



FINAL REPORT FOR CTIA

5G MID-BAND SPECTRUM GLOBAL UPDATE

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1 Executive summary

In April 2018, Analysys Mason published a report (the ‘5G readiness report’¹), describing 5G spectrum and infrastructure policies in leading markets around the world. We benchmarked the situation in the US to that in nine other countries, specifically: Canada, China, France, Germany, Japan, Russia, Singapore, South Korea, and the UK.

The past few months have highlighted the continued push toward mid-band 5G, with auctions taking place in several markets. The next 12–18 months are likely to prove to be critical, with assignment confirmed or expected to take place in each of our remaining benchmark countries over that timescale.

This latest report provides an update to the earlier 5G readiness report, exclusively focusing on mid-band² spectrum plans for 5G. In this report, we have extended our benchmark countries to include Australia, Spain and Sweden, as well as the original list of countries.

Key Finding: Since April 2018, four of our benchmark countries (Japan, South Korea, Spain, and the UK) have auctioned or assigned mid-band spectrum. Several countries have also confirmed that mid-band spectrum will be assigned by June 2019 (e.g. Australia, Germany and Japan).

Key Finding: Among the benchmark countries, nearly 200MHz of mid-band spectrum per country is expected to be available by June 2019. By the end of 2020, an average of nearly 300MHz of mid-band spectrum will be available per country.

Key Finding: 5G trials using mid-band spectrum have continued or expanded in all our benchmark countries since our previous report. Since April 2018, mobile network operators (MNOs) have completed or announced over 20 independent 5G trials (based on Analysys Mason research³) in these markets using mid-band spectrum.

Section 2 provides further details and analysis for each of our benchmark countries.

¹ ‘Global race to 5G – spectrum and infrastructure plans and priorities’. We refer to this report as the ‘5G readiness report’. See https://api.ctia.org/wp-content/uploads/2018/04/Analysys-Mason-Global-Race-To-5G_2018.pdf

² Mid-band spectrum is defined as spectrum in the 3–24GHz range. We therefore exclude lower frequency spectrum (e.g. the 2.6GHz band) which may be relevant to 5G.

³ We further note that, in August 2018, the Global mobile Suppliers Association (GSA) “identified 154 operators in 66 countries that have demonstrated, are testing or trialing, or have been licensed to conduct, field trials of 5G-enabling and candidate technologies (up from 134 operators in April 2018)”. See GSA report ‘Evolution from LTE to 5G: Global Market Status’.

1.1 Update: mid-band 5G spectrum release

Around the world, mid-band 5G spectrum plans are being developed, with several countries at an advanced stage with their plans. A summary of the plans in each of our benchmark countries is shown in Figure 1.1 below:

Figure 1.1: Mid-band spectrum release plans in benchmark countries [Source: Analysys Mason, 2018]

Country	Details
Australia	<ul style="list-style-type: none"> 3425–3492.5MHz and 3542.5–3575MHz ranges (a total of 100MHz) have been licensed in specific areas of Australia An auction of spectrum in the 3575–3700MHz range (a total of 125MHz) is planned for November 2018.
Canada	<ul style="list-style-type: none"> In June 2018, Canada published 'Spectrum Outlook 2018–2022' as well as a specific consultation on the 3450–3650 MHz band, with an auction for that band planned for late 2020 The regulator is also seeking preliminary comments on use of the 3400–3450MHz and 3650–4200MHz bands for 5G.
China	<ul style="list-style-type: none"> 500MHz of spectrum (within 3.3–3.6GHz and 4.8–5.0GHz) will be released in China, with the 3.3–3.4GHz range subject to indoor use Details are hard to source in the public domain, but in June 2018 MIIT indicated that spectrum assignment is likely to take place between H2 2019 and H1 2020 Reports also indicate that China is likely to assign the 3.6–4.2GHz range to 5G use in the future, subject to co-ordination with existing satellite use.
France	<ul style="list-style-type: none"> 40MHz of spectrum at 3420–3460MHz is to be reserved for fixed wireless access (FWA) use in currently underserved areas (with an additional 10MHz (3410–3420MHz) in certain areas) An auction of the remaining spectrum in the 3410–3800MHz range for mobile use is expected in 2019/20. ARCEP expects 300MHz of contiguous spectrum to be available for 5G by 2020, and 340MHz (390MHz in areas with no FWA) by 2026 In June 2018, ARCEP published a notice providing for the gradual release of the 3.4–3.6GHz band (by region) by March 2020, at the latest.
Germany	<ul style="list-style-type: none"> 126MHz (3410–3473/3510–3573MHz) is currently assigned to MNOs on a national basis for FWA use Germany plans to award the entire 3.4–3.8GHz band to mobile in early 2019. The 3.4–3.7GHz range (for nationwide use) will be auctioned; the 3.7–3.8GHz will be for regional/local use.
Japan	<ul style="list-style-type: none"> The 3.4–3.6GHz band is currently assigned to MNOs on a national basis The regulator has stated aims to release up to 500MHz of spectrum within the 3.6–4.2GHz and 4.4–4.9GHz ranges by March 2019.
Russia	<ul style="list-style-type: none"> 5G spectrum assignment plans are unclear, with the government's 5G roadmap scheduling a formal decision regarding spectrum to be made in 2018 However, SCRF has allocated test licenses in the 3.4–3.8GHz range to some operators.
Singapore	<ul style="list-style-type: none"> IMDA's 2017 5G consultation states that the regulator is 'exploring the possibility' of assigning spectrum from the 3.4–3.6GHz band for mobile use.
South Korea	<ul style="list-style-type: none"> In June 2018, South Korea auctioned 280MHz of spectrum in the 3420–3700MHz range on a national basis, raising a total of ~USD2.89 billion.
Spain	<ul style="list-style-type: none"> In June and July 2018, MNO Mas Movil privately acquired two 2×20MHz national licenses in the 3.4–3.6GHz band; two of Spain's other MNOs (Orange and Telefónica) already own 2×20MHz national licenses in this band Later in July 2018, Spain auctioned 200MHz of spectrum in the 3.6–3.8GHz range.

Country	Details
Sweden	<ul style="list-style-type: none"> 80MHz (3600–3640/3700–3740MHz) has been assigned to MNOs on a national basis; (technology neutral) regional licenses have also been assigned in the 3.4–3.8GHz band Sweden plans to award the entire 3.4–3.8GHz band to mobile. The 3.4–3.7GHz range (for nationwide use) is scheduled for auction in late 2019 or early 2020; the 3.7–3.8GHz will be for regional/local use.
UK	<ul style="list-style-type: none"> UK MNO Three already holds national licenses in the 3480–3500MHz, 3580–3600MHz, 3605–3689MHz and 3925–4009MHz ranges, originally awarded for FWA use⁴ In April 2018, the UK auctioned 150MHz of spectrum from the 3.4–3.6GHz band, which was awarded to four operators, raising a total of ~USD1.50 billion The UK anticipates awarding spectrum in the 3.6–3.8GHz band in 2019; the spectrum is expected to 'be deployed in many areas from around 2020, and nationwide by 2022'. The 3.8–4.2GHz range is 'a candidate band for enhanced spectrum sharing'.
US	<ul style="list-style-type: none"> The US is making 150MHz in the 3550–3700MHz (CBRS) band available, with 70MHz to be auctioned (potentially in 2019) and the remaining 80MHz to be available on a shared or unlicensed basis (in early 2019) The FCC is exploring the 3.7–4.2GHz, adopting an NPRM in July 2018, a move that could open up large additional blocks of mid-band spectrum The US is also studying the 3.45–3.55GHz band, but there is no specific timing on the study or the availability of spectrum.

The amount of mid-band spectrum currently assigned to mobile in our benchmark countries, and the amount expected to be assigned or auctioned by June 2019, and by end-2020, is shown in Figure 1.2 below.

Figure 1.2: Mid-band spectrum assignments for mobile⁵ [Source: Analysys Mason, 2018]

Country	Current assignment (MHz)	Additional assignment expected by June 2019 (MHz)	Total assignment expected by June 2019 (MHz)	Total assignment expected by end-2020 (MHz)
Australia	100 [*]	125	225	225
Canada ⁶	-	-	-	200
China	-	-	-	500 ⁷
France ⁸	-	-	-	300
Germany ⁹	-	400 ¹⁰	400	400

⁴ Three has requested to shift its 3605–3689MHz license to 3600–3680MHz (thereby giving the MNO 100MHz of contiguous 5G-suitable spectrum). In August 2018 Ofcom concluded a consultation on Three's request, which it is expected to grant.

⁵ Spectrum assigned explicitly for FWA is excluded. However, spectrum intended/used for FWA but licensed under service-neutral terms is included.

⁶ Regional FWA licenses are assigned in the 3475–3625MHz range.

⁷ 100MHz of which (3300–3400MHz) for indoor use only.

⁸ Regional FWA licenses are assigned (and currently available) in the 3410–3460MHz range.

⁹ Each of the three MNOs in Germany currently owns 2x21MHz of spectrum in the 3410–3473/3510–3573MHz range on a nationwide basis. Licenses are technology neutral but limited to FWA use (i.e. not suitable for mobile) and expire in December 2021. Various regional FWA licenses have also been assigned in the 3473–3494MHz and 3573–3594MHz ranges, expiring between 2020 and 2022.

¹⁰ The entire 3.4–3.8GHz band will be assigned in early 2019, though not all the spectrum will be available until 2022 (when existing licenses expire).

Country	Current assignment (MHz)	Additional assignment expected by June 2019 (MHz)	Total assignment expected by June 2019 (MHz)	Total assignment expected by end-2020 (MHz)
Japan	200	500 ¹¹	700	700
Russia ¹²	N/d	-	-	N/d
Singapore ¹³	-	-	-	N/d
South Korea	280	-	280	280
Spain	360	-	360	360
Sweden ¹⁴	80*	-	80*	300 ¹⁵
UK ¹⁶	274	-	274	390
US	-	80 ¹⁷	80	150

* Further spectrum has also been licensed in certain regions (see Section 2 for details)

It should be emphasized that several other countries, not included in our benchmark, have either already assigned mid-band spectrum (e.g. Ireland¹⁸, Italy¹⁹) or committed to doing so by June 2019 (e.g. Hong Kong,²⁰ Austria²¹).

¹¹ Up to 500MHz to be released across the 3.6–4.2GHz and 4.4–4.9GHz ranges.

¹² It is likely that Russia will have assigned spectrum by end-2020, however we are not aware of official details published by the NRA.

¹³ It is likely that Singapore will have assigned spectrum by end-2020, however we are not aware of official details published by the NRA.

¹⁴ Regional FWA licenses are assigned in the 3410–3438MHz and 3510–3538MHz ranges; licenses expire in March 2023.

¹⁵ 3400–3700MHz to be assigned in late 2019 or early 2020; date of access depends on expiry of incumbent licenses. 3700–3800MHz to be assigned regionally from 2023.

¹⁶ Figures include Three's spectrum license at 3605–3689MHz but not Three's spectrum license at 3925–4009MHz since this license is for FWA only.

¹⁷ This is unlicensed spectrum.

¹⁸ Ireland conducted a regional auction of 350MHz in the 3.4–3.8GHz range in May 2017. In each of nine regions, there was one 25MHz 'A' lot available (3410–3435MHz) and sixty-five 5MHz 'B' lots available (3475–3800MHz). Five different operators won spectrum. See <https://www.comreg.ie/industry/radio-spectrum/spectrum-awards/3-6ghz-band-spectrum-award/>

¹⁹ Italy completed its multi-band 5G auction on October 2, 2018. Two 80MHz blocks and two 20MHz blocks were auctioned in the 3.6–3.8GHz range (with a spectrum cap of 100MHz per operator). Final results can be found here: <http://www.sviluppoeconomico.gov.it/index.php/it/per-i-media/comunicati-stampa/it/194-comunicati-stampa/2038666-gara-5g>

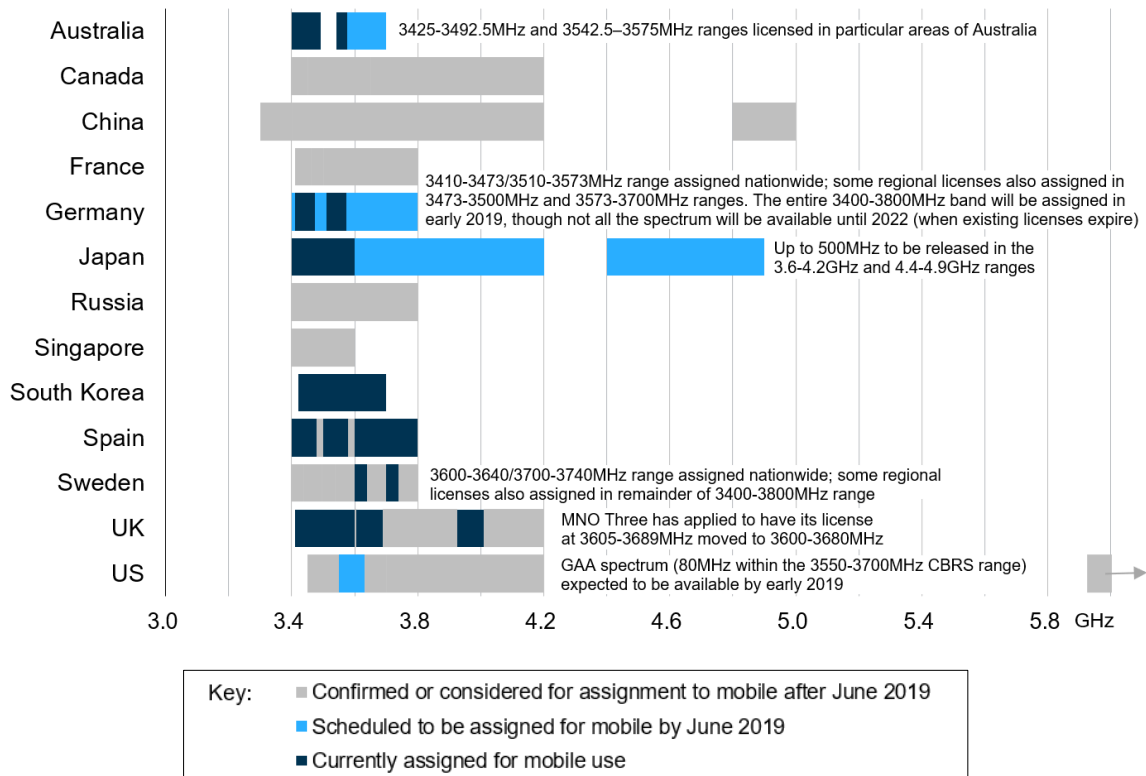
²⁰ On May 2, 2018, the CA published a consultation entitled "Arrangements for Assignment of the Spectrum in the 3.4–3.6GHz Band [i.e. 200MHz] for the Provision of Public Mobile Services and the Related Spectrum Utilisation Fee". The assignment is scheduled for H2-2019/ See: [https://www.ofca.gov.hk/filemanager/ofca/listarticle/en/upload/1688/OFCA%20Presentation%20\(12%20Jun%202018\)%20-%20Mr%20Chaucer%20Leung%20\(Eng\).pdf](https://www.ofca.gov.hk/filemanager/ofca/listarticle/en/upload/1688/OFCA%20Presentation%20(12%20Jun%202018)%20-%20Mr%20Chaucer%20Leung%20(Eng).pdf)

On August 28, 2018, the Secretary for Commerce and Economic Development (SCED) and the Communications Authority (CA) jointly launched a public consultation on the assignment of a total of 200MHz in the 3.3–3.4GHz band (for indoor use) and the 4.83–4.93GHz band (for nationwide use). The CA proposes that the spectrum is assigned via auction, planned for mid-2019. See https://www.coms-auth.hk/en/media_focus/press_releases/index_id_1762.html

²¹ On September 19, 2018, the RTR published a tender for the auction of 190MHz of spectrum in the 3410MHz–3600MHz range and 200MHz in the 3600MHz–3800MHz range, scheduled to take place in Q1 2019. See <https://www.rtr.at/en/pr/PI19092018TK> and <https://www.rtr.at/en/tk/5G-Auction-Tender-Documents>

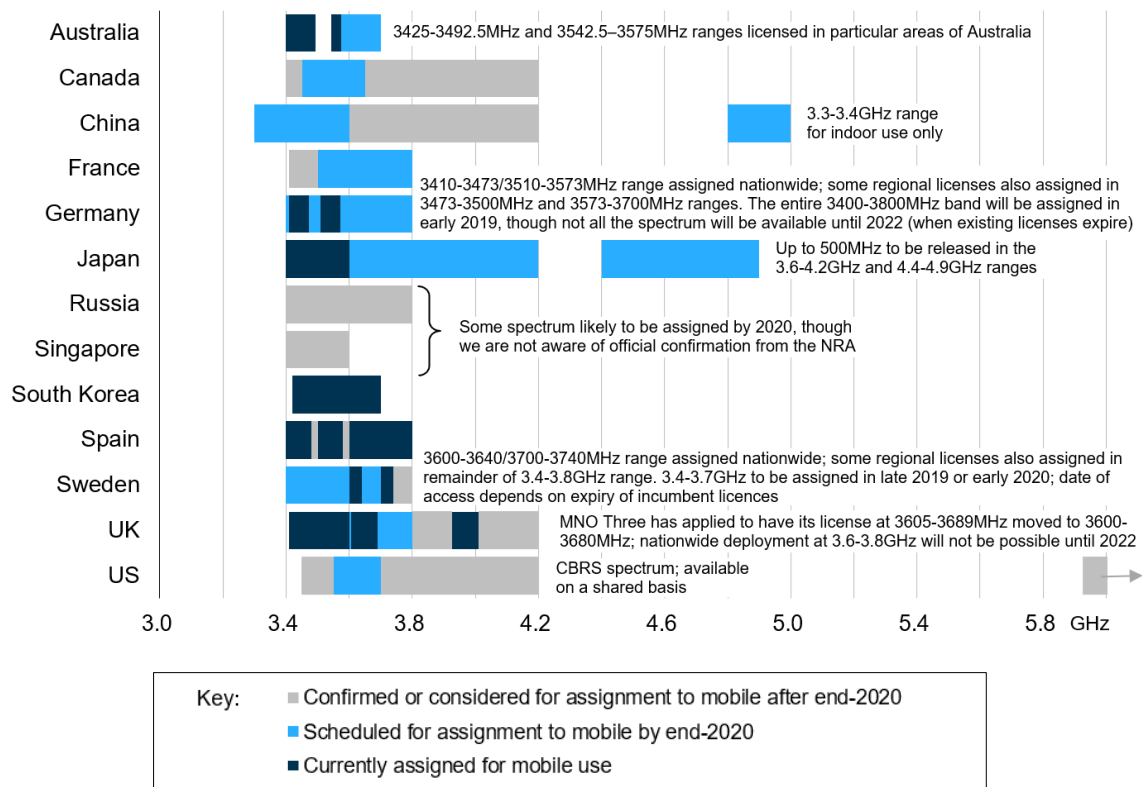
The mid-band spectrum ranges for each of our benchmark countries (highlighting the expected assignments by June 2019) are shown in Figure 1.3 below.

Figure 1.3: Mid-band spectrum for mobile use in benchmark countries [Source: Analysys Mason, 2018]



The mid-band spectrum ranges for each of our benchmark countries (highlighting the expected assignments by end-2020) are shown in Figure 1.3 below.

Figure 1.4: Mid-band spectrum for mobile use in benchmark countries [Source: Analysys Mason, 2018]



2 Country profiles

The following section provides details of the expected release of mid-band spectrum for 5G in each of our benchmark countries. For each country we provide:

- an overview of the mid-band 5G spectrum situation
- an update covering any relevant developments since the publication of the 5G readiness report in April 2018
- information regarding the expected date for mid-band spectrum release and auction details.

2.1 Australia

Current assignment: 3425–3492.5MHz and 3542.5–3575MHz ranges (a total of 100MHz) have been licensed in specific areas of Australia.

Future assignment: Australia plans to hold an auction of the 3575–3700MHz range in November 2018. Licenses will be available in a total of 14 regions.

Overview of mid-band 5G spectrum

MNOs Optus and Telstra own various regional blocks of spectrum in the 3425–3492.5MHz and 3542.5–3575MHz ranges.²² The spectrum is suitable for LTE or 5G use.

In October 2016, the Australian Communications and Media Authority (ACMA) released²³ a discussion paper on the future use of the 3575–3700MHz range. After various consultations and decisions,²⁴ ACMA published²⁵ its final auction rules on August 6, 2018. A total of 125MHz (the

²² In April 2000, the relevant government minister made the Radiocommunications (Spectrum Reallocation) Declaration 2000 (the 3.4GHz reallocation declaration) that allowed the introduction of spectrum licensing in the 3425–3492.5MHz and 3542.5–3575MHz ranges (the 3.4GHz band) in particular areas of Australia.

The majority of spectrum licenses were allocated at auction in October 2000. Of the available 482 lots, 22 went unsold. These 22 lots were re-offered in 2002; however, they again remained unsold. These lots were offered for assignment on a quarterly basis from 2004 to 2008.

The original spectrum licenses reached their expiry in December 2015. The majority of spectrum licenses were re-issued to the same licensees, with a new expiry date of December 13, 2030.

In December 2017, ACMA's 'residual auction' made available 3.4GHz spectrum, consisting of a combination of the spectrum that was not reissued in 2015 and unsold lots from the preceding 3.4GHz assignments.

See https://www.acma.gov.au/-/media/Spectrum-Licensing-Policy/Information/Multiband-auction/Multiband-residual-lots_Auction-guide-pdf.pdf

See Table 3 of ACMA's December 2016 consultation: https://www.acma.gov.au/theACMA/spectrum-licensing-2ghz-and-3_4ghz

Current holdings in the 3.4GHz band are shown in Table 9 of the August 2018 auction guide (see below)

²³ See https://www.acma.gov.au/theACMA/future-use-of-the-1_5-ghz-and-3_6-ghz-bands-2

²⁴ An index of relevant documentation is available at <https://www.acma.gov.au/Industry/Spectrum/Spectrum-projects/3-6-GHz-band>

²⁵ See <https://www.acma.gov.au/theACMA/applicant-information-package-3-6-ghz-band-auction>

entire 3575–3700MHz range) is scheduled to be auctioned in late November 2018, with licenses being made available on a regional basis in 14 different areas; further details are provided below.

Some Australian operators have conducted 5G trials using mid-band spectrum. For example:

- On April 10, 2018, NBN Co. announced²⁶ plans to conduct 5G FWA trials in Melbourne using 100MHz of spectrum in the 3.5GHz band.
- On July 16, 2018, Telstra, Ericsson, and Intel announced²⁷ that they had conducted an end-to-end 5G commercial network data call over licensed 3.5GHz spectrum.

Developments since 5G readiness report

Not applicable (country not included in 5G readiness report).

Expected date for mid-band spectrum release and auction details

Figure 2.1: Details of 5G mid-band spectrum assignment in Australia [Source: ACMA, 2018]

Category	Details
Spectrum to be released	125MHz (3575–3700MHz).
Expected date	Late November 2018. The August 2018 auction guide outlines an indicative timeline with an application deadline of August 31, 2018, and estimated auction commencement of late November 2018.
Lot sizes	25 unpaired 5MHz blocks per region. ²⁸
Geographic area	Spectrum will be auctioned in 14 regions: 6 'metropolitan areas' and 8 'regional areas'. Details of these regions are provided below.
License length	Spectrum licenses in all regions will commence on March 30, 2020 (i.e. the end of the two-year reallocation period for metropolitan areas – see below). Licensees are able to apply for 'early access' licenses in the intervening period in any unencumbered areas. The expiry date will be December 13, 2030, to align with the expiry date for current spectrum licenses in the adjacent 3.4GHz band. The license duration will therefore be approximately 10 years, 8 months.

²⁶ See <https://www.itnews.com.au/news/nbn-co-to-run-5g-tests-in-melbourne-488643>

²⁷ See <https://www.ericsson.com/es/en/press-releases/2018/7/ericsson-telstra-and-intel-achieve-first-end-to-end-multi-vendor-5g-commercial-network-data-call-over-licensed-3.5ghz-spectrum>

²⁸ In Perth, the spectrum will be configured into two categories, due to usage of the lower 16 lots (80MHz) by an existing 3.6GHz licensee during the five-year reallocation period, that is, until March 30, 2023: (1) 16×5MHz lots (3575–3655MHz) and (2) 9×5MHz lots (3655–3700MHz). See August 2018 auction guide for details.

2.2 Canada

Current assignment: no mid-band spectrum is currently assigned for mobile.

Future assignment: an auction of the 3450–3650MHz range is expected in late 2020. The geographical licensing arrangements have not yet been specified, but radio spectrum has always been licensed on a regional basis in Canada.

Overview of mid-band 5G spectrum

The 3475–3650MHz had been auctioned on a regional basis for FWA use.²⁹

In October 2017, Innovation, Science, and Economic Development Canada (ISED) launched its ‘Spectrum Outlook’ consultation,³⁰ intended to ‘inform ISED’s overall approach and planning related to potential spectrum releases in the 2018 to 2022 timeframe’. Recognizing the importance of mid-band spectrum for 5G, the consultation resolves to expand the band for review (beyond the original 3.4–3.8GHz band) to include the full 3.4–4.2GHz range.

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- 5G trials using mid-band spectrum have continued:
 - On May 3, 2018, Shaw announced³¹ the successful completion of 5G technical trials involving the 3.5GHz band.
 - On July 25, 2018, Xplornet (a rural FWA provider) announced³² a CAD36 million (USD28 million) project to boost internet speeds in Ontario. The project involves deploying small cells in the 3.5GHz band.
- In June 2018, ISED published³³ its ‘Spectrum Outlook 2018 to 2022’:
 - The document states that ISED “is anticipating [that] 3500MHz spectrum will be released for flexible use in late 2020”.

²⁹ See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf09434.html and <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09311.html>

³⁰ See <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11333.html#s6.1>. Comments on the consultation were due by January 9, 2018, and replies to the comments were due by February 8, 2018.

³¹ See <http://newsroom.shaw.ca/materialDetail.aspx?MaterialID=6442452113>

³² See <https://www.xplornet.com/about/news/xplornet-bringing-faster-internet-speeds-and-5g-ready-services-to-eastern-ontario/>

³³ See <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11403.html>

- All comments which were submitted as part of the consultation have been published.³⁴
- ISED also published³⁵ a new consultation on the 3450–3650MHz band. The consultation:
 - Proposes revisions to the 3450–3650MHz band to accommodate flexible use for fixed and mobile services.
 - Includes a decision to issue a moratorium on new applications for first-come first-served spectrum licensing in the 3475–3650MHz band.
 - Seeks comments on a number of issues related to the 3450–3650MHz band (e.g. provision for incumbents, transition of incumbents, co-existence issues, etc.). The consultation also seeks preliminary comments on the 3400–3450MHz and 3650–4200MHz bands.

Expected date for mid-band spectrum release and auction details

Figure 2.2: Details of 5G mid-band spectrum assignment in Canada [Source: ISED, 2018]

Category	Details
Spectrum to be released	200MHz (3450–3650MHz) scheduled for assignment 600MHz (3400–3450MHz, 3650–4200MHz) for initial consultation
Expected date	3450–3650MHz, late 2020 3400–3450MHz and 3650–4200MHz, no date provided
Lot sizes	20 unpaired 10MHz blocks
Geographic area	Details of the regions have not yet been provided, however we note that Tier 4 service areas (see below) were used ³⁶ by ISED for the 3475–3650MHz auction in 2004 Four ³⁷ types of regions ('service areas') have been defined by ISED for spectrum auctions in Canada: <ul style="list-style-type: none"> • Tier 1 – nationwide • Tier 2 – 14 provincial and large regional service areas³⁸ (subdivisions of Tier 1) • Tier 3 – 59 smaller regional service areas (subdivisions of Tier 2) • Tier 4 – 172 localized service areas³⁹ (subdivisions of Tier 3)

³⁴ See <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11377.html> and <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11385.html>

³⁵ See <http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf11401.html>

³⁶ See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf05472.html

³⁷ An additional group of service areas was developed to accommodate the transition of non-auctioned Cellular and Personal Communications Services (PCS) licenses from apparatus-based licenses to spectrum licenses and generally corresponding to the wireline services areas of the telephone companies operating in Quebec, Ontario and British Columbia. These service areas are known as Local Telephone Service Areas (TEL).

³⁸ Two additional Tier 2 areas, created for the Province of Alberta and the Province of Saskatchewan, generally adhere to the Alberta-Saskatchewan interprovincial border and maintain the territorial integrity of each province. These two Tier 2 service areas do not have associated Tier 3 and Tier 4 service areas. These were created for the 700MHz auction held in 2014.

³⁹ The Tier 4 localized service area boundaries were initially developed using contiguous groupings of Statistics Canada's 1996 census subdivisions. During development, service area borderlines were placed through lesser populated and more remote areas, wherever possible, in order to minimize potential interference problems.

Category	Details
	All previous spectrum auctions in Canada have been regional (i.e. used Tier 2, 3, or 4 service areas). As of 2011, the population of Canada was 33.5 million. The average population of Tier 2, 3, and 4 service areas in 2011 was therefore 2.1 million, 567,000, and 195,000 respectively. Full details are available ⁴⁰ from the ISED website.
License length	N/d

⁴⁰ See http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/h_sf01627.html

2.3 China

Current assignment: no mid-band spectrum is currently assigned for mobile.

Future assignment: 500MHz (3.3–3.6GHz and 4.8–5.0GHz) will be released in China. Details have not been specified, but assignment is expected in 2019/20 to meet commercial launch timelines. We are not aware of plans indicating a geographic licensing approach; we note that current mobile licenses are nationwide and hence we assume a similar approach will apply here.

Overview of mid-band 5G spectrum

A presentation released⁴¹ in November 2016 states that ‘to enable business success of 5G eMBB [enhanced mobile broadband] deployment’, the Ministry of Industry and Information Technology (MIIT) intend to make more than 100MHz of additional mid-band spectrum available per operator.

In June 2017, MIIT released⁴² a consultation on using spectrum in the 3.3–3.6GHz and 4.8–5.0GHz ranges for 5G technologies, with the 3.3–3.4GHz range limited to indoor use. These ranges were confirmed in a subsequent announcement⁴³ in November 2017, with MIIT adding that it would not approve any further fixed or satellite licenses in these bands. Reports further stated⁴⁴ that China is likely to assign the 3.6–4.2GHz range to 5G in the future.

We are not aware of an official timeline for the spectrum release, however we understand that license awards are expected to take place in 2019/20, in line with announced commercial launch timelines.⁴⁵ We are not aware of any public documentation indicating a geographic licensing approach; current mobile licenses are nationwide.

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- 5G trials using mid-band spectrum have continued.

⁴¹ See https://5g-ppp.eu/wp-content/uploads/2016/11/03_9-Nov_Session-2_Chang-Ruoting-1.pdf. The presentation also references the 4.4–4.5GHz range for 5G. See also ‘Radio Spectrum Management in China’, Bureau of Radio Regulation, MIIT, September 11, 2017.

⁴² See <https://www.fiercewireless.com/wireless/china-reserves-spectrum-for-5g-says-more-low-band-frequencies-coming-report>. We understand that MIIT also sought comment on non-exclusive use of the 24.75-27.5GHz and 37-42.5GHz bands in June 2017; see <https://www.qualcomm.com/media/documents/spectrum-4g-and-5g>

⁴³ See <http://www.miit.gov.cn/n1146295/n1652858/n1652930/n3757020/c5907905/content.html>, <http://www.miit.gov.cn/n1146290/n4388791/c5906943/content.html>, http://www.caict.ac.cn/xwdt/hyxxw/201711/t20171115_2214806.htm and <http://www.srrc.org.cn/en/news3434.aspx>

⁴⁴ See <http://www.atimes.com/article/china-reserves-spectrum-5g-services/>

⁴⁵ See <http://www.scmp.com/tech/china-tech/article/2075179/china-mobile-targets-steady-build-out-5g-infrastructure-2018>. Note that this source also references spectrum allocation in the 4.5GHz band.

- On July 10, 2018, China Mobile, Huawei, and Intel announced⁴⁶ that they had completed “interoperability and development testing (IODT)” of the 5G New Radio (NR) standard using C-band spectrum.
- On July 18, 2018, the China Academy of Information and Communications Technology (CAICT) reported⁴⁷ that most of its members had begun pre-commercial 5G testing in the 3.3–3.6GHz band.⁴⁸
- On June 22, 2018, MIIT confirmed⁴⁹ that policies would be rolled out to “accelerate the commercialization of 5G” and ensure the timely assignment of 5G spectrum licenses. MIIT said that 5G license would “most likely [be issued] between the second half of 2019 and the first half of 2020.”

Expected date for mid-band spectrum release and auction details

Figure 2.3: Details of 5G mid-band spectrum assignment in China [Source: MIIT, CAICT, 2018]

Category	Details
Spectrum to be released	500MHz (3.3–3.6GHz and 4.8–5.0GHz). Reports indicate that China is likely to assign the 3.6–4.2GHz range to 5G in the future.
Expected date	No official auction date published, however a date of 2019/20 is likely for initial spectrum release, in line with announced commercial launch timelines.
Lot sizes	No specific consultation/details released. (3.3–3.4GHz range to be restricted to indoor use).
Geographic area	
License length	

⁴⁶ See <https://www.huawei.com/en/press-events/news/2018/7/ChinaMobile-Intel-Huawei-5G-NR-IODT>

⁴⁷ See http://www.caict.ac.cn/email/hydt/201807/t20180718_180465.html

⁴⁸ We understand the “3.5GHz band” (referred to by the CAICT) to mean the 3.3-3.6GHz range

⁴⁹ See <http://www.chinadaily.com.cn/a/201806/22/WS5b2c2e08a3103349141dda52.html>

2.4 France

Current assignment: no mid-band spectrum is currently assigned for mobile use.

Future assignment: 300MHz of contiguous C-band spectrum is planned to be released for 5G by 2020, and 340MHz (3460–3800MHz) by 2026. Further details have not been specified, though if using a similar approach to previous mobile spectrum awards in France, we consider it likely that spectrum will be licensed on a nationwide basis, although current FWA assignments are regional.

Overview of mid-band 5G spectrum

The French regulator, Autorité de Régulation des Communications Electroniques et des Postes (ARCEP), ran a public consultation⁵⁰ on new spectrum for 5G from January to March 2017. On June 22, 2017, ARCEP published responses to the consultation⁵¹ and preliminary decisions⁵² regarding the future allocation of spectrum. The regulator confirmed its intention to allocate:

- 40MHz at 3420–3460MHz⁵³ to FWA in specific geographical areas^{54,55} (with an additional 10MHz at 3410–3420MHz in certain areas, depending on coexistence constraints). This spectrum is technology neutral, though it is expected to be used for LTE.
- 300MHz of contiguous C-band spectrum for 5G by 2020, and 340MHz⁵⁶ (3460–3800MHz) by 2026.

ARCEP's announcement also encouraged industry players to conduct 5G pilots. It nominated 80MHz (3600–3680MHz) of spectrum for that purpose, and identified six cities where pilot projects could be carried out (Lyon, Nantes, Lille, Le Havre, Saint-Etienne and Grenoble).⁵⁷ On January 16,

⁵⁰ See https://www.arcep.fr/uploads/tx_gspublication/consult-frequences-terr-entreprises-5G-innov.pdf

⁵¹ See https://www.arcep.fr/uploads/tx_gspublication/synth-consult-frequences-5g-entreprises-juin2017.pdf

⁵² See [https://www.arcep.fr/index.php?id=8571&no_cache=0&L=0&no_cache=0&tx_gsactualite_pi1\[uid\]=2063&tx_gsactualite_pi1\[annee\]=&tx_gsactualite_pi1\[theme\]=&tx_gsactualite_pi1\[motscle\]=&tx_gsactualite_pi1\[backID\]=26&cHash=0b883993e79c11e684d43c456e864432](https://www.arcep.fr/index.php?id=8571&no_cache=0&L=0&no_cache=0&tx_gsactualite_pi1[uid]=2063&tx_gsactualite_pi1[annee]=&tx_gsactualite_pi1[theme]=&tx_gsactualite_pi1[motscle]=&tx_gsactualite_pi1[backID]=26&cHash=0b883993e79c11e684d43c456e864432)

⁵³ The entire 3420–3460MHz range is not available in all departments. See <https://www.arcep.fr/index.php?id=13756>.

⁵⁴ I.e. areas not covered by FTTH deployments (the purpose of assigning the spectrum for FWA is to boost high-speed connectivity in France). Operators can apply for a license within a particular department, but coverage is only permitted in areas not covered by FTTH. For example, in the Seine-et-Marne department, operator Sem@for77 is licensed to cover 142 communes representing 33% of the total area of the department.

See https://www.arcep.fr/fileadmin/reprise/dossiers/thd-radio/FichesSynthese/Fiche_77__Semafor77.pdf

⁵⁵ A consultation on FWA spectrum was published on July 13, 2017, and a document outlining the assignment approach on December 11, 2017. As of March 2018, players are able to request regional FWA licenses from the regulator. See: https://www.arcep.fr/uploads/tx_gspublication/consult-attribution-THD_radio-juil2017.pdf
https://www.arcep.fr/uploads/tx_gspublication/modalites_attribution_THD_radio-dec2017.pdf
<https://www.arcep.fr/?id=7108>

⁵⁶ 390MHz in areas where 3410–3460MHz has not been assigned for FWA. ARCEP will reorganize the current 3.4–3.6GHz users toward the bottom of the band to achieve this. ARCEP states that it will contact existing licensees in the 3.4–3.6GHz band 'without delay', aiming to complete the required reorganization by YE 2017.

⁵⁷ The announcement notes that 3.4–3.8GHz spectrum is already available for 5G pilots in the six cities mentioned above, but that those cities are 'not exhaustive and may change'. The interview with ARCEP's president (link below) states that there are nine pilot cities – Bordeaux, Douai and Montpellier, in addition to the six mentioned above.

2018, ARCEP formally opened a ‘5G pilot window’.⁵⁸ The first pilot licenses were issued by ARCEP (in the 3.4–3.8GHz band) to Orange and Bouygues in February 2018.⁵⁹

ARCEP has not indicated what geographic licensing approach it will adopt for the 3.4–3.8GHz band. However, we consider it likely that spectrum will (predominately) be awarded on a nationwide basis (as has been the case historically for mobile licenses in France).

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- 5G trials using mid-band spectrum have continued:
 - On May 7, 2018, Nokia and SFR announced⁶⁰ the successful completion of a 5G NR call using 3.4–3.8GHz spectrum.⁶¹
 - On May 24, 2018, SFR reported⁶² achieving bitrates of 1.6Gbit/s in a 5G NR trial using the 3.4–3.8GHz band⁶³ and massive MIMO; equipment was provided by Huawei.
 - On July 3, 2018, Bouygues reported⁶⁴ it had conducted 5G trials in Bordeaux (using the 3645–3745MHz trial license issued by ARCEP in February 2018).
 - On July 4, 2018, SFR and Orange made separate announcements⁶⁵ stating that ARCEP had approved the expansion of their mid-band 5G tests to additional locations.
 - On July 16, 2018, ARCEP published a 5G roadmap (see below), which states that 22 trial licenses have been granted in the 3.4–3.8GHz band.

⁵⁸ See [https://www.arcep.fr/index.php?id=8571&no_cache=0&tx_gsactualite_pi1\[uid\]=2119&tx_gsactualite_pi1\[annee\]=&tx_gsactualite_pi1\[theme\]=&tx_gsactualite_pi1\[motscle\]=&tx_gsactualite_pi1\[backID\]=26&cHash=7a322a2c0239bb9c53b8f95be9d7e7e2](https://www.arcep.fr/index.php?id=8571&no_cache=0&tx_gsactualite_pi1[uid]=2119&tx_gsactualite_pi1[annee]=&tx_gsactualite_pi1[theme]=&tx_gsactualite_pi1[motscle]=&tx_gsactualite_pi1[backID]=26&cHash=7a322a2c0239bb9c53b8f95be9d7e7e2)

⁵⁹ See <https://www.telegeography.com/products/commsupdate/articles/2018/03/02/arcep-issues-two-5g-trial-licences-assigns-3-5ghz-spectrum-in-saint-martin>

⁶⁰ See https://www.nokia.com/en_int/news/releases/2018/05/07/nokia-and-sfr-first-in-france-to-conduct-a-5g-new-radio-call-using-35-ghz-spectrum

⁶¹ Details of the exact spectrum range have not been published in the public domain.

⁶² See <https://www.telegeography.com/products/commsupdate/articles/2018/05/24/sfr-achieves-1-6gbps-speeds-in-a-5g-trial/index.html>

⁶³ Details of the exact spectrum range have not been published in the public domain.

⁶⁴ See <https://www.telecompaper.com/news/bouygues-telecom-reaches-speed-of-23-gbps-in-live-5g-test-in-bordeaux--1251173>

⁶⁵ See <https://www.mobileworldlive.com/featured-content/top-three/operators-tussle-for-france-5g-leadership/>

- On May 25, 2018, ARCEP announced⁶⁶ that Covage subsidiary Sem@for77 became the first operator to be allocated spectrum in the 3410–3460MHz band for regional FWA (in the Seine-et-Marne region).
- On June 9, 2018, ARCEP published⁶⁷ an official notice regarding the release schedule for the 3.4–3.6GHz band. The notice states that the band will be progressively vacated (by department) of incumbent wireless backhaul links (used by the Ministry of Internal Affairs' PPDR network) by March 1, 2020, at the latest.
- On July 16, 2018, ARCEP published a 5G roadmap.⁶⁸ The roadmap outlines a schedule in which a consultation on spectrum assignment is held in October 2018, and a call for applications in mid-2019.

Expected date for mid-band spectrum release and auction details

Figure 2.4: Details of 5G mid-band spectrum assignment in France [Source: ARCEP, 2018]

Category	Details
Spectrum to be released	300MHz of contiguous spectrum by 2020, and 340MHz (3460–3800MHz) by 2026 (390MHz in areas where 3410–3460MHz has not been allocated for FWA)
Expected date	Assignment likely in 2019/20
Lot sizes	
Geographic area	No specific consultation/details released
License length	

⁶⁶ See <https://www.arcep.fr/index.php?id=13756>

⁶⁷ See https://www.arcep.fr/uploads/tx_gsavis/18-0538.pdf

⁶⁸ See https://www.arcep.fr/index.php?id=8571&no_cache=1&no_cache=1&tx_gsactualite_pi1%5Buid%5D=2161&tx_gsactualite_pi1%5Bannee%5D=&tx_gsactualite_pi1%5Btheme%5D=&tx_gsactualite_pi1%5Bmotscle%5D=&tx_gsactualite_pi1%5BbackID%5D=26&cHash=d2b75603f42a5369ce848acb5c207816&L=1

2.5 Germany

Current assignment: no mid-band spectrum is currently assigned for mobile use.

Future assignment: 300MHz (3.4–3.7GHz) to be awarded nationwide and 100MHz (3.7–3.8GHz) to be awarded on a regional/local basis in early 2019.

Overview of mid-band 5G spectrum

Each of the three MNOs in Germany currently owns 2×21MHz of spectrum in the 3410–3473/3510–3573MHz range on a nationwide basis;^{69,70} licenses are technology neutral but limited to FWA use (i.e. not suitable for mobile) and expire in December 2021. Various regional FWA licenses have also been assigned in the 3473–3500MHz and 3573–3700MHz ranges, expiring between 2020 and 2022.⁷¹

In its ‘framework’ document issued^{72,73} on June 27, 2017, German regulator Bundesnetzagentur (BNetzA) identified 400MHz in the 3.4–3.8GHz range for 5G.⁷⁴ On January 31, 2018, BNetzA published a draft decision,⁷⁵ confirming its intention to auction 300MHz in the 3400–3700MHz range (for nationwide use), and 100MHz in the 3700–3800MHz range on a regional/local basis.

⁶⁹ Four 2×21MHz lots (3410–3494/3510–3594MHz) were made available for FWA in each of 28 regions at an auction in 2006. The first lot was won by Clearwire (subsequently WiMee-Connect) in all regions. The second lot was won by Inquam (subsequently WiMee Plus) in all regions. Telefónica subsequently acquired both operators. The third lot was won by DBD in all regions. We understand that T-Mobile subsequently acquired DBD. See https://www.bundesnetzagentur.de/EN/Areas/Telecommunications/Companies/FrequencyManagement/BroadbandWirelessAccess/broadbandwirelessaccess_node.html

We note that BNetzA’s recent consultation states that one assignment holder holds licenses in the third lot in 27 out of the 28 regions (as well as the fourth lot in the remaining region).

⁷⁰ See https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/Mobilfunk/DrahtloserNetzzugang/Projekt2016/Frequenzen700bis1800_pdf.pdf?__blob=publicationFile&v=3.

On February 21, 2018, Telefonica announced that it had sold half of its spectrum in the 3410–3452/3510–3552MHz range (i.e. 2×21MHz) to Vodafone. See <https://www.telefonica.de/fixed/news/6094/more-high-speed-for-germany-vodafone-and-telefonica-deutschland-to-cooperate-over-fast-fibre-optic-connections-for-mobile-networks.html>

⁷¹ These licenses were assigned on an individual basis. There are currently around 80 regional FWA assignments; licensees are generally SMEs. The latest expiry date of these licenses is December 2022.

⁷² See https://www.bundesnetzagentur.de/SharedDocs/Pressemitteilungen/DE/2017/27062017_Frequenzen.html?nn=26577. The ‘5G Strategy in Germany’ paper was published in September but reiterates previous BNetzA documentation.

⁷³ This follows the ‘Frequency Compass’ and ‘Points of Orientation’ documents published in 2016; see https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/Mobilfunknetze/mobilfunknetze-node.html

⁷⁴ Both the 2.1GHz and C-band spectrum will be awarded technology-neutral, with licenses expiring on December 31, 2040.

⁷⁵ See https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/Mobilfunknetze/mobilfunknetze-node.html

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- 5G trials using mid-band spectrum have continued. For example, on May 3, 2018, Deutsche Telekom announced⁷⁶ that it was operating 5G antennas in Berlin using 3.7GHz spectrum.⁷⁷
- BNetzA published⁷⁸ responses to its 5G consultation and issued⁷⁹ an ‘auction decisions’ document.
- On September 17, 2018, BNetzA published⁸⁰ draft rules for the 3.4–3.7GHz auction. The proposed rules will be reviewed by the regulator’s Advisory Council on September 24, 2018; a final decision is scheduled to be made in November 2018, with the auction planned for Q1 2019.
- BNetzA published⁸¹ a separate consultation on its proposed approach for the assignment of the 3700–3800MHz range. The proposed licensing arrangement is as follows:
 - Individual assignments; no right to national roaming on national networks in the 3400–3700MHz range.
 - To be eligible for a license, and applicant cannot hold nationwide licenses in the 700MHz or 3.4–3.7GHz bands.
 - For outdoor use, up to 80MHz (3700–3780MHz) will be available for regional use, and 20MHz (3780–3800MHz) for local use.
 - For (local) indoor use, up to 100MHz is to be made available using a simplified assignment procedure. Local indoor use is to co-exist with regional outdoor use.
- A number of industrial manufacturing companies (including Daimler, Volkswagen, Audi, BASF, and Siemens) have signaled interest⁸² in obtaining local or regional licenses for 5G.

⁷⁶ See <https://www.telekom.com/en/media/media-information/archive/5g-rollout-in-germany-523636>

⁷⁷ Details of the exact spectrum range have not been published in the public domain.

⁷⁸ See https://www.bundesnetzagentur.de/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/Mobilfunknetze/mobilfunknetze-node.html

⁷⁹ Ibid.

⁸⁰ See https://www.bundesnetzagentur.de/DE/Allgemeines/Presse/Reden/5GVergabebedingungen.pdf?__blob=publicationFile&v=2

⁸¹ See https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/RegionaleNetze/Entwurf%20Antragsverfahren%203,7%20-%203,8%20GHz.pdf?__blob=publicationFile&v=2

⁸² On May 18, 2018, Telecompaper paper (citing business publication WirtschaftsWoche) reported that fifteen industrial manufacturing companies had signaled an interest in obtaining licenses for 5G. “The interested companies... want to use 5G in their production plants to connect machines”.

*Expected date for mid-band spectrum release and auction details**Figure 2.5: Details of 5G mid-band spectrum assignment in Germany [Source: BNetzA, 2018]*

Category	Details
Spectrum to be released	300MHz (3.4–3.7GHz) to be auctioned for nationwide use 100MHz (3.7–3.8GHz) awarded on an individual basis for regional/local use ⁸³
Expected date	Early 2019
Lot sizes	Thirty unpaired 10MHz blocks (for nationwide use)
Geographic area	National and regional/local (see above) Details of the region size for licenses in the 3.7–3.8GHz range have not been provided; all previous spectrum assignments for mobile use have been on a nationwide basis. We note that in the previous ⁸⁴ 3.6–3.8GHz (BWA) auction in 2006, Germany was divided into 28 regions ⁸⁵
License length	3.4–3.7GHz spectrum will be assigned until December 31, 2040, at the latest. Most of 3.4–3.7GHz spectrum will become available in 2022 when current licenses expire 3.7–3.8GHz licenses will be valid for up to 10 years (not exceeding December 31, 2040)

⁸³ Any guard bands necessary between the nationwide and regional networks are to be implemented by the regional network operators. Therefore, the full 100MHz of spectrum will not always be available for regional assignments.

⁸⁴ See https://www.bundesnetzagentur.de/SharedDocs/Downloads/DE/Sachgebiete/Telekommunikation/Unternehmen_Institutionen/Frequenzen/OffentlicheNetze/Mobilfunk/DrahtloserNetzzugang/Mobilfunk2020/20180514_5GAuktion_EntscheidungI&II.pdf?__blob=publicationFile&v=2

⁸⁵ For further details, see https://www.bundesnetzagentur.de/EN/Areas/Telecommunications/Companies/FrequencyManagement/BroadbandWirelessAccess/broadbandwirelessaccess_node.html

2.6 Japan

Current assignment: 3.4–3.6GHz range assigned to MNOs on a national basis.

Future assignment: up to 500MHz within the 3.6–4.2GHz and 4.4–4.9GHz ranges to be released by March 2019. Further details have not been specified, though we consider it likely that spectrum will be licensed on a nationwide basis based on historical mobile licenses.

Overview of mid-band 5G spectrum

Each of the three MNOs in Japan were licensed to use 40MHz of spectrum in the 3.48–3.6GHz range in 2014 on a national basis.⁸⁶ The exact status of the usage of this spectrum is unclear, though we understand that licenses permit mobile LTE services to be offered. We understand that the 3.4–3.48GHz range was assigned to NTT DOCOMO and Softbank in April 2018 (see below).

The Ministry of Internal Affairs and Communications (MIC) published a 5G roadmap⁸⁷ on June 28, 2016, which outlines its aim ‘to realize 5G in 2020’ in time for the Tokyo Olympics. MIC subsequently published a 5G consultation⁸⁸ in July 2017, providing further details on the expected bands and timeline for assignments. MIC published an updated roadmap⁸⁹ on June 28, 2018. We are not aware of any public documentation indicating a geographic licensing approach; current mobile licenses are nationwide.

MIC is proposing to authorize 5G use in several bands,⁹⁰ including 3.6–4.2GHz and 4.4–4.9GHz. MIC aims to allocate these to mobile by March 2019, sharing with existing systems. Given sharing constraints, a maximum of 500MHz is expected to be allocated to mobile.

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- 5G trials using mid-band spectrum have continued. For example:

⁸⁶ See <http://www.gtigroup.org/news/ind/2014-12-25/5208.html>

⁸⁷ See https://www.gsma.com/spectrum/wp-content/uploads/2016/08/MIC_Spectrum-for-5G-MIC-Kuniko-OGAWA.pdf. MIC has since published a number of similar iterations of the presentation; see https://5g-ppp.eu/wp-content/uploads/2016/11/Opening-1_Yuji-Nakamura.pdf (November 9, 2016), https://5g-ppp.eu/wp-content/uploads/2016/11/04_9-Nov_Session-2_Yuji-Nakamura.pdf (November 9, 2016) and http://5gmf.jp/wp/wp-content/uploads/2017/06/02-Opening-Session-1_Isao-Sugino.pdf (May 24, 2017).

⁸⁸ ‘Draft report from New generation mobile communication system committee’, July 28, 2017 (in Japanese); see http://www.soumu.go.jp/main_content/000499652.pdf. See also section 9 of the 5GMF white paper version 1.1.

⁸⁹ See https://www.gsma.com/spectrum/wp-content/uploads/2018/07/Kohei-Sato-MWC-Shanghai_MIC-Japan-1.pdf

⁹⁰ The June 2016 roadmap indicated that MIC also aimed to share the 5.15–5.35GHz band with 5G; however, this band is not mentioned in subsequent documentation.

- On May 31, 2018, NTT DOCOMO and NEC reported⁹¹ trials in the 4.4–4.9GHz band.⁹²
 - On August 17, 2018, NTT DOCOMO and Huawei announced⁹³ that they had conducted a wide-scale 5G field-trial using the C-band.
 - The roadmap published⁹⁴ by MIC in June 2018 provides details of a number of ongoing 5G field-trials in Japan using mid-band spectrum.
- Progress toward 5G commercialization has continued. For example, on June 29, 2018, NTT DOCOMO announced⁹⁵ plans to launch 5G technology ‘within 800 days.’
 - On April 6, 2018, MIC approved⁹⁶ a bid from internet retailer Rakuten to become Japan’s fourth MNO, assigning the company 1.7GHz (1730–1750/1825–1845MHz) spectrum.⁹⁷ On May 10, 2018, Rakuten published⁹⁸ its Q1 financial results for FY2018, indicating its intention to launch services in October 2019 using the 1.7GHz band.
 - We understand that Rakuten had previously submitted⁹⁹ an application to MIC for 4G suitable spectrum in both the 1.7GHz and 3.4GHz bands (3400–3480MHz), however the 3.4GHz spectrum was awarded¹⁰⁰ to Softbank (3400–3440MHz) and NTT DOCOMO (3440–3480MHz).

Expected date for mid-band spectrum release and auction details

Figure 2.6: Details of 5G mid-band spectrum assignment in Japan [Source: MIC, 2018]

Category	Details
Spectrum to be released	Up to 500MHz within the 3.6–4.2GHz and 4.4–4.9GHz ranges
Expected date	March 2019
Lot sizes	

⁹¹ See <https://www.rcrwireless.com/20180531/5g/nec-ntt-docomo-carry-out-5g-trial-multiple-base-stations-japan-tag23>

⁹² We understand the “4.5GHz band” (referred to in the report) to mean the 4.4–4.9GHz range.

⁹³ See <https://www.telegeography.com/products/commsupdate/articles/2018/08/17/huawei-and-ntt-docomo-carry-out-large-scale-5g-field-trial-in-japan/>

⁹⁴ See https://www.gsma.com/spectrum/wp-content/uploads/2018/07/Kohei-Satoh-MWC-Shanghai_MIC-Japan-1.pdf

⁹⁵ See <https://www.mobileworldlive.com/featured-content/top-three/docomo-starts-countdown-to-5g/>

⁹⁶ See <https://www.telegeography.com/products/commsupdate/articles/2018/04/09/mic-advisory-panel-gives-green-light-to-rakutens-mobile-bid/>

⁹⁷ A consultation released by MIC in December 2017 proposed draft rules for releasing this band. See http://www.soumu.go.jp/main_content/000517622.pdf. We understand that MIC also allocated the 1710–1750/1805–1825MHz range to KDDI, and the 1765–1785/1860–1880MHz range (which was previously shared) to NTT DOCOMO in the Tokyo, Nagoya, and Osaka areas.

⁹⁸ See https://global.rakuten.com/corp/investors/assets/doc/documents/18Q1PPT_E.pdf

⁹⁹ See <https://www.telegeography.com/products/commsupdate/articles/2018/02/27/japanese-e-tailer-rakuten-submits-application-for-mobile-frequencies/>

¹⁰⁰ See http://www.soumu.go.jp/menu_news/s-news/01kiban14_02000333.html

Category	Details
Geographic area	No specific consultation/details released. Historically, mobile licenses in Japan have been assigned on a national basis via beauty contest rather than auctioned.
License length	However, an article published ¹⁰¹ by the Asia Nikkei review on November 28, 2017, stated that MIC is planning to conduct a competitive auction process for assigning 5G spectrum

2.7 Russia

Current assignment: limited data available. We are not aware of any mid-band spectrum currently assigned for mobile in Russia.

Future assignment: details have not been specified. We understand that current mobile authorizations in Russia are a mixture of regional and national licenses.

Overview of mid-band 5G spectrum

The government's 5G roadmap¹⁰² schedules a formal decision on 5G spectrum allocation¹⁰³ for 2018. At the time of publication of this report, we understand that no decision has been announced.

However, on July 4, 2017, the State Commission for Radio Frequencies (SCRF) announced¹⁰⁴ a decision to allocate 3.4–3.8GHz to MegaFon for 5G network testing ahead of the 2018 World Cup.¹⁰⁵ Fixed incumbent Rostelecom has also received a test license in the 3.4–3.8GHz band,¹⁰⁶ while Beeline's request for a test license (submitted to the SCRF in September 2017) was declined on interference grounds.¹⁰⁷

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

¹⁰¹ See <https://asia.nikkei.com/Politics-Economy/Policy-Politics/Japan-to-invite-new-faces-to-5G-party>. See also <https://www.mckinsey.com/industries/telecommunications/our-insights/japan-at-a-crossroads-the-4g-to-5g-revolution>

¹⁰² On July 28, 2017, the Russian government published its 'Digital economy of the Russian Federation' plan, which includes a 5G roadmap. See <http://static.government.ru/media/files/9gFM4FHj4PsB79I5v7yLVuPgu4bvR7M0.pdf>

¹⁰³ Some sources claim that the Russian Digital Economy plan indicates 5G networks will be built in the 694–790MHz, 3.4–3.8GHz, 4.4–4.99GHz, 5.9GHz, 24.25–29, 5GHz, 30–55GHz, 66–76GHz and 81–86GHz bands. However, we are not aware of this explicitly stated in the public documentation; see <http://www.tadviser.ru>. An article published on TDaily.ru in March 2018 states that 5G spectrum will not be approved until 2019. See <http://www.tdaily.ru/news/novosti-korotkoi-strokoi/44151>

¹⁰⁴ See <http://minsvyaz.ru/ru/events/37119/>

¹⁰⁵ In March 2018 reports emerged that the Russian regulator had started issuing licenses for the 2018 FIFA World Cup. See <https://www.telecompaper.com/news/russia-issues-spectrum-permits-for-world-cup--1235619>

¹⁰⁶ See <https://www.kommersant.ru/doc/3521675>. The link includes a list of regions covered by the licenses.

¹⁰⁷ Beeline's request was postponed until the SCRF's next meeting, see <https://www.telegeography.com/products/commsupdate/articles/2017/09/22/beeline-mts-make-5g-frequency-applications/> and <https://www.telegeography.com/products/commsupdate/articles/2018/01/04/scrf-declines-to-issue-spectrum-for-russian-5g-testing/>

- 5G trials using mid-band spectrum have continued. For example, Rostelecom and Ericsson launched¹⁰⁸ a 5G trial network in St Petersburg using the 3.4–3.8GHz band.¹⁰⁹
- MegaFon acquired Neosprint (an operator that owns 24MHz of spectrum in the 3.4–3.6GHz band in Moscow) for RUB720 million (USD12 million).¹¹⁰ We understand that MegaFon used the spectrum in June 2018 to deploy test 5G networks in stadiums hosting the 2018 World Cup in Russia.
- Beeline had a second request for a 5G test license denied by SCRF.¹¹¹
- On September 5, 2018, the Russian deputy prime minister was reported¹¹² as saying that 5G mobile services should be launched commercially in major cities across Russia by the end of 2021 (one year later than the 2020 target set out in previous government announcements).
- On October 3, 2018, reports emerged¹¹³ that SCRF will consider allocating additional spectrum for 5G testing in the 3.4–4.2GHz and 4.4–4.99GHz ranges to MTS, Beeline, and Tele2. Separately, SCRF is also considering a request from Beeline to conduct 5G testing in the 3.4–3.8GHz and 4.4–4.5GHz ranges in Moscow city, the Moscow region, St Petersburg, the Novosibirsk region, the Republic of Tatarstan, and the Krasnodar region.

Expected date for mid-band spectrum release and auction details

Figure 2.7: Details of 5G mid-band spectrum assignment in Russia [Source: Analysys Mason, 2018]

Category	Details
Spectrum to be released date	No specific details/consultation released
Expected	
Lot sizes	
Geographic area	
License length	

¹⁰⁸ See <https://www.ericsson.com/en/news/2018/5/5g-zone-at-the-hermitage>

¹⁰⁹ Details of the exact spectrum range have not been published in the public domain.

¹¹⁰ See <https://corp.megaфон.com/press/news/20180427-2006.html>

¹¹¹ See <https://www.telegeography.com/products/commsupdate/articles/2018/04/09/vimpelcoms-application-to-test-5g-frequencies-denied/>

¹¹² See <https://www.kommersant.ru/doc/3732337>

¹¹³ See <http://www.tdaily.ru/news/all/95/47473>

2.8 Singapore

Current assignment: we are not aware of any mid-band spectrum currently assigned for mobile in Singapore.

Future assignment: Singapore is exploring the possibility of assigning the 3.4–3.6GHz range in 2019. Further details have not been specified, though we expect licenses to be national (as has historically been the case for Singapore mobile licensing).

Overview of mid-band 5G spectrum

IMDA ran a public consultation¹¹⁴ ‘5G mobile services and networks’ from May to July 2017. The document states that IMDA is ‘exploring the possibility’ of allocating the 3.4–3.6GHz range for IMT services (including 5G).¹¹⁵ In the consultation’s model of future spectrum supply, the 3.4–3.6GHz range is released in 2019.

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- 5G trials using mid-band spectrum have continued
 - On June 21, 2018, M1 and Huawei announced¹¹⁶ plans to conduct “the first 3.5GHz with Non-Standalone (NSA) standards compliance field trial in Southeast Asia by end 2018, as well as the first 28GHz and 3.5GHz with Standalone (SA) standards compliance field trial in South East Asia by mid-2019”
 - On July 23, 2018, Singtel and Ericsson announced¹¹⁷ plans to conduct a trial of 5G services in Q4 2018, using trial spectrum¹¹⁸ awarded by IMDA

¹¹⁴ See <https://www.imda.gov.sg/regulations-licensing-and-consultations/consultations/consultation-papers/2017/public-consultation-on-5g-mobile-services-and-networks>

¹¹⁵ The consultation notes that, based on the current users and assignments, although the 3.4–3.6GHz range is generally under-utilised, there is still a lack of contiguous spectrum to support the deployment of new services. Considering the geographical size of Singapore, co-channel operations of both IMT and FSS (downlink) services may not be possible. In the event that IMDA makes available the extended C-band for IMT services, IMDA will have to consider either: i) A full migration, which involves moving all satellite users out of the extended C-band and making available approximately 200MHz of spectrum for IMT; or ii) A partial migration, which involves moving part of the users to the upper ranges of the extended C-band and making available part of the 200MHz spectrum for IMT.

¹¹⁶ See <https://www.m1.com.sg/AboutM1/NewsReleases/2018/M1%20and%20Huawei%20embark%20on%20first%20end-to-end%205G%20live%20tests%20in%20Singapore.aspx>

¹¹⁷ See <https://www.ericsson.com/en/press-releases/2018/7/singtel-and-ericsson-to-launch-singapores-first-5g-pilot-network>

¹¹⁸ In May 2017, IMDA announced that it would waive the frequency fees associated with 5G trials until December 2019, intending to encourage 5G R&D within the industry. See <https://www.imda.gov.sg/-/media/imda/files/regulation-licensing-and-consultations/frameworks-and-policies/spectrum-management-and-coordination/spectrum-planning/5g-technology-annex-a.pdf?la=en>

*Expected date for mid-band spectrum release and auction details**Figure 2.8: Details of 5G mid-band spectrum assignment in Singapore [Source: IMDA, 2018]*

Category	Details
Spectrum to be released	200MHz (3400–3600MHz)
Expected date	2019
Lot sizes	
Geographic area	No specific consultation/details released
License length	

2.9 Spain

Current assignment: Spain completed an auction of spectrum in the 3600–3800MHz range in July 2018. Spectrum was made available on a national basis.

Future assignment: none scheduled.

Overview of mid-band 5G spectrum

Three of Spain's MNOs own national licenses in the 3.4–3.6GHz band:¹¹⁹ Orange (2×20MHz), Telefónica (2×20MHz) and Mas Movil (2×40MHz).

The remaining 2×20MHz of the 3.4–3.6GHz band is used by the military for radiolocation services; a consultation issued by the Ministry of Energy, Tourism and Digital Agenda (MINTEAD) in July 2017 indicates that this block is not expected to be reallocated.¹²⁰

MINTEAD completed an auction of the 3.6–3.8GHz range in July 2018:

- Forty 5MHz blocks were available in the 3600–3800MHz band.
- Licenses are national, technology neutral and without coverage obligations; license duration is twenty years.
- The spectrum won is shown in Figure 2.9 below:

Figure 2.9: Outcome of the Spain's 3.6–3.8GHz auction in July 2018 [Source: MINTEAD, 2018]

Operator	Spectrum won	Spectrum range (MHz) ¹²¹
Vodafone	90MHz	N/d
Telefónica	50MHz	N/d
Orange	60MHz	N/d
Mas Movil	-	-
Total	200MHz	-

A number of operators have conducted 5G trials (or announced plans for the launch of 5G services) using mid-band spectrum. For example:

¹¹⁹ The exact assignments are as follows: Mas Movil (3400–3440/3500–3540MHz), Telefónica (3440–3460/3540–3560MHz), and Orange (3460–3480/3560–3580MHz). See https://sedesaplicaciones.minetur.gob.es/setsi_regconcesiones/default.aspx

¹²⁰ See <http://www.mincotur.gob.es/telecomunicaciones/es-ES/Participacion/Documents/Plan-Nacional-5G.pdf>

¹²¹ The spectrum was awarded as generic blocks; we understand that exact assignments are yet to be confirmed.

- On March 1, 2018, Orange announced¹²² that it is in the process of selecting cities in which to launch commercial 5G services in 2019 using its spectrum in the 3460–3480/3560–3580MHz range.
- On July 30, 2018, Vodafone confirmed¹²³ that it had deployed pre-commercial 5G antenna across several cities using Huawei equipment operating in the 3.6–3.8GHz band.

Developments since 5G readiness report

Not applicable (country not included in 5G readiness report).

Expected date for mid-band spectrum release and auction details

The 3400–3600MHz range was awarded in July 2018. Spain has not indicated that further mid-band spectrum is planned for release.

¹²² See <https://www.telegeography.com/products/commsupdate/articles/2018/03/01/orange-espana-earmarks-3-5ghz-band-for-5g-eyes-four-city-launch-in-2019/>

¹²³ See <https://www.telegeography.com/products/commsupdate/articles/2018/07/30/vodafone-tests-5g-in-madrid-barcelona-seville-malaga-bilbao-and-valencia/>

2.10 South Korea

Current assignment: South Korea auctioned the 3420–3700MHz range on a national basis in June 2018 for 5G use, raising a total of USD2.69 billion.

Future assignment: none scheduled.

Overview of mid-band 5G spectrum

In early 2017, the Ministry of Science and ICT (MSIT) released^{124, 125} a national broadband/spectrum plan ('K-ICT'), indicating that it planned to allocate 300MHz in the 3.4–3.7GHz¹²⁶ band to 5G by 2018. The 3.4–3.7GHz band (along with spectrum in the 28GHz band) was auctioned in June 2018 (see below).

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- MSIT confirmed¹²⁷ the details and date of the auction (see Figure 2.10 below). The auction was held as scheduled. MSIT announced¹²⁸ results on June 18, 2018 (see Figure 2.10 below).
 - Twenty-eight 10MHz blocks were available in the 3420–3700MHz range.
 - Licenses start on December 1, 2018, and last 10 years; licenses are national.

Figure 2.10: Outcome of South Korea's 3420–3700MHz auction in June 2018 [Source: MSIT,¹²⁹ 2018]

Operator	Spectrum won	Spectrum range (MHz)
LGU+	80MHz	3420–3500MHz
KT	100MHz	3500–3600MHz
SKT	100MHz	3600–3700MHz
Total	280MHz	3420–3700MHz

Expected date for mid-band spectrum release and auction details

The 3420–3700MHz range was awarded in June 2018. South Korea have not indicated that further mid-band spectrum is planned for release.

¹²⁴ See https://blog.naver.com/with_msip/220917986508.

¹²⁵ See also a notice released by MSIT in July 2017 indicating that the government may be reserving 3.1–3.735GHz for 5G; see <http://www.msit.go.kr/web/msipContents/contentsView.do?catelId=mssw352&artId=1364893>

¹²⁶ See https://www.ituaj.jp/wp-content/uploads/2017/05/nb29-2_web.pdf

¹²⁷ See <http://www.msit.go.kr/web/msipContents/contentsView.do?catelId=mssw311&artId=1381784>

¹²⁸ See <http://www.msit.go.kr/web/msipContents/contentsView.do?catelId=mssw311&artId=1386500>

¹²⁹ Ibid.

2.11 Sweden

Current assignment: 80MHz (3600–3640/3700–3740MHz) assigned to MNOs on a national basis; some (technology neutral) regional licenses assigned in the 3.4–3.8GHz band.

Future assignment: 300MHz (3.4–3.7GHz) to be awarded nationwide by late 2019 or early 2020 and 100MHz (3.7–3.8GHz) to be awarded on a regional basis from 2023 onwards.

Overview of mid-band 5G spectrum

Two MNOs in Sweden own national¹³⁰ 2×20MHz licenses in the 3.6–3.8GHz band: TDC Sverige (owned by Tele2) (3600–3620MHz, 3700–3720MHz) and B2 Bredband (owned by Telenor) (3620–3640MHz, 3720–3740MHz). These licenses are technology and service neutral and expire in December 2022. The remaining spectrum in the 3.6–3.8GHz range was auctioned on a regional basis, though most of the licenses have not been assigned.

Until recently, two MNOs in Sweden also owned national licenses in the 3.4–3.6GHz band: Telia-Sonera (3438–3466MHz, 3538–3566MHz) and Tele2 (3466–3494MHz, 3566–3594MHz). However, these licenses expired in December 2017. The 3410–3438MHz and 3510–3538MHz ranges are currently allocated to several local operators with regional¹³¹ based technology-neutral licenses which expire in March 2023.

Swedish telecom regulator Post- och telestyrelsen (PTS) issued¹³² a consultation on August 30, 2016, analyzing the need for the award of spectrum in the 3438–3510MHz and 3538–3600MHz ranges. The consultation proposed that the two bands be handled together, and therefore that PTS would hold off on a new assignment “until the [entire] 3.4–3.8GHz band can be reassigned”. This approach was confirmed in a statement^{133, 134} released by PTS on October 14, 2016.

On February 3, 2017, PTS published¹³⁵ a spectrum plan for 5G tests in the 3.4–3.6GHz band from 2017, with comments to be submitted by February 24, 2017. On March 31, 2017, PTS announced

¹³⁰ In 2007, PTS auctioned four 40MHz blocks (two FDD and two TDD) in the 3.6–3.8GHz band in each of Sweden's 290 municipalities. B2 Bredband won one FDD block in every municipality, meaning that it effectively holds a national license of 2×20MHz. Of the remaining 870 licenses, the majority (758) remained unsold and were re-auctioned in 2009. 265 of these licenses are now assigned; these licenses are spread out geographically across the country (most assigned licenses are in the more northerly municipalities). The 2009 auction also made available a national 2×20MHz block, which was won by TDC Sverige. All licenses expire in December 2022. See February 2018 consultation.

¹³¹ The licenses in the 3.4–3.6GHz band were originally assigned on a county basis, but the charging base for the annual fees is comprised of population by municipality. There are licenses assigned in 98 out of 290 municipalities. We understand that the majority of license holders are not using their licenses (see February 2018 consultation). On October 16, 2018, PTS announced that it had asked all licensees who were not using (or lightly using) their licenses to return them to the regulator. See <https://www.pts.se/sv/nyheter/radio/2018/pts-vill-att-kommunala-frekvenstillstand-i-35-ghz-bandet-lamnas-tillbaka/>

¹³² See <http://www.pts.se/upload/Remisser/2016/Spektrum/3-5-GHz-forstudie-2016-25.pdf>

¹³³ See <http://www.pts.se/sv/Dokument/Rapporter/Radio/2016/Analys-av-behov-och-efterfragan-for-en-ny-tilldelning-genom-urvalsfarande-i-frekvensomradena-34383510-och-35383600-MHz/>

¹³⁴ PTS also re-released the consultation document, with an additional section on stakeholder responses, claiming that all stakeholders who responded to the consultation (Hi3G, Huawei, Tele2, Telenor, TeliaSonera) endorsed its recommendations.

¹³⁵ See <http://www.pts.se/upload/Remisser/2017/Spektrum/5G-tester/forslag-spektrumplan-5G-tester-170203.pdf>

that it received (generally supportive) responses from nine parties. PTS therefore launched its plans for the 5G tests, making 100–200MHz available in the 3.4–3.6GHz band “from 2017”. The press release also stated that PTS planned to launch those frequencies for long-term use “from 2020”. On February 28, 2018, PTS announced that it had made a contiguous 200MHz block of spectrum (3.4–3.6GHz) available for 5G tests in Stockholm County.

On February 15, 2018, PTS published¹³⁶ a consultation on releasing the 3.4–3.8GHz for 5G. On May 3, 2018, PTS published¹³⁷ responses to the consultation and its revised proposals for assigning the spectrum. PTS has since confirmed¹³⁸ its intention to assign the 3.4–3.7GHz range on a nationwide basis in late 2019 or early 2020, and the 3.7–3.8GHz range on a regional basis from 2023; further details are provided below.

Developments since 5G readiness report

Not applicable (country not included in 5G readiness report)

Expected date for mid-band spectrum release and auction details

Figure 2.11: Details of 5G mid-band spectrum assignment in Sweden [Source: PTS, 2018]

Category	Details
Spectrum to be released	3.4–3.8GHz (400MHz).
Expected date	Assignment of 3.4–3.7GHz band proposed for late 2019 or early 2020 (although the potential date of access differs depending on when existing licenses expire). Assignment of the 3.7–3.8GHz band proposed for 2023.
Lot sizes	The February 2018 consultation states that some industry players have requested block sizes of 80–100MHz, but an alternative option (which provides more flexibility) is block sizes of 5–10MHz. PTS states further consideration will be made before the award. In October 2018, PTS published ¹³⁹ a consultation outlining different options for the 3.7–3.8GHz band; block sizes of 80–100MHz or 40–50MHz are envisaged. ¹⁴⁰

¹³⁶ See <https://www.pts.se/contentassets/9057a944959742878f4b3ce0e7ade9f7/remiss-av-rapport-infor-framtida-tilldelning-av-frekvenser-for-5g/forstudie-frekvenser-5g-remissrapport.pdf> (English version also available)

¹³⁷ See <https://www.pts.se/contentassets/9057a944959742878f4b3ce0e7ade9f7/inriktning-frekvenser-for-5g-bemotande-remissvar.pdf> (English version also available)

¹³⁸ See <https://pts.se/globalassets/startpage/dokument/listningar-pa-textsidor/35-ghz/infomote-21-sep.pdf>

¹³⁹ See <https://pts.se/globalassets/startpage/dokument/icke-legala-dokument/remisser/2018/radio/konsultation-1---23-och-35-ghz/2.-forslag-for-tilldelning-av-lokala-blocktillstand.pdf>

¹⁴⁰ Three options are outlined: (1) 3.7–3.8GHz spectrum is exclusively assigned for site-by-site licensees (80–100MHz block size), (2) previous option, but 100MHz blocks of spectrum are also assigned in the 3.8–4.2GHz band for local coverage providers, and (3) 3.7–3.8GHz spectrum is shared between site-by-site licensees and local coverage providers (40–50MHz block size)

Category	Details
Geographic area ¹⁴¹	<p>300MHz (3.4–3.7GHz) for nationwide use; spectrum will be assigned using a selection procedure (i.e. some form of competitive bid process¹⁴²).</p> <p>100MHz (3.7–3.8GHz) awarded on a regional basis; spectrum will be assigned without a selection procedure (i.e. some form of administrative assignment¹⁴³). The October 2018 3.7–3.8GHz consultation considers an option where spectrum is licensed exclusively on a site-by-site basis, as well as an option where spectrum is shared between local coverage providers and site-by-site licensees. Details of the region size for local coverage licenses have not been provided. We note that in the previous 3.4–3.8GHz auctions lots have been made available in each of Sweden's 290 municipalities. At the time of the 3.6–3.8GHz auction in 2007, the average municipality population was ~33,000.¹⁴⁴</p>
License length	The October 2018 3.7–3.8GHz consultation proposes 10-year licenses.

¹⁴¹ The original consultation had proposed a different arrangement which distinguished between high density/demand areas and other areas. However, given consultation responses, PTS proposed the national/regional arrangement shown (in line with the approach adopted in Germany).

¹⁴² See <https://pts.se/sv/bransch/radio/auktioner/>

¹⁴³ PTS states that the issue of how regional licenses will be assigned in situations where demand exceeds supply will be investigated further.

¹⁴⁴ Municipality population varies between ~2400 (Västerbotten – Bjurholm) and ~894 200 (Stockholm – Stockholm).

2.12 UK

Current assignment: the UK completed the auction of 150MHz of 3.4–3.6GHz spectrum in June 2018. MNO Three also holds various mid-band spectrum licenses on a national basis.

Future assignment: the UK is planning to award spectrum from the 3.6–3.8MHz range in 2019. Further details have not been specified, though we consider it likely that the majority of spectrum will be awarded for 5G use on a nationwide basis (as in the recent 3.4–3.6GHz auction). The UK is also considering use of 3.8–4.2GHz for 5G on a shared basis with existing satellite services. Details of the approach to sharing (e.g. national licenses with geographic restrictions on use, or regional licenses) have not yet been confirmed.

Overview of mid-band 5G spectrum

MNOs recently acquired national licenses suitable for 5G in the 3.4–3.6GHz band (see below). Furthermore, FWA operator UK Broadband (owned by MNO Three), owns national licenses in the 3480–3500MHz, 3580–3600MHz,¹⁴⁵ 3605–3689MHz, and 3925–4009MHz¹⁴⁶ mid-band ranges.

The UK telecom regulator, Ofcom, released¹⁴⁷ a consultation on October 6, 2016, to examine whether 3.6–3.8GHz spectrum¹⁴⁸ could be allocated to future 5G enhanced mobile broadband (eMBB) services. On October 26, 2017, Ofcom released¹⁴⁹ a statement confirming the release of this band and beginning the process of vacating existing users. Ofcom stated that it expects the spectrum to ‘be deployed in many areas from around 2020, and nationwide by 2022’.¹⁵⁰ This timeline was confirmed in an announcement¹⁵¹ made on February 2, 2018, which stated that the

¹⁴⁵ In June 2003, the Radiocommunications Agency (RA) held a regional 3.4–3.6GHz FWA auction. Two 20MHz TDD blocks (3480–3500MHz and 3580–3600MHz) were made available under a single license in each of 15 regions; the 15 regions collectively covered the entirety of the UK. Poundradio (which changed its name to UK Broadband shortly after the auction) won licenses in 13 out of the 15 regions. It subsequently acquired the remaining two licenses, by buying the companies (Red Spectrum and Public Hub) that won them in the auction. In March 2007, Ofcom agreed to combine UK Broadband’s licenses into a single nationwide license. Later in 2007, UK Broadband successfully requested a variation to its license conditions to allow technology and application neutrality (thereby allowing mobile as well as FWA use). In June 2014, Ofcom extended the duration of the license to be indefinite (the original licenses expired after 15 years). See: https://www.ofcom.org.uk/research-and-data/telecoms-research/broadband-research/oftel_internet_broadband_brief <https://www.ofcom.org.uk/consultations-and-statements/category-2/uk-broadband-licence>

¹⁴⁶ Unlike UK Broadband’s other mid-band spectrum licenses, this license is for FWA only and allows individual deployments on a first-come, first-served basis, subject to co-ordination by Ofcom (with incumbent satellite earth stations and fixed links).

¹⁴⁷ See <https://www.ofcom.org.uk/consultations-and-statements/category-1/future-use-at-3.6-3.8-ghz>

¹⁴⁸ This excludes the portion already owned by MNO Three (via subsidiary UK Broadband), i.e. 3605–3689MHz

¹⁴⁹ See https://www.ofcom.org.uk/consultations-and-statements/category-1/future-use-at-3.6-3.8-ghz?utm_source=updates&utm_medium=email&utm_campaign=3.6-3.8. This followed the statement and consultation which ran from July 28, 2017 to September 22, 2017. See https://www.ofcom.org.uk/_data/assets/pdf_file/0017/103355/3-6-3-8ghz-statement.pdf

¹⁵⁰ Ofcom has said that it will revoke all fixed-link licenses in the 3600–3800MHz band in 2022 as well as stop protecting earth station licensees from interference in 2020.

¹⁵¹ See https://www.ofcom.org.uk/_data/assets/pdf_file/0018/110718/3.6GHz-3.8GHz-update-timing-spectrum-availability.pdf

award was planned for 2019. Ofcom's proposed annual plan for 2018/19 states that a consultation for the band is due to be published in Q3 2018/19.

In 2016, Ofcom ran a 'Call for Input' on the 3.8–4.2GHz range as 'a candidate band for enhanced spectrum sharing', and for 'potential new innovative applications'.¹⁵² Most recently, Ofcom's 'Enabling 5G in the UK' paper, published in March 2018, confirmed its intention to consider the band for the possibility of shared use. A consultation is expected to be released later in 2018.¹⁵³

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- 5G trials using mid-band spectrum have continued:
 - In April 2018, Vodafone announced¹⁵⁴ it had completed a 3.4GHz 5G trial. On June 20, 2018, Vodafone further announced^{155,156} that it plans to begin trials (using its 3410–3460MHz spectrum) in seven cities between October and December 2018, and to roll out 5G in certain locations in 2019.
 - EE has announced¹⁵⁷ that it will conduct 5G trials in October 2018. The operator also confirmed¹⁵⁸ plans to launch 5G commercially in 2019.
- Government initiatives to encourage 5G deployment have been announced/developed:
 - A smart city roadmap for London was published¹⁵⁹ in June 2018, including a number of measures aimed at enabling 5G.
 - On July 23, 2018, the Government published its "Future Telecoms Infrastructure Review".
 - On September 4, 2018, the Government selected¹⁶⁰ the West Midlands region to become the UK's first large-scale 5G testbed.

¹⁵² See https://www.ofcom.org.uk/__data/assets/pdf_file/0031/79564/3.8-GHz-to-4.2-GHz-band-Opportunities-for-Innovation.pdf

¹⁵³ Ofcom's 'Fixed Wireless Spectrum Strategy' and 'Review of the authorization regime for spectrum access' published on December 7, 2017, both stated that the regulator will publish a consultation on further sharing of the 3.8–4.2GHz band in 2018.

¹⁵⁴ See <https://mediacentre.vodafone.co.uk/pressrelease/first-test-new-5g-spectrum-across-live-network/>

¹⁵⁵ See <https://mediacentre.vodafone.co.uk/pressrelease/5g-trial-seven-cities/>

¹⁵⁶ See <https://mediacentre.vodafone.co.uk/news/vodafone-makes-uks-first-holographic-call-using-5g/>

¹⁵⁷ See <http://newsroom.ee.co.uk/ee-set-to-switch-on-uks-first-5g-trial-network-in-londons-tech-city-east-london/>

¹⁵⁸ See <http://newsroom.ee.co.uk/ee-turns-3g-into-4g-to-boost-smartphone-speeds-and-lay-foundation-for-5g-launch-in-2019/>

¹⁵⁹ See https://www.london.gov.uk/sites/default/files/smarter_london_together_v1.64_-_published.pdf

¹⁶⁰ See <https://www.gov.uk/government/news/west-midlands-to-become-uks-first-large-scale-5g-testbed>

- The 3.4–3.6GHz (and 2.3GHz) auction took place in April 2018:¹⁶¹
 - Thirty 5MHz blocks were available in the 3410–3480MHz and 3500–3580MHz¹⁶² bands at a reserve price of GBP1million (USD1.3 million) per block.
 - Licenses are national, technology neutral and without coverage obligations. Licenses were awarded in perpetuity (with further payment required after 20 years¹⁶³).
 - The spectrum won by the four MNOs is shown in Figure 2.12 below:

Figure 2.12: Outcome of the UK's 3.4–3.6GHz auction in April 2018 [Source: Ofcom, 2018]

Operator	Spectrum won	Spectrum range (MHz)
O2	40MHz	3500–3540
BT/EE	40MHz	3540–3580
Vodafone	50MHz	3410–3460
Three	20MHz	3460–3480
Total	150MHz	-

- On June 27, 2018, Ofcom published¹⁶⁴ a consultation on varying Three's license¹⁶⁵ in the 3605–3689MHz range:
 - UK Broadband (owned by Three) has requested a number of changes to this license, including: shifting it down by 5MHz, surrendering its rights to use 4MHz of spectrum in that block, and changing the applicable technical conditions.
 - The consultation (which closed on August 8, 2018) sets out Ofcom's provisional view that it is “minded to agree” to the requested variation.

Expected date for mid-band spectrum release and auction details

Figure 2.13: Details of 5G mid-band spectrum assignment in the UK [Source: Ofcom, 2018]

Category	Details
Spectrum to be released	200MHz (3.6–3.8GHz) 3.8–4.2GHz is a “candidate band for enhanced spectrum sharing”

¹⁶¹ See <https://www.ofcom.org.uk/spectrum/spectrum-management/spectrum-awards/awards-archive/2-3-and-3-4-ghz-auction>

¹⁶² The spectrum already owned by MNO Three (via subsidiary UK Broadband), i.e. 3480–3500MHz and 3580–3600MHz, was not included in the auction.

¹⁶³ See auction documentation for details: <https://www.ofcom.org.uk/spectrum/spectrum-management/spectrum-awards/awards-archive/2-3-and-3-4-ghz-auction>

¹⁶⁴ See <https://www.ofcom.org.uk/consultations-and-statements/category-2/variation-uk-broadbands-spectrum-access-licence-3-6-ghz>

¹⁶⁵ For details of its existing license, see https://www.ofcom.org.uk/_data/assets/pdf_file/0028/96913/UK-Broadband.pdf

Category	Details
Expected date	Award planned for 2019. Under the expected timeline for migration of incumbent users of the spectrum, Ofcom expects the 3.6–3.8GHz spectrum to be 'be deployed in many areas from around 2020, and nationwide by 2022'
Lot sizes	
Geographic area	No specific consultation/details released
License length	

2.13 US

Current assignment: we are not aware of any mid-band spectrum currently assigned for mobile in the US.

Future assignment: the US is making 150MHz in the 3550–3700MHz (CBRS) band available, with 70MHz to be auctioned (potentially in 2019) and the remaining 80MHz to be licensed on a shared basis (in early 2019). The Federal Communications Commission (FCC) is also exploring the 3.7–4.2GHz band, adopting an NPRM in July 2018 that could open up large additional blocks of mid-band spectrum. The US is also studying the 3.45–3.55GHz band, but there is no specific timing on the study or the availability of spectrum.

Overview of mid-band 5G spectrum

The FCC is in the process of releasing the citizens broadband radio service (CBRS) band (3550–3700MHz) for shared wireless broadband use.¹⁶⁶ The band is governed by a three-tier authorization framework that allows commercial users to share spectrum with existing federal and non-federal users:

- Tier 1 consists of incumbent users¹⁶⁷ (primarily the US military), which have top priority.
- Tier 2 consists of priority access licenses (PALs), which will be granted for a fee. A maximum of seven PALs, each 10MHz in size, will be licensed in any given geographical area in the bottom 3550–3650MHz range. Use of these bands can be pre-empted by Tier 1 users.
- Tier 3 users have general authorized access (GAA) – opportunistic use of any available block of the 3550–3700MHz band without a defined license term. We understand that use of GAA spectrum can begin as soon as the necessary equipment and spectrum management databases have been certified, which is expected in early 2019.

Furthermore, on August 3, 2017, the FCC issued¹⁶⁸ an NOI entitled ‘*Exploring Flexible Use in Mid-Band Spectrum Between 3.7 GHz and 24 GHz*’. The NOI consults on three specific mid-range bands (3.7–4.2GHz, 5.925–6.425GHz and 6.425–7.125GHz) for ‘expanded flexible use’ and seeks comment on further bands between 3.7GHz and 24GHz which might also be suitable. On July 13, 2018, the FCC issued an NPRM on the 3.7–4.2GHz range (see below), and in October 2018, the agency issued an NPRM on the 5.925–6.425GHz and 6.425–7.125 GHz bands.¹⁶⁹

¹⁶⁶ See <https://www.fcc.gov/rulemaking/12-354#block-menu-block-4> for an index of FCC CBRS documentation

¹⁶⁷ Tier 1 incumbent users mainly use these bands for naval radar applications in coastal areas, so this capacity remains largely unused in inland areas.

¹⁶⁸ See http://transition.fcc.gov/Daily_Releases/Daily_Business/2017/db0713/DOC-345789A1.pdf and <https://commlawmonitor2.lexblogplatformthree.com/wp-content/uploads/sites/512/2017/08/Mid-Band-Spectrum-NOI.pdf>

¹⁶⁹ See <https://transition.fcc.gov/oet/ea/presentations/files/oct18/3.1-Rulemakings-JSP.PDF>

On February 26, 2018, the National Telecommunications and Information Administration (NTIA), in co-ordination with the Department of Defense (DOD) and other federal agencies, announced¹⁷⁰ that it had identified 100MHz (3450–3550MHz) for ‘potential repurposing to... commercial wireless’. The ‘DOD plans to submit a proposal under the Spectrum Pipeline Act to carry out a comprehensive radio-frequency engineering study to determine the potential for introducing advanced wireless services in this band (which is currently used for military radar) without harming critical government operations’.

Developments since 5G readiness report

The following developments have taken place since the publication of the 5G readiness report:

- 5G/LTE trials using mid-band spectrum have continued. For example:
 - On May 16, 2018, Verizon announced¹⁷¹ that it has successfully tested LTE using the CBRS band in partnership with Ericsson, Federated Wireless and Qualcomm
 - On July 23, 2018, Boingo (a DAS, small cell and Wi-Fi provider) announced¹⁷² that it had successfully deployed a private LTE network using the CBRS band at Dallas Love Field Airport (DAL)
- Developments in the 3.7–4.2GHz band (C-band):
 - On April 19, 2018, the FCC instituted¹⁷³ a ‘freeze’ on applications for new receive-only earth stations in the C-band. It also initiated a 90-day window (to July 18, 2018) in which existing earth stations can verify the accuracy of existing registration and license information. The registration window was subsequently extended for another 90-day period (to October 17, 2018)
 - On May 1, 2018, the FCC issued¹⁷⁴ a public notice seeking comment on an upcoming report that will address the feasibility of allowing commercial wireless services to use or share use of the 3.7–4.2GHz band. The deadline for comments was May 31, 2018, with reply comments due by June 15, 2018

¹⁷⁰ See <https://www.ntia.doc.gov/blog/2018/ntia-identifies-3450-3550-mhz-study-potential-band-wireless-broadband-use>. The ‘DOD plans to submit a proposal under the Spectrum Pipeline Act to carry out a comprehensive radio-frequency engineering study to determine the potential for introducing advanced wireless services in this band [which is currently used for military radar] without harming critical government operations.’

¹⁷¹ See <https://www.fiercewireless.com/wireless/verizon-touts-commercial-cbrs-deployment-ericsson-federated-wireless-qualcomm>

¹⁷² See <http://www.boingo.com/press-releases/boingo-deploys-cbrs-at-dallas-love-field-airport/>

¹⁷³ See <https://edit.ses.com/sites/default/files/2018-05/FCC%20Registration%20of%20C-band%20Rx-only%20Earth%20Stations.pdf>

¹⁷⁴ See https://apps.fcc.gov/edocs_public/attachmatch/DA-18-446A1.pdf

- On July 13, 2018, the FCC unanimously voted to adopt an NPRM, seeking comment on repurposing the 3.7–4.2 GHz band for flexible use, including mobile broadband.¹⁷⁵ Comments were due on October 29, 2018, and reply comments are due on November 27, 2018
- Developments in the CBRS band:
 - On May 8, 2018, the CBRS Alliance¹⁷⁶ launched¹⁷⁷ the ‘OnGo’ brand and certification program
 - On May 10, 2018, six conditionally approved SAS Administrators (Amdocs, CommScope, Federated Wireless, Google, Key Bridge, and Sony) met with regulators to discuss possible SAS field-testing scenarios.¹⁷⁸ Nokia has also requested¹⁷⁹ to operate as a SAS Administrator and ESC operator
 - On July 12, 2018, Wireless Innovation Forum announced¹⁸⁰ approved the first six test labs that will bear the “WinnForum CBRS Approved” logo for CBRS Device (CBSD) testing
 - On July 27, 2018, the FCC issued¹⁸¹ a public notice establishing procedures for filing initial Spectrum Access System (SAS) commercial deployment proposals. The deadline for proposals was September 10, 2018
 - On October 23, 2018, the FCC held its October open meeting.¹⁸² Proposals to increase the size of PAL license areas from census tracts to counties (and extend the license duration to 10 years with an expectation of renewal) were voted through.
- Developments in other mid-band spectrum ranges:
 - FCC Commissioner Michael O’Rielly indicated that the FCC may investigate opening up the 4940–4990MHz band¹⁸³

¹⁷⁵ See <https://www.fcc.gov/document/fcc-expands-flexible-use-mid-band-spectrum>

¹⁷⁶ See <https://www.cbrrsalliance.org/about-us/>

¹⁷⁷ See <https://www.cbrrsalliance.org/news/cbrrs-alliance-launches-ongo-brand-and-ongo-certification-program/>

¹⁷⁸ See [https://ecfsapi.fcc.gov/file/10510250686420/2018-05-10%20Ex%20Parte%20re%20SAS%20Field%20Testing%20\(GN%2015-319\).pdf](https://ecfsapi.fcc.gov/file/10510250686420/2018-05-10%20Ex%20Parte%20re%20SAS%20Field%20Testing%20(GN%2015-319).pdf)

¹⁷⁹ See <https://ecfsapi.fcc.gov/file/1052267429439/Suri%20and%20Corker%20Ex%20Parte%205-18-2018%20FINAL.pdf>

¹⁸⁰ See <https://www.businesswire.com/news/home/20180712005761/en/Wireless-Innovation-Forum-Announces-CBRS-CBSD-Standards>

¹⁸¹ See <https://docs.fcc.gov/public/attachments/DA-18-783A1.pdf>

¹⁸² See <https://www.fcc.gov/document/fcc-announces-tentative-agenda-october-open-meeting-4>

¹⁸³ See <https://www.fiercewireless.com/tech/fcc-commissioner-targets-mid-band-spectrum-for-5g-within-2-years>

- At the FCC’s October 2018 open meeting, the agency adopted an NPRM proposing “to allow unlicensed devices to operate under the Commission’s Part 15 rules only in locations and frequencies where they would not cause harmful interference to the licensed services in the band.”¹⁸⁴

Expected date for mid-band spectrum release and auction details

Figure 2.14: Details of 5G mid-band spectrum assignment in the US [Source: FCC, 2018]

Category	Details
Spectrum to be released	Three-tiered sharing arrangement in the CBRS band (3550–3700MHz range): Tier 1 – protected spectrum for incumbents in certain locations Tier 2 – 70MHz (within the 3550–3650MHz range) to be auctioned Tier 3 – Remaining spectrum (at least 80MHz) to be made available on an unlicensed (GAA) basis 3450–3550MHz and 3700–4200MHz also being considered for release
Expected date	CBRS band: Tier 2 – spectrum potentially auctioned in 2019 Tier 3 – GAA spectrum expected to be available in early 2019
Lot sizes	Tier 2 spectrum will be auctioned in seven blocks of 10MHz. Tier 2 licenses are known as priority access licenses (PALs)
Geographic area	PALs will be assigned by county, with an option in the largest markets to bid for all counties in those markets as a package.
License length	License length is ten years, with expectation of renewal

¹⁸⁴ See <https://www.fcc.gov/document/promoting-unlicensed-use-6-ghz-band>