Qualcomm Incorporated

1730 Pennsylvania Ave., NW ■ Suite 850 ■ Washington, DC 20006 ■ Tel: 202.263.0022 www.qualcomm.com

November 15, 2019

***Ex Parte* Notice**

Ms. Marlene Dortch
Secretary
Federal Communications Commission
445 12th Street, SW
Washington, DC 20554

Re: Unlicensed Use of the 6 GHz Band - ET Docket No. 18-295
Expanding Flexible Use in Mid-Band Spectrum Between 3.7 and 24 GHz - GN Docket No. 17-183

Dear Ms. Dortch:

On November 13, 2019, Dean Brenner, Aleksandar Damnjanovic, Yongbin Wei, Tevfik Yucek, and the undersigned, representing Qualcomm, met with the Commission's Office of Engineering and Technology ("OET") staff to discuss the enablement of 5G New Radio-Unlicensed ("5G NR-U") technology in the new 6 GHz unlicensed band. OET was represented in the meeting by Bahman Badipour, Michael Ha, Julius Knapp, Nicholas Oros, Aspasia Paroutsas, Barbara Pavon, Jamison Prime, Karen Rackley, Hugh Van Tuyl, and Aole Wilkinsel. Ms. Pavon and Mr. Yucek participated in the meeting via telephone.

Enabling Advanced Spectral Sharing Techniques in the New 6 GHz Unlicensed Band on a Technology Neutral Basis

Qualcomm presented the information in the attached slide deck that includes a regulatory proposal — which the Commission requested in a prior meeting — to enable advanced spectrum sharing techniques that will be important for the deployment of 5G NR-U, which is being standardized in 3GPP Release 16, and the next generation of Wi-Fi, *i.e.*, IEEE 802.11be (EHT) in the new 6 GHz band. Each of these new technologies is being designed to take advantage of time synchronization. Time synchronized access to spectrum is essential to supporting advanced spectrum sharing techniques that use highly flexible, spatial sharing to provide more predictable access and thus improved throughput and latency, as detailed in our presentation. Given that the 6 GHz band is greenfield spectrum for Wi-Fi, 5G NR-U, and future unlicensed technologies, Qualcomm explained that now is the time to include this proposed rule to ensure that current and future spectrum access techniques can thrive in this new band.

The Benefits of Time-Synchronized Spectrum Access

We explained how enabling time synchronization in unlicensed spectrum enables Coordinated Multi-Point ("CoMP") techniques and other advanced techniques in order to support demanding Industrial IoT applications, which require ultra-low latency, and more reliable connectivity than what can currently be supported in unlicensed bands. As we explained in the meeting and as described herein, synchronization in new unlicensed mid-band spectrum, such as the 6 GHz

band, enables alignment of the medium contention windows among all local nodes to improve latency and to enhance Quality of Service ("QoS") for all users. Next generation technologies that use synchronized spectrum access, such as IEEE 802.11be (EHT) and 5G NR-U, will be hamstrung, actually penalized, in favor of legacy technologies that use asynchronous access, absent the FCC rule Qualcomm proposes.

The synchronization of medium contention windows among competing nodes ensures all nodes at a given location sense the medium at the same instant of time, allowing for the realization of CoMP gains and improving performance for all nodes. In addition, the resulting alignment of contention windows can ensure that no node is blocked for an extended period of time, thereby guaranteeing access for all users of both synchronous and asynchronous systems and enabling greater overall utilization of the spectrum. This feature also provides an opportunity for future research that can further improve efficiency and quality of service in unlicensed spectrum. Enabling these techniques in the new 6 GHz band, which will support wider-bandwidth unlicensed applications using 80/160/320-MHz-wide channels, is critically important to the continued future success of the band.

Indeed, given that there is no other large swath of unlicensed mid-band spectrum on the drawing board, or even on the horizon, Qualcomm seeks to ensure the new 6 GHz unlicensed band can support the necessary growth and evolution of 5G NR and Wi-Fi unlicensed services, and unlicensed services based on other technologies, which this band will need to support well into the future. The 6 GHz band offers a prime opportunity to realize this goal.

A Technology-Neutral Proposal to Support 5G NR-U and 802.11be, While Fully Enabling Today's LAA and 802.11ax Systems

The goal of this regulatory proposal is to provide a simple, time-based spectrum access rule that is technology neutral and fair to all users of the spectrum and does not favor or disfavor synchronous access or asynchronous access or any unlicensed technology. Today's IEEE 802.11ax Wi-Fi, 3GPP-based Licensed Assisted Access, and 5G NR-U Release 16 technologies conform to the proposed rule and, more importantly, future IEEE 802.11be (EHT) Wi-Fi and 5G NR-U releases can further exploit this rule and continue improving coexistence and overall performance of future systems.

Without an FCC rule, asynchronous access systems can starve synchronous access systems because asynchronous systems could access the medium at any point in time and prevent equal access by synchronized access systems. The proposed rule relies on the conditional relaxation of the maximum Channel Occupancy Time ("COT") to achieve synchronization and ensures fair medium access for all technologies, those operating asynchronously and those operating synchronously, and enables advanced sharing techniques described above that use time synchronization.

The proposed rule text, presented on slides 18 and 19 of the attached deck, specifies the maximum COT for asynchronous and synchronous systems and utilizes synchronization reference boundaries based on Coordinated Universal Time ("UTC"). The maximum COT for asynchronous access systems is fixed while the maximum COT for synchronous access systems is variable; the COT can be extended beyond nominal value only if it is utilized to synchronize medium access. The proposed rule is summarized as shown in the table below, which is from Slide 20 of the deck.

Mode	**Channel Occupancy Time** ("COT")
Sync Access	COT ≤ 6 milliseconds COT < 12 milliseconds if: COT ends at the sync boundary, and The channel was occupied at the beginning of the sync interval where the COT started
Async Access	COT ≤ 10 milliseconds

If the COT utilized by asynchronous systems stops 6 milliseconds after the most recent medium busy-to-idle transition, asynchronous nodes (which typically use a COT of up to 6 milliseconds) will have exactly equal medium use with synchronous nodes, as illustrated on Slide 21. If asynchronous nodes do not adjust their COT to end 6 milliseconds after the most recent busy-to-idle transition, synchronous nodes may extend their COT up to 12 milliseconds as shown in Slide 22. While the extended COT can be up to 12 milliseconds, the average length would be approximately 9 milliseconds, which is comparable to the maximum COT of 10 milliseconds for asynchronous access. Because the typical maximum COT for asynchronous nodes is 6 milliseconds but may extend up to 10 milliseconds in certain circumstances,[1] this rule would not disadvantage asynchronous access and effectively enable "sync-like" access for systems comprised of both synchronous and asynchronous nodes.

The FCC should adopt this proposed rule designed to control fairness of access between asynchronous and synchronized nodes and support advanced sharing techniques that require synchronized access. Without such a rule, systems that access spectrum asynchronously could prevent equal access by synchronized systems that can provide greatly improved performance as detailed in Slides 25 to 29 of the attached deck.

The FCC Record Supports Promulgation of the Proposed Rule

There is a deep FCC record on the appropriate means of improving spectrum access in the 6 GHz band — the issue Qualcomm addressed in our meeting and in our proposal. In our initial Comments on the 6 GHz NPRM, Qualcomm asked the FCC to implement a rule to enable advanced spectrum access techniques in a portion of the 6 GHz band, specifically the proposed U-NII-7 band at 6.525 - 6.875 GHz, by adopting a technology-neutral rule optimized for synchronization-capable unlicensed systems, such as 5G NR-U and IEEE 802.11be (EHT).[2] Qualcomm described this approach in detail in its Comments and thereafter met with the Commission staff in March 2019 to further explain the benefits offered by synchronized spectrum access.[3]

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[1] *See* ETSI EN 301 893 V2.1.1 (2017-05) 5 GHz RLAN; Harmonised Standard covering the essential requirements of article 3.2 of Directive 2014/53/EU, at 30 (Tables 7 and 8).

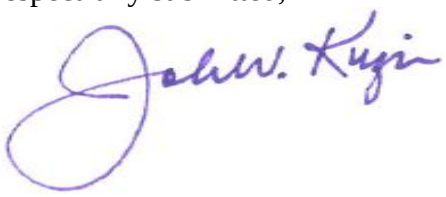
[2] *See* Qualcomm Comments (filed Feb. 15, 2019) at 18-23.

[3] *See* Qualcomm *Ex Parte* Letter and Presentation (filed Mar. 8, 2019).

In Reply Comments, several parties asserted this proposal — which at the time did not include specific regulatory text — would foreclose Wi-Fi deployments in the U-NII-7 band.[4] However, Qualcomm's goal, as stated in its prior filings and made explicit in the regulatory text provided herein, is not to foreclose or disadvantage any technology, including Wi-Fi or 5G NR-U, which are being designed to take advantage of spectrum access techniques that use synchronized access. Indeed, the proposed rule fairly enables both asynchronous and synchronous access systems and does not disadvantage current or future spectrum access techniques. Therefore, Qualcomm requests that the Commission consider applying this rule not just within the U-NII-7 sub-band, but across the entire 6 GHz band.

The FCC should adopt the technology neutral rule we propose because unless the Commission does so, consumers will be deprived of advanced spectrum sharing techniques which will enable better, faster, and more robust mobile broadband connectivity in the new 6 GHz unlicensed band.

Respectfully submitted,



John W. Kuzin
Vice President and Regulatory Counsel

Att.

cc (w/ Att.): Bahman Badipour
Michael Ha
Julius Knapp
Nicholas Oros
Aspasia Paroutsas
Barbara Pavon
Jamison Prime
Karen Rackley
Hugh Van Tuyl
Aole Wilkinsel

[4] *See* Hewlett Packard Enterprise Reply Comments (filed Mar. 18, 2019) at 16-21; Broadcom Reply Comments (filed Mar. 18, 2019) at 25-26.

November 13, 2019

5G NR-Unlicensed in the new 6 GHz unlicensed band

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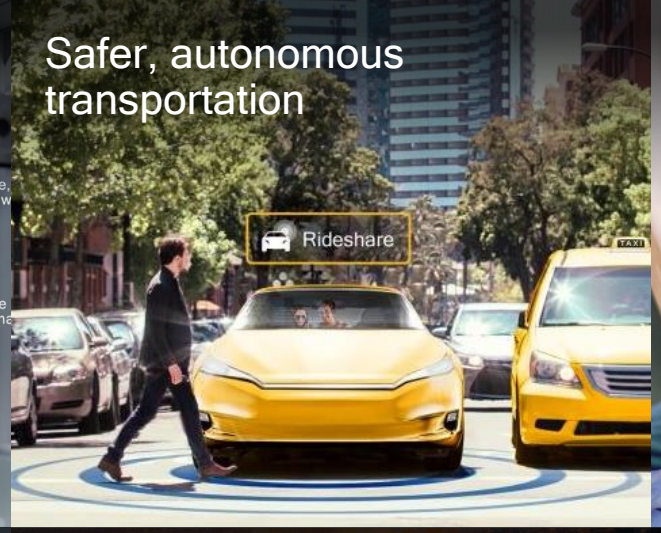
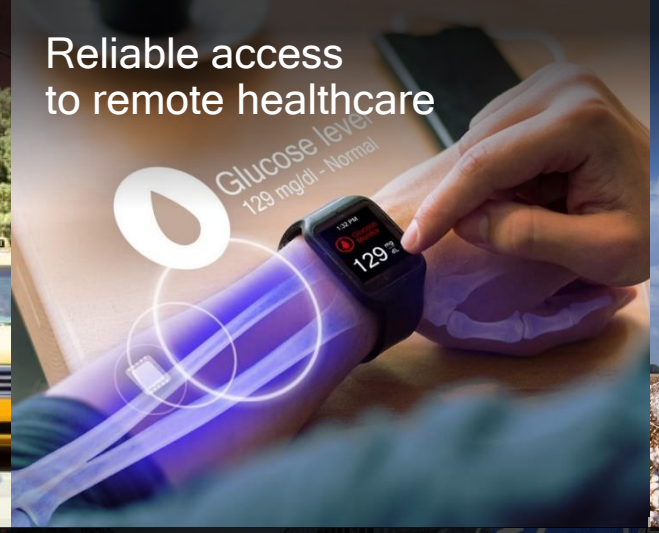
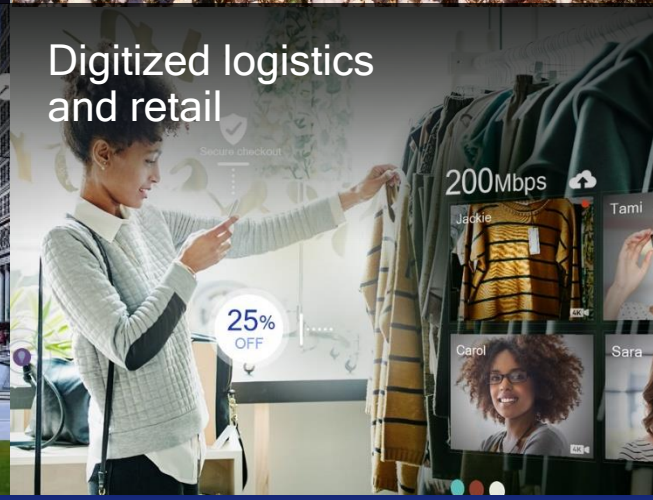






5G

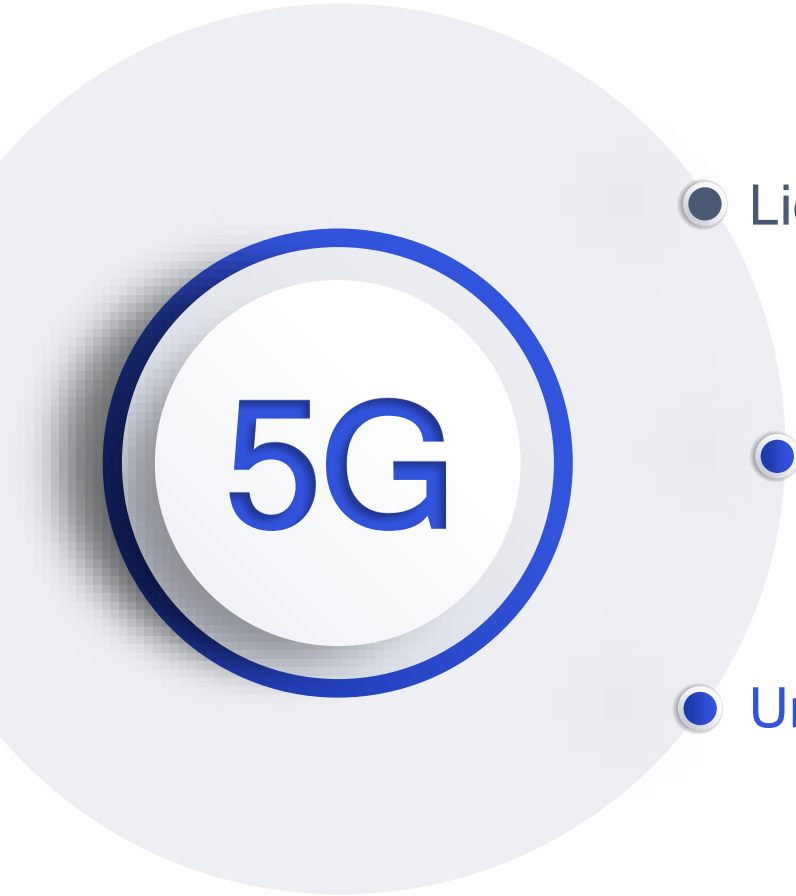
5G will expand the mobile ecosystem to new industries

Powering the digital economy

>$13.2 Trillion

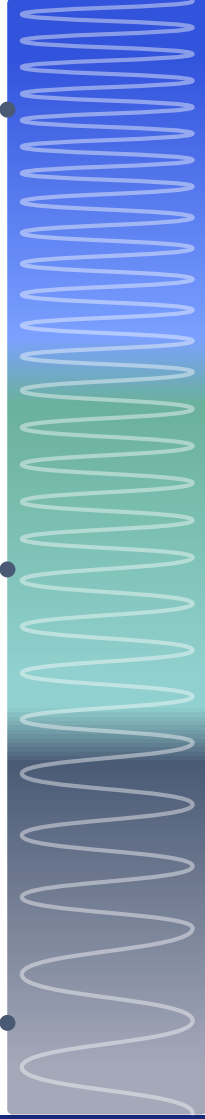
in goods and services by 2035*

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



- Licensed spectrum
- Shared spectrum
- Unlicensed spectrum

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



Shared and unlicensed spectrum creates new opportunities and expands the ecosystem

5G NR-U valuable for wide range of deployments

5G NR Rel-16 in unlicensed spectrum, fair coexistence with other technologies

Licensed assisted NR-U

Aggregate licensed and unlicensed spectrum

Boosting existing deployments

Better user experience with higher speeds

Stand-alone NR-U

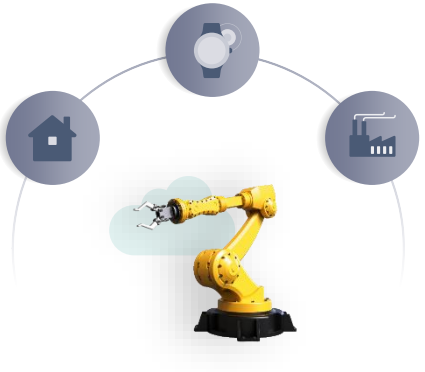
5G NR deployment with unlicensed spectrum only

Open mobile broadband

Neutral host, neighborhood network

Private networks[1]

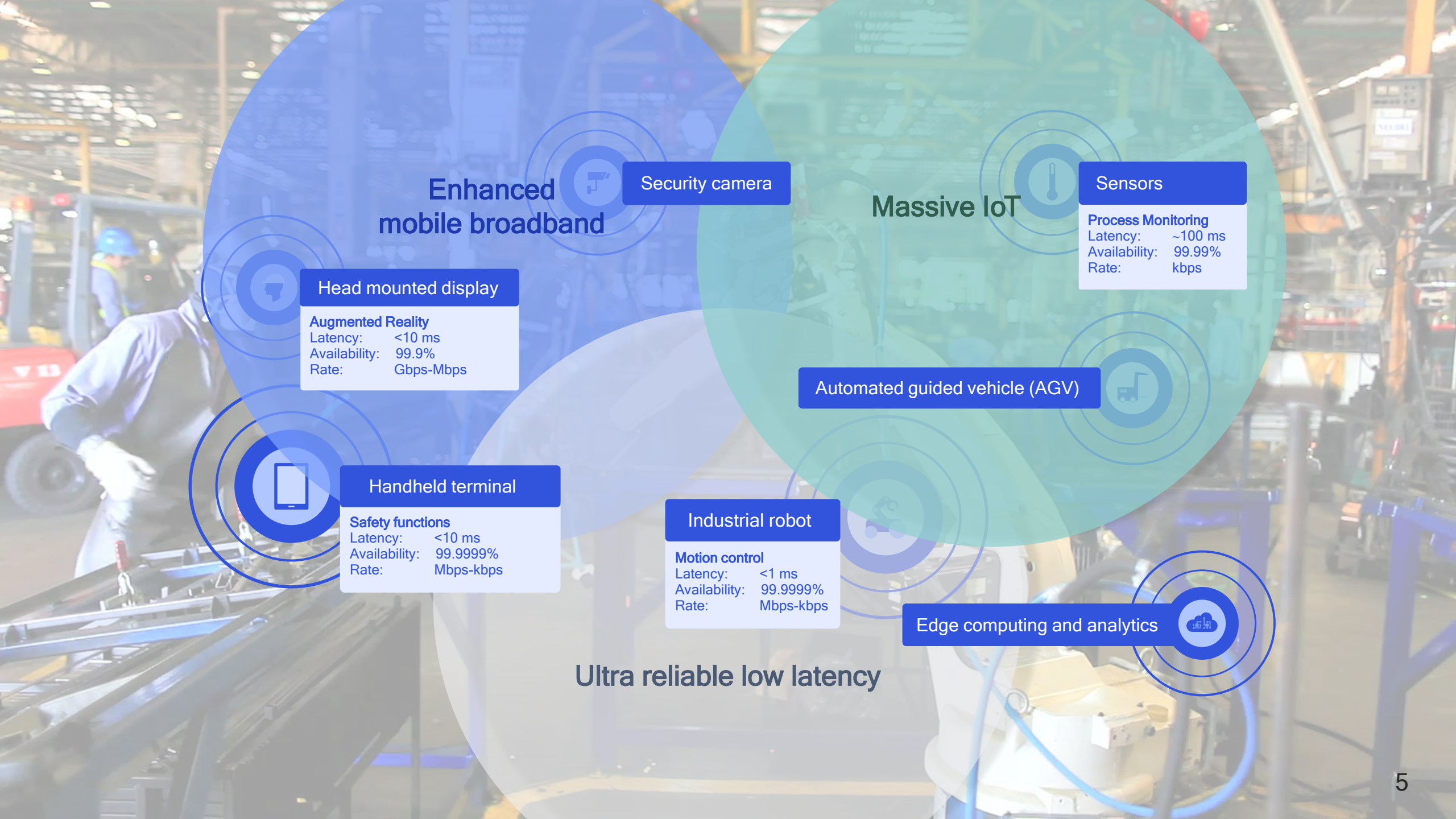
Industrial IoT, enterprise broadband



Aggregating licensed and unlicensed spectrum

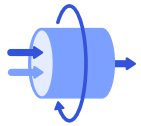
Expanding 5G market with new types of deployments

1) A private network can also support generic traffic as a neutral host; for example, at a hospital it can provide dedicated services for employees/equipment and operate as a neutral host for visitors.


Enhanced mobile broadband
Security camera
Head mounted display
Augmented Reality
Latency: <10 ms
Availability: 99.9%
Rate: Gbps-Mbps
Massive IoT
Sensors
Process Monitoring
Latency: ~100 ms
Availability: 99.99%
Rate: kbps
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

How to maximize spectral efficiency and reduce latency?

Present (5 GHz)



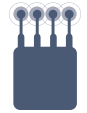
- Asynchronous LBT
- Not optimized for low latency, CoMP and other advanced sharing techniques

5G

Time synchronization
provides great potential to share spectrum more efficiently

Future (6 GHz)

More predictable resources



5G CoMP

Flexible sharing

Spatial sharing

Time synchronization benefits

Benefits of time synchronization

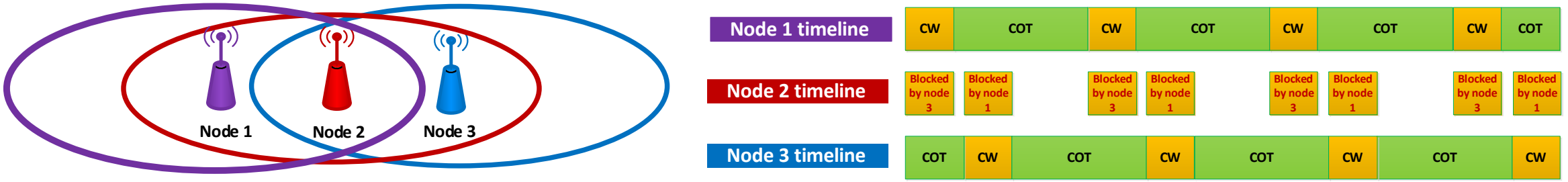
- Time synchronization has become increasingly important for wireless communication for licensed, unlicensed and shared spectrum
  - Adjacent nodes of the same network in TDD spectrum
  - Adjacent CoMP nodes in the same network in FDD/TDD spectrum
  - Nodes of different networks that share the same spectrum, such as the CBRS band

- Time synchronization is especially beneficial for unlicensed spectrum
  - Improves service predictability and user experience
  - Enables advanced technologies such as CoMP to improve spectrum efficiency and reliability
  - Facilitates flexible sharing
  - Enables advanced sharing such as spatial domain multiplexing to improve spectrum utilization

Improved predictability

Illustration of issues encountered with asynchronous access

- Node in the middle that is utilizing channel sensing procedure, referred to as Listen Before Talk (LBT), may be blocked from accessing the system for a lengthy period of time



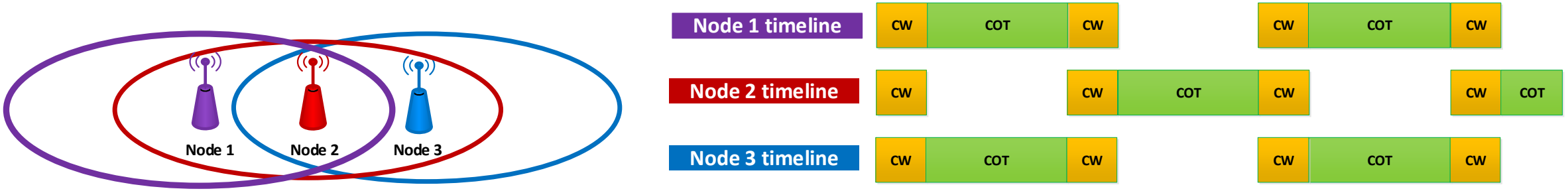
- Node 1 and Node 3 may block Node 2 for a long period of time – poor user experience

Improved predictability – continued

Illustration of the benefits of synchronous access

We can do better in new unlicensed bands, particularly the 6 GHz band.

- Synchronization allows overlapping of the contention windows among all nodes and minimizes access latency

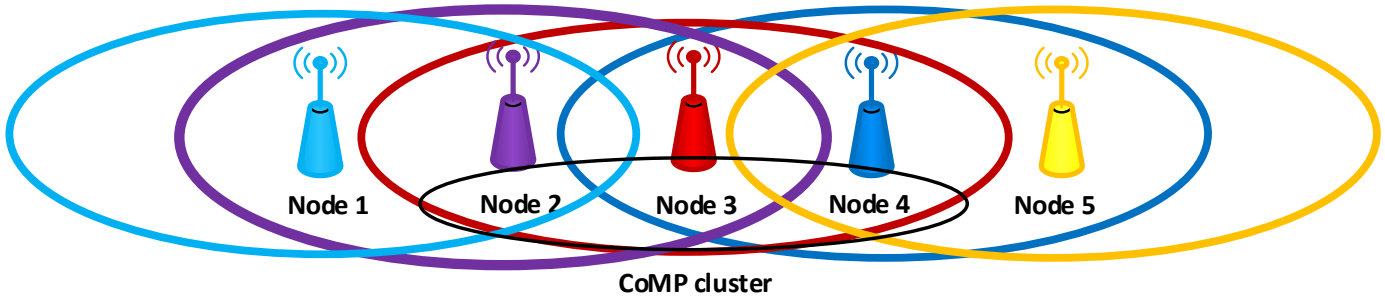


- No node is blocked from accessing the medium for a long period of time – improved user experience

CoMP

Illustration of issues encountered using CoMP with asynchronous nodes

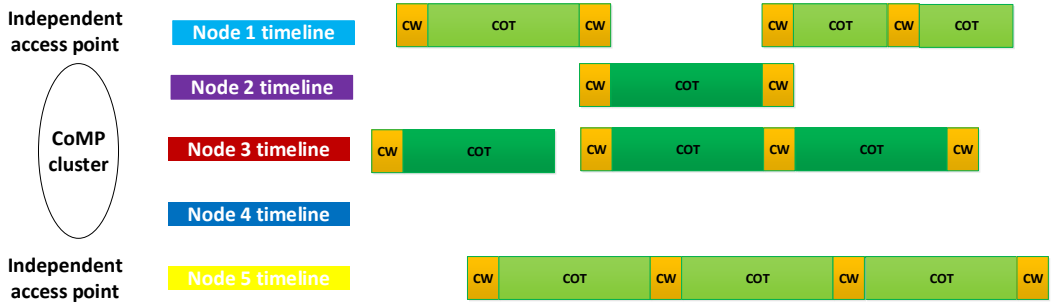
- CoMP (Coordinated Multi-Point) is latest development of network MIMO technology to increase spectrum efficiency and improve wireless link reliability
- In the CoMP scenario, adjacent nodes, commonly referred to as transmission points (TRPs) belonging to the same CoMP cluster, may block each other's channel access
- Moreover, CoMP -- based on independent asynchronous TRP contention -- is constrained by asynchronous medium access by neighboring nodes
- As a consequence, CoMP gains are difficult to realize with asynchronous nodes



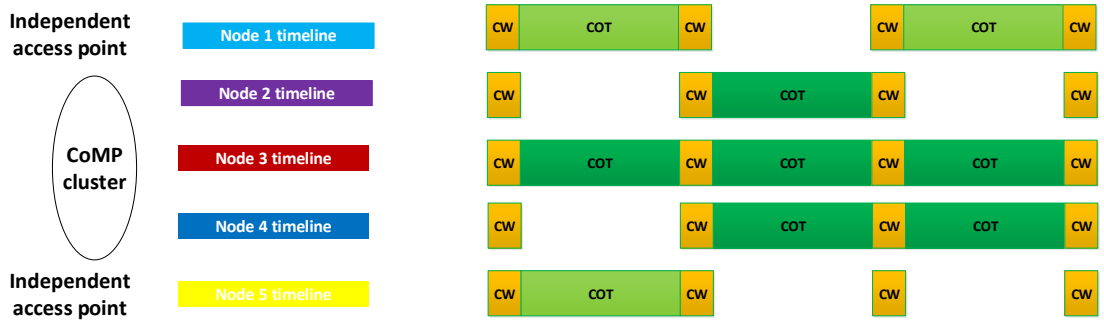
CoMP – continued

Illustration of the benefits of synchronous access

- Synchronization allows overlapping of the contention windows among all nodes and allows realization of CoMP gains
  - When medium access is successful, much better performance for every node is attained



Asynchronous contention – difficult to realize CoMP mode

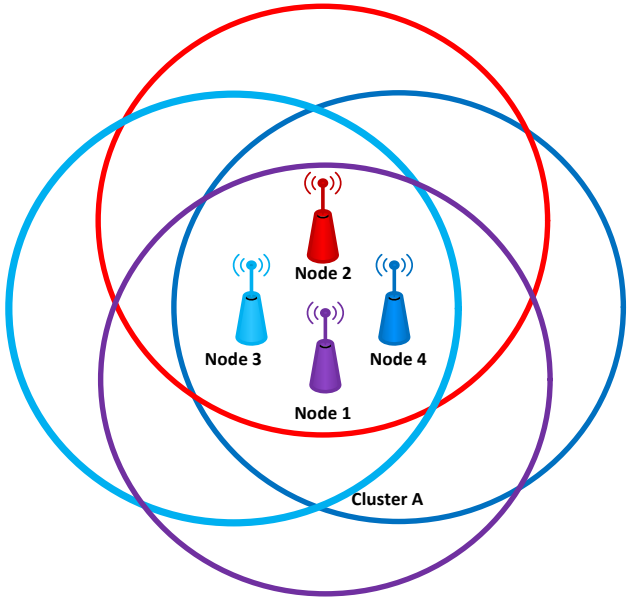


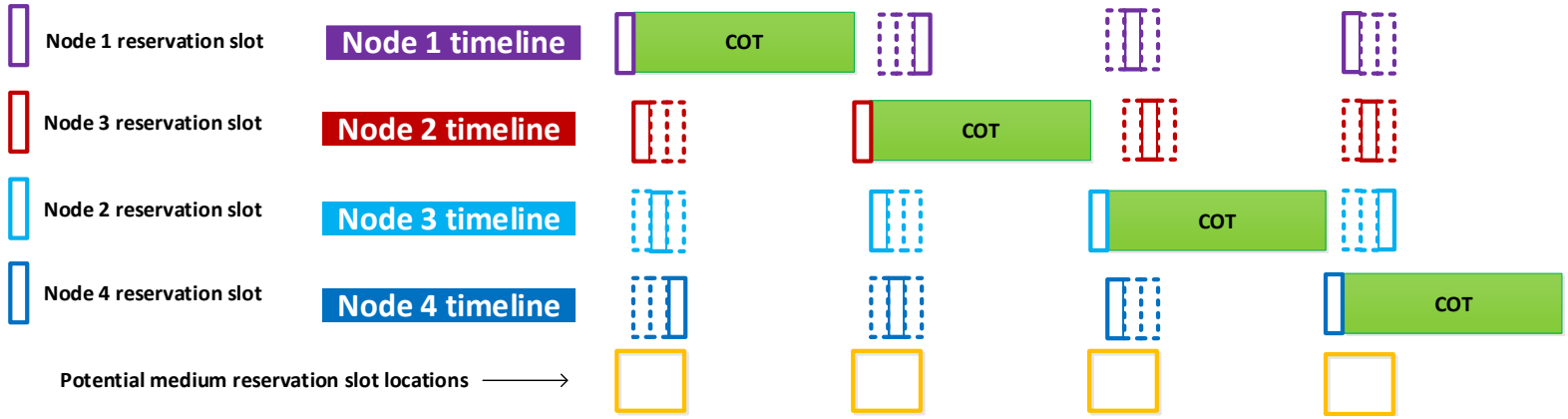
Synchronous contention – much greater probability of utilizing CoMP mode

Flexible sharing

Illustration of the benefits of synchronous access for flexible sharing

- Synchronization and overlapping of the contention windows can also enable flexible sharing schemes where depending on the reservation slot structure, medium access procedure can potentially completely avoid collisions among nodes



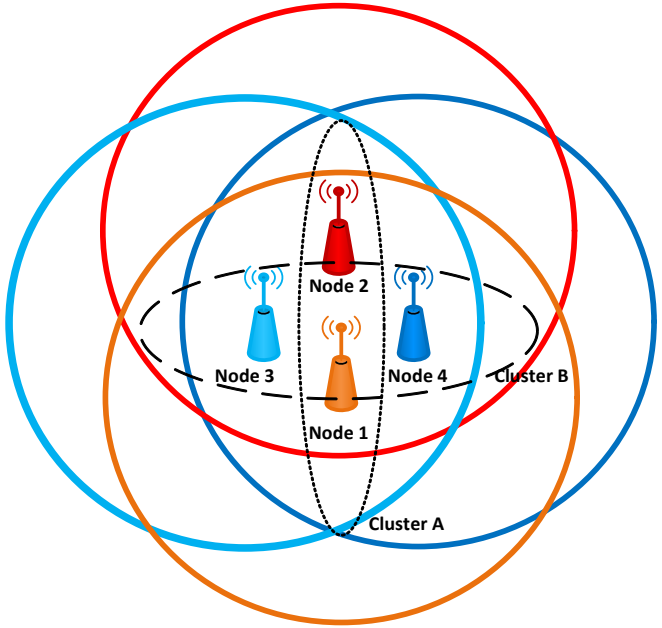


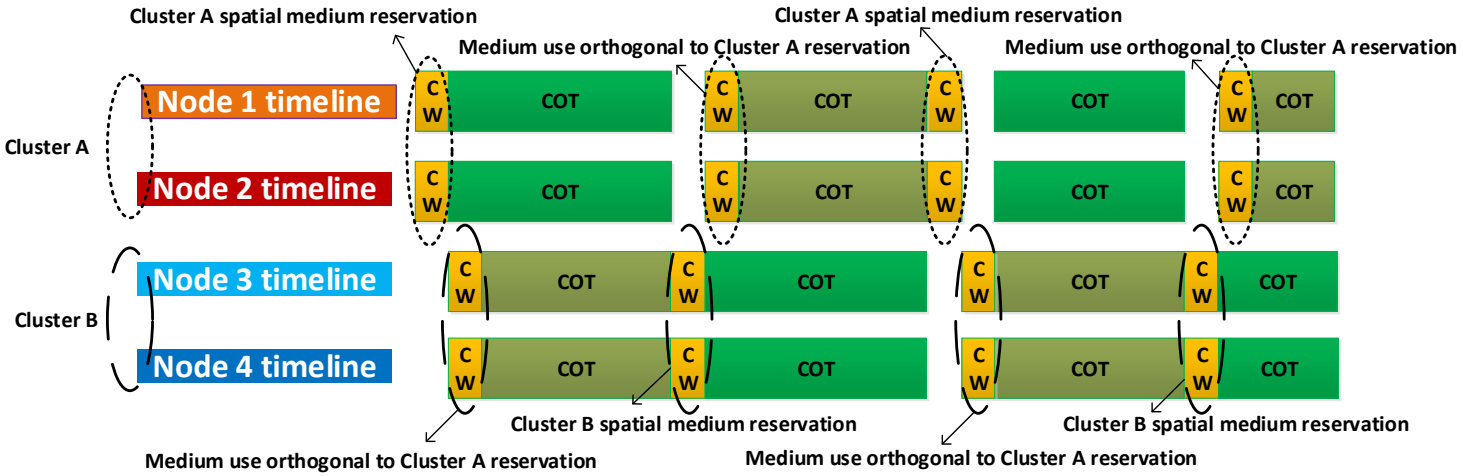
- Reservation slot structure can ensure that no node is blocked from accessing the medium for an extended period of time, and channel use is “guaranteed”

Spatial sharing

Illustration of the benefits of synchronous access for spatial sharing

- Synchronization and overlapping of the contention windows enables development of more advanced spatial division multiplexing (SDM) schemes that can further improve medium use efficiency and at the same ensure reliability





- No node is blocked from accessing the medium when the transmission can be spatially multiplexed with ongoing transmissions

Proposed access rule

Goal of proposed FCC 6 GHz regulation

Facilitate advanced sharing techniques, ensure fairness & technology neutrality

- Current medium access procedure in 5 GHz is essentially aggressive async access with persistent channel sensing
  - As soon as it becomes idle, the medium can be accessed if it remains idle for a short random back off interval - this minimizes idle periods in medium use, but is unsuitable for advanced techniques that require coordinated synchronous access for multiple nodes
- **Without an FCC rule**, an async access procedure can starve sync access, which requires periodic coordinated silence intervals
  - Use of advanced techniques that require sync access would be discouraged/disfavored
  - Implementation of innovative spectrum sharing tools would be suppressed
- **With the proposed FCC rule**, fair medium use for all technologies, using async or sync access, is ensured and advanced techniques requiring sync access to improve efficiency of spectral use and latency may be supported in unlicensed bands
- **Proposed FCC rule is technology neutral and fair**, ensures 6 GHz can be used by all technologies, and does not favor or disfavor any technology or form of access – sync or async

Proposed regulatory approach in new 6 GHz band

FCC sync access

- **FCC specifies** rule in the form of
  - Synchronous boundaries to facilitate sync access across technologies
    - Each technology can develop medium access procedure utilizing the same time reference boundaries provided by regulation
  - Maximum Channel Occupancy Time (COT) to control fairness between async and sync access
    - Maximum COT for async access is fixed
    - Maximum COT for sync access is variable
      - Function of time of access relative to the sync boundary
      - In a coexistence scenario, to ensure fairness, the average COT for both access mechanisms is comparable
- Each technology can develop its own procedure conforming to the FCC regulation
  - **Existing IEEE 802.11ax and 5G NR-U Rel-16 technologies conform to the proposed rule**
  - Future Wi-Fi and 5G NR-U releases can further exploit this rule and continue improving performance and coexistence

Rule text proposal (for new 6 GHz band)

Addition to Title 47 Part 15 → Subpart E → §15.407

(a) Synchronous communications mode: The nominal maximum channel occupancy time shall not exceed 6 milliseconds. Channel occupancy time can be extended to span up to two consecutive sync intervals if the channel occupancy time ends at the synchronization boundary and the channel was occupied at the beginning of the sync interval when the channel occupancy time started.

(b) Master devices shall either limit the maximum channel occupancy time to 10 milliseconds or meet the requirements in paragraph (a).

Rule text proposal (for new 6 GHz band) – definitions

Addition to Title 47 Part 15 → Subpart E → §15.403

Synchronized Communications Mode. The synchronized communications mode utilizes synchronization reference boundaries based on Coordinated Universal Time (UTC) that repeat every N=6 milliseconds, starting from 00:00:00 on Gregorian calendar date 1 January, 1900 (midnight between Sunday, December 31, 1899 and Monday, January 1, 1900). The time between two consecutive synchronization reference boundaries is referred to as the sync interval.

Channel Occupancy Time. The channel occupancy time consists of the total transmission time of the master device and any granted transmission time of the slave devices as defined by the technology and bounded by idle time on both sides.

Sync and async modes

COT extension for sync nodes to end channel occupancy at sync boundary

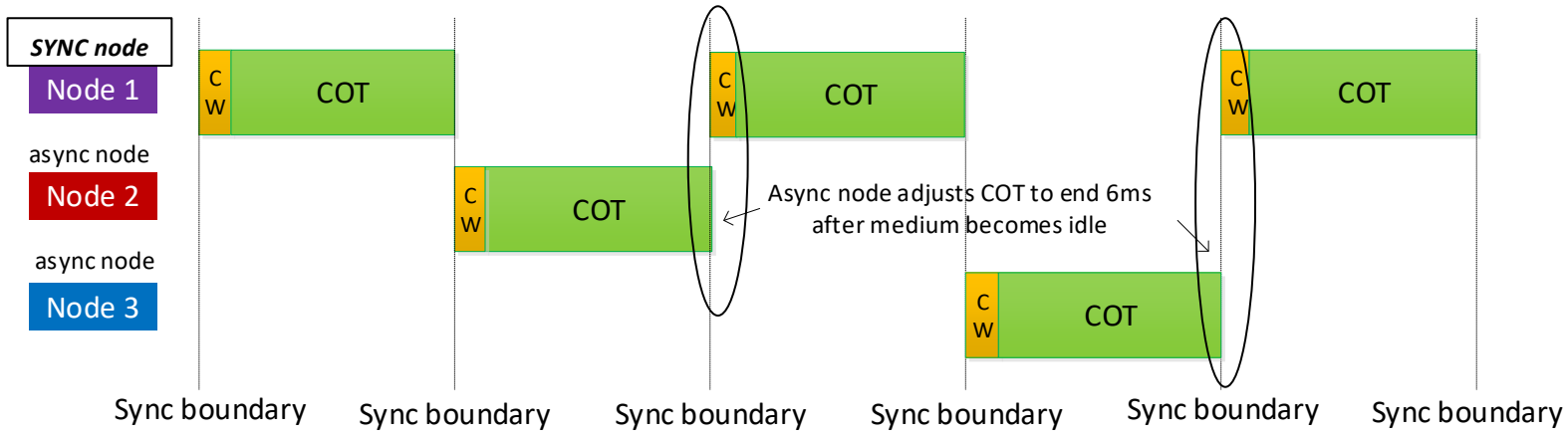
- Sync boundaries repeat every 6 ms
- Time between two consecutive sync boundaries is referred to as sync interval
- Contention window size is not addressed by regulation

Mode	COT selection
Sync	COT ≤ 6 ms
	COT < 12 ms if the following is true: COT ends at the sync boundary, and The channel was occupied at the beginning of the sync interval where COT started.
Async	COT ≤ 10 ms

Fairness illustration

Sync/async node fairness

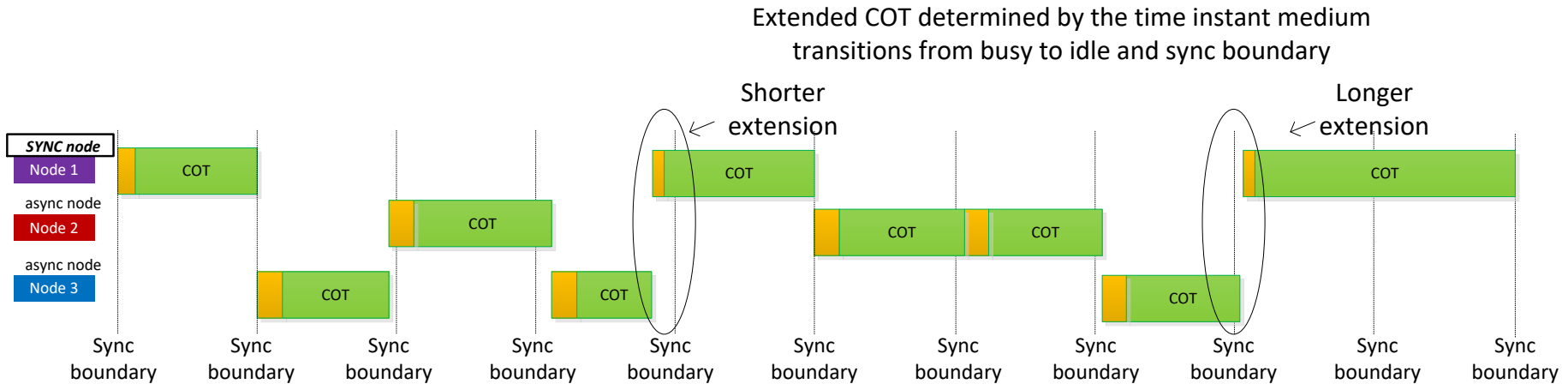
- By adjusting COT to end 6 milliseconds after the most recent medium busy to idle transition, async nodes ensure equal medium use with sync nodes, and also establish and maintain synchronization even among async nodes



Fairness illustration – continued

Sync/async node fairness

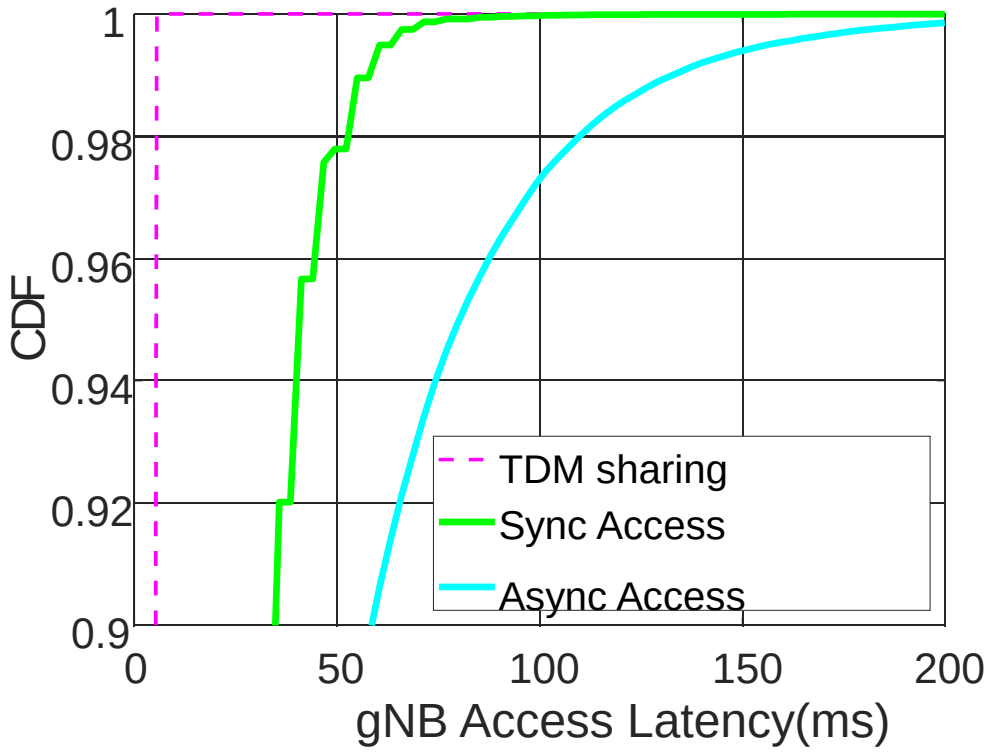
- If async nodes do not adjust COT to end 6 ms after the most recent medium busy to idle transition, sync nodes will extend COT beyond 6 ms (up to 12 ms)
  - However, the average COT of two access types would still be comparable as max COT for async access is 10 ms
  - Without COT extension provision for “sync” access, “async” access would have significant advantage in terms of medium use and would discourage “sync” access



Appendix - Benefits of synchronous contention on access latency

3GPP Indoor simulation model

3GPP Rel-13 Indoor, 40MHz, MIMO 4x4, 2MB burst size, 0.5:0.5 DL:UL



- Sync access reduces the tail access latency (98%-tile) by 50% without any modification of LBT procedure
- Sync access can approach TDM sharing performance if LBT procedure is optimized for sync access

Appendix - Benefits of CoMP with synchronous contention

Simulation scenarios and legends

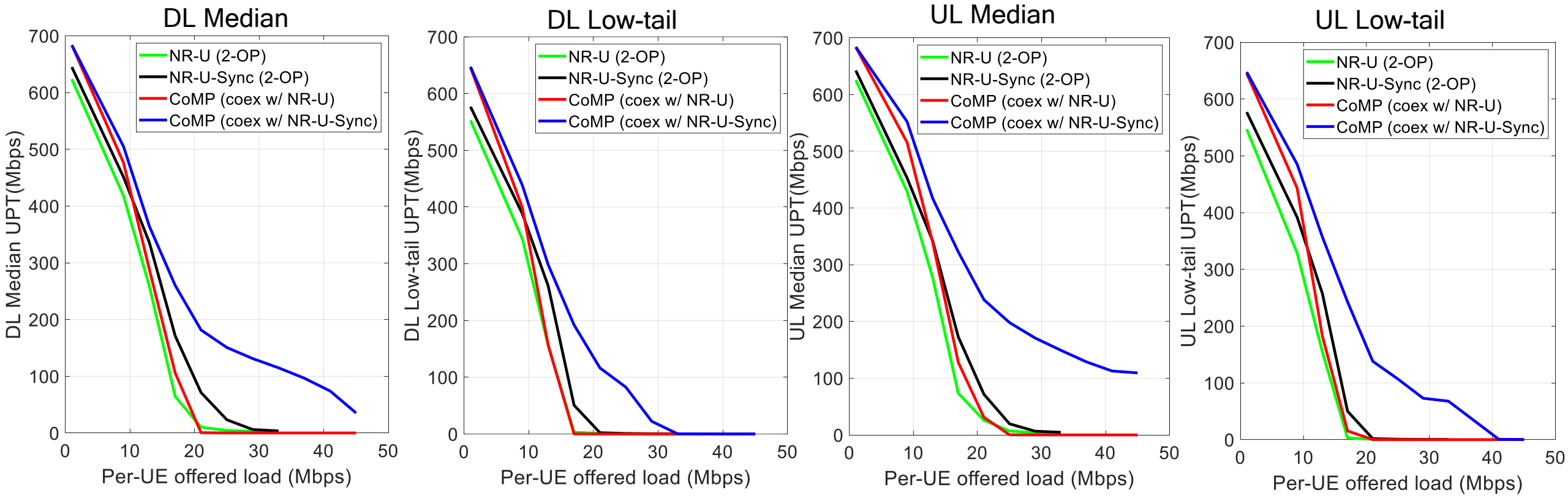
3GPP simulations scenarios

- 3GPP Rel 13 and Rel-16 simulation scenarios
  - Simulated system bandwidth is 40MHz
  - MIMO 4x4, 2MB burst size, and 50%:50% split between DL and UL traffic

	Description	Performance	Legend
NR-U + NR-U	A NR-U operator co-exists with another NR-U operator	Across operators	NR-U (2-OP)
NR-U-Sync + NR-U-Sync	A NR-U-Sync operator co-exists with another NR-U-Sync operator	Across operators	NR-U-Sync (2-OP)
CoMP + NR-U	A CoMP operator co-exists with a NR-U operator	CoMP operator	CoMP (coex w/ NR-U)
		NR-U operator	NR-U (coex w/ CoMP)
CoMP + NR-U-Sync	A CoMP operator co-exists with a NR-U Sync operator	CoMP operator	CoMP (coex w/ NR-U-Sync)
		NR-U-Sync operator	NR-U-Sync (coex w/ CoMP)

User perceived throughput vs offered load

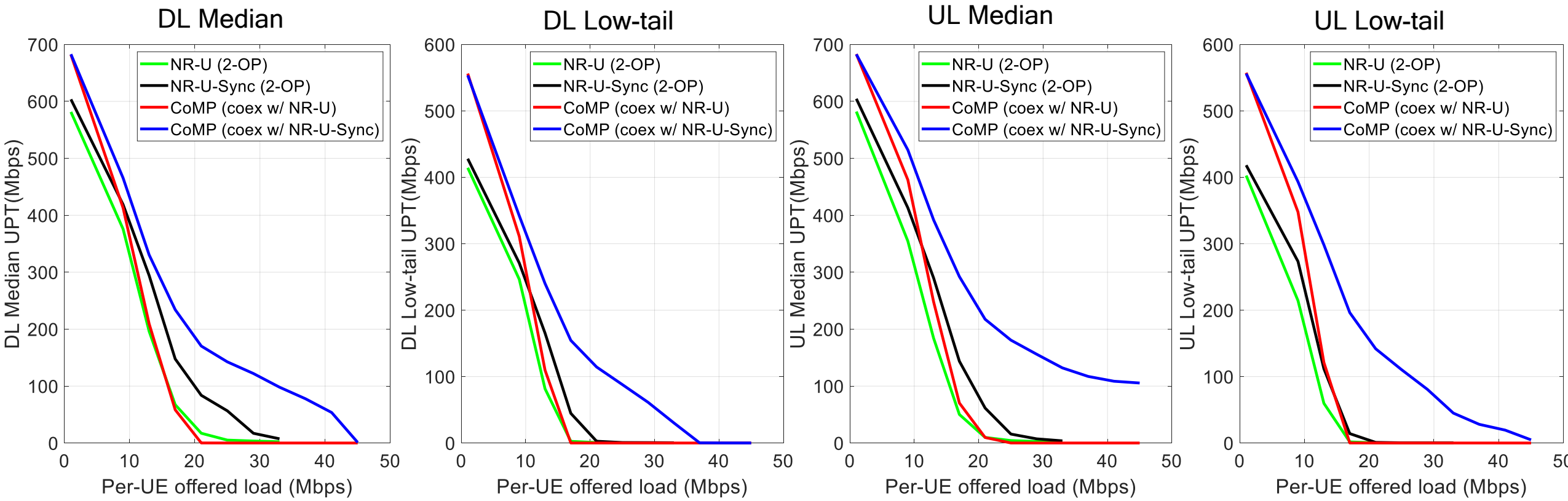
3GPP Rel-13 Indoor model



- NR-U Sync provides ≥ 10-20% capacity gain over async baseline (5 GHz LBT medium access procedure).
  - Observed at UPT of 100 Mbps
- Advanced techniques that make use of synchronized medium access, such as CoMP can easily provide further gains in excess of 100%.
  - Observed at UPT of 100 Mbps

User perceived throughput vs offered load

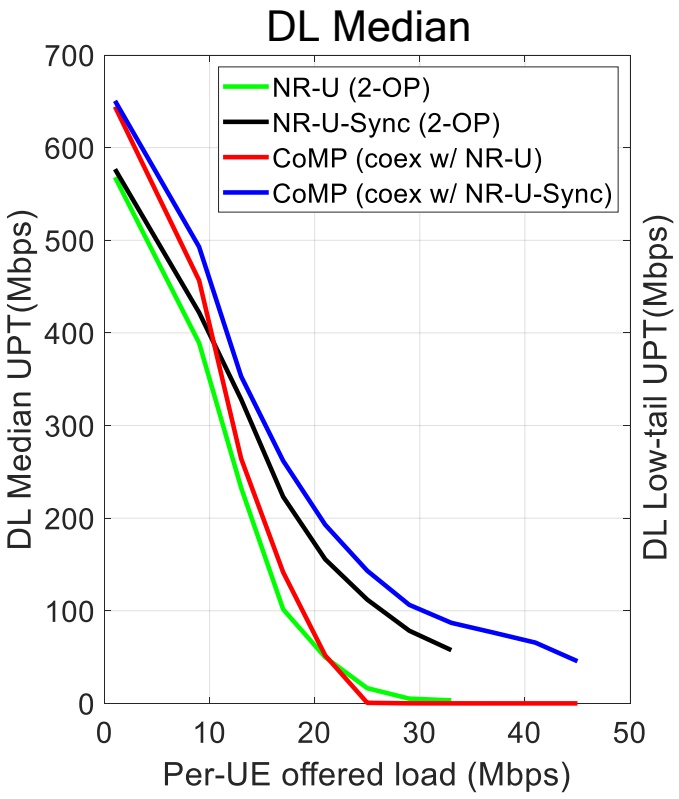
3GPP Rel-13 Outdoor model

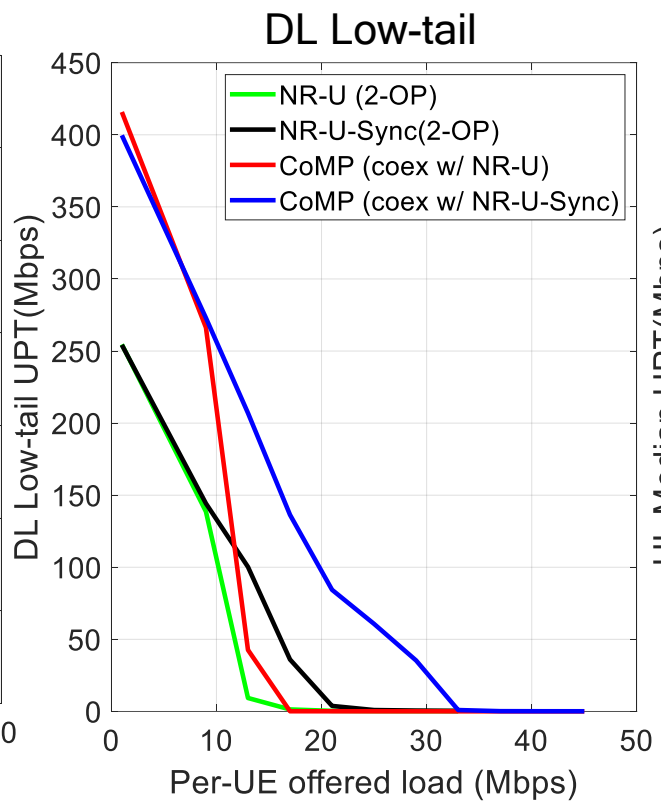


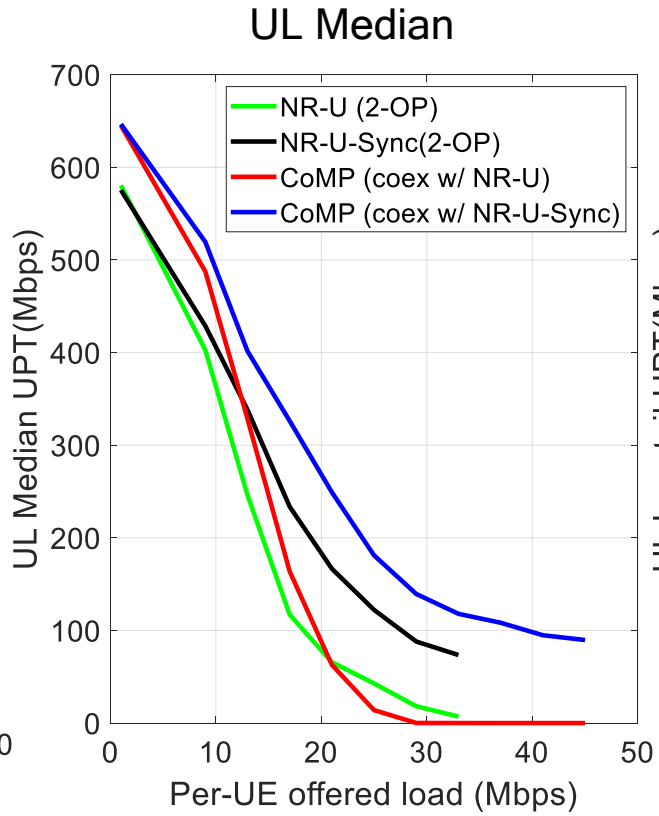
- NR-U Sync provides ≥ 10-20% capacity gain over async baseline (5 GHz LBT medium access procedure).
  - Observed at UPT of 100 Mbps
- Advanced techniques that make use of synchronized medium access, such as CoMP can easily provide further gains in excess of 100%.
  - Observed at UPT of 100 Mbps

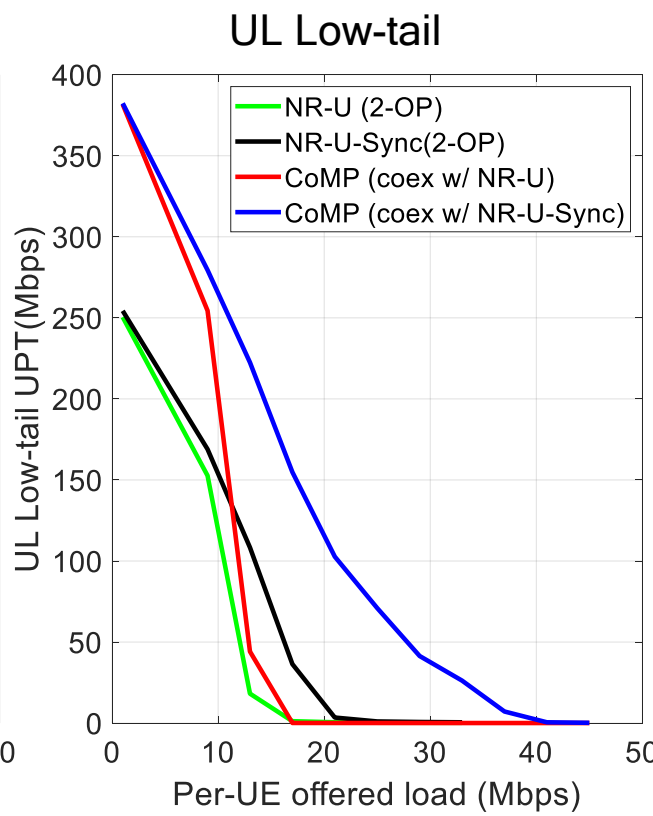
User perceived throughput vs offered load – continued

3GPP Rel-16 Indoor model









- NR-U Sync provides ≥ 30-50% capacity gain over async baseline (5 GHz LBT medium access procedure)
  - Observed at UPT of 100 Mbps
- Advanced techniques that make use of synchronized medium access, such as CoMP provide further gains, ranging from 20% to close to 100%.
  - Observed at UPT of 100 Mbps

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Thank you

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