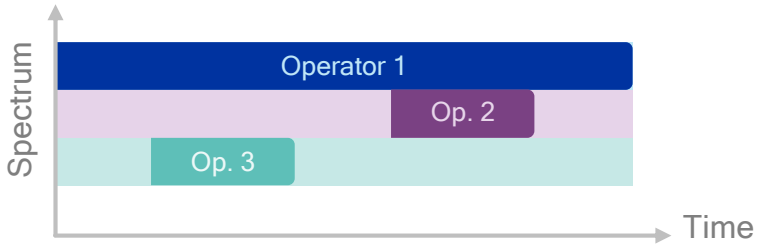
1. Listen before talk (LBT)

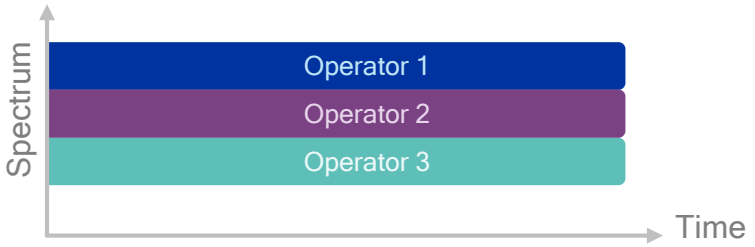
Better spectrum utilization with guaranteed bandwidth

Asymmetric traffic

Full traffic

Licensed spectrum (FDM)

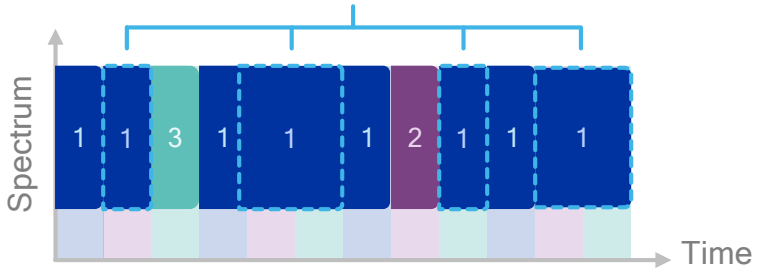




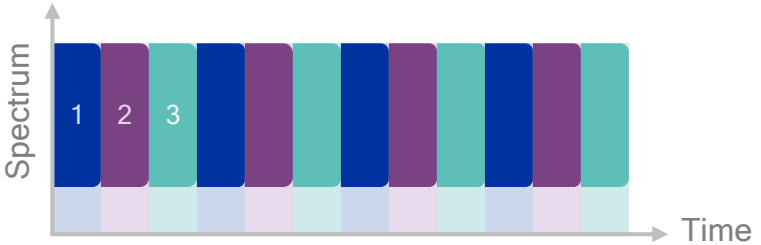
Unused slots available

Operator 1 has additional offered traffic and opportunistically use these slots

NR-SS with guaranteed resources



Guaranteed resources rotate over operators



Guaranteed resources rotate over operators

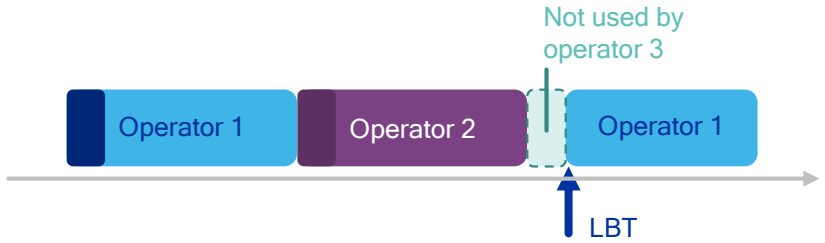
Higher user data speeds from opportunistic sharing of a wider bandwidth (aka trunking gains)

Guaranteed bandwidth similar to licensed spectrum

Supports both horizontal and vertical sharing

Horizontal sharing

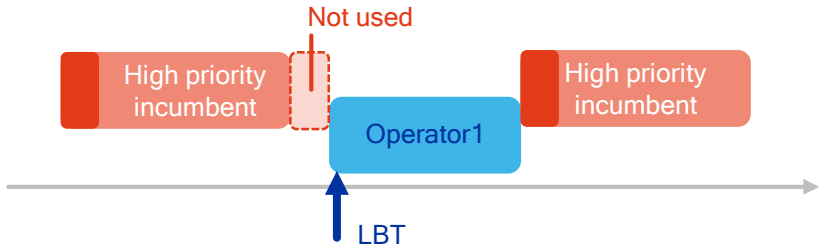
Multiple operators sharing the spectrum with the same priority



Rotating between guaranteed resources. If not used, becomes opportunistic resources

Vertical sharing

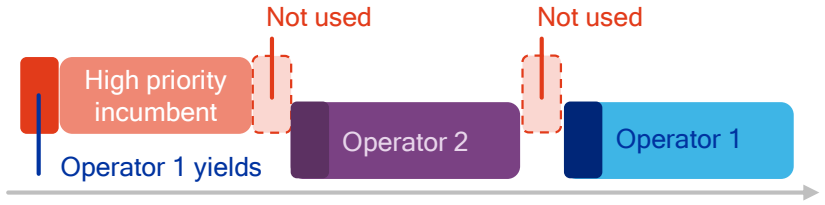
Multiple operators at different priority; higher tier not interfered by lower ones



Priority tier: Always guaranteed resources. Lower tiers: Always opportunistic resources

Combined sharing

Vertical sharing plus horizontal sharing in at least one of the tiers

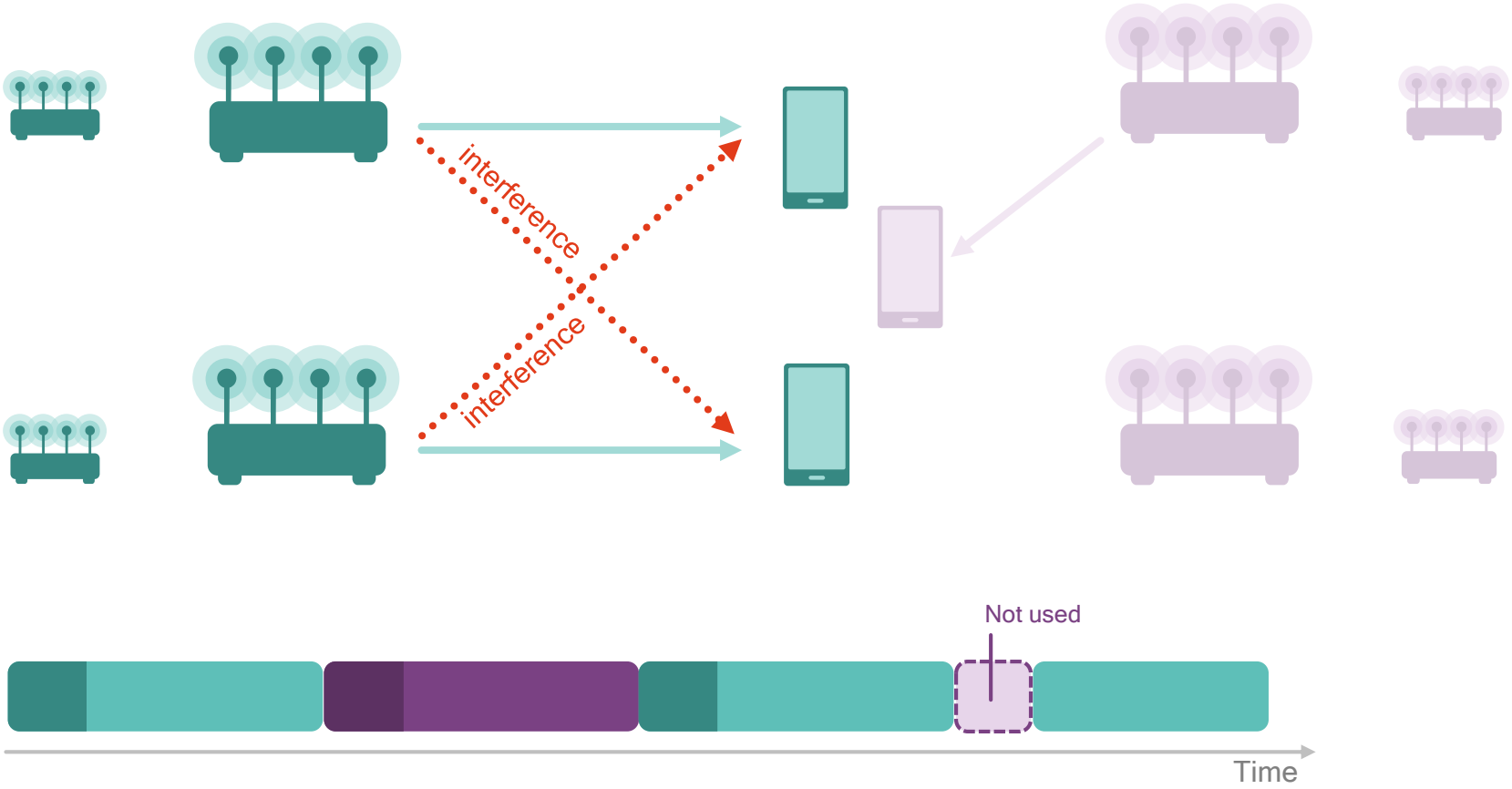


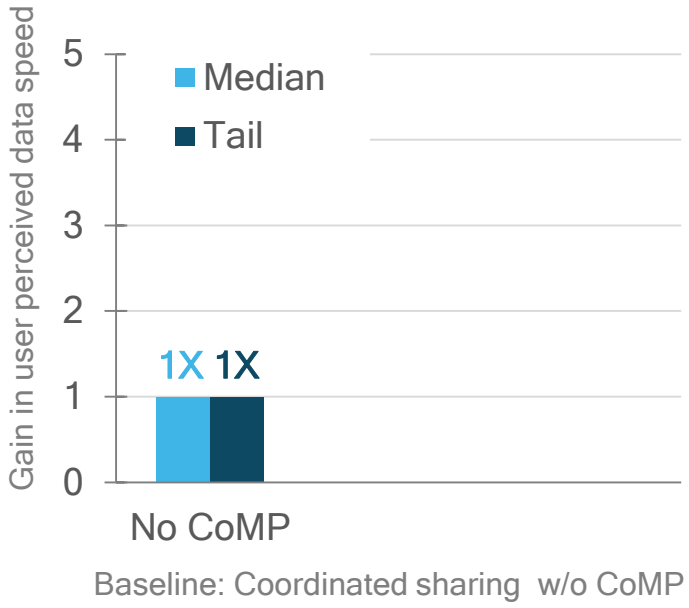
Channel reservation signaling can support multiple operators, e.g., high priority and rotating guaranteed resources.

CoMP provides significant gains

Network MIMO with large number of antennas serve as foundation for CoMP

Two operators sharing spectrum





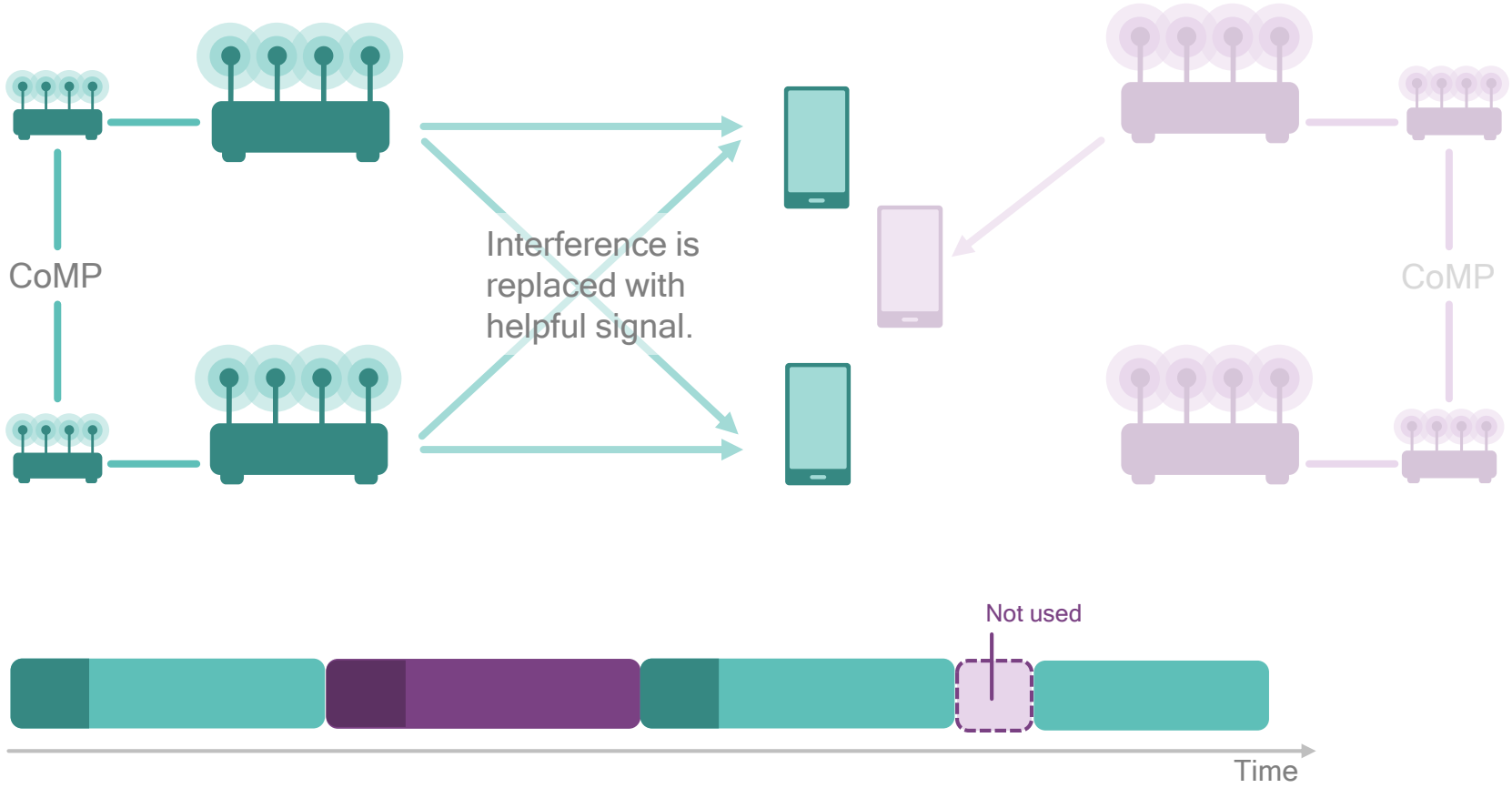
Baseline: Coordinated sharing w/o CoMP

1) 3GPP indoor model, downlink, 2 operators in 40MHz, 4x4 MIMO, 0.5:0.5 mixed DL/UL traffic, bursty traffic, high traffic load, coordinated sharing (time synchronous)

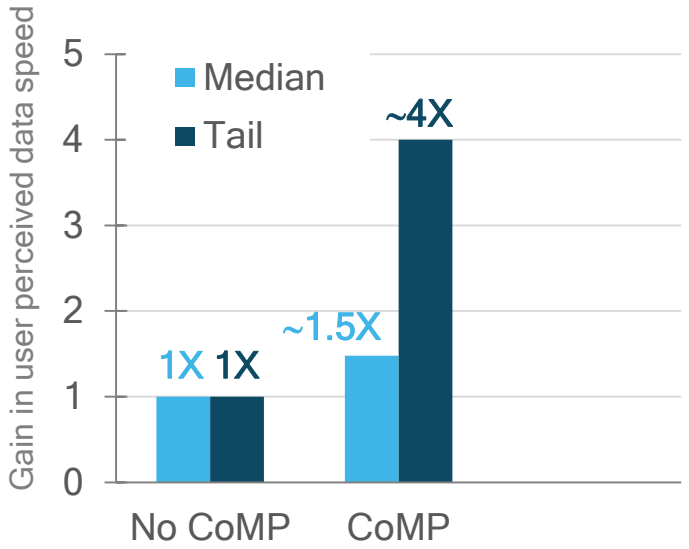
CoMP provides significant gains

Network MIMO with large number of antennas serve as foundation for CoMP

Two operators sharing spectrum with intra-operator CoMP



Significant gains in user data speeds, both for median and tail users



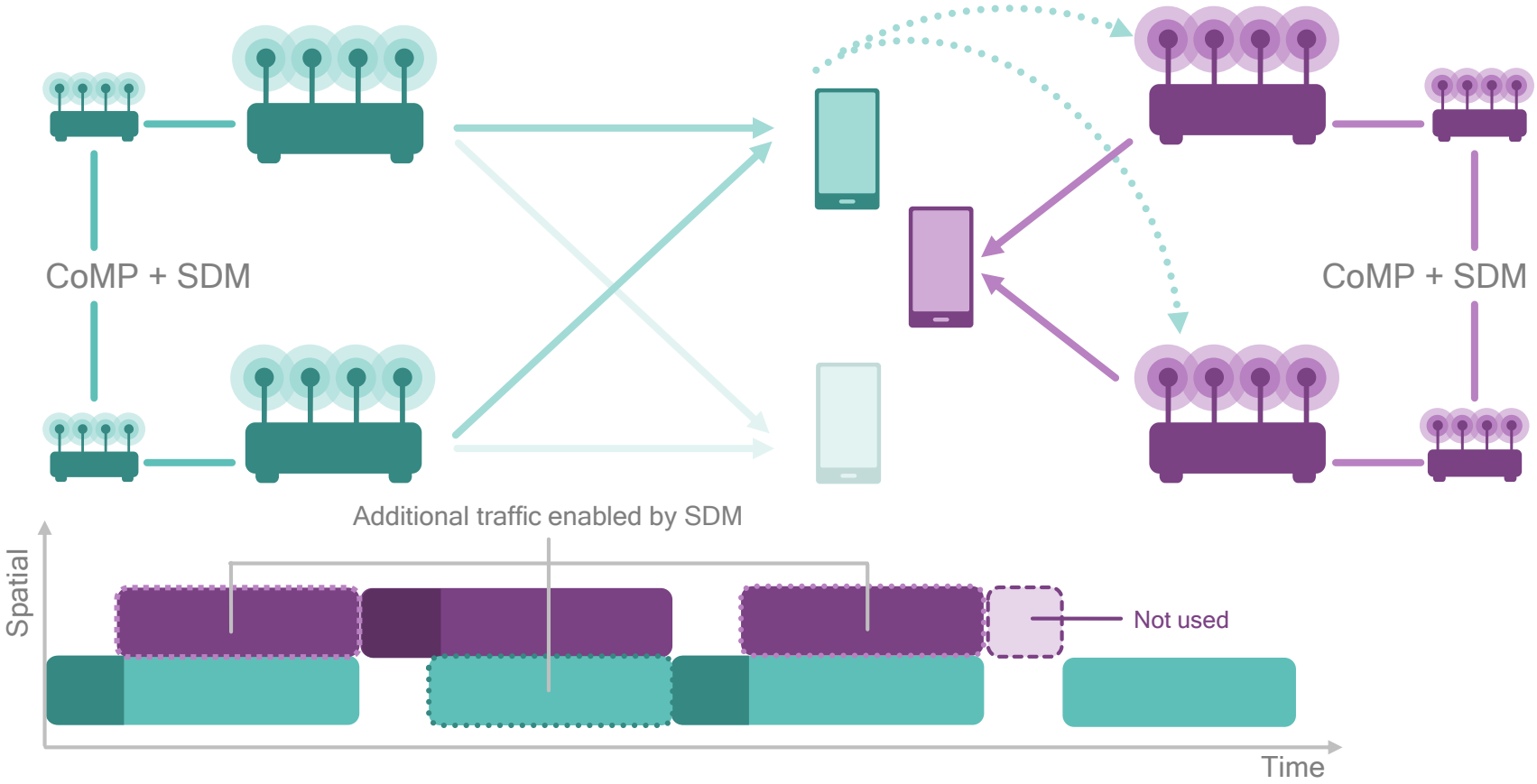
Baseline: Coordinated sharing w/o CoMP

1) 3GPP indoor model, downlink, 2 operators in 40MHz, 4x4 MIMO, 0.5:0.5 mixed DL/UL traffic, bursty traffic, high traffic load, coordinated sharing (time synchronous)

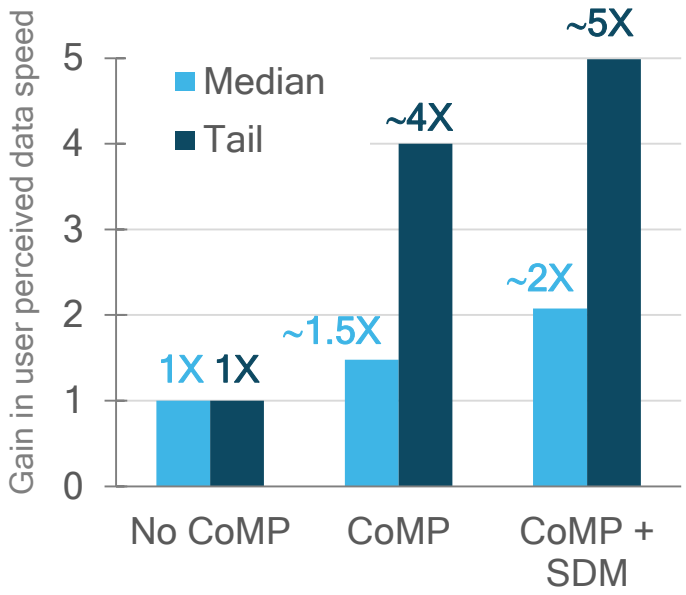
Extending CoMP with spatial division multiplexing (SDM)

With time-synchronization, operators can opportunistically share spectrum spatially

Intra-operator CoMP with inter-operator SDM



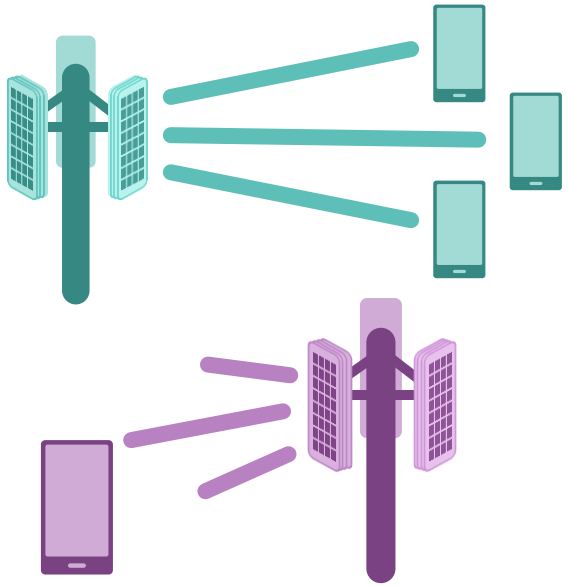
SDM provides additional gains that grows with number of operators



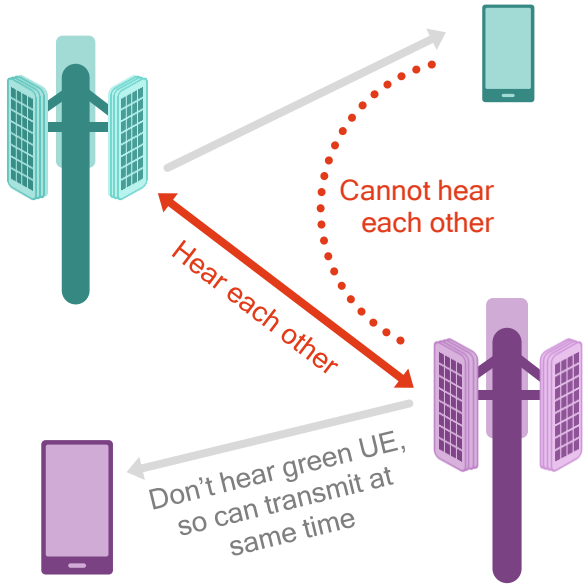
1) 3GPP indoor model, downlink, 2 operators in 40MHz, 4x4 MIMO, 0.5:0.5 mixed DL/UL traffic, bursty traffic, high traffic load, coordinated sharing (time synchronous)

Additional opportunistic spatial sharing

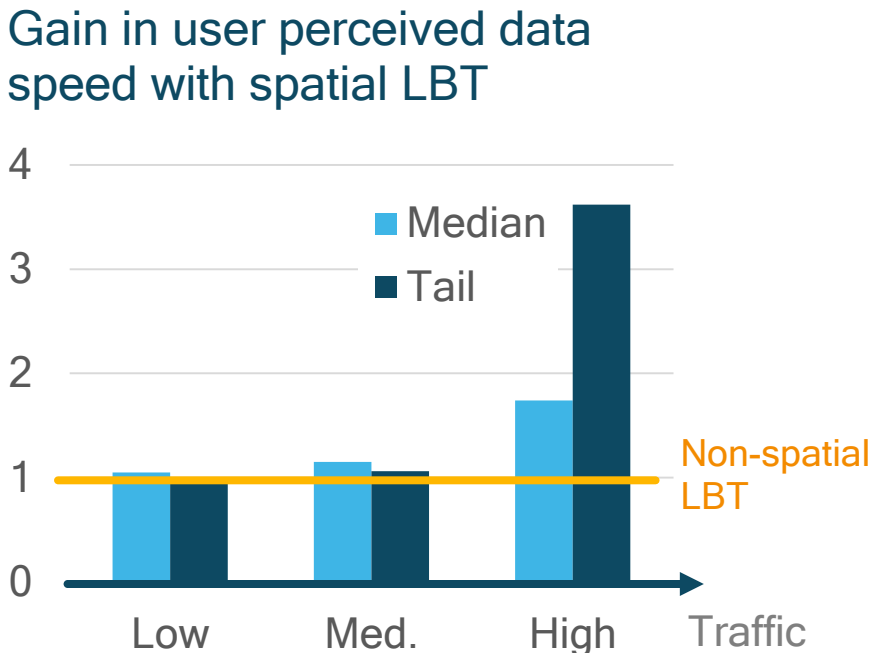
More antennas enable spatial LBT for directional channel sensing and reservation



With more antennas, links becomes more directional and less likely to interfere



With directional links the interference dynamics are different at transmitter and receiver

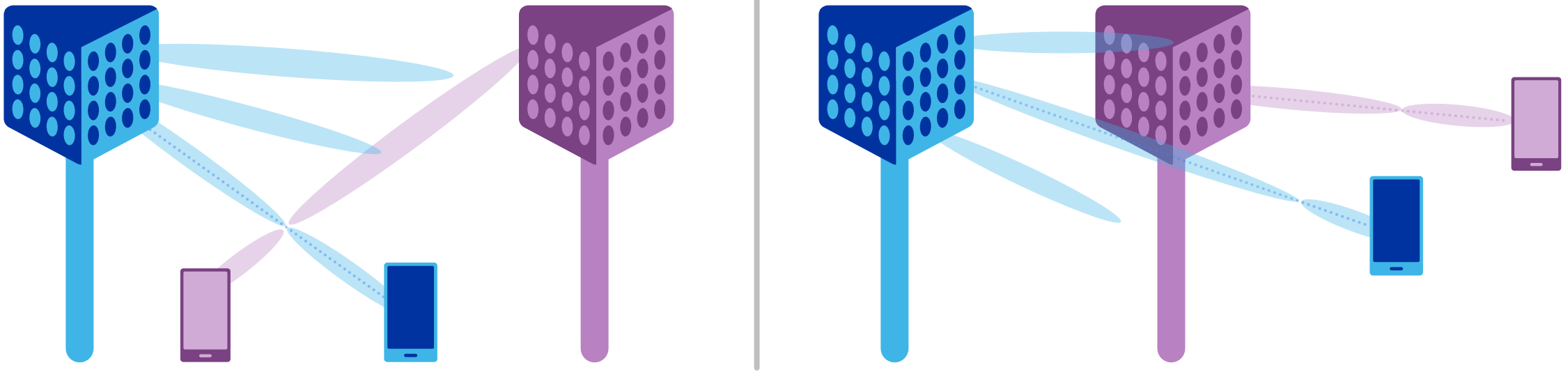


Spatial LBT provides significant performance gains as traffic load increases[1]

1) 3GPP outdoor model, downlink, 4x4 MIMO, 0.5:0.5 mixed DL/UL traffic, bursty traffic, uncoordinated sharing (not time synchronous)

mmWave naturally suitable for sharing

Concept: On-demand LBT



mmWave with narrow beams may not require LBT for majority of connections

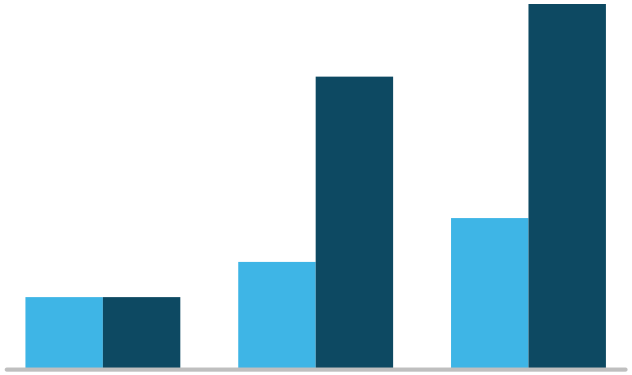
On-demand LBT: Only activate LBT for specific node pairs in mutual-interfering situation

Benefits from 5G NR Spectrum Sharing (NR-SS)

Opportunity to introduce also a revolutionary path

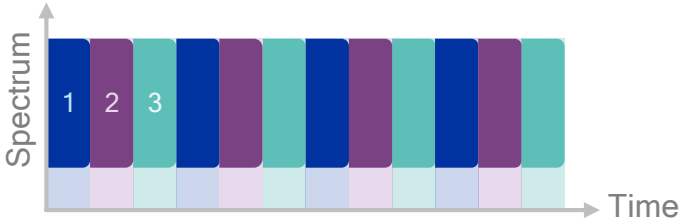
Flexible framework

Supports wide range of sharing scenarios: horizontal, vertical, combined, any spectrum bands including mmWave



Significant gains

Increased user data speeds from access to a wider spectrum combined with increased spectrum efficiency, especially at high traffic loads



QoS

Similar QoS as with exclusive spectrum (static FDM) thanks to prioritized guaranteed resources

Industry kicked-off 5G NR work for NR spectrum sharing

Qualcomm hosted the first workshop on Oct 3-4, 2017 in San Diego

Broad participations

20+ companies with 50+ delegates from around the world representing vendors, mobile operators and cable operators

Wide range of topics

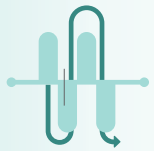
From deployment models, spectrum/regulatory, radio access design, and standalone mode, to network architectures

Sharing of ideas

Multiple companies shared the views and technical concept for NR shared spectrum

5G NR will natively support all different spectrum types

5G NR



Licensed Spectrum
Exclusive use

Shared Spectrum
New shared spectrum paradigms

Unlicensed Spectrum
Shared use

High bands (mmWave) above 24 GHz
Extreme bandwidths

Mid bands between 1-7 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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