Global update on 5G spectrum
Spectrum is critical for 5G success
Using all spectrum types and bands

- **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: 2.4 GHz / 5.9-7.1 GHz / 57-71 GHz global

**High bands**
above 24GHz (mmWave)

**Mid bands**
1GHz to 7GHz

**Low bands**
below 1GHz
# Significant RF complexity with 5G

## 10,000+ early 5G band combinations

### North America
- **LTE bands:** 71, 29, 12, 13, 14, 5/26, 25, 4/66, 7, 30, 41, 46, 48
- **5G NR bands:** n71, n66, n2, n41, n5, n12, n25, n48, n78, n258, n260, 261
- **LTE 2CA:** 2+4/66, 25+41, 4+7, 7+30
- **LTE 3CA:** 2+66+30, 2+4+7
- **LTE 4x4 MIMO bands:** 2/4/66, 7, 25, 30
- **LTE UL CA:**
  - **EN-DC:** 2+n66, 25+n41, 5+n12, 41+n41, 2+n66+30

### Europe
- **LTE bands:** 28A, 20, 8, 32, 1, 3, 7, 38, 46
- **5G NR bands:** n78, n28A, n8, n20, n38, n1, n3, n7, n75/76, n257, n258
- **LTE 2CA:** 8+20, 20+28A, 1+3, 1/3+7, 1/3+38, 3+32
- **LTE 3CA:** 1+3, 7, 3+7, 3+38, 3+7+32
- **LTE 4x4 MIMO bands:** 1, 3, 7, 38
- **5G NR UL-MIMO:** n78
- **EN-DC:** 8+20+n28A, 1+3+7+n75/n78

### Middle East / Africa
- **LTE bands:** 20, 8, 1, 3, 7, 38, 40, 41
- **5G NR bands:** no confirmed plans available
- **LTE 2CA:** 1+3, 3+7, 3+40, 3+41
- **LTE 3CA:** 1+3+7
- **LTE 4x4 MIMO bands:** 1, 3, 7, 38, 40
- **LTE UL CA:**
  - **EN-DC:**

### Latin America
- **LTE bands:** 28, 12, 5/26, 8, 1, 2, 3, 4/66, 7, 38, 41, 42, 46
- **5G NR bands:** no confirmed plans available
- **LTE 2CA:** 1+3, 1/3+7, 2+4, 4+7
- **LTE 3CA:** 1+3+7
- **LTE 4x4 MIMO bands:** 1, 2, 3, 4, 7
- **LTE UL CA:**
  - **EN-DC:**

### China (incl. Taiwan and Hong Kong)
- **LTE bands:** 5, 8, 1, 3, 7, 34, 39, 40, 41, 412, 20, 38 roaming
- **5G NR bands:** 41+, 79, 1, 3, 78
- **LTE 2CA:** 39+41, 3+41, 1+3
- **LTE 3CA:**
  - **LTE 4x4 MIMO bands:** 1, 3, 39, 41
  - **5G NR UL-MIMO in SA:** n41, n78, n79
  - **EN-DC:** 3+n41, 39+n41, 3+n79, 1/3+n79, 5/8+n78

### India
- **LTE bands:** 5, 8, 1, 3, 40, 41
- **5G NR bands:** no confirmed plans available
- **LTE 2CA:** 3+40, 3+41
- **LTE 3CA:** 1+3+41
- **LTE 4x4 MIMO bands:** 1, 3, 40, 41
- **LTE UL CA:**
  - **EN-DC:**

### Japan
- **LTE bands:** 28, 26, 8, 11, 19, 21, 1, 3, 4, 12, 20, 38, 46
- **5G NR bands:** n77, n78, n79, n1, n3, n257
- **LTE 2CA:** 18+28A, 1+3, 1+7, 3+41
- **LTE 3CA:** 1+3, 41
- **LTE 4x4 MIMO bands:** 1, 3, 40, 41
- **5G NR UL-MIMO in NSA:** n77, n79
- **EN-DC:** 3+n77/n79, 41+n77/n79, 42Rx+n79

### South East Asia / Oceania
- **LTE bands:** 28, 20, 5, 8, 1, 3, 7, 38, 40, 41
- **5G NR bands:** n78, n2, n40, n257, n258
- **LTE 2CA:** 1+3, 7, 3+40, 3+41
- **LTE 3CA:** 1+3+7, 7+40
- **LTE 4x4 MIMO bands:** 1, 3, 7, 38, 40, 41
- **LTE UL CA:**
  - **EN-DC:**
Global Spectrum Status
### Global snapshot of allocated/targeted 5G spectrum

5G is being designed for diverse spectrum types/bands.

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<tr>
<th>Frequency Range</th>
<th>Licensed</th>
<th>Unlicensed/shared</th>
<th>Existing band</th>
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<td>2.5/2.6GHz (B41/n41)</td>
<td>3.45-3.55GHz, 3.7-4.2GHz</td>
<td>5.9-7.1GHz</td>
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<td>37-42.5GHz</td>
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<td>37-37.6GHz, 37.6-40GHz</td>
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<td>64-71GHz</td>
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*New 5G 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 completed in March 2017
- 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**
- **CBRS**
  - 3.4-3.5 GHz and 3.7-4.2 GHz
  - Opening up 150 MHz in 3.5 GHz band with 3-tier sharing with incumbents, PAL, GAA
  - In Sept 2019, FCC approved initial GAA deployments
  - In June 2020, FCC will auction PAL licenses (up to 70 MHz per county)
  - Adopted NPRM of 3.7-4.2 GHz & 5.9-7.1 GHz
  - NTIA is studying repurposing 3.45-3.55 GHz & 3.1 to 3.45 GHz for commercial use.

**High-band**
FCC has allocated 12.55 GHz so far & its largest auction will occur in 2019
- In 2016, FCC allocated 10.85 GHz in multiple mmWave bands, 70% of newly opened spectrum is shared or unlicensed
- In Jun. 2018, FCC proposed making 25.25-27.5 and 42-42.5 GHz for flexible wireless use
- FCC has held auctions in 28 & 24 GHz bands.
- In Dec. 2019, FCC will auction Upper 37, 39, & 47 GHz bands.

1 Citizen Broadband Radio Services; 2 Priority Access Licenses to be auctioned; 3 General Authorized Access; 4 FCC ruling FCC 16-89 on 7/14/2016 allocated 3.25 GHz of licensed spectrum and 7.6 GHz of shared/unlicensed spectrum.
Low-band: 600 MHz LTE initially deployed in areas already clear of TV stations – now will be used for 5G

Meeting 5G timeline
Completed auction in March 2017; process of clearing the spectrum & repacking TV stations to end in 39 months. Process is on track.

Greater capacity and wider coverage
Low-band spectrum is optimized for long-range macro deployments - optimal for connecting the wide-area IoT and more

Broad industry support
Qualcomm Technologies Inc. is working closely with operators & OEMs to enable early launches, incorporating our industry-leading modem, transceiver, and RFFE
Mid-band: CBRS introduces a 3-tiered shared spectrum

FCC optimized rules in Oct 2018, allowed initial GAA deployments in Sept 2019, and will hold PAL auction in June 2020

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**Tier 1**

*Incumbents*

- Incumbents are protected from interference from PAL and GAA

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**Tier 2**

*Priority Access Licenses (PAL)*

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

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**Tier 3**

*General Authorized Access (GAA)*

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

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1 Wireless ISP transitioning from incumbent to PAL/GAA after 5 years; 2 Fixed satellite service - receiving only; 3 Citizen Broadband Radio Service (CBRS)
High-band: FCC rapidly bringing mmWave spectrum to market

- **FCC adopted second order allocating additional mmWave spectrum**
  - 24.25-24.45 GHz, 24.75-25.25 GHz, and 47.2-48.2 GHz

- **FCC announced first wave of mmWave auctions**
  - November 2018: 24 GHz and 28 GHz
  - 2H2019: 37 GHz, 39 GHz, and 47 GHz

- **FCC opened total of 10.85 GHz as part of the Spectrum Frontiers Ruling**
  - Licensed: 27.5-28.35 GHz (2x425 MHz); 37.6-38.6 GHz (5x200 MHz); 38.6-40 GHz (7x200 MHz)
  - Shared/unlicensed: 37-37.6 GHz (3x200 MHz); 64-71 GHz that expands the existing 60 GHz band

- **FCC proposed making mmWave spectrum for flexible**
  - 25.25-27.5 GHz and 42-42.5 GHz

- **FCC announced procedures for the largest mmWave auction**
  - Auction to start on Dec. 10th, 2019
  - Will include 37.6-38.6 GHz and 47.2-48.2 GHz across the US and some licenses for 38.6-40 GHz
European Commission driving a Gigabit Society

Deploying 5G across Europe by 2020 with pre-commercial trials starting in 2018

- Early trials in 2017, pre-commercial trials from 2018
- Full commercial 5G services (one major city per country) in 2020
- All urban areas and major terrestrial transport paths with 5G coverage by 2025

Pioneer spectrum bands for 5G (low: 700 MHz, mid: 3.4-3.8 GHz, high: 24.25-27.5 GHz)
- EC Mandate to CEPT focusing on 3.5 GHz and 26 GHz pioneering bands – completed in 2018
- Additional EC Mandate to CEPT on extended L band (1427 - 1518 MHz) – completed in 2018
- CEPT harmonization of the 26 GHz band ahead of WRC-19 – completed in June 2018
- EC working on binding decision for EU Member States – completed in Q1 2019
- 5G commercial services to use both 3.4-3.8 GHz and 26 GHz in Europe – targeting 2020

Full set of 5G spectrum bands and implementation measures
- EC mandate to CEPT on the development of harmonized technical conditions suitable for 5G in the 900 MHz, 1.8 GHz, 2.6 GHz, and the paired terrestrial 2 GHz frequency bands – completed in 1H 2019
- RSPG\(^2\) working on how to defragment 3.4-3.8 GHz band and on the impact of the future use of 5G in areas other than MBB\(^3\)

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5G spectrum status dashboard in Europe
Commercial targets focusing on 3.4-3.8 GHz and/or 26 GHz

<table>
<thead>
<tr>
<th>Country</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.K.</td>
<td>3.4 - 3.6 GHz (150 MHz) Auctioned, 3.6 - 3.8 GHz (120 MHz) Q1 2020, 3.8 - 4.2 GHz Q4 2019 - Local, 24.25 - 26.5 GHz Q4 2019 - Local, 26.5 - 27.5 GHz 2020</td>
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<tr>
<td>Italy</td>
<td>3.6 - 3.8 GHz Auctioned, 26.5 - 27.5 GHz Auctioned - Club Use</td>
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<td>France</td>
<td>3.46 - 3.8 GHz Q4 2019, 26 GHz 2020</td>
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<tr>
<td>Spain</td>
<td>3.6-3.8 GHz Auctioned 2020, 26.5 - 27.5 GHz</td>
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<td>Switzerland</td>
<td>3.4 - 3.8 GHz Auctioned, 26.5 - 27.5 GHz 2022</td>
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<td>Finland</td>
<td>3.4 - 3.8 GHz, 26 GHz</td>
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<td>Romania</td>
<td>3.4 - 3.8 GHz Q4 2019, 26.5 - 27.5 GHz Q4 2020</td>
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<tr>
<td>Hungary</td>
<td>3.4 - 3.8 GHz Q4 2019, 26 GHz 2020</td>
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<tr>
<td>Czech Republic</td>
<td>3.4 - 3.8 GHz 2020</td>
</tr>
<tr>
<td>Ireland</td>
<td>3.4 - 3.8 GHz Auctioned</td>
</tr>
</tbody>
</table>

Note: Club Use indicates the spectrum is reserved for specific professional or club use.

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5G spectrum status dashboard

- Commercial targets focusing on 3.4-3.8 GHz and/or 26 GHz
- Auctioned: Spectrum has been auctioned
- Q4 2019 - Local: Spectrum available for local use in Q4 2019
- 2020: Spectrum available in 2020
# 5G spectrum in Europe

## Focus on mid-band (3.4-3.8 GHz) and 26 GHz (24.25-27.5 GHz) for 2019+

EC RSC, CEPT, key European Member States are driving regulatory activities to accelerate 5G rollout in EU. Intense regulatory activities for 3.4-3.8 GHz and 26 GHz with more auctions occurring in 2019 and 2020.

### U.K.
- Government 5G strategy for UK published in March 2017 - DCMS and HM Treasury
- Ofcom auctioned 150 MHz in 3.4-3.6 GHz in 2018, more spectrum (120MHz) in 3.6-3.8 GHz in Q1 2020
- Multi-band auction in Q1 2020 including (700MHz, 3.6-3.8GHz)
- For mmWave, Ofcom has initiated a work program on 26 GHz band availability for early 5G deployment
- Local licenses in 24.5-26.5 GHz from Q4 2019

### Ireland
- Ireland successful auction of 350 MHz of spectrum for 5G
- 26GHz auction in 2018

### Spain
- In Spain, the 3.6-3.8 GHz band was auctioned in Q3 2018
- Organizing trials on 26 GHz band - at least 1.4 GHz available for release from 2019 depending on market demand

### Finland
- Auction completed in Sept. 2018: 3410-3800 MHz
- Ficora is looking at "large-scale 5G tests" in 26 GHz, decided to make available up to 1 GHz for it in 2017—commercial in 2020

### Sweden
- PTS is looking at "large-scale 5G tests" in 26 GHz, decided to make available up to 1 GHz for it in 2017
- Commitment to make available pioneering bands starting in Q4 2019

### Switzerland
- 3.5-3.8 GHz auction completed, for commercial use from Q2 2019

### Italy
- Auction completed in 2018:700MHz, 3.6-3.8GHz, 26.5-27.5GHz

### Austria
- Spectrum auction completed, 3.6-3.8 GHz for commercial use starting from Q2 2019
5G spectrum status in China, South Korea, and Japan

**China**
- MIIT officially allocated 3.3-3.6 GHz & 4.8-5.0 GHz as official 5G bands; in addition, in Dec’18, 2.6 GHz (Band n41) has been allowed for both 4G & 5G deployments
- mmWave in longer term. Chinese gov’t solicited public opinion for candidate bands of 24.25-27.5 GHz & 37-42.5 GHz non-exclusively in Jun’17
- Chinese government approved 5G technology R&D trial frequencies usage in 24.75-27.5 GHz & 37-42.5 GHz mmWave ranges in Jul’17

**Japan**
- Technical rules for licensed bands in 3.6 - 4.2 GHz, 4.4 - 4.9 GHz and 27 - 29.5 GHz have been specified
- In Apr’19, MIC assigned 5G spectrum to operators
- Technical rules for private network bands in 2575-2595 GHz (NSA) and 28.2-28.3 GHz have also been specified. New regulations will be enacted by Dec’19
- Technical rules for additional licensed spectrum (4.8-5 GHz, 26.5-27 GHz, 37-43.5 GHz) & private spectrum (4.6-4.8 GHz, 28.3-29.1 GHz) are being developed

**South Korea**
- MSIT has successfully completed 5G spectrum auction in June 2018 for both sub-7 and mmWave, including 3.42-3.7 GHz and 26.5-28.9 GHz
- The world first commercial 5G smartphone for sub-7 was launched in Apr’19. Carriers plan to launch mmWave service in 1H 2020
- Achieved over 3 million 5G subscribers as of Sep’19

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**3.6-4.1 GHz**
- NTT DoCoMo
- KDDI
- Rakuten
- Softbank
- KDDI

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<tr>
<td>NTT DoCoMo</td>
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<td>Softbank</td>
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**4.5-4.8 GHz**
- NTT DoCoMo
- Private Use

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**27-29.5 GHz**
- Rakuten
- NTT DoCoMo
- Rakuten
- Private Use
- Rakuten

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<td>Private Use</td>
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5G spectrum status in Oceania, South East Asia, and India

**Australia**
- 3.6 GHz: remaining 125 MHz auctioned in Oct’18 (total 3.4-3.7 GHz) and 5G has been commercially deployed
- 26 GHz: government has proposed:
  - unlicensed access to 24.25-25.1 GHz
  - area defined spectrum & apparatus licenses in 25.1-27.5 GHz
  - national apparatus licenses in 24.7-25.1 GHz
  - auction spectrum licenses 26 GHz in 2020
- 28 GHz: regulator has consulted on 28 GHz spectrum, and will announce a planning decision in 3Q19

**New Zealand**
- 3.5 GHz: 3400-3590 MHz assigned until 2022
- 5G commercial deployment started in 2019
- Longer term access to be provided prior to 2022, access to 3590-3800 MHz will be provided in 2020

**Hong Kong**
- 3.5 GHz: 5G Spectrum auction scheduled for Oct’19
- 26/28 GHz: 3 operators awarded 400 MHz each, with 400 MHz reserved for local licensing

**Taiwan**
- 3.5 GHz: auction planned for 4Q19
- 28 GHz: auction planned for 4Q19
- Completed second round of consultation in Jul’19, proposing release of spectrum in 3.5 GHz and 26/28 GHz in initial tranche, and plan to finalize policy decision in 2019

**Indonesia**
- Government plans to conduct trial in 3.5 GHz
- Government announced that it will consult on 5G policy and 3.5 GHz, 26 GHz and other spectrum bands in 2019, and finalize policy in 2020.

**Malaysia**
- Regulator and Industry recommendations to government:
  - 3.5 GHz: 5G access in 1H21
  - 26/28 GHz: 5G access in 1H21

**Philippines**
- 3.5 GHz band assigned

**Thailand**
- 3.5 GHz: Auction planned for 2H20
- 26/28 GHz: Auction planned for 1H20

**Vietnam**
- Government has announced timeframe for planned commercialization in 2020
- Proposed consideration of portions of 3.5 GHz band and 26/28 GHz in ongoing consultation process

**Singapore**
- High Level Forum submitted 5G recommendation in Aug’18
- 617-698 MHz in planning; 698-803 MHz auction in Q1’20
- 3.3-3.6 GHz auction in Q1’20
- 24.25-27.5 GHz, 27.5-29.5 GHz preferred mmWave bands – two years free for trials; also looking at 37-43.5 GHz
5G update in LATAM

Studies under way for both C-Band & mmWave spectrum in key countries

- Brazil has auction of C-band & 26 GHz planned for March 2020
- Peru has C-Band auction planned for 2020
- Uruguay has very small fixed wireless deployment
- Colombia and Chile have consultations underway

<table>
<thead>
<tr>
<th>Country</th>
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<th>5G NR n77</th>
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Global snapshot of spectrum optimized for industrial IoT / vertical / private network use – local licensing or sharing

**USA**
- 3.5 GHz CBRS band, exclusive and shared licenses, deployments in 2H 2019
- 37-37.6 GHz shared spectrum/local licenses, under evaluation

**Germany**
- 3.7 - 3.8 GHz
- Local licenses. Assignment complete; available 2H 2019

**U.K.**
- 3.8-4.2 GHz
- Local licenses (50 meters square); regulator database; decision formalized; applications invited from end 2019

**Sweden**
- 3.7-3.8 GHz
- In consultations

**Finland**
- Sub-licensing of 3.4-3.8 GHz
- Local permission via operator lease; assignment complete

**Netherlands**
- 3.5 GHz for local industrial use; 3.7-3.8 GHz (in consultations); 2.3-2.4 GHz (licensed shared access online booking system)
- 3.5 GHz for local industrial use; however users may need to move to 3.7-3.8 GHz, if allocated; 2.3 GHz approved for PMSE

**France**
- 2.6 GHz
- Regulator database and approval. 20 MHz approved for Professional Mobile Radio

**Australia**
- 24.25-27.5 GHz
- Under evaluation

**Hong Kong**
- 24.25-28.35 (400 MHz)
- Local licenses; regulator approval. Approved; available 3Q 2019

**Japan**
- Phase 1: 2,575-2,595 MHz (as NSA anchor) and 28.2-28.3 GHz; Local licenses, legislation planned in December 2019.
- Phase 2: 4.6-4.8 GHz & 28.3-29.1 GHz: local license, possible regulator database. Consultation planned October 2019, legislation planned 3Q 2020
Global 4G LTE spectrum landscape
Over 1,000 band combinations now supported for LTE

U.S. / Canada
- 600/700/850 MHz (FDD)
- 1700/1900 MHz (FDD)
- 2300/2600 MHz (FDD/TDD)
- 2500 MHz (TDD)

Europe
- 450/800/900 MHz (FDD)
- 1800/2100 MHz (FDD)
- 2600 MHz (FDD/TDD)

Latin America
- 700 MHz (FDD)
- 1700/1800/1900 MHz (FDD)
- 2600 MHz (FDD/TDD)

China
- 800/1800/2100 MHz (FDD)
- 1900/2300/2500/2600 MHz (TDD)

MENA
- 800/1800 MHz (FDD)
- 2300 MHz (FDD/TDD)
- 2600 MHz (FDD/TDD)

India
- 850/1800 MHz (FDD)
- 2300 MHz (TDD)

South Korea
- 850/900 MHz (FDD)
- 1800/2100/2600 MHz (FDD)

Japan
- 700/850/900 MHz (FDD)
- 1500/1800/2100 MHz (FDD)
- 2500/3500 MHz (TDD)

SE Asia
- 700/850/900 MHz (FDD)
- 1800/2100/2600 MHz (FDD)
- 2300 MHz (TDD)

Australia
- 700/850/900 MHz (FDD)
- 1800/2100/2600 MHz (FDD)
- 2300 MHz (TDD)
Thank you!

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